CHAPTER 2

SIMULATION TECHNIQUES IN FOREST-RANGE MANAGEMENT

Clifford A. Myers and Pat O. Currie

Apollo 11, the first manned flight to the surface of the moon, was a spectacular feat. A major reason the flight was so successful was that Apollo 11 had already made the trip a great many times -- theoretically -- in a computer. What a mess the first flights must have been! But, they were made without loss of astronauts, resources, or time.

The technique used by NASA is available to, and being used by, managers and scientists in many fields. It has, however, had only limited use so far in land management. This valuable tool is the study of a system in a computer through simulation of changes in the system during some period of time (Chorafas 1965, Evans et al. 1967). The system of interest here is a forest range made up of such components as soil precipitation, sunlight, vegetation, and livestock. The term "simulation" can be explained by describing the things a range manager could do to develop and use simulation as a land management tool.

NATURE OF SIMULATION

Simulations usually start with construction of a model of the system of interest. Initially, a model is a series of mathematical statements that describe the process studied, but with many numerical values represented by names or other symbols. For example, one statement could be: "Grass plus soil plus rain plus sunlight equals increased grass." Another statement could be "Grass plus cows equals more cows and less grass." These statements model a system at a rather elementary level. Our range manager would have need for far more detail before his model was completed.

A system can be just about any group of components and processes that will answer the questions of interest. Systems can be grouped into larger systems or subdivided into smaller systems. Only as much detail is needed as is necessary to answer the questions. Sometimes, a whole complex of factors can be represented by a single factor. One such simplification is the representation of a group of soil factors by a single measure such as soil depth.

Next, the range manager must conduct some experiments and read the literature. He needs numbers from the real world, from the system being studied, to replace the symbols in the model. For example, in one forested area, the statement that grass plus soil and other factors equals more grass may be expressed in part as:

Logarithm of herbage production = 3.2226 - 0.00936 x basal area per acre of the tree cover (Pase 1958).

Names are replaced by numbers that describe the relationships observed.

Experimentation provides a valuable payoff from simulation long before we are ready to simulate a system. We must be specific when developing a model, and rigidly specific when writing the model for a computer. What we know, what we only think we know, and what we do not know become obvious. Such information--or lack of it--can direct administrative studies and research along profitable lines. Studies that have been repeated often enough and studies that are really only case histories of very local value cannot be justified in the presence of a need for strong data. Instead, we are forced to identify the factors involved, how they affect each other, and their contributions to forest-range systems. Then, regardless of whether we simulate or not, we have information useful for more areas and conditions than only those where measurements were made.

Models are rewritten as computer programs, usually in a higher level computer language such as FORTRAN. There are specialized simulation languages but they are not widely available. Some specialized languages specify that actions proceed from event to event, and are not well suited to the biological three-ring circus that is land management.

The completed computer program is run with data from a specific area where both the initial conditions and the outcome are known. The purpose here is, in effect, to apply the same initial values to the real system and to the program. Results obtained from the program are then compared with measurements from the actual system to see if they may be considered equal. The range manager must know that the computer program duplicates the model, and that the program and the model represent the system. Representation need not be complete but must be close enough to provide the answers needed.

It is not always possible to compare program results with a real system. For example, we cannot examine range conditions under a forest overstory that has been well managed for 100 years. No such systems exist in this country. We must, in such cases, validate the model and the program by testing sections of each. Validation, however done, is essential.

Finally, the manager can run his program on a suitable computer and obtain data needed to make management decisions. Usefulness of the results will depend on the degree to which the model approximates the actual system, and to the suitability of the mathematical relationships used. Fortunately, there are many questions in all fields that can be answered by simple models. Many times, approximate relationships can provide useful information while better data are being obtained. It is necessary, however, to keep interpretations of the results and the things we say about them within the limitations of our tools.

AN APPLICATION OF SIMULATION

An example of what the results of a complete simulation job look like is provided by Program MANAGD (Myers 1968). Examination of this program and of forest-range problems emphasizes that information gathered by foresters and range managers can be combined for mutual advantage. Such coordination provides a big step toward solution of the real problem - good land management.

Program MANAGD simulates a forest where tree density is controlled throughout the life of each stand. Stands grow, are thinned, are reproduced, or are destroyed by fire or other catastrophe. Changes also occur in the economic environment. Stumpage prices, allowable cuts, minimum commercial cuts, costs of thinning or other operations, all may change as the years pass at the rate of about one year per half second. The timber manager can get an idea of what continuously managed stands will produce even before such stands exist. He can examine alternatives and determine management goals without disrupting his forest or his bank balance, and without waiting many years for his sample stands to live through a management cycle.

Program MANAGD computes basal area per acre for each stand whenever growth or cutting are to be accounted for. We therefore obtain a useful measure for estimating the production of both the range and timber resources on any single area (Pase 1958). Addition of soil depth to an equation that predicts forage amounts would probably improve the estimates (Klemmedson and Murray 1963). The usual index of timber productivity, site index, is correlated with soil depth in many forest regions (Myers and Van Deusen

1960). This soil characteristic can, therefore, provide a second variable useful in predictions of both resources.

Relationships between forage and growth factors could be added to the program every place basal area is computed. Forage production could then be estimated for every year of the simulation. Other statements would be needed to reduce total forage production to potential utilization, and to convert the latter to pounds of meat or other products of interest. Product yields should be converted to gross and net dollar values to compare management alternatives. Lack of data to write all these statements is no basis for condemnation of simulation. Quite the opposite. One big payoff of simulation is the indication of some of the things we should know but don't.

Many more problems will appear before a simulation job can be completed. For example, in the equation for predicting herbage production from basal area, repetition of the field measurements should not produce the same numerical values. Graphically, results for two years may plot as parallel lines with the upper line representing measurements made in the year of greater precipitation. Forage equations probably should include some measure of precipitation to be useful prediction tools. Work with crested wheatgrass (*Agropyron cristatum*) showed that total precipitation during certain months is a more useful variable than annual totals, and that the best indicator months depend on the season in which the range is to be used (Currie and Peterson 1966). These items as well as such things as stocking rate of livestock can be added relatively easily to models and simulation programs.

Precipitation variability is simulated the same way unpredictable variation is simulated for industrial systems or repair shops. Totals of seasonal precipitation for all the years of record are examined to determine the pattern or distribution of the values. During each year of a simulation, a precipitation total is drawn at random from this distribution. Results to be used in making decisions do not come from one computer run, but from the analysis of several runs, each with its own set of random draws from the possible values of precipitation. Selection and use of values at random is one feature of simulation that makes it a more powerful tool for many problems than the conventional approaches.

SUMMARY

A forest-range system can be simulated and examined if we know enough about the relationships involved to model the system. Fortunately, only enough of the system need be modelled to answer the questions raised. Duplication need not be step for step, nor account directly for every factor involved. A word of caution is in order: Simulation is not easy nor is it a magical solution of all our problems. It does appear capable, however, of offering enough benefits to warrant serious consideration as a research and land management tool.