COMMUNITY ECONOMICS: A SIMULATION MODEL FOR RURAL DEVELOPMENT PLANNERS

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Rural areas and small towns are facing new challenges as their economies grow and develop. The population influx to nonmetropolitan areas has brought new and increasing demands for community services. Preliminary 1980 census figures indicate that nonmetropolitan counties increased by about 15 percent, whereas metropolitan counties increased by about 9 percent from 1970 to 1980 (Beale). Many mining, resort-retirement, and urban fringe counties increased in population by 40 to 50 percent or more. At the other extreme, nearly 500 of the 2,485 nonmetropolitan counties continued to decline in population during the 1970s (Secretary of Agriculture).

The trend toward fiscal federalism, inflationary pressures, and high interest rates creates planning and development problems for local decision-makers. Rapid population growth greatly magnifies these already serious problems. Since planning community services often entails large capital outlays, it is important to base plans on available employment, income, and population information. A water or sewer treatment plant built too large or too small can be very expensive and embarrassing to elected officials. Similarly, decision-makers in declining or stagnating rural areas need to properly plan so that their scarce resources are efficiently allocated.

This paper illustrates how extension professionals can utilize community simulation models to aid local decision-makers. More specifically, the objectives are (1) to review several community impact models, (2) to present an overview of methodology used in a community simulation model, and (3) to present an application of the community simulation model.

REVIEW OF IMPACT MODELS USED TO ANALYZE COMMUNITY GROWTH AND DEVELOPMENT

Impact models describe economic and demographic changes affecting both the public and private sectors. Private sectors impacts include changes in employment, income, and output by industry or group. Public sector impacts include changes in local government revenue and changes in the need for public services. Population changes and demographic trends are related to these impacts. With shifting populations, economic changes, and energy development, reliable impact models are increasingly useful. Many types of models and methodologies have been developed. These range from economic-base analysis to complicated community simulation models. Some are briefly summarized below (see Murdock and Leistritz for a more complete review).

An early version of an impact model was developed by Shaffer and Tweeten. It was designed to measure the impact of new industry on rural communities in Oklahoma. The model provides results for the private sector, public sector, and school district. A framework for calculating net gain (loss) to the community was also included. This calculation of net gain (loss) allowed community leaders to evaluate any inducements they were considering offering a prospective industry. The model is notable because of the emphasis placed on making it useful and understandable to local leaders. The model utilizes partial budgeting techniques and is a single-period tool with no dynamic time considerations. Shaffer and Tweeten note the difficulty of estimating the indirect and induced effects at the community level because there are no published rural community input-output tables. Two of the authors' conclusions are that industrial impacts vary over different economic sectors and that they differ among communities.

Ford presents a computer model, BOOM 1, that is designed to describe the impacts of locating large power plants near small, isolated communities. Small towns in the western states that experience this type of impact generally go through an initial "boom" period of rapid expansion. Following the initial construction phase, economic and demographic changes level off. Characteristics of the population immigrating during the construction phase are often quite different from the characteristics of the indigenous population. Public service capital and economic activity are often expanded to support the rapid population growth, putting a strain on the budget of the public sector. Following completion of the energy project, a "bust" period often follows. Tax revenues decrease, and the local government is left with excess capacity in the public sector. The BOOM 1 model provides annual economic, demographic, public service, and fiscal projections of the

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proposed impacts for the city of interest. A series of feedback loops is utilized to provide dynamic projections from year to year.

A community-level impact model was developed for use in Florida (Clayton and Whittington). The model is an *ex ante* evaluation of the impacts of community growth. Output of the model includes employment and population changes resulting from an outside impact, such as a new industry. Private sector impacts include such variables as direct, indirect, and induced sales from the impact being analyzed. Public sector impacts include projection of local revenues and expenditures. A net fiscal surplus (deficit) is calculated, along with a break-even property-assessment rate. City, county, and school district levels of government are included. The Florida model emphasis user access by providing default data when local data are not available. Default data are averages or research-based estimates used when actual local data are not available. This type of data availability increases the usefulness of the model and allows more timely analysis.

A model has been developed in North Dakota (Leistritz et al.) to measure the impact of energy developments. The model provides annual impact and base-line projections of the following key variables: employment, population, settlement patterns, school enrollments, housing requirements, and public sector costs and revenues. Like the model for Florida, the North Dakota model relies heavily on the input-output portion of the model. Output of the model is provided at the state, county, city, and school district level. The complex process of interfacing economic projections with population growth is well documented.

