"Computer Simulation in Pastoral Nomadic Development"

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COMPUTER SIMULATION IN PASTORAL NOMADIC DEVELOPMENT

by Dan Boneh

What are the potential applications of computer simulation techniques in development efforts concerning pastoral nomadic populations? This paper briefly explains the concept of simulation and explores the ways in which it can be applied to pastoral nomadic development.

Computer simulation in anthropology is utilized in those areas where quantitative analysis seems plausible. Several simulation models were developed in demographic analysis concerning questions such as human population structures, population survival, the effect of infant death on birth intervals; also addressed by such models have been anthropological concerns such as residence rules and cousin marriages and their effect on population structures. A detailed survey of these studies can be found in Dyke and MacCluer (1973) and Dyke (1981). Simulation models are also used by archaeologists in their attempts to project from fragmentary evidence to prehistoric settlement types (Doran 1972; Hodder 1978), as well as by working in the reverse order, examining modern population sites and simulating models for what existed in prehistoric times (Ammerman et al 1978). Of relevance to scholars of pastoral nomadism are simulation studies of human ecosystems of which there are a few using data from an Andean population group (Blakenship and Thomas 1977; McRae 1983), and others using the system dynamics approach (Gutierrez 1980; Picardi 1975).

The use of computer simulation in international development efforts has only recently begun with a microcomputer simulation package dealing with population dynamics in developing countries. USAID is presently offering a RAPID program on the Apple II microcomputer with which it is able to simulate, for the host country, different trends in population dynamics and future developments that are likely to occur depending on different policy alternatives.

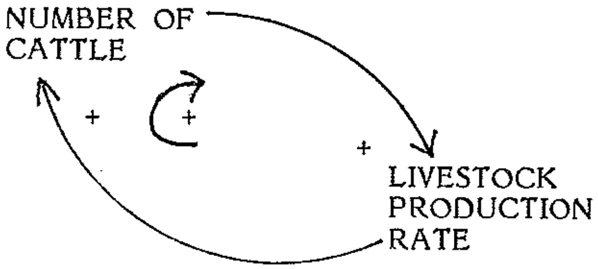
Simulation "is the process of designing a model of a real system and conducting experiments with this model either for the purpose of understanding the behavior of the system, or of evaluating various strategies for the operation of the system" (Shannon 1984:95). A simulation model seeks to provide structure and definition to a particular phenomenon (viewed as a system), to identify key variables, to quantify them and examine the interactions between the variables. In any complex and dynamic system, each variable is considered by the simulation model as a customer arriving at a service facility. The service analogy denotes the incorporation of the variable's values into the system. Since a complex system receives many customers (or incorporates several variables), these wait in line, or queue, to receive service. Depending upon an order of priority, customers receive service and then depart from the system. Built into the simulation is the time required to service individual customers, the length of the queue, and the amount of time a customer spends in the system. All these are calculated by probability calculations which are performed by the computer based on the model designer's input. In a hypothetical pastoral nomadic ecosystem model, a drought condition is considered one such customer (effecting multiple variables). Variables associated with the drought enter into the model and their values are recorded based on specific priority and for a specified, or assumed, period of time.

Behavioral systems are presumed to change continuously due to the time-varying behavior of all quantities in the system. Behavioral patterns are governed primarily by rates of change which are analysed by the computer using differential equations and numerical integration, concepts which cannot be elaborated here but which are the backbone of abstract simulation models. A model designer has to quantify variables so that meaningful levels, or states, at which a particular variable is measured, are known. Equally important is the need to code rates of change for all variables with reference to time spans involved with each variable. All computations of differential equations are then performed by the computer internally.

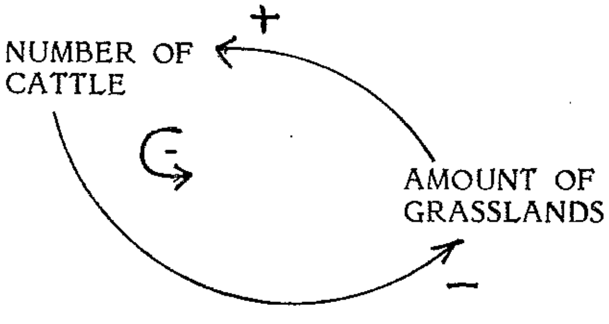
While the above principles are typical of simulation in general (see Bronson (1984) for a review), the one model which is specifically designed for social science applications is the system dynamics approach developed by Jay W. Forrester during the 1950s at the Massachusetts Institute of Technology. The system dynamics approach views variables as interacting elements that function together with feedback cycles characterizing the relationships between them over varying time spans. While this is not radically different from human mental thinking about phenomena, the computer is much better equipped to take into account many factors at once and to impose order upon the thousands of possible relationships that could be included in a study of a complex problem (Roberts et al 1983:7).

