MODELING GROWTH AND DEVELOPMENT OF POTATOES TO PREDICT YIELD AND QUALITY

by
Gail S. Lee and Robert E. Thornton *

Growers who consistently grow high yielding good quality potatoes are conceptual modellers. They understand instinctively the relationship between the potato crop and controllable cultural practices and uncontrollable factors such as the weather. Within each mind is a storehouse of facts and information gleaned from years and years of observations. Synthesizing this information into a form where others can use and learn from the years of experience and the years of research is the goal of developing a computer simulation potato model for the Columbia Basin.

Examples of the use of modelling can range from the microprocessor control systems of circle sprinklers to financial decision software. Models are information processors. The circle sprinkler systems can be monitored and controlled by a computer. Information from field climate sensors would be sent to the microprocessor on the sprinkler by radio signals. The microprocessor would relay the climate data and sprinkler status information to the computer where the information would be evaluated by a computer program and decisions automatically made and returned to the sprinkler controller for action or the alternatives listed for the grower to make a decision. This computer program which processes the information available and chooses a course of action is a model. Another example of a model would be the financial computer software packages such as spreadsheets. With these spreadsheets the financial information of the whole farm, ranch, or orchard can be detailed. The grower can then ask what if questions and instantaneously see the results in dollars and cents without risk.

DEFINING THE SYSTEM OF THE MODEL

Development of a model follows a logical sequence of steps (Figure 1). At each step the model is evaluated as to whether the objectives are being met. The first step is to define the system or the limits of the model. What level of complexity is the model going to address (Figure 2)? One can visualize many layers of systems from the world to an individual plant on a particular farm. The complexity of the model is dependent on the desired outcome of the modelling effort. The degree of complexity is also limited by the memory of the computer system.

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* Assistant Professor/Assistant Horticulturist and Extension Horticulturist.

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Figure 1. The methodology of developing a dynamic simulation model.