As can be seen from a very brief review of selected impact models, a wide range of methodologies exists. Some models measure energy resource development impacts, some measure the results of industrial development. Some impact models can also project base-line growth for comparison with the resulting growth from some outside impact. Developing new and innovative methodologies is necessary to continually improve the models. Adaptation of existing models provides additional checks on model validity. Model builders should utilize the 1980 census results to improve and verify modeling efforts.

Model adaptation involves converting a model used in one state for use in another state or area. This process can be successfully accomplished if care is taken to replace original data with more appropriate data for the new area being considered. This can take considerable time, but may be more efficient than developing a new model. An example of model adaptation is the model developed for Virginia by McNamara and Brokaw. The Virginia model draws from the work of Shaffer and Tweeten and provides similar output. Another adaptation is the model developed for Texas by Reinschmiedt et al., which also draws from the Shaffer-Tweeten methodology. The Texas model is notable because of computerization and a complete user package, which makes the model accessible and easy to understand for potential extension clientele (Woods and Jones).

Another model developed for Texas measures the impact of large-scale energy projects on rural areas (Murdock et al. 1979). The model draws from methodology developed with the North Dakota model (Leistritz, et al.). Extensive effort was necessary to apply the model in Texas. Alternate data sources and estimating techniques should be considered when adapting a model for use in another state. Murdock et al. (1980) note that the effort should not be taken lightly. If possible, a member of the team building the original model should be consulted during the effort.

The community simulation model discussed in this paper was recently developed at Oklahoma State University (Woods) and builds on the works summarized above. To facilitate extension application, special efforts have been made to make the model dynamic, community-specific, and easy to adapt.

THE COMMUNITY SIMULATION MODEL

The community simulation model has four accounts: an economic account, a capital account, a demographic account, and a government account. The accounts contain the data utilized in the simulation model equations. An overview of the community social accounting system is presented in Figure 1.

The economic account utilizes a national or state input-output (I-O) transactions table to derive a local I-O table. The national I-O table is aggregated to nine endogenous sectors as specified in Table 1. A location quotient procedure similar to that described by Mustafa and Jones is employed to estimate the local I-O table using national sector output values, local and national employment by sector, and labor productivity rates. The resulting local I-O transactions table has nine endogenous sectors and final demand categories for household consumption, private capital formation, inventory charge, net exports, state and local government expenditures, and federal government expenditures.

Total final demand (FD) is estimated as the sum of individual demand components:

Table 1. Projected Employment by Sector for Holdenville, Oklahoma, Selected Years, 1972–1990

SECTOR	EMPLOYMENT 1972	1975	1980	1985	1990
AGRICULTURE, MINING	164	184	220	273	343
CONSTRUCTION	34	62	63	98	156
MANUFACTURING--NONDURABLE	178	153	117	109	109
MANUFACTURING--DURABLE	1	143	121	142	168
TRANSPORTATION	25	30	30	34	41
COMMUNICATION, UTILITIES	60	43	30	30	31
WHOLESALE AND RETAIL TRADE	252	312	365	493	693
FINANCE, INSURANCE AND REAL ESTATE	256	298	355	461	616
EDUCATIONAL AND PROFESSIONAL SERVICES	629	703	803	989	1,262
TOTAL WAGE AND SALARY	1,599	1,928	2,104	2,629	3,419
TOTAL PROPRIETOR	1,112	1,161	1,106	1,125	1,133
TOTAL	2,711	3,089	3,210	3,754	4,552

