Management Effects of Spatially Dispersed Land Tracts: A Simulation Analysis

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A sequential simulation model is used to test a way to study the relationship between net farm income and land tract dispersion, total acres, machinery size and rainfall. The model simulates the day-to-day sequence of field work on a hypothetical farm situation varying crop acreage, machinery size and for a wet and dry rainfall situation. Data generated by this model are then analyzed using a regression equation estimating the influence of studied variables on net farm income.

Increases in size, power, and mobility of most types of farm machinery in recent years have enabled farmers to operate more land at greater distances from the home base in order to increase their farm size. The increase in size and greater machine utilization enhances efficiency of operation through attaining economies of size, and increases the farmer's income generating capacity. However, most studies about firm growth and increasing farm size have not explicitly considered the dispersion of land tracts.

This study develops and tests a sequential simulation model for analyzing the relationships of tract dispersion, crop acres, and machinery size to farm profits. We limited the effects of dispersion on profits to two aspects: (a) the effect of increased travel on costs and (b) the possible reduction in crop yield per acre resulting from lost fieldwork time and, hence, nontimely planting and harvesting. We used the results to evaluate the approach, the model, and data requirements.

We considered the simulation approach instead of surveying farmers to estimate the effect of dispersion and distance on costs and yield per acre in order to control the range in value of variable factors. Simulation, even more so than a fertilizer or feeding experiment, approaches a totally controlled experiment. The important part of using simulation is to define and quantify the real situation studied. However, by holding some factors constant, we were able to study a situation atypical of an actual farm situation.

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Problems with Spatial Dispersion

The absence of past research on dispersion of land tracts makes it difficult to evaluate its effects on efficiency of operation. As a result, our approach here is to cite observations on the problem made by other analysts, to offer evidence on changing sizes of farms in Kansas, and to characterize some of the likely problems associated with land dispersion.

Warren Johnston showed that "... the dispersion of farmed land was more widespread with increasing farm size." A recent issue of a farm magazine reports: "If adding to the home farm was a simple matter of annexing the field across the fence, large machinery wouldn't pose such a problem. But, in many communities you're lucky to find extra acres in the same county — much less right next door." This article also touches on the problem of field time lost because of moves: "... A field-to-field switch that eats up the better half of a day instead of the better part of an hour."

A Kansas farm management extension economist suggests that the extent of dispersion of tracts depends on how aggressively the farmer pursues growth in land size. If a farmer senses the need to acquire cropland rapidly to achieve firm growth or to include a son in the business, then he likely will end up with farm tracts quite widely dispersed.

Table 1 uses Northeast Kansas farm management association records to compare farm size reported in 1973 with size of the same farm in 1977. The underlined numbers on the diagonal are the number of farms with crop acreage in the same size group in both years. Fifty-one percent of the farms stayed in the same size group, 35 percent are in a larger size group in 1977 than in 1973; and 14 percent are in a smaller size group in 1977. In eastern Kansas, farms with 640 acres or more are likely not in one contiguous tract because of the terrain and the history of land ownership with many people owning relatively small tracts. In 1973, 20 percent of the farms were over 640 acres whereas by 1977, 40 percent were over 640 acres. Most farms in northeast Kansas are small enough so that tracts farmed are likely less dispersed. But many farms are expanding to sizes where dispersion is a problem.

On widely dispersed farmland, an operator may experience difficulties not common on a contiguous tract. A light rain on one tract may interrupt on-going field work there; another tract, located several miles away but on the dispersed farmland, may not have received the rain. Determining amount of rainfall on various tracts could require time and quite likely increase travel costs. Although devices like two-way radios can greatly facilitate communication among laborers working at different tracts, they are of limited use in a one-man farm situation.

Narrow bridges with limited load capacities may also increase farmers' travel time between widely dispersed tracts, as will time spent in preparing equipment for transport. Purchasing special equipment to trans-

TABLE 1. Number of Northeast Kansas farms by Size Group in 1973 and Size of Same Farm in 1977

Cropland acres of same farm in 1977	Cropland acres in 1973: 0–160	161–320	321–480	481–640	641–800	801–960	961–1120	1121–1280	1281–1440	1441–1600	1601–1760	over 1760
0-160	20	9	1	1								
161-320	15	59	13	2								
321-480	3	12	41	7	1							
481-640	1	5	12	27	5							
641-800			7	15	11	4	1	2				
801-960			3	4	8	2						1
961-1120		1		2	8	4	3					
1121-1280				1	2	2	1	1				
1281-1440						2			2			
1441-1600				1	1				1	—		
1601-1760									1	1	—	
over 1760			2							1		2

port large machines would further add to equipment cost.

Among some advantages of spatial dispersion are the possibility of rain occurring on tracts other than the one of on-going field work and the possibility of reduced risk of hail loss. Our model accounts for the first possibility but not for the second.

