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Modeling approaches to redesign ruminant production toward sustainability—the state of the art from a literature perspective

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Integrated systems allow the redesign of productive landscapes due to the insertion of different species of trees and shrubs. A diversified pasture provides the animal with a wider range and a greater amount of phytonutrients than animals fed on grains, and beyond that, tree legumes have great potential for producing biomass with excellent levels of crude protein, as well as the capacity for symbiotic nitrogen fixation. Assuming that modeling can be a relevant tool to address systemic changes, we sought to answer the following question: "how can ruminant husbandry systems be modeled to help farmers, considering the combination of pasture and crop production?" Thus, this work aims to create a modeling framework to guide the redesign of productive landscapes for ruminants in tropical conditions at the farm level. The activities to be carried out will be divided into four stages: a) bibliographical research on existing indicators and/or models for ruminant livestock farming; b) writing opinion articles (already published) and review articles (this article); c) indicating parameters for modeling the redesign of ruminant production landscapes with the use of multifunctional forage plants; and d) demonstrating the novelty by building a decision-making model for rural properties. The hypothesis of this work is that the redesign of multifunctional production landscapes can be guided by modeling obtained from experimental variables that already exist and/or are under construction, as well as from published literature.

KEYWORDS

animal welfare, biodiversity, digestibility, ecosystem, environmental impacts, sustainability

Introduction

The ancestors of today's ruminants evolved within environments that contained a diversity of plant species (Provenza et al., 2007; Gregorini, 2015). Currently, integrated systems allow the redesign of productive landscapes due to the insertion of different tree and shrub species, where many experiences and analyses point to biodiversity as a precursor to the biological stability found in these diversified productive agroecosystems (Lopes, 2014).

A diverse pasture provides the animal with a wider range and greater quantity of phytonutrients, such as terpenoids, phenols, carotenoids, and antioxidants, than animals fed on grains. In addition, the various phytochemical compounds and their management improve animal health, and these nutrients also benefit human health (Viet et al., 2004; Kuhnen et al., 2022).

Tree legumes have great potential for producing biomass with excellent levels of crude protein, as well as the capacity for symbiotic nitrogen fixation (Mochiutti and Meirelles, 1999). The use of these forages can achieve meat production levels similar to those of animals supplemented with commercial concentrates (Setchell et al., 1987), given the prices of protein supplements, which are beyond feasibility in the context of ruminant production, emphasizing the scientific density of this project.

Based on the above overview, modeling tools can be seen as a decision support system (Keen and Morton, 1978). They produce important results for strategic decision-making in activities related to the preservation and conservation of biodiversity because they can be applied to analyze the influence of different environmental and biological variables.

Subsections relevant for the subject

Argumentation concerns for the practical conduct of the project

Assuming that modeling can be a relevant tool for dealing with such systemic changes, we will seek to answer the following question: "how can ruminant husbandry systems be modeled to help farmers, considering the combination of pasture and crop production?" To this end, a bibliographic review of existing models for livestock systems involving ruminants that have been published is being carried out. Parameters mentioned in these models will be taken into account when proposing the model or when pointing out the need for other data that need to be considered so that producers can make their decisions more easily.

In this way, a modeling tool can be used to propose the redesign of productive landscapes, increasing the assertiveness of the model to be implemented. The work team involved in this proposal has the knowledge and expertise needed to provide answers on the subject for tropical conditions.

At the same time, the massive acquisition of data has led to the revival of an old topic: simulations of biological systems. Simulations are being used successfully and routinely to understand and predict the quantitative behavior of complex systems, opening the door to their permanent adoption in everyday research. They are capable of creating a maximum-precision replica of a system, the "*in silico*" simulation (Di Ventura et al., 2006), harking to the Silicon Valley, in this case, with the computer as the main research tool.

For this proposal, the postdoctoral researcher, who is the first author of this manuscript, proposes modeling landscape redesigns using data from the literature and knowledge of technical experts and local livestock farmers, as well as pointing out the new scientific challenges in redesign studies. The project was approved by the largest research funding body in Brazil, FAPESP (FAPESP n.2022/14349-4).

Purposes and suppositions

Create a modeling framework to guide the redesign of productive landscapes for ruminants under tropical conditions, using alternative forage in the diet that will contribute to the development of sustainable management strategies; and through a prediction model, consider what the redesign of a rural farm would look like with productive, ecosystemic, and environmental impact mitigation characteristics and new inserted species. The model can be used in any region or biome by changing only the parameter values.

Thus, the hypothesis of this work is that it is possible for the redesign of multifunctional productive landscapes to be guided by modeling obtained from experimental variables that already exist and/or are under construction, as well as from published literature.

Method of carrying out

The project will be carried out at the Agricultural Studies and Work Group (GETAP) at the Agricultural Sciences Center of the Federal University of São Carlos (UFSCar), Araras Campus, under the supervision of Prof. Dr. Jozivaldo Prudêncio Gomes de Morais.

The activities to be carried out will be divided into four stages for the purposes of understanding: a) a literature search will be carried out on existing indicators and/or models for ruminant livestock farming; b) writing opinion articles (already published) and review articles (this article); c) indication of parameters for modeling the redesign of productive landscapes for ruminants using multifunctional forage; and d) showing the novelty through the construction of a decision-making model for rural farms.

Bibliographic survey of existing models

An extensive literature review of published national and international journals will be undertaken to answer the question "How can the variables of ruminant production systems be modeled to help farmers make decisions to redesign their farms?"

An analysis grid based on three considerations will be used as a system definition: the intended use of the model and how farmers' decision-making processes are represented, and how researchers and farmers are involved in the modeling processes. The focus is on concluding what the specific requirements for modeling should be if farmers were to be supported in redesigning their whole livestock systems using models.

Writing scientific articles on all the stages proposed

An opinion article has recently been accepted by the impactful and innovative journal Frontiers in Environmental Science, in the Environmental Economics and Management section. The title of the article is Opinion Paper: Indicators for Modeling Redesign from Conventional to Sustainable Silvopastoral Systems: An Expert's Opinion.

In addition to this review article, a comparative methodology article will be written, as well as an article describing the model created using indicators and parameters.

Developing modeling parameters for redesign

To answer the research question, we will use an analysis grid based on three considerations: system definition, the intended use of the model and how farmers' decision-making processes are represented, and how researchers and farmers are involved in the modeling

TABLE 1 State-of-art, based on starts literature, of models to redesign activities.

Benchmark	Approach
Domain	
Hill and McRae (1996)	Use of efficiency, sufficiency, and redesign (ESR) model with parameters for forage, herd size, and animal waste to transition from conventional to sustainable agriculture and show the unique benefit of a redesign that is proactive and can potentially generate permanent solutions to problems. Ecological and selective control, intensive stocking system in the area, and integrated system
Scott and Cacho (2000)	Pasture fertilizer benefits to grass
Van de Ven et al. (2003)	Ecology design production system
Bonnemaire and Osty (2004)	How is the model intended to be used? Do supporting changes in livestock farming contribute through the simulation or optimization model?
Cournut and Dedieu (2004)	Flock management decisions at the production level of the ewes and the distribution of production within the annual calendar
Pacini et al. (2004)	Nitrogen leaching, soil erosion, surface water balance, herbaceous plant biodegradability, hedge length, and manure surplus
Viet et al. (2004)	Sanitary viewpoint
Costa and Rehman (2005)	Brazilian beef farmers with pasture perennity and overgrazing
Kaine and Tozer (2005)	Pasture-based beef production
Veysset et al. (2005)	Cash crops, fodder area, herd size, livestock feed requirements, grain sold, and animals sold
Villalba et al. (2006)	Effects of feed and reproduction
Andrieu et al. (2007)	
Van Calker et al. (2007)	Indicators suggested by experts and stakeholders
Kustermann et al. (2008)	Greenhouse gases
Gameiro et al. (2010)	Animal feed, machinery and equipment used, labor dedicated to production, animal feed, zootechnical indices, costs, land use, and native species planted. Use in ruminant nutrition and flocks
Gouttenoire et al. (2011)	A review that assumes that modeling can be a relevant tool to address such systemic changes, we sought to answer the following question: "how can livestock farming systems be modeled to help farmers redesign their whole farming systems?"
Dumont et al. (2014)	Redesign and evaluation of new agrosilvopastoral systems and animal adaptative capacities
Optimization models	
Park (1991)	Linear programming model for replacement heifers to increase the farmer's income
Dijkstra et al. (1992)	Linear programming model for impact assessment: land use, ruminant nutritional needs, ruminant weight variation, milk production, profit margin, and model validation
Ávila et al. (1994)	Milk production: VALPESQ
Grinspan et al. (1994)	Linear programming model: animal feed
JJF and Zaalmink. (1994))	Linear programming mode: feeding and grazing as a variable
Allore et al. (1995)	SIMMAST: reduce mastistis in dairy cattle
Hirata et al. (1996)	Linear programming model: low-input properties
Van Alem and Van Scheppingen, (1996)	Linear programming model: application of manure to pastures and feed production
Braga et al. (1997)	DELEITE: dairy feed, health, and reproduction
Lopes et al. (2000)	HERDSIZE: quantifying herd size according to profit
Martin et al. (1997)	NTIA: cost of milk production and CUSTAGRI (the best activity for a given area of the property)
Rodrigues (1997)	PAC_LEITE: milk yield production
Pietersma et al. (1998)	Using a linear programming model, artificial intelligence, and statistical analysis
Montagnini et al. (2013), Villanueva et al. (2018)	Greenhouse gas mitigation and carbon sequestration in silvopastoral systems with forages with good digestibility and tannin concentrations

Lobo et al., 2000.

processes. The focus will be on concluding what the specific requirements for modeling should be if farmers were to be supported in redesigning their whole livestock systems using models.

It is important to highlight the parameters and emphasize that they were chosen through gaps left by the current literature. The parameters include dry matter consumption, greenhouse gas balance as an environmental aspect, metabolic profile (urea, albumin, and total protein for protein assessment; and glucose, beta-hydroxybutyrate (BHB), free fatty acids (FFAs), and cholesterol for energy assessment), stocking rate, amount of manure, total digestible nutrients, protein and metabolizable energy content, average daily gain, wood produced in the cycle, supplements, and nitrogen, phosphorus, potassium, calcium, and magnesium as fertilizer. The input data will address information such as plant and animal production at a given time of year, the area available for cultivation, greenhouse gas emissions and sequestration, and animal and plant nutritional requirements.

Discussion

To build the model, indicators will be selected on the basis of starts literature (Table 1) in conjunction with researchers who are experts in the field. The parameters will be entered into the model. Consequently, this present research will contribute to constructing model indicators and parameters. The model itself will be a deterministic model, where the input data are known, and the research technique is linear programming in an objective function, where the objective is the evaluation of environmental impacts (Gameiro et al., 2010; Marins, 2011).

It is important to emphasize the lack of robust silvopastoral system models for the whole farm (Gómez et al., 2020) since Barbosa et al. (2002) published the main revisions to their work. Some references are shown in the table below.

It is important to make the possible challenges and restrictions that could affect the generalizability and applicability of the results, such as unanimously reaching the interested public, clear here in the discussion. We do not foresee any issues that specialized technical assistance cannot solve. Thus, deterministic linear programming was chosen as a way of making the most appropriate decision for each design, which makes the model more robust than others, such as stochastic or Bayesian models. In this way, the model contributes to the scientific understanding of ruminant production systems.

Conclusion

Therefore, our research group firmly believes that it will be able to answer the question and solve the proposed problem by creating the decision-making model outlined in the article.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material; further inquiries can be directed to the corresponding author.

Author contributions

AL: data curation, investigation, methodology, writing–original draft, and writing–review and editing. MC: writing–review and editing. AG: writing–review and editing. JM: supervision and writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2024.1345313/full#supplementary-material

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