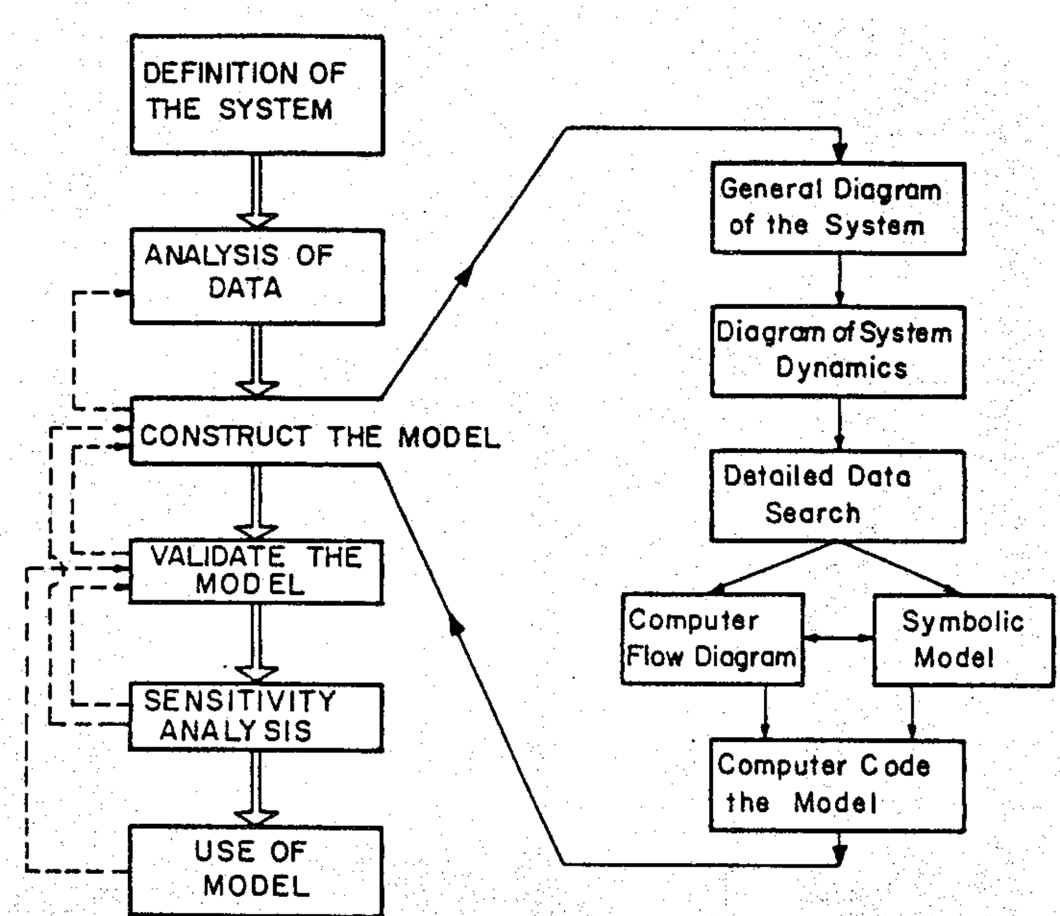
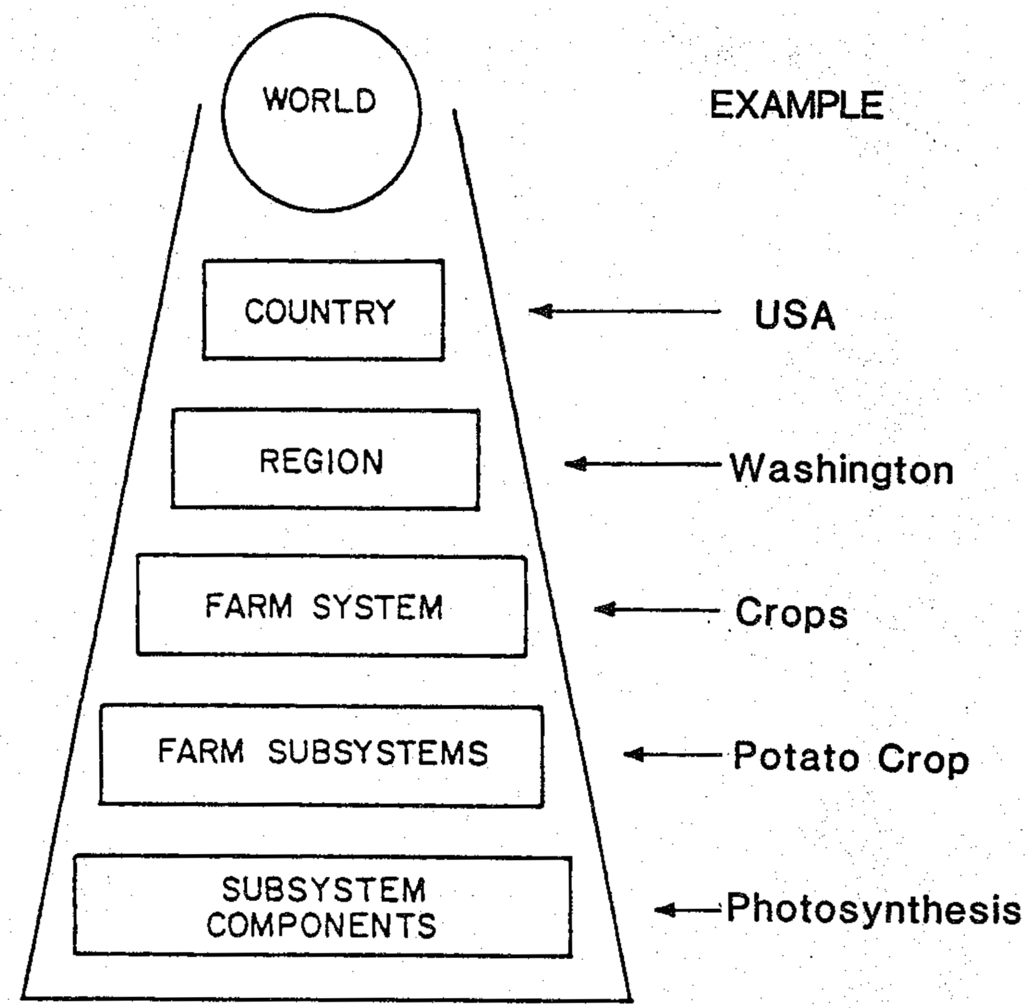


Figure 2. The hierarchy of agricultural systems from which the level of modeling is determined and the sub-systems to be included are identified.



