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Modelling livestock systems: bottom-up, top-down, or a meeting in the middle?

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Abstract: Livestock systems are highly variable and so require varied approaches to modelling. We outline the different approaches to modelling livestock systems in APSIM along with their limitations, constraints and possibilities. We have separated the approaches into those that start at the bottom of the system with the soil and plants ('bottom-up') and a 'top-down' approach that begins with considering management of the system. We conclude with speculation that as these two approaches are further developed, they may one day meet in the middle.

Keywords: *APSIM, rangeland systems, pastoral systems, crop-livestock systems*

1. INTRODUCTION

Modelling of agricultural systems requires representing a complex system comprised of a combination of biophysical processes and management decisions – all within the constraints of the biophysical environment and available resources. Livestock and mixed farming systems are a common across the world, ranging from intensive grazing and dairy systems to extensive rangelands. Within this range, livestock fulfil many functions including provision of food and fibre and system services such as weed control and labour (draught). All of these systems include multiple interactions and feedbacks (Figure 1) that need consideration.

As this symposium has shown, APSIM has a long and strong history of model capability in cropping systems but its capability in livestock systems is also growing. Modelling of livestock systems can range between highly constrained system boundaries of only the soil-plant system to full inclusion of multiple stock types with herd/flock dynamics and resource-constrained management decisions.

This presentation will outline the various approaches to modelling livestock systems in APSIM along with their limitations, constraints and possibilities. We have separated the approached into those that start at the 'bottom' of the system with the soil and plants ('bottom-up') and a 'top-down' approach that begins with considering management of the system. We conclude with speculation on the possibility that these two approaches may meet in the middle.

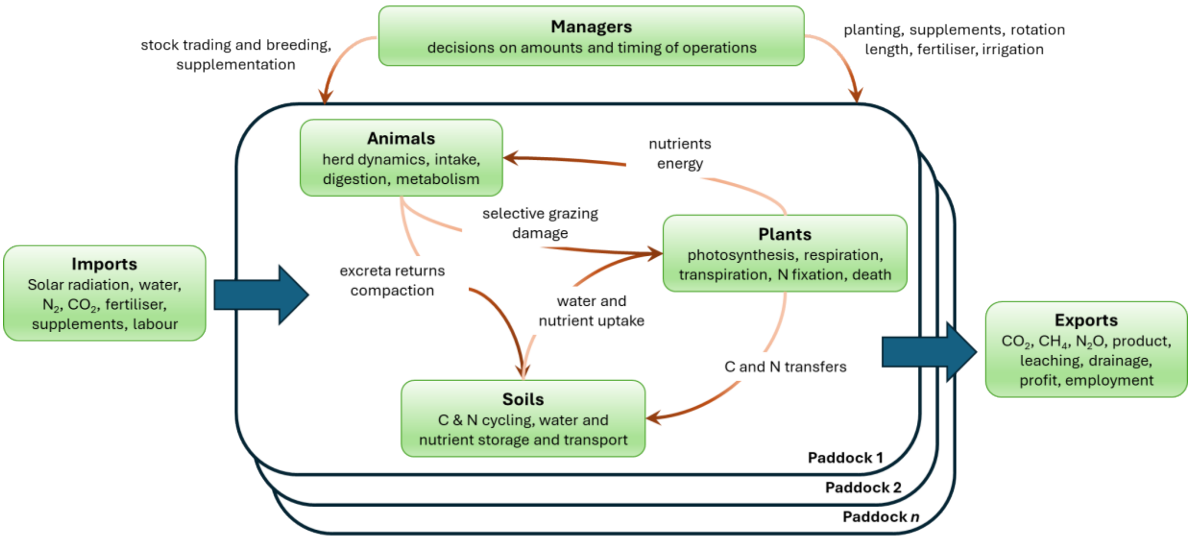

Figure 1. Diagram of the major flows in, out and within a livestock agroecosystem. Note that the system boundaries can be drawn at the whole farm level (which includes managers), the paddock level, or at the soil and/or plant level.

2. BOTTOM-UP APPROACHES

Bottom-up approaches involve simulating dynamics subject to a range of limitations/constraints in detail from the soil on upwards. At the most constrained scale, this might only be the effects of animals and their activities (limited to forage removal and excreta return) on the soil-plant system (e.g., Vogeler et al., 2013). These approaches can also be by modelling a single zone as a representative area or paddock on the farm (e.g., Snow et al., 2025) with a simplified animal model, while others calculate animal production externally to the simulation (e.g., Peterson et al., 2020; Watt and Bell, 2024). In these approaches, animals are more usually handled very simply using either some variation of a feed conversion ratio or requiring feeding to a defined production level.

All the above approaches exclude consideration of herd dynamics, but much more complex bottom-up simulations are also possible. The Stock model, which includes herd dynamics, from AusFarm (Herrmann et al. 2024) was ported to APSIM in 2021 and more recently the pasture model has also been converted (D.P. Holzworth, pers. comm.). With these components, whole-farm modelling will be possible, albeit complex.

3. A TOP-DOWN APPROACH - THE CROP-LIVESTOCK ENTERPRISE MODEL

The top-down approach starts with the inputs and outputs of the farm operation, adding detail until the required level is provided. The Crop Livestock Enterprise Model (CLEM, Liedloff et al., 2025; An-Vo et al., 2024) has been developed to meet the challenges of whole-farm modelling. This model tracks all resources (e.g. financial, physical and biological resources) where shortfalls influence farm operation and relies on some detailed biophysical understanding. Managing resources requires the introduction of arbitration to allocate resources when in shortfall, and the process code needs to handle the implications. The model has a strong focus on the farm tasks and their associated decisions with a generic approach used to allow actions across resources and specific tasks. The model must enable simulations outside the usual scope of building farm models, such as where a collapse in the herd, or the death of a critical individual, occurs. Forages are handled as an external input to the system. These processes require a stochastic aspect to be included in the model which further allows simulations to assess risk in the system, a critical measure for best farm management and always considered in farm decisions. This model also works with the best data available as inputs, from detailed model output to expert opinion.

4. A MEETING IN THE MIDDLE?

We consider it unlikely that neither the current top-down nor the various bottom-up approaches will fully meet the wide-ranging needs for researchers working in livestock systems. We speculate that: both approaches will likely be needed for the foreseeable future; and that the approaches are likely to evolve to meet (and probably overlap) somewhere in the middle. For CLEM, this is likely to mean that forages will be formally included in the simulation with excreta returns and other grazing effects included as well as the development of a more details ruminant production model where this detail is needed. For the various bottom-up approaches, it is likely to include expansion to consider the issues associated with managing multiple paddocks, using more complex animal models and other system constraints. Each of these expansions will involve considerably greater complexity of the model for the user so a clear understanding of both the advantages and the limitations of the choice of approach will need to be well-understood.

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