The system dynamics approach first requires a substantive knowledge of the phenomenon selected for simulation. A simulation of a development project involving pastoralists thus requires the input of specialists in the field who can organize and structure the knowledge which exists about pastoral nomads in general and about the specific context in which the problem to be analysed exists. These specialists need to define the relevant variables that should be incorporated into the simulation model. A second step calls for designating a set of logical diagrams showing cause and effect relationships between the variables comprising the system. Ideally, the model should strive to be "an account of the total set of forces that are believed to have caused and to sustain some problematic state of affairs. Like the informal mental model, it is derived from a variety of data sources including facts, theories and educated guesses. Unlike the mental model, it is comprehensive, unambiguous, flexible and subject to rigorous logical manipulation and testing" (Roberts, E.B. 1981:6).

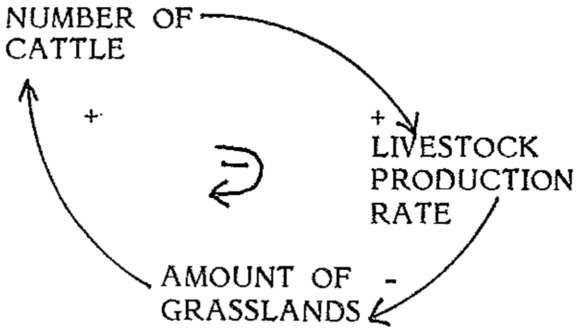
Having thus far designed system dynamics as relying primarily on variable levels, rates of change, and feedback relationships, it is necessary to add that the approach seeks to find feedback loops in which change in one variable effects changes in another variable which in turn bring about change in the first. This phenomenon is well known to those concerned with development and is the primary reason behavioral systems are continuously changing (although in theory they often achieve equilibrium as well). System dynamics modeling is concerned initially with the attempt to create several feedback loops which can be found to operate in a particular behavioral system. An example of such a loop derived from a pastoral nomadic ecosystem can be that of the variable: NUMBER OF CATTLE and the variable: LIVESTOCK PRODUCTION RATE. An arrow connecting the two in the following diagram indicates the direction of change with + or - signs. The + sign indicates that an increase or decrease in the first variable causes an increase or decrease (respectively) also in the second, while a - sign indicates a reverse effect, i.e. an increase in the first variable causes a decrease in the second, or a decrease in the first variable causes an increase in the second.



This closed loop acts to reinforce variable changes in the same direction as the change so that sustained growth (or sustained decline) operates in both variables. If the number of cattle increases or decreases so will the rate of livestock production. This feedback loop is positive and is signed by a + sign. Conversely, a loop can have a feedback relationship which acts to resist or counter variable change so that fluctuation or equilibrium is maintained. An example can be that of placing the variable: AMOUNT OF GRASSLANDS in a loop with the variable: NUMBER OF CATTLE. The feedback relationships between them is negative, i.e. more animals grazing will decrease the amount of grasslands. Note that when the loop in this example closes again the arrow is signed positively because when the amount of grasslands decreases it then decreases the number of cattle, i.e. the direction of change is the same and the arrow is therefore signed with a + sign. The loop itself is negative in that every cycle around the loop causes a reverse in the values of the affected variable. The sign for the loop is the symbol -.



