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AGRICULTURAL MODELLING IN MALAYSIA

Christopher Teh B.S.
Department of Land Management, Universiti Putra Malaysia,
43400 UPM Serdang, Selangor, Malaysia

INTRODUCTION

In Malaysia, there is a dearth of agriculture modellers. While there may be researchers who use and modify existing models, there are very few researchers who are able to create models from scratch. Consequently, modelling is unfortunately still in its infancy stage here. There are several reasons for this: 1) we find it difficult to conceptualise a real system and to develop equations, 2) we are unclear of what modelling is, what models can and cannot do, and the benefits of models, and 3) we lack formal training in applied mathematics and computer programming. Consequently, it is the aim of this paper to explain what modelling is and its potential benefits in research, as well as to discuss briefly the processes involved in modelling. Some current challenges in agriculture modelling and the recommendation will be discussed.

WHAT IS MODELLING?

The observed behaviour of a given process in the real world can be studied via two pathways. Firstly, we could set up a field or laboratory experiment to attempt to replicate what we have observed previously. Alternatively, we could describe the behaviour of the given process by an equation, or more commonly, by a series of equations. This second pathway is called mathematical modelling which is a simplified representation of a behaviour of a given process in a mathematical form. The keywords here are "represent" and "simple". For any model to represent *exactly* the real world is no more useful than the real world itself, no more subject to experimental manipulation and no easier to understand (Spedding, 1970). The real world must be represented—and in a simpler form—as models so that they can be manipulated and controlled to be studied; thus, via models, the behaviour of processes in the real world become more comprehensible.

There are two kinds of models: those that represent how we think the real world works, and those that represent what we choose to say is the way the real world works. Models always represent what we think the real world is like, never what it really is, and always represent an approximation (Spedding, 1970). Models do not only represent the real world in a simpler form, but through the interaction of the various model components (or equations), they can reveal something new – something not known before. The original, known facts applied into the model is organised and emerges into new knowledge and revelation. It is in this way that models not only aids but deepens and widens our understanding of the real world.

Models are usually created or used to solve practical problems, but it is important to note that there is no one right and proper model for a given problem. The same problem could be solved by two or more models. Some models may give more accurate or more in-depth answers but they may only do so in certain conditions.

BENEFITS OF MODELLING

1. Hypotheses expressed in mathematics can provide a quantitative description and understanding of biological problems.
2. The requirement of a model for mathematical completeness can provide a conceptual framework which may help pinpoint areas where knowledge is lacking, and it might stimulate new ideas and experimental approaches.
3. Modelling may lead to less *ad hoc* experimentation, as models sometimes make it easier to design experiments to answer particular questions, or to discriminate between alternative mechanisms.

4. In a system of several components, a model provides a way of bringing together knowledge about the various parts and to give a coherent view of the behaviour of the whole system.
5. A model may provide powerful means of using, summarising and organising data as well as for interpolation and cautious extrapolation.
6. Some data are expensive or difficult to obtain; a model can make more complete use of these data.
7. The predictive power of a successful model may be used in many ways: priorities in research and development, management and planning. For example, a model can be used to answer "What if?" scenarios.(France and Thornley, 1984).

THE MODELLING PROCESS

Modelling is part art and part science because it depends strongly on our ability to identify patterns, concepts or abstractions of a given process. Once these patterns, concepts or abstractions have been identified, they have to be translated into mathematical forms. This step includes: 1) identifying and distinguishing all the important and relevant factors, and 2) knowing how these factors are related to each other *mathematically*. The mathematical formulation of a model is greatly aided by the use of assumptions because assumptions help us to eliminate unimportant factors – those that have too small or insignificant contribution. Having detailed or too many factors can complicate or obscure our understanding of the system; thus, making it difficult to formulate the model. Most importantly, however, assumptions aid the development of a model that is as simple as possible but yet still accurate. There is a balance between model simplicity and accuracy. At times, we may require only a rough prediction estimate from a simple model, rather than a highly accurate, detailed estimate from a complex, difficult-to-use model. Once the model has been developed, it should be checked or tested against the real world by comparing model estimates with the measured values. Comparisons can be rigorous by statistical analysis, or less rigorous (and more commonly practised) simply by plotting the simulations against the measured values in graphs to determine the degree of their agreement and to detect any error bias. Errors generally should not exceed 20%.