Model

Our approach was to simulate the day-to-day sequence of events relating to field preparation, planting, and harvesting on a representative farm in Northeast Kansas. Each situation studied was based on a different number of land tracts and on alternative machinery sizes, levels of dispersion, and rainfall amounts. We formulated the study as a discrete system by using a version of the programming language of the General Purpose Simulation System.

We related net farm income to four controlled, variable factors and to some fixed factors. The experimental design included variables over a range, with some other factors fixed at specified levels.

Control Variables

Land, equipment capacity, dispersion, and rainfall were the control variables specified in the simulation model. Cropland studied was for 320, 480, 640, 1,120, and 1,440 acres. Tracts were in increments of 160 acres. Sizes of various implements for alternative equipment capacity levels studied are given in Table 2.

The pattern of tract dispersion was defined as the location of tracts in relation to each other and to the base of operations. We used a circular pattern with the base tract as the center; added tracts were situated as nearly as possible in a circle, with equal distances between tracts and from the base tract.

Defining level of dispersion as the distance the circular pattern is from the base tract, we considered three levels: (1) contiguous with tracts adjacent to the base tract and to each other; (2) moderately dispersed, with each tract about 6 miles from the base tract and with equal distances between adjacent tracts; and (3) widely dispersed, with each tract about 16 miles from the base tract and with nearly equal distances between adjacent

TABLE 2. Machine Sizes For Each Size of Equipment Capacity by Type of Equipment

Machine	Equipment capacity 4	Equipment capacity 5	Equipment capacity 6	Equipment capacity 7
Plow	4-16″	5-16″	6-16″	7-16″
Offset disc	16′	18′	20′	24′
Springtooth harrow	16′	18′	20′	24′
Spiketooth harrow	18′	20′	22′	24′
Rotary hoe	4-40″	6-30″	8-30″	12-30″
Cultivator	4-40″	6-30″	8-30″	12-30″
Planter	4-40″	6-30″	8-30″	12-30″
Grain Drill	10.5′	12.2′	12.2′	14.5′
NH_4 applicator	12.5′	12.5′	17.5′	17.5′
Bulk spreader	24′	24′	24′	24′
Combine	185 bu./hr.	230 bu./hr.	325 bu./hr.	325 bu./hr.
Cornhead	2-40″	3-30″	4-30″	6-30″
Grainhead	12′	14′	16′	16′

tracts. Using the same pattern at each level of dispersion would affect variable costs.

Combinations of acreage, machinery capacity, and dispersion level were studied for two rainfall amounts: 19.1 inches during a relatively dry growing season and 28.8 inches during a relatively wet growing season. These rainfall extremes were selected to estimate the upper and lower bounds on net farm income as affected by rainfall.

Eventually we combined results from the dry and wet situations to present the analysis in a decision-making framework. Farmers work in a variety of weather situations and do not adjust size, dispersion, and equipment capacity on a year-to-year basis in response to anticipated weather conditions. Therefore the combined estimates from the dry and wet situations would represent more nearly an average situation.

Assumptions About Other Factors

Yield per acre per crop was the same on each tract except as dispersion affected timeliness, which in turn could affect yields. We did not consider the effect of different rainfall patterns on the physiological development of the crop plant, and consequently on yield. A model to formulate this complex yield-rainfall relationship was not available; thus, it was omitted. Consequently, profit estimates for dry compared with wet situations likely differ less in this model than in an actual situation.

Soil differences, which inevitably occur as dispersion increases and which affect yield and tillage practices, were not considered. Labor available was based on one full-time operator; hiring labor and custom harvesting were not considered. Family labor was assumed available to help during harvest. Planting and harvesting were scheduled to begin on a specified day, if field conditions would permit, for all equipment capacities, dispersion levels, and acreages. For corn and soybeans, tract acreage might vary if corn planting had been so delayed that it became more profitable to plant soybeans.

Flow Diagram and Sequence of Field Jobs

The day-to-day sequence of field jobs, simulated in a sequence of days, began April 1 and lasted until November 1. Job assignments and their priorities were made for each day. Optimum planting and harvest dates were based on recommended practices and information obtained from a survey of Kansas farmers published by Kansas Crop and Livestock Reporting Service. Figure 1 illustrates the job assignments and priorities each day for May, June, and July; the procedure was the same for other months. Field jobs were assigned priorities from 1 to 4, with 1 the highest priority. For example, highest priority on June 20 was to plant soybeans; then, wheat harvest would begin and, when completed, soybeans would be hoed.

Figure 2 is the flow diagram showing, in general, the decision process in the model. Each day, the model searched various tracts to determine field conditions and any job to be done and on which field.

Input data included the number of land tracts, size of tract, distance from dispersed tracts to home base of operation, distance between dispersed tracts, crop costs and returns based on expected yields (travel costs excluded), maximum hours of labor available each day, number and type jobs required on each tract, job priorities for each day, and field time of each job.