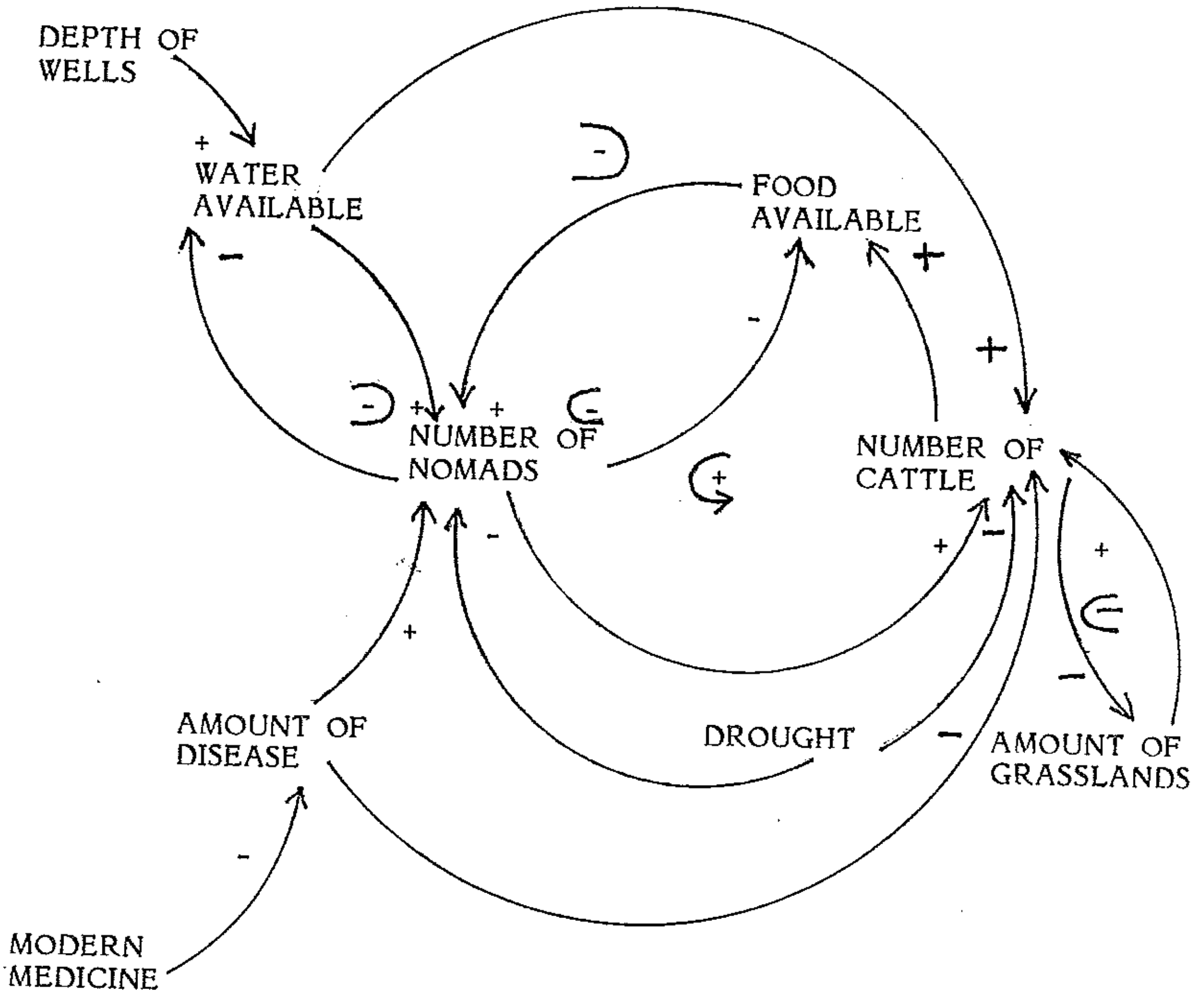
When we loop all three variables: NUMBER OF CATTLE, RATE OF LIVESTOCK PRODUCTION, and AMOUNT OF GRASSLANDS we get the following diagram:



The increase in the number of cattle increases the rate of livestock production (+) which decreases the amount of grasslands (-) which in turn decreases the number of cattle (+). If we continue with the loop, this decrease in the number of cattle will decrease the rate of livestock production (still a + sign since the same direction of change is operative). The decrease in livestock production will in turn deplete the herd and increase the amount of grasslands (a - sign since a change of direction is assumed). We return again to an increase cycle and so on, as in a loop, ad infinitum.