AGRICULTURE MODELS: SOME CHALLENGES

Today, agriculture models are more easily created or modified, aided with the easy availability of fast and affordable computers as well as more user-friendly software (such as statistical, spreadsheet, mathematical and computer programming packages). Several well-established models in agriculture (to name a few) are such as:

1. SUCROS (Van Keulen *et al.,* 1991), CERES (Uehara and Tsuji, 1998)– generic crop growth and development models
2. CENTURY (Metherall *et al.*, 1993) – plant-soil nutrient cycling model
3. RUSLE (Renard *et. al.*, 1991), WEPP (Alberts *et. al.*, 1987) – soil erosion models
4. DSSAT (Uehara and Tsuji, 1998), SWEAT (Daamen and Simmonds, 1996) – soil-plant-atmosphere models
5. SWMS_3D model (Simunek *et al.*, 1995) – soil water movement model

An important component in all of these agriculture models is the plant. An active research area is modelling the plant's foliage distribution or canopy architecture. The goal here is to consider the plant as an individual geometrical object and constituting as a crop when the individual plants are aggregated or taken as a whole; thereby modelling more realistically the distribution or heterogeneity of the plant aerial space as found in the field. For this purpose, L-systems (Lindenmayer systems) have been used as a versatile tool for plant and herbaceous plant modelling. L-systems is a relatively new method to simulate architecturally realistic plant structures and vegetation cover using a simple, recursive algorithm (Prusinkiewicz and Hanan, 1990). Plants such as maize, oil palm, beans have been simulated realistically using L-systems. Advances using the L-systems include "growing a virtual plant" whereby the correct space-time relation between plant parts was identified to reproduce the various developmental growth stages.

One advantage of being able to simulate plant structures is that detailed architectural vegetation features could be obtained easily (because they are simulated) such as the shape and size of vegetation cover, clumping and mutual shading. Such information is vital to determine the outcome of the interaction of different plants with their environment such as the competition for water and solar radiation. This is also an opportunity to setup a "virtual laboratory", whereby based on a chosen crop type or crop combination (two or more crop types) and their planting density and arrangement, a virtual environment of plants with their vegetation cover could be simulated using L-systems. The interaction between these virtual plants with their environment could then be determined by using the L-systems model in conjunction with models of meteorology, soil water, erosion, and evapotranspiration. The plant-radiation regime can be modelled in 3-D by dividing the aerial space into a network of 3-D cuboids, where in each cuboid information of the plant architecture is determined from simulation. Ray tracing and radiosity theory can be used to track the length of travel of solar beams and reflection within the canopy, respectively.

Another increasingly important issue in agriculture modelling is the progressive development of models. Currently, models are usually built to meet immediate research objectives and used in limited situations, then discarded for newer ones. Agriculture models are currently designed to be too rigid to be *reusable* and *extendible*. Reusability means a model written by one person can be easily shared, used or incorporated into another model written by a different person (*e.g.*, a soil water model incorporated into a plant growth model). On the other hand, extendibility means a model can evolve easily as progressively new knowledge is acquired. It is often the case in agriculture that to achieve model compatibility, the source code of two or more models will have to be modified extensively. As new insights are gained into the system, or if a modeller wishes to cover other aspects of system, agriculture models will not evolve easily and likely be modified heavily (hence, breaking the original design structure) just to accommodate these improvements or new requirements. Consequently, this has seriously hampered the progress, use and sharing of agriculture models. Loomis (1985) and Seligman (1990) emphasised that, in the agricultural context, modelling progress is best achieved by testing and improving the best of existing models rather than writing new ones from scratch which is akin to trying to "re-invent the wheel".

Nevertheless, a few agriculturists (Van Evert and Campbell, 1994; Gauthier *et al.*, 1999; Rossiter and Riha, 1999) have attempted to create reusable and extendible modelling frameworks by applying the principles of object-orientation (OO). OO is a way of design and analysis of a given system and it enables model reusability and extendibility following key principles so that any extension or improvement of a model's capabilities could be achieved without rewriting the old code. OO also prepares a model for the possibility that new, unspecified code might be added in the near future – again, without rewriting the old code.

Unfortunately the development of OO agriculture models has been very slow. Moreover, it is a personal observation that some of the current OO agricultural models, though claiming to be reusable and extendible, are too poorly designed to achieve their claims. A common misconception among agricultural modellers is that by merely using a computer language that supports OO (such as C++), their models automatically achieve qualities of reusability and extendibility. These two properties are instead achieved mainly by the modeller's ability to find abstractions or to conceptualise the system (Meyer, 1997). Current OO agriculture models are also non-portable because they have been designed to be used on a specific platform and operating system only.

RECOMMENDATION

1. Increase the use of models in research. Just as statistics is commonly used in research to summarise data and detect patterns and differences, model should also be commonly used in conjunction with experiments to further deepen our understanding of a particular phenomena.

In particular, models are useful in answering "What if?" scenarios. This can be useful especially for expensive, laborious or time-consuming experiments.

2. Increase the number of modellers in Malaysia: people who are not only able to use and modify existing models but able to create models from scratch. Agriculture students in universities, in particular, must be trained in modelling, mathematics and computer programming and usage.
3. Models developed must include qualities that enable a high degree of model reuse (sharing) and extendibility (evolution). This will aid co-operation among agriculturists of many diverse background and research interests as well as encourage systems thinking and approach in agriculture.

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