26th International Congress on Modelling and Simulation, Adelaide, SA, Australia, 30 Nov–4 Dec 2025
mssanz.org.au/modsim2025

Assumptions tracking in system models: Case studies from digital twins in agriculture and horticulture

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Abstract: Digital twins for agriculture, horticulture, and ecology depend on assumptions that evolve as data, domain knowledge, and operational contexts change. Despite the importance of assumptions and simplifications in system modelling, their definition, role and treatment in simulation studies are poorly understood. We propose a standardised framework for identification, categorising and managing assumptions in modelling processes. More specifically, we investigated two questions:

RQ1: Can model assumptions be categorised based on their trackability?

RQ2: What are potential methods for managing and tracking model assumptions in system models and digital twins (DTs)/assistive digital twins (ADTs) in agriculture and horticulture?

In this review, we propose naming assumptions systematically: high-level **simplifications** that define the model boundary by omitting or generalising external or internal processes not explicitly modelled; **hypothesis** type assumptions describe causal, mechanistic, or functional relationships between variables, based on theory, expert judgement or interpreted data patterns; assumptions required for valid **statistical** inference or model fitting; and **data representation** assumptions that concern how data are structured, transformed, or encoded for use within a model.

Many model assumptions are either unknown or acknowledged and documented, but empirical measurements to validate such assumptions are not practical. These are non-trackable assumptions. On the other hand, trackable assumptions can be monitored throughout the model's lifecycle, allowing researchers to observe and adjust these assumptions as needed. Data science tools for fully automated tracking and validation of certain model assumptions exist often in fields with high-dimensional data requirements. However, these tools are commonly developed and used in a specific science domain and lack of generