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Review Article

Features Mathematical Modeling in a Sustainable Silvopastoral System - A Further Experts' Opinion

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Abstract

Creating decision-making models to optimise tropical ruminant landscapes requires a sophisticated understanding of modelling structures. While deterministic forecasting simplifies predictions, it ignores system variability, contrasting with the richer insights provided by probabilistic forecasting. By considering variables such as supplementary nutrition and system maintenance costs, this study aims to elucidate the key elements of modelling frameworks essential for redesigning tropical ruminant landscapes in order to guide stakeholders toward socially, environmentally and economically viable landscape management strategies. Despite their simplicity, deterministic models are important for making profitable decisions in the redesign of productive landscapes, taking into account the importance of their additional elements, such as sensitivity analysis, dimensional analysis and simulated scenarios, which are emphasised to strengthen the robustness of the model and the integration of relevant parameters for sustainable landscapes.

Keywords: Decision-Making; Deterministic Model; Productive Landscapes; Robustness; Simulated Scenarios; Tool

Introduction

An opinion article referred to as [6] was recently published. This article complements the previous one so that the next step of the work is the construction of the model. This, however, opens the range of content present in the model. In this case, what should a model contain to serve as a decision-making tool?

Modeling is the mathematical representation of a real system and should, as far as possible, be validated with practical experience, to minimize the time spent, as the state of the system can be known at any time and one can even observe processes that are impossible to visualize in real life [11] model adopts deterministic forecasts, which implies considering a single future scenario in its prognoses, making them simpler but less comprehensive. The results indicate that, on average, decisions are improved when using probabilistic forecasts, since they provide more valuable information to decision-makers [5].

The main objective of the work as a whole is to show the elements of the modeling framework to guide the redesign of productive landscapes for ruminants in tropical conditions.

Subsections relevant to the subject: novel elements in modeling of productive landscapes

Model characterization and validation

A deterministic model is a type of mathematical model in which all variables are defined by specific parameters and initial conditions, assuming characteristics of absence of randomness, where all variables and results are completely determined by specific parameters and initial conditions, without considering uncertainty or randomness [12], possibility of reproducibility, where given the same parameters and initial conditions, the model will always produce the same results, which allows its validation and replication and limitations in capturing real variability by not considering randomness.

Deterministic models may not adequately capture the variability and uncertainty present in many real-world systems [13] due to the absence of random elements, whereas deterministic models tend to be simpler conceptually, making them easier to understand and implement [1]. In this way, the behavior of the model in response to stimuli is completely predictable and does not vary between different runs of the model [8]. These characteristics then define a deterministic model and provide a framework for understanding its applicability and implications in modeling complex systems.

Discussion

In deterministic mathematical modeling, it is crucial to respect certain assumptions and guidelines to ensure the correct functioning of the model [4,9] Some important considerations include the topics detailed as an important discussion.

Dimensional analysis

Dimensional analysis is basically a method for reducing the number and complexity of the experimental variables affecting a given physical phenomenon, by applying the compression technique. If a phenomenon depends on n-dimensional variables, the dimensional analysis will reduce the problem to just k dimensionless variables, these are the so-called dimensionless numbers, where the reduction n - k = 1, 2, 3 or 4 depending on the complexity of the problem. Generally, n - k is equal to the number of different dimensions governing the problem [3,16]. When the units of the left-hand side (LHS) and the right-hand side (RHS) of an equation are different, it is necessary to perform a conversion to ensure that both parts are in the same unit. This is essential for the equation to be mathematically valid. Therefore, in mathematical equations, the units are just as important as the numerical values. To ensure that an equation is coherent, the units must be consistent on both sides of the equation [14].

Sensitivity analysis

Sensitivity analysis in deterministic models involves systematically changing the model's input parameters to observe how these changes affect the results. This analysis is crucial to understanding how the parameters affect the model's output and highlighting the most impactful ones [13]. For example, in a profit maximization model, it is known that productivity has a major impact on the production projection, while other parameters have a more limited influence, such as farm-level area.

Average of a variable as its representative value

Working with average values in modeling is an approach that involves representing variables as averages of a distribution, rather than considering individual values. This can be useful when individual values are difficult to obtain or are not as relevant to the modeling objectives. Average values in modeling simplify modeling, reducing complexity and making it easier to interpret the results. This approach is commonly used in situations where individual values are uncertain or random variables are not easily defined. By using mean values, models can provide useful insights and make reasonable predictions, even in the face of uncertainty [10].

Simulated scenarios

In deterministic mathematical modeling, scenarios are sets of specific conditions that represent different situations or contexts in which the model is applied. These scenarios can vary in terms of parameter values, initial conditions, or other relevant variables, and are used to explore how the model behaves in different circumstances and in the face of unpredictability, decision-making becomes challenging. An effective approach must consider a wide range of future scenarios to ensure that planning choices result in minimal costs for the farmers [1,7].

An example of an agricultural production scenario (design) that combines different elements in the system could be an integrated sustainable agricultural production system. In this scenario, different aspects of crop and livestock production are combined synergistically to optimize productivity, reduce environmental impacts, and promote sustainability. These are just some of the elements that can be combined in an integrated sustainable agricultural production system. The key is to seek a holistic approach that considers the economic, social, and environmental aspects of crop and livestock production, with a view to long-term sustainability [15].

Parameters and Variables

In mathematical modeling, parameters are essential elements that represent fixed, constant, or variable characteristics of the system under study. They influence the behavior and dynamics of the model, determining its properties and results. According to [2], parameters in mathematical modeling are defined as "fixed or variable quantities that specify the behavior of a physical or biological system or process. The parameters will be relevant data that will have an impact on the farmer's production, such as cost, area, plant, and animal productivity. For the model in question, parameters will be used that respond to the desired variables in the model, which will be described below.

Together with the parameters and obeying the restrictions of area, nutritional requirements of the plants and animals, the amount of supplement provided in winter, remembering that there will be no need to provide energy-protein supplement in winter, only complementary macro and microminerals as the plant will already provide enough energy and protein for the animals' optimum weight gain, the variables will respond to the profit maximization objective function proposed as the model's response according to their inputs such as number of animals, number of plants, grazing area, amount of supplement, greenhouse gas emissions, amount of fertilizer, dry matter intake, total digestible nutrient intake, energy intake and protein intake.

Extra expenses and productivity

Extra costs for system maintenance are necessary to maintain the health of the herd, the production of plants and the management of the system, involving people who will be responsible for maintaining the quality of the production system and guarantee the productivity of the system so that it can be socially, environmentally, and economically profitable.

Conclusion

In summary, creating a decision-making model to reshape productive landscapes in tropical environments requires a refined understanding of modeling structures, such as those discussed in this text, since deterministic models offer simplicity in making profitable decisions. Thereby, sensitivity analysis, dimensionality and simulated scenarios are crucial to strengthen the robustness of the model and integrate relevant parameters to promote sustainable landscapes, requiring the adoption of probabilistic forecasts and holistic approaches for informed farming and cattle-raising decisions. This emphasis on sustainability aligns with broader trends in agricultural research and policy, highlighting the importance of integrated solutions for long-term viability and resilience.

Author Contributions

The authors confirm the whole contributions of this work and have approved it for publication.

Conflict of Interest

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