Simulating Rainfall

A computer-simulation-probabilisitc model developed by Ison, Feyerhern and Bark was used to estimate the sequence of wet and dry days and the amount of rainfall occurring each day from April 1 to November 1. Each day was divided into four 6-hour periods with a probability of a storm beginning for each period based on research by Changnon. The probability that a storm would begin during one of the periods changed as the seasons changed. Even if the program specified rain on a given day, field work might not be delayed the entire day,

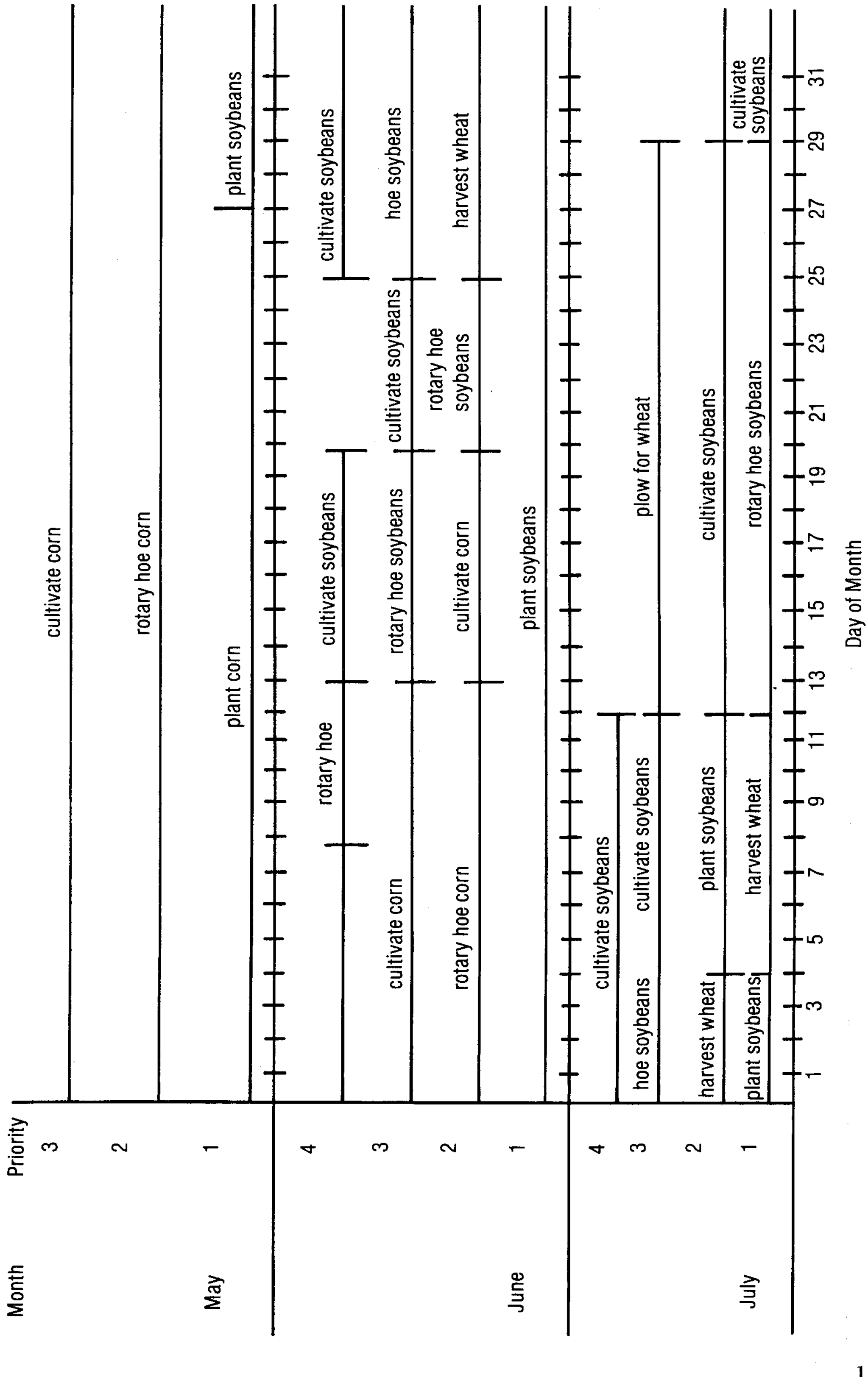

Figure 1: Sequence of daily field work with assigned priorities.