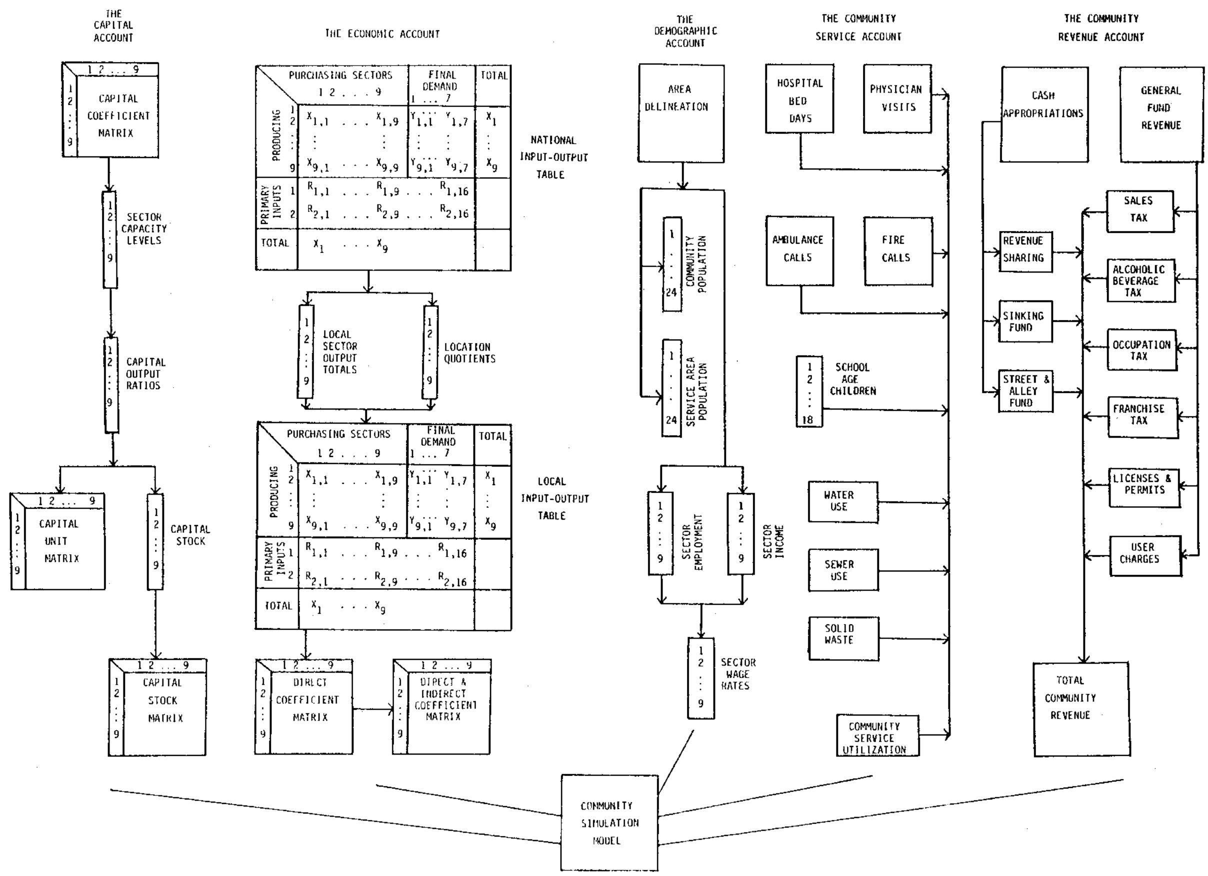

Figure 1. Overview of the Community Social Accounting System

$$(FD)_t = (HHT)_t + (PCF)_t + (CINV)_t + (FG)_t + (GSL)_t + (EX)_t$$

where:

$(FD)_t$ = a column vector of total final demand in year t,
$(HHT)_t$ = column vector of total household expenditures in year t, with individual estimating equations for durable, nondurable, and service purchases included,
$(PCF)_t$ = column vector of composition of total investment in year t,
$(CINV)_t$ = column vector of net inventory change in year t,
$(FG)_t$ = column vector of federal government purchases in year t,
$(GSL)_t$ = column vector of state and local government purchases in year t, and
$(EX)_t$ = total net export demand by sector for year t.

Final demand values are projected annually for the various categories. Historical values are derived from local data if available. Output by sector required to produce estimated final demand is: $(\text{output})_t = (I - A)^{-1}(FD)_t$. The $(I - A)^{-1}$ term is the inverse matrix where A is the direct coefficient matrix. These final demand projections and associated output levels are the driving force of the model.

The capital account contains data necessary for estimating another final demand category, private capital formation. Capital expenditures consist of new plant and equipment investment, as well as replacement investment used to replace old or depreciated capital. Capacity output is estimated as:

$$(XDC)_t = (XDC)_{t-1} + \left[\frac{1}{(A4)_{t-1}} (VN)_{t-1}\right]$$

where:

$(XDC)_t$ = column vector of sector output at capacity level in year t,
$(VN)_{t-1}$ = column vector of new plant and equipment investment in year t − 1, and
$(A4)_{t-1}$ = column vector containing average capital-output ratios.