The important descriptors of the potato system can be divided into uncontrollable, partially controllable and entirely controllable factors (Table 1).

Table 1. Descriptors of the potato system classified according to the ability of the grower to control the factor.

UNCONTROLLABLE	PARTIALLY CONTROLLABLE	CONTROLLABLE
Frost-free period	Soil temperature	Days grown
Air temperature	Wind	Fertilizers
Light intensity	Moisture	Seed quality
Day length	Variety	Seed piece size
Humidity		Insects
		Diseases
		Weeds
		Plant populations
		Timely operations

From the descriptors one selects the key uncontrollable and partially controllable climate factors which form the input variables for the model (Table 2). The weather data can be easily obtained from on-site sensors. This information can then be fed directly into the computer system for the model to process.

Table 2. Identification of the key input variables, the important plant physiological processes, and the information that the model calculates and prints out.

INPUTS	PROCESSES	OUTPUTS
TEMPERATURE	PHOTOSYNTHESIS	PLANT GROWTH PATTERNS
LIGHT	RESPIRATION	CARBOHYDRATE STORAGE
DAY LENGTH	GROWTH	TUBER YIELD QUALITY
WATER	TRANSLOCATION	
SOIL FERTILITY	SENESCENCE	

Another aspect in defining the potato system for modelling is to decide on the important plant processes to be included in the model. Developing a model based on the basic plant processes such as:

PHOTOSYNTHESIS--the production of carbohydrates from the carbon dioxide of the air and the energy of the sun;

RESPIRATION--the cost of producing and maintaining the molecules of life;

GROWTH--the change over time of the plant in response to such factors as climate and fertility, usually measured as an increase in size or weight;

TRANSLOCATION--the movement of carbohydrate molecules (usually sucrose) throughout the plant as a function of the demand of the various parts such as the leaves and the tubers;

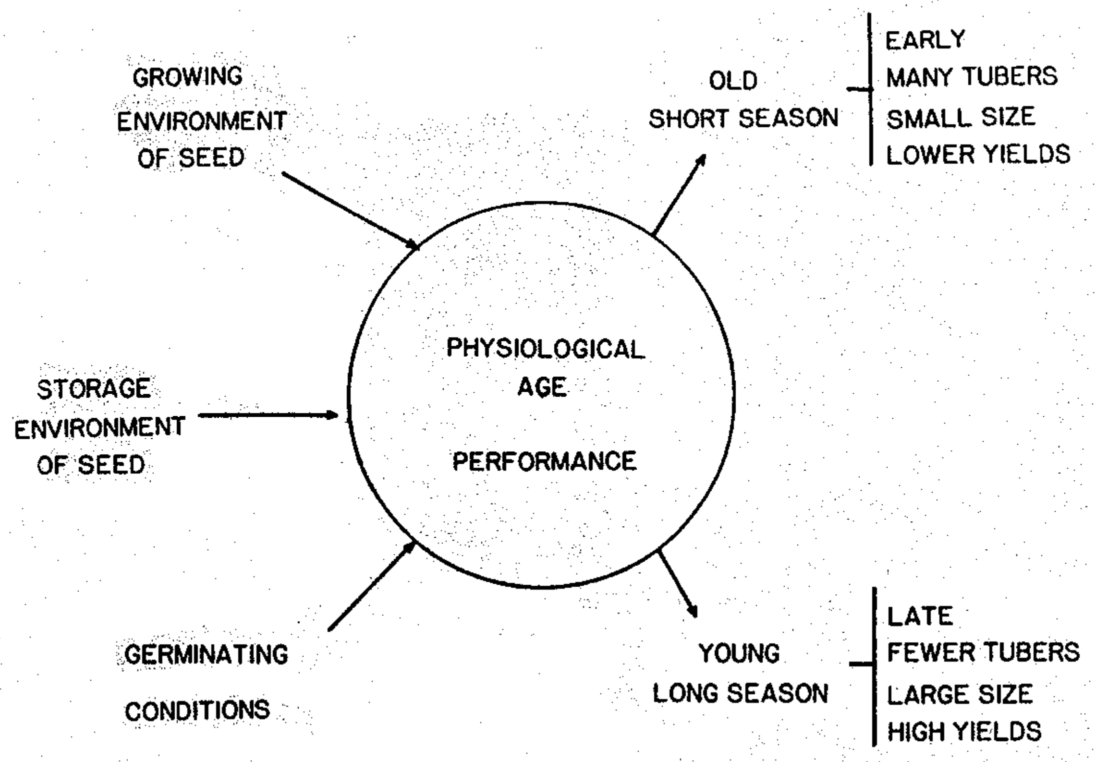
SENESCENCE--the death of parts of the plant and the loss of dry matter as the result.