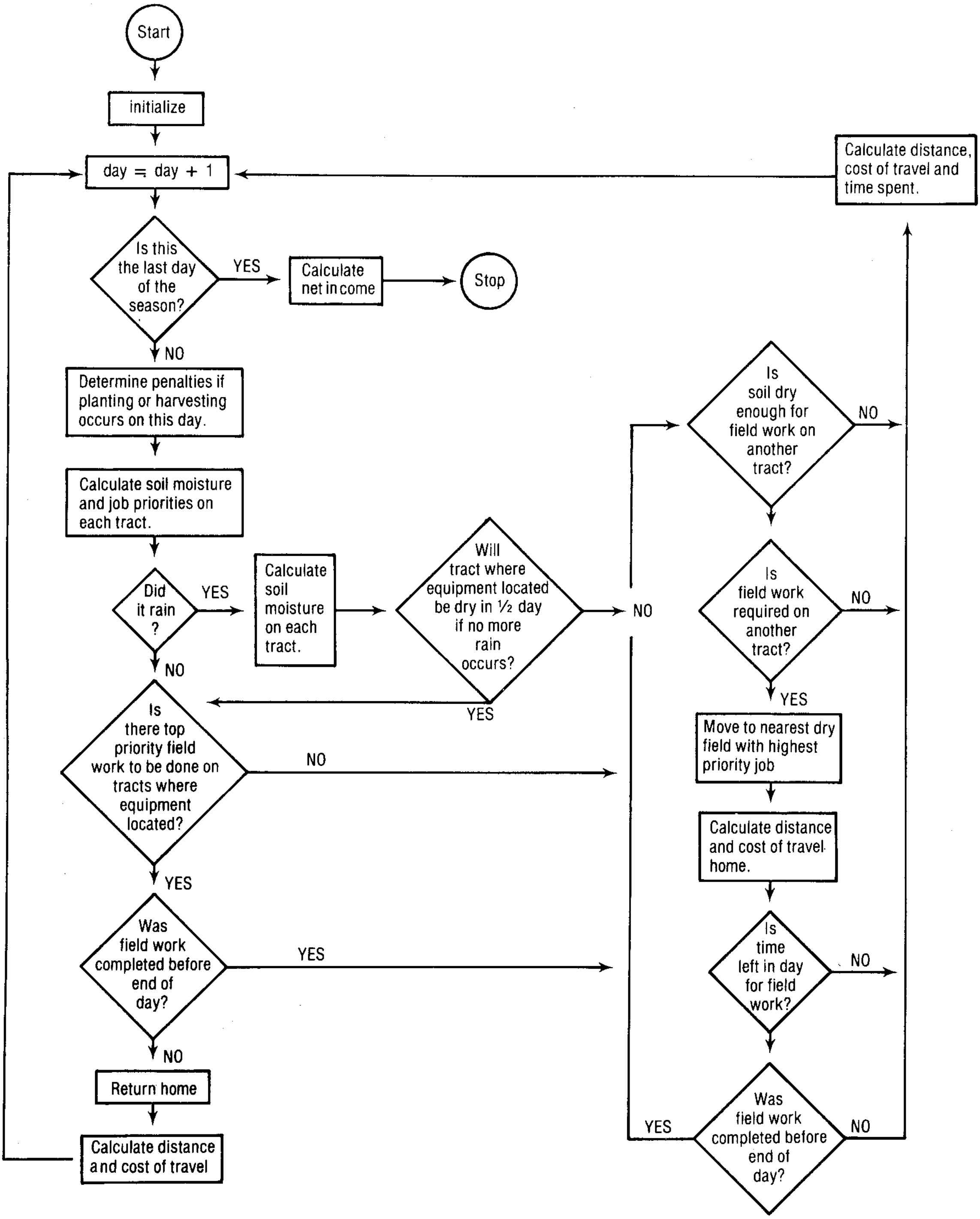

Figure 2: A Flow Diagram Showing the General Nature of the Decisions.

because rainstorms could be initiated at the beginning of any of the four periods. The model first determined, for each tract whether or not rain would occur on each day and at what time of day. If the weather check revealed that the amount of rain was sufficient to stop field work at a particular location, then the search for a dry field would begin.

Delay in Field Work

The length of delays in field work attributed to rainfall depends on the amount of rain. During field preparation and planting time, the exposed bare soil would dry relatively fast; a mature crop would shade the soil so that less evaporation would occur, and hence the soil would dry more slowly. However, for summer and fall harvest, the soil could be more moist than for tillage operations — just dry enough to support harvesting equipment. Because of lack of data, we assumed that precipitation during harvest time would cause the same delay as during field preparation and planting time. Table 3 gives the estimate of the delay in field work for specified amounts of precipitation in northeastern Kansas provided by William Powers.

Rainstorm Patterns

Rainstorm patterns for northeastern Kansas were estimated using rainfall data for Horton, Kansas and a model developed by F. A. Huff and are assumed appropriate for northeastern Kansas. Though most storms in that region move southwest to northeast, for simplicity we simulated their movement from west to east. We also assumed that rainstorms originate outside the area of the dispersed tracts, and then pass through it.

Amount of rainfall decreases as distance from the storm center increases. Consequently, it was important to determine the storm center in relation to the location of dispersed tracts. The north-south location of the storm center was determined, by using a pseudo-random number technique, so that for each simulation run the same location of storm centers would be repeated.

The relationship between amount of rainfall at the storm center and amount at various distances from the center is:

$$\log R = -1.359 + .51P^{1/2} + .33 \log D,$$

where R is the average difference between total rainfall at the storm center and at points located at distance D (miles) from the center, when rainfall (inches) at the storm is P. This relation is for warm seasons of spring, summer, and fall. Thus, whether or not dispersed tracts would receive the same amount of rainfall depends on their north-south distances from the storm center and the amount of rainfall at the storm center.