New plant and equipment investment is estimated as:

$$\text{IF } (XD)_{t-1} \leqslant (XDC)_t \, S8$$

$$\text{THEN } (VN)_t = 0$$

IF $(XD)_{t-1} > (XDC)_t S8$

THEN $(VN)_t = (A4)_t[(XD)_{t-1} - (XDC)_t S8]$

where:

$(XD)_{t-1}$ = column vector of sector output necessary to meet estimated final demand in year $t-1$, and

S8 = 90 percent of the upper limit of capacity.

Therefore, when a sector reaches an output level above 90 percent of possible capacity, investment in the new plant and equipment occurs. Replacement investment $(VR)_t$ is based on annual capital stock levels and depreciation rates by sector. Total investment $(V)_t$ then is:

$$(V)_t = (VN)_t + (VR)_t.$$

The capital account contains data on capital/output ratios, capacity levels, and stock levels by sector, as well as rates of growth allowing annual projections. The capital investment information allows more realistic projections over time. The capital equations also provide an entry point for impact analysis. A new industry and the associated capital/output relations can be simulated through the equations.

The demographic account contains information related to the community population as well as the service area of the community. A gravity model is employed to estimate the community service area. The gravity model compares the population of a given community to that of a nearby competing community to determine a community service area. The form of the gravity model (Carroll) is as follows:

$$\frac{P_i}{D_i x} = \frac{P_j}{D_j x} \quad \text{or } D_j = \sqrt[x]{P_j/P_i} \quad D_i$$

where:

P_i, P_j = population names of cities i and j respectively,

D_i, D_j = distances from the respective cities to the point of equal influence, and

x = exponent showing the effect of distance.

The boundary for a community service area was estimated using a coordinate system. The community of interest has coordinates (0,0), and competing communities are given locational (x,y) coordinates. Four competing communities form a boundary with city (0,0), and a geometric figure representing the service area is formed. The area in square miles within the service area is then estimated. Based on county and city population values, the service area is assigned a proportion of the total country population. This information is useful in analyzing the communities' service area and in planning for services such as emergency medical care.

The demographic account also contains equations comprising a cohort-survival population predictor. Using birth rates, death rates, and migration rates, the population of both community and service area are predicted annually by age-sex categories. The economic account and demographic account are linked through an interface procedure. The economic account provides projections of final demand, which through I-O coefficients provide sector output estimates. Employment requirements by economic sector are estimated using labor productivity rates. The demographic account simultaneously provides population projections. Labor force participation rates are used to estimate the available labor force. Net migration is then based on a comparison of employment requirements with the available labor force. Migration is not immediate, but occurs within acceptable boundaries of the local unallocated labor pool (Murdock et al. 1979). This interfacing procedure occurs for each year with the previous year's net migration included in the demographic account.

The government account contains coefficients allowing projection of community revenue by source and need for community services. The sources of revenue include sales tax, alcoholic beverage tax, occupation and franchise taxes, licenses and permits, fines, and user charges for services. The Oklahoma State Board of Equalization requires all cities to file annual reports dealing with revenue and income estimates, so this information is readily available. Detailed community service information is also included in this account. Based on the economic and demographic projections of the model, annual projections for the following are provided: hospital bed days, physician visits, ambulance calls, fire calls, school-age children, water requirements, sewer volume, and solid-waste generation. In all cases except for water, sewer, and solid waste, the estimates are provided for the city and the service area separately. Research-based coefficients are used to estimate the various community service requirements. For example, the estimate of hospital bed days is based on work by Dunn and Doeksen and estimates of bed days by disease category are based on specific age-sex population categories. Total bed days are then summed across disease categories.

The complete simulation model contains over 200 equations linking the various accounts and describing the community economy. The model is described in detail by Woods.