Thinking in terms of feedback loops is at the core of model formulation in system dynamics. Here causal relationships are established, although changes in these relationships and manipulations of the various loops are possible throughout the simulation process. The following stage features the quantification of variables and the designation of time delays. In the example above, time delays would be introduced to account for the time it takes a depleted herd to return to a certain level following a recovery of the ecological carrying capacity of a certain area. Time delays would have to be calculated for such phenomena as seasonal changes, the time it takes a herd to achieve a certain rate of livestock production. It is important to remember that a system dynamics model will attempt to account for all participating variables in a phenomenon so long as these are taken into consideration by the model and are quantifiable. The example above, using three variables, would have to be supplemented by scores of additional variables that would be deemed relevant. Arrows and loops will be determined and quantification and coding of them precede their entry into the computer for simulation.

The example below draws on a system dynamics model entitled: The Tragedy of the Sahel (Roberts, N. et al 1983:68). The model provides a general description of pastoral nomadic ecosystems in the pre-development situation with a consideration of two intervening influences of development: the introduction of medicine (accounting for population growth), and techniques for increasing the availability of water (deep wells). The model then isolates two key variables in the system: NUMBER OF NOMADS and NUMBER OF CATTLE. To each key variable are added variables that affect and are affected by the number of nomads and number of cattle. The resulting model, incorporating both the exogamous intervention of modern medicine and deep wells, is characterized by several negative loops indicating the adverse effects of allowing both the nomad population and the cattle population to grow far larger than their ecosystem could support.



The model of The Tragedy of the Sahel is not developed further by Roberts et al. The model appears early in their INTRODUCTION TO COMPUTER SIMULATION: THE SYSTEM DYNAMICS APPROACH (1983) and is used to illustrate the system dynamics way of addressing a problem through isolating relevant variables and establishing causal relationships and feedback loops. A later attempt in the book to simulate the ecological dynamics of deer populations in the Kaibab Plateau in the American Grand Canyon is fully explored with quantification of variables, designation of time delays, and rates of change which are all explained and demonstrated in three different models. The pastoral nomadic model was derived from popular notions on the causes for the tragedy in the Sahel without any use of hard data on the subject. Specialists in pastoral nomadic development and those familiar with problems in the Sahel will want to include other variables in addition to those suggested by Roberts et al. Such variables can be those that are lumped in the desertification phenomenon, variables in the ecological environment, aspects of movement, and an entire array of factors involved in husbandry and herd management.

The Tragedy of the Sahel model should not be criticized for its apparent simplicity for it was used only as a conceptual example demonstrating the system dynamics approach. An M.I.T. thesis by Picardi (1975) which was not available to the author, offers, no doubt, a better and more complete system dynamics simulation of pastoralism in the West African Sahel. What is important and relevant to pastoral nomadic specialists is the extent to which the system dynamics approach can offer an analytical tool in dealing with pastoral nomadic development. What makes pastoral nomadic ecosystems particularly suitable for a system dynamics simulation is the quantitative nature of many studies concerned with the problem. Like population dynamics, which is grounded in numbers of people being born, dying, and migrating, so studies of pastoral nomadic systems typically involve information on the size of the nomadic group, the number and types of animals, age structure and sex ratio in the herd. Equally important is data on ecological variables such as amount of rainfall and its seasonal intervals, temperature ranges and intensity, vegetation type, soil composition, water availability (brackish and fresh), and several other quantitative variables. Given that system dynamics claims an ability to incorporate a multiplicity of variables, restricted only by the logic of their relevance, it is conceivable that such factors as marriage patterns, properly quantified, can eventually be tested for relevance and incorporated into a human ecosystem simulation model. Of equal importance is the ability to incorporate development efforts into existing behavioral systems. Many development inputs are quantifiable and can be specified as to positive and negative contributions. Whether nutritional aid, access to health care, irrigation, husbandry technology or education, development efforts which are initially measured in currency form are usually translatable quantitatively through some other measure. If a development project is aimed toward making more water available to pastoral nomads or supplying additional grain to livestock, its effect can be measured with reference to the increase in production resulting from the development effort.

The fact that the system dynamics approach to simulation was originally conceived as a management tool also adds to its appeal to development specialists. System dynamics offers a method for simulating system behavior where uncertainty prevails with regard to the effect of development on the system. The stimulation method, by its ability to incorporate any relevant quantitative variable, can allow development specialists to examine the effect of intervention, to consider the respective importance of speculative variables, and to have an important tool in their decision making process.

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