These basic process when used to form the basis of the model allow the researcher to study what if questions on the yield and quality parameters of potato growth and development.

The final category which the modeller must decide is the model output or the information that the model calculates and prints out (Table 2). This information will be used by the model builder to evaluate the adequacy of the model to represent the growth and development of the potato crop. After the model has progressed out of the development phase to the user phase, then the output information may change to reflect the needs of the grower or the extension agent or the fieldman. If the critical concern is the scheduling of irrigation, then the model must address the need to output the criteria for deciding whether or not to irrigate. Or, if the critical concern is deciding whether the crop is mature and ready for vine-killing or for digging, then the output must provide the information to the grower to enable him to make a decision.

In discussing the development of a potato model for the current year's crop, one must be aware that the seed tubers planted this year are influenced by the conditions of the prior year. Dr. Iritani's research has shown that the production and storage of seed potatoes significantly alters the response of the future potato crop (Figure 3). The growing environment of the seed, the storage environment of the seed, and the germinating conditions interact to determine the physiological age of the seed potatoes. Seed generally can be classified as old or young. The old seed will produce many small tubers and thus have a lower yield while the young seed will produce fewer tubers of a larger size and thus produce a greater yield. As one approaches the development of a model of the potato crop, he or she must be aware of these many interacting systems which transend the current year's crop.

Figure 3. Conditions under which seed potatoes are produced and stored can significantly alter the response of future potato crops. (Personal communication W.M. Iritani)



The last aspect in defining the potato crop system is to identify the developmental stages the potato plant undergoes during the growing season. The four stages of development in the potato can be identified as:

1. The VEGETATIVE stage which occurs from emergence of the plant until approximately 60 days after planting;

2. The TUBERIZATION stage which is initiated when tuber begins to form and lasts approximately 10 to 20 days;

3. The TUBER GROWTH or TUBER BULKING stage where the tubers are increasing in size and dry matter;

4. The MATURING stage where the top growth or leaves and stems enter a phase of decline and eventually senescence.

ANALYSIS OF THE DATA

With a visualization of the limits and components of the potato system in mind, the modeler next searches the research data available to quantify the relationships between the uncontrollable climate input variables and the basic plant growth processes. One must search the literature and examine the results of colleagues to gather information such as:

1. The functional relationship of germination temperature and average number of stems per seed piece from the work of Dr. W. Iritani;

2. The functional relationship of average stem number per seed piece and total yield also from the work of Dr. W. Iritani;

3. The effect of seed size and spacing on potato growth and development as researched by Dr. R.E. Thornton;

4. The functional relationship of the number of days after planting and the potential yield of Russet Burbank potatoes as reported by Dr. R. Kunkel;

5. The response of potatoes to varying fertility practices;

6. The growth responses of various cuts of seed potatoes as reported in this proceedings by Dr. R. Thornton on research conducted by our graduate student Rhonda Conlon;

7. The relationship between the canopy which is the source of carbohydrates and the tubers which are the sink for those carbohydrate molecules which is research reported on in these proceedings by my graduate student Beverly Clark;

All this research plus the work being done by the other potato researchers at WSU and other places form the framework for developing a model.

CONSTRUCTING THE MODEL

The construction of the model involves synthesizing the research that has already been conducted into mathematical relationships which can be coded into a computer language. At each phase of the construction the model is evaluated as to ability to represent the system it was designed to model. New research may need to be conducted to obtain information found lacking.

For the potato crop several models have been developed in the United States and overseas. The majority of these models have not been based on the Russet Burbank potato. In the Pacific Northwest Idaho has developed a model which has gone through various adaptions and revisions for use in several states for more than the Russet Burbank cultivar. Oregon is working on a model in association with the plant disease work of Dr. Mary Powelson. At Washington State University Dr. Bill Dean developed a temperature-based model. We are studying these models and evaluating their ability to model potatoes under the unique growing conditions of the Columbia Basin.