MODEL APPLICATION

To illustrate the model, a recent application for Holdenville, Oklahoma, is presented. The first step is to estimate a "base-line run" associated with historical growth rates and trends with no outside impact, such as a new industry. The model simulated values for economic and demographic variables by year from 1972 to 1990. Base-line projections are presented in Tables 1 through 4. Projections of employment for selected years are presented in Table 1. Many of the future jobs are expected to be in the service type sectors of wholesale and retail trade, finance and insurance, and educational and professional services. Proprietor employment is projected to increase slightly. The model projects population by age and sex categories. Aggregate data for the community and for the service area are shown in Table 2. Population is projected to increase from 8,756 in 1972 to 11,182 in 1990. The 1980 population was projected to be 8,939, while preliminary 1980 census data show a population of 9,201.

The government component, which predicts service needs, may be the most useful section of the model. Base-line projections of community service needs for the Holdenville area are shown in Table 3. Hospital bed days per year are projected to increase from 16,508 in 1980 to 19,319 in 1990. These estimates are based on hospital utilization rates for each age and sex category as estimated in the model (May, Doeksen, and Green). For each community service, detailed research has been completed to facilitate usage predictions based on local conditions. For a summary of community service studies, see Doeksen and Nelson.

The projections of service needs should be combined with local information on "excess capacity." Often, growth will be desirable; for example, unused hospital beds or empty classrooms could be fully utilized. The degree of excess capacity will vary by community and type of service. An estimate of general-fund revenue available to Holdenville to support additional services and other local government functions was made for each year from 1972 through 1990. Estimated annual revenues for selected years are presented in Table 4.

The second step of the analysis involves simulating the impact of the prospective new industry as a deviation from the base-line run. In this case, a new plant employing 50 workers was considering locating in Holdenville in 1982. The community leaders wanted to project the impact of the plant. The Oklahoma State University (OSU) community simulation model was run, and through comparisons of these estimates to base-line estimates, the impact of the plant was measured. Selected impacts measured in this way are presented in Table 5. These are the net impacts or additional jobs, service requirements, and so forth associated with a new plant location in the community. The simulation model projects wage and salary employment to increase by 115 in 1982 and 94 in 1990, due to the new plant. Likewise, physician visits are projected to increase due to the plant by 799 per year in 1982 and 550 per year by 1990.

One function of the OSU community simulation model is to allow decision-makers to estimate the impact of a change in their community's service needs and revenues. They can then determine when the capacities of existing systems will be reached and what additional capacities should be designed into system constructions or renovations.

USER CHARACTERISTICS OF THE COMMUNITY SIMULATION MODEL

Debertin and Goldman list several functions for extension professionals in impact analysis: (1) education

Table 2. Projected Population for Holdenville, Oklahoma, and Service Area, Selected Years, 1972–1990

	POPULATION YEAR					
AREA	1972	1975	1980	1980 a	1985	1990
HOLDENVILLE	5,222	5,388	5,215	5,373	5,662	6,397
SERVICE AREA	3,534	3,723	3,724	3,828	4,152	4,785
TOTAL	8,756	9,109	8,939	9,201	9,814	11,182

[a] Census Data

Table 3. Projected Community Service Needs for Holdenville and Service Area, Selected Years, 1972–1990

MEASURE OF COMMUNITY SERVICE NEEDS	YEAR 1973	1975	1980	1985	1990
HOSPITAL BED DAYS (PER YEAR)	16,364	17,163	16,508	17,536	19,319
PHYSICIAN VISITS (CLINIC) (PER YEAR)	30,744	32,240	31,565	34,535	39,224
AMBULANCE CALLS (PER YEAR)					
HOLDENVILLE	227	240	233	244	261
SERVICE AREA	108	118	124	140	162
TOTAL	335	358	357	384	423
FIRE CALLS (PER YEAR)					
HOLDENVILLE	83	86	84	91	103
SERVICE AREA	56	60	60	66	77
TOTAL	139	146	144	157	180
WATER a (THOUSAND GALLONS/YEAR)	168,600	176,158	170,764	185,893	209,486
SEWER a (GALLONS/DAY)	519,328	541,656	524,553	569,796	643,512
SOLID WASTE a (CUBIC YARDS/DAY)	389	406	393	427	483

[a] Holdenville Community Only

Table 4. Projections for General Fund Revenue for Holdenville, Selected Years, 1972–1990