Interrupting Field Work

How long field work should be delayed depends on the amount of rain on the tract where field work is in progress and on other dispersed fields. The model was designed so that after a rainfall, if a field was judged too wet for work, a dry field would be sought.

TABLE 3. Field-Work Delays by Precipitation Level, Northeastern Kansas

Amounts of precipitation (inches)	Days field work is delayed
.05 or less	0
.05 to .20	1
.20 to .50	2
.50 to 1.00	3
1.00 to 3.00	4
3.00 to 10.00	5

Based on the equation above, if precipitation at one tract should exceed .5 inch, a farmer could expect to travel more than 20 miles to find a dry field. For some field operations several trips would be required to move all equipment (planter, spring tooth harrow, seed, fertilizer, and herbicide applicator) from one location to another. In our model, if less than .5 inch rain should fall on a field being planted, a move is made to a dry field, if within 20 miles. Should rainfall exceed .5 inch at the field being planted, however, no move would be scheduled that day because there could be no dry fields within 20 miles. The decision would be re-evaluated the next day.

Cost of Travel

Crop budgets include the usual variable costs for seed, fertilizer, fuel, oil, repairs associated with field work, herbicides, and hauling. For dispersed farmland, variable travel costs estimated at $.13 per mile for tractor fuel, oil, and repairs are added. With distance between fields provided in the initial input data, travel costs are determined as the product of the number of trips times distance times cost per mile. Thus, as distance or number of trips increased, because of rainfall interrupting work and requiring added travel to complete field work, total variable costs would also increase.

Crop Penalties

When rainfall frequently interrupts field work or equipment capacity is too small relative to crop acreage, crop planting or harvesting may be extended beyond the recommended period. Consequently, crop penalties would occur if planting is delayed past the optimum planting period, or if harvest is delayed past optimum harvest time. In the model the costs of these penalties are reductions in yields estimated from studies by Cooper, Laude, Pauli, Stickler and Luchele. Penalties resulting from both delayed planting and delayed harvest were specified in the model on the basis of relationships shown in

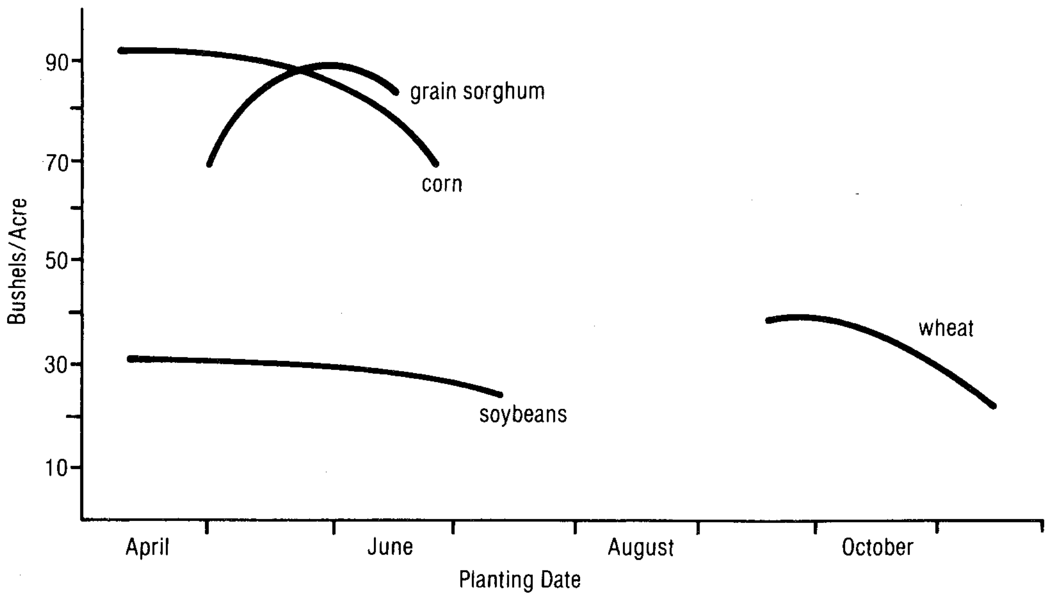

Figure 3: Expected yield per acre by planting dates for corn, soybeans, grain sorghum, and wheat.

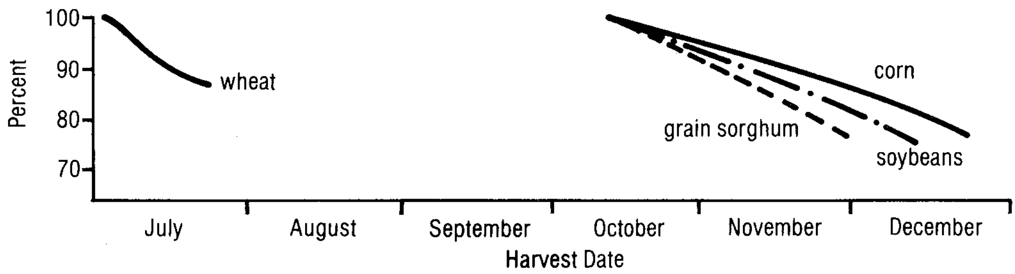

Figure 4: Percent of expected yield per acre harvested by harvest date for corn, soybeans, grain sorghum, and wheat.