	YEAR				
REVENUE SOURCE	1973	1975	1980	1985	1990
	THOUSANDS OF CURRENT DOLLARS				
SALES TAX	223	309	519	922	1,688
ALCOHOLIC BEVERAGE TAX	30	32	31	33	38
USER CHARGES AND OTHER	200	207	200	218	246
TOTAL	453	548	750	1,173	1,972

Table 5. Projected Impact Due to New Plant Locating in Holdenville in 1982, 1982–1990 Selected Years

	YEAR 1982	1985	1987	1990
WAGE AND SALARY EMPLOYMENT	115	166	115	94
POPULATION (PER YEAR) a	225	317	208	156
HOSPITAL BED DAYS (PER YEAR) a	440	603	388	283
PHYSICIAN VISITS (PER YEAR) a	799	1,122	735	550
AMBULANCE CALLS (PER YEAR) a	10	15	9	7
FIRE CALLS (PER YEAR) a	4	5	4	3
WATER a (MILLION GALLONS/YEAR)	7.3	10.5	6.8	5.2
SEWER a (THOUSAND GALLONS/DAY)	23	33	21	16
SOLID WASTE a (CUBIC YARDS/WEEK)	17	25	16	12
GENERAL REVENUE ($1000) (PER YEAR)	25	37	27	25

[a] Holdenville Community Only

and training, (2) assistance in interpreting and understanding a report, (3) working with local government in doing an impact analysis, and (4) advice on selecting consultants.

Use of the OSU community simulation model by Oklahoma extension personnel addresses categories 1, 2, and 3. In working with local government leaders to conduct an impact analysis, researchers must assist with the interpretation of the analysis. Working closely with local officials provides an educational opportunity for which extension personnel are well trained.

For the successful utilization of any impact model, outputs must be suitable for use and understandable to decision-makers. Fox discusses the development of impact models from a user's viewpoint. Governments at all levels are faced with decisions that would be greatly aided by impact model forecasts. Fox emphasizes the fact that user confidence will be enhanced by more accurate and useful models, thus increasing clientele support. For users to utilize models to best advantage, they need to understand the basic model assumptions and structures. If information is clearly communicated to layman users, less misinterpretation will occur. Users should be encouraged to ask as many questions as necessary to understand the model.

An important key for local government is to conduct the impact analysis and link the findings to important variables such as water usage, sewer volume, and other community services. Leaders can compare service needs to available capacity levels. When additional information is needed for a specific service, say a water system, budgets analyzing capital and operating costs can be used (Doeksen and Nelson).

Several aspects of the delivery of community-impact information to local decision-makers are critically important to extension workers. Community simulation and impact models must be easily adaptable to specific communities and accessible for quick delivery. The OSU model requires community-specific data for employment, income, population, and miles from neighboring communities. Once these data are entered, it can be run for any community. The interactive computer program provides timely results for the user and also allows repeated runs using alternative assumptions.

It is important to respond to the information needs of local decision-makers as rapidly as possible. The OSU model is written to facilitate rapid output of information that can be readily compiled into a community report. OSU personnel attempt to complete analyses within two to four weeks of a request. A computer terminal is then taken to the field when the study is presented so that additional community simulation runs can be made if local decision-makers wish to change certain variables.

SUMMARY

Rural development planners are facing new challenges as rural economies grow and develop. This paper has presented a simulation model developed for analysis of community economic development and change. The simulation model contains four major accounts or data bases: an economic account, a capital account, a demographic account, and a government account. The complete simulation model contains over 200 equations linking the various accounts and describing the community economy.

Useful characteristics of the Oklahoma model not always present in previous work include the community-specific analysis. Also, use of a gravity-model analysis to estimate the community service area is an addition to impact analysis. Finally, the model contains much information on community services and facilities based on primary research in the region where the model is being used. The model simulates a community economy and provides more information (employment, services, population by age) than normally found in impact models.

A limitation of the model in its present form is the use of a location quotient technique to estimate a local input-output table. The nonsurvey technique is not as accurate as a survey, but time and cost prohibited a survey. Further work should concentrate on refining community service relations to a community economy. Also, use of impact models for communities with declining economic bases would provide useful planning information.

In summarizing use of this model or others, extension workers need to provide (1) community-specific analyses, (2) quick responses to community requests, and (3) written reports of the results of analyses to each community. Community simulation models, presented in this manner, will serve to build an extension clientele as assistance is given to leaders of rural communities.

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