Figures 3 and 4. The computer was programmed to begin as though planting and harvesting would occur to give the highest yield. Then, if delays caused by rainfall or lack of field work time should reduce yield, the estimated yields could be adjusted accordingly.

Crop Distribution and Decisions

Crop acreages were based on an average calculated from farm records of Northeastern Kansas farmers showing that in 1972, 12 percent of the cropland was planted to winter wheat and 88 percent to spring crops. That same allocation of cropland was used for each tract. Priority of land use among spring crops was based on net return per acre. In this region corn has higher expected average per-acre returns than does either grain sorghum or soybeans if it is planted before the end of May; thus, corn was given highest priority. If rainfall or size of equipment in relation to acreage should delay planting past May 30, then many farmers replace corn with grain sorghum and soybeans as most profitable crops for land-use changes. But to simplify the model, we did not include grain sorghum, because there are only three to five calendar days when planting grain sorghum would have priority over planting corn or soybeans. Thus, acreages in corn and soybeans were determined by number of field work days, size of equipment, and acres of cropland.

Calculating Net Farm Income

Explaining how we calculated net farm income probably can best summarize how the various variables interacted. The input data provided cost and return data for each crop. Variable costs included those for seed, fertilizer, herbicides, insecticide, fuel and oil for field work time, and repairs, as well as cost related to field work time and marketing or hauling. As the simulation run progressed through the sequence of day-to-day events, travel costs to and from fields — which included those for fuel, oil, and repairs associated with distance traveled — were added to the variable costs. As interruptions caused by rain increased or as distances to fields increased, the more costly the travel component becomes.

Also provided as input data was the maximum number of hours of field time available each day. Subtracting the time required for travel and time to allow a field to dry from the maximum time specified for each day determined how many days would be required to plant or harvest a specified number of acres. If the time required indicated there would be delays sufficient to cause a penalty in yield, the expected yield per acre would be reduced to make the appropriate calculation of gross income.

Depreciation, taxes, and insurance of equipment were included in calculating cost to show the increased ownership cost of large-sized equipment. Labor cost and cost of owning land were not included. Thus, gross income initially calculated could be adjusted by subtracting the usual variable costs, as well as costs for travel, equipment ownership, and any loss in income from crop penalties.

Validating the Model

The net returns for the simulation run of 320 acres and equipment capacity 4 ranged (at 1972 prices) from $15,269 to $17,766, depending on dispersion level and weather. Based on Farm Management Association records for 1972, the average size cash-crop farm in Brown County, Kansas was 365 acres. Net income of that average farm for 1972, if adjusted to a 320-acre basis, would be $16,271. The estimated profit of the actual farm then would lie within the profit range of the simulated farm.

In the simulation the range in farm size that minimizes total costs with equipment capacity 4 would be 565 to 645 acres, depending on the dispersion level and weather. The average Brown County cash-crop farm, however, might be smaller than that of the simulated situation because most crop farmers in that county also have livestock, though their main source of income is from crops. Thus, labor availability could reduce the number of acres the farmer could till. Also, Brown County farmers could have limitations on credit and capital available, which would limit the acres farmed.

Results

Tables 4 and 5 report the calculated profits for various combinations of acreage, dispersion level, and equipment capacity for the dry and wet years, without regard to higher yields probable with the wet year. Though rainfall usually increases yields and profits, we ignored that response to study only how rainfall would affect costs associated with increased travel and losses due to timeliness of work.

Profits are greatly influenced by the product prices and input costs, which remained constant in various situations studied. We believe that the general character or relationship among variables would hold for a reasonable price range.

TABLE 4. Estimated Total Profits for Alternative Farm Sizes, Dispersion Levels, and Equipment Capacities, During Dry Weather

		Farm size (acres)					
Disp. level	Equip. capacity	320	480	640	800	1120	1440
		Profits (dollars)					
A	4	17,463	27,117	31,810	31,362	-	-
	5	16,975	26,774	31,804	32,195	-	18,630
	6	16,299	26,354	30,858	31,775	32,416	29,610
	7	14,558	24,904	29,561	30,438	31,756	32,106
B	4	17,766	26,559	30,795	29,515	-	-
	5	17,148	26,082	30,581	30,605	-	16,449
	6	16,462	25,493	29,514	30,998	29,432	18,383
	7	15,019	24,000	28,059	28,815	28,842	27,580
C	4	15,336	24,222	27,932	25,132	-	-
	5	14,934	24,224	28,583	27,438	-	-
	6	14,406	23,869	27,915	28,975	20,222	9,466
	7	13,082	22,550	25,998	26,792	25,750	18,640

[a]Dispersion level A, contiguous tracts; B, moderately dispersed tracts approximately 6 miles from base; and C, widely dispersed tracts approximately 16 miles from base.

TABLE 5. Estimated Total Profits for Alternative Farm Sizes Dispersion Levels, and Equipment Capacities, During Wet Weather

		Farm size (acres)					
Disp. level	Equip. capacity	320	480	640	800	1120	1440
		Profits (dollars)					
A	4	17,446	27,033	31,793	30,747	-	-
	5	16,810	26,704	31,781	31,998	-	15,430
	6	16,194	26,197	30,721	31,760	32,009	-
	7	17,696	24,713	29,438	30,167	31,192	31,464
B	4	17,753	26,536	30,631	29,248	-	-
	5	17,060	26,024	30,532	30,391	-	12,243
	6	16,365	25,362	29,482	30,812	27,202	13,980
	7	14,935	23,841	28,020	28,616	28,195	25,583
C	4	15,269	24,029	27,434	24,169	-	-
	5	14,905	24,205	28,453	26,933	-	-
	6	14,390	23,849	27,736	28,444	17,250	5,456
	7	13,058	22,426	25,802	26,564	23,589	12,735

[a]See footnote Table 4.

Data from Tables 4 and 5 were combined and a quadratic equation fitted because farmers do not know at planting time whether the year will be wet or dry. Thus, the following equation based on combined data would probably be better than using equations based on the dry and wet situation for evaluating the effect of different combinations of sizes, acres, and dispersion:

$$(1)\quad NFI = 14646 + 54.47S + 224.7D - 3512.12C - .0449S^2 - .8177 (S) \cdot (D) + 5.2807 (S) \cdot (C)$$
$$R^2 = .89,\ F(6,116) = 150,$$

where NFI is net farm income, S is size in acres, D is dispersion in miles, and C is equipment capacity expressed as moldboard plow size. Variables allowing for diminishing profits to dispersion and capacity were tested, but estimates from the equations were less satisfactory than estimates using equation 1.

The relation shows that profit increased at a decreasing rate as size increased. However, increases in dispersion level and equipment capacity could be associated with increases in size.

The relationship of size, dispersion, and machinery capacity is evaluated by differentiating equation 1 with respect to each variable:

$$(2)\quad \frac{dNFI}{ds} = 54.57 - .0898S - .817D + 5.2807C$$

$$(3)\quad \frac{dNFI}{dD} = 224.72 - .8177S$$

$$(4)\quad \frac{dNFI}{dC} = 3512.13 + 5.2807S$$

Equation 3 shows that increasing dispersion would decrease NFI for size exceeding 275 acres. With the machine capacity considered in the study, the effect of tract dispersion would be relatively unimportant on small acreages.

Equation 4 shows that increasing machine capacity above capacity level 4 would increase NFI only for sizes larger than 665 acres. NFI would be larger if tract dispersion were less; however, NFI would be the same for all machinery capacities at the 665 acreage.

The most profitable farm size for various dispersion levels and equipment capacities can be calculated by using equation 2. The results are shown in Table 6. The most profitable size can be estimated by specifying alternative sizes of equipment and dispersion distances, and then finding the value for the acreage. The interaction of size with dispersion and equipment capacity shows that the benefits from large equipment can offset costs of dispersion as size increases.

Table 6 indicates that an increase in equipment capacity of one plow would be needed to offset a 6.5 mile increase in dispersion. However, if size is increased (and consequently dispersion), the effect of increasing equipment capacity to offset costs would be much greater. If farm size is increased by 160 acres, and that increase also increases the dispersion level by one mile, then equipment capacity must increase by 1.6.

The most profitable size in crop acres increases about 59 acres with each unit increase in machinery capacity. That increase held for all dispersion distances studied. Profits increased at an increasing rate of about $300 for each increase of 59 acres and each unit increase in machinery capacity. Most profitable size decreases about 8 acres for each mile of increase in dispersion; that decrease held for all dispersion distances studied.

NFI decreases as dispersion increases; NFI increases as machinery capacity increases. The decrease in most profitable size more than offset the effect of larger equipment. However, with a given machinery capacity, the decrease in profits was constant for each mile increase in dispersion. Some of these relationships were based on characteristics of a quadratic equation, and so the statistical fit of the equation to the data was important here. The statistical measures of R-squared and F were reasonably good. Thus, we believe the equation described the data at an acceptable level of reliability.

Implications

Farm management researchers should be explicit about the extent of cropland dispersion that is assumed when studying economies of farm size. Increased travel costs, less time for field work and the effect of non-timely field work on crop yields are several of the problems that may cause per unit variable costs to increase or per unit net income to decline if land tracts are widely dispersed. Studies of economies of size focus on per unit costs in relation to output, but the effect of nontimely field work reducing crop production is to reduce gross income and not to increase cost. Thus, the total effect of in-

TABLE 6. Most Profitable Farm Size for Dispersion Distances and Equipment Capacities

Size, acres	Equipment capacity	Dispersion (miles)	Net Farm income (dollars)
833	4	1	31,957
892	5	1	32,995
950	6	1	34,346
1009	7	1	36,998
787	4	6	29,767
846	5	6	30,568
905	6	6	31,678
964	7	6	33,099
696	4	16	25,950
755	5	16	26,269
814	6	16	26,899
873	7	16	27,839

creasing output by increasing acreage that is widely dispersed will not be included if the study relates only to cost.

The reduction in income caused by dispersion may be offset, within limits, by machinery of greater capacity. The model estimates that an increase in plow capacity of 1 unit is needed to offset the effect of 6.5 mile increase in dispersion. Thus, two farms with the same crop acreage but one with acreage dispersed an average of 6.5 miles more would need 1 plow capacity larger to get the same amount of field work done in the same number of days. If crop acreage increases 160 and consequently dispersion increases an average of 1 mile, the estimate is that an additional 1.6 plow capacity is needed.

In general, the results agree with the observations of the authors and of farm management extension economists: relatively small farms can be widely dispersed without greatly affecting net income; farmers with many widely dispersed tracts have trouble getting their field work done on time during critical periods and need larger equipment. The parameters of the equation developed seem reasonable, although the results show a bias in the model in the amount of field work that can be done at each capacity level, and consequently farm size and net farm income for equipment capacity studied are too high. However, all cases studied have the same bias; thus, differences among situations studied could still be correct.

Although this study was of a northeast Kansas farm situation, the problem exists in western regions of the Great Plains as well. Although many farms may be of a size so that the tracts need not be widely dispersed, increasing numbers of farmers face the management problems associated with widely dispersed tracts. Results estimate that increasing dispersion may decrease net farm income if crop acreage exceeds 275. Northeast Kansas farm management association records show 64 percent of farms larger than 320 acres. Thus, based on the results, most farmers in northeast Kansas are of the size that land dispersion may have an economic effect.

In evaluating the model, we believe the approach used to be very useful. However, programming rainfall events for each of four daily periods was probably the most difficult aspect of the model. Although the time of day when rain storms begin varies from April through October, it is doubtful that the trouble of adding that degree of realism would have been worth the increased accuracy. We believe it was well to simulate the rain event as though it would occur at the beginning of each day and calculate the delay from that time.

Since this model was developed, improved methods of estimating soil moisture have been developed. It is difficult to evaluate accurately how well the model would have depicted the delay in field work caused by rainfall. Results simulated for a dry and a wet situation did not show as much difference as anticipated. Thus, using a soil-moisture-estimator program as a subroutine in the model to estimate the soil moisture at each tract each day might have improved results.

Developing a discrete sequential simulation model for the type of problem studied requires data in form and type not now readily available or obtainable. Such modeling, however, can specify types of data that might be useful to a farmer and often are needed by researchers. Since we began our study, more information on weather, soils and equipment is becoming available for use in improving this type of a model.

References

Changnon, Stanley., Jr. "Precipitation in a 550-square mile area of Southern Illinois," Reprint from Transactions of the Illinois State Academy of Science, 56(1963):177-78.

Cooper, Richard L. "Influence of Soybean Production Practices on Lodging and Seed Yield in Highly Productive Environment," *Agronomy Journal*, 63(1971):490-493.

Greenberg, Stanley. *General Purpose Simulation System Primer.* New York: Wiley-Interscience Division of Wiley and Sons, Inc. 1972.

Huff, F. A. "Rainfall Gradients in Warm Season Rainfall," *Journal of Applied Meterology,* 6(1967):435-437.

Ison, N. T., A. M. Feyerherm and Dean Bark. "Wet Period Precipitation and the Gamma Distribution," *Journal of Applied Meterology,* 10(1971): 658-665.

Johnston, Warren E. "Economies of Size and the Spatial Distribution of Land in Farm Units," *American Journal of Agricultural Economies,* 10(1972):645-657.

Laude, et. al. *Growing Wheat in Kansas,* Kansas Agricultural Experiment Station Bulletin, 370(1955):21.

Luchele, W. F., M. Farrell, H. Waelti. "Progress Report on Losses Associated With Corn Harvesting in Iowa," *Journal of Agricultural Engineering Research,* 14(1969):134-138.

Pauli, A. W. and F. L. Stickler, *Yield and Yield Components of Grain Sorghum as Influenced by Date of Planting,* Kansas Agricultural Experiment Station Technical Bulletin, 130, August 1963.

Powers, William. Department of Agronomy, Kansas State University, Manhattan, Kansas.

Stickler, F. C., R. F. Sloan and M. A. Younis, *Kansas Crops, Planting to Harvest,* Kansas Crop and Livestock Reporting Service, Topeka, Kansas, 1974.

Response of Grain Sorghum Hybrids of Varying Maturity to Planting Date, Kansas Agricultural Experiment Station Report of Progress 109, June 1965, Figure 2.

"Planting Crops in Kansas." Cooperative Extension Service, Kansas State University, 1970.

Successful Farming, "New Machines That Work Wider — Fold Narrower," February, 1978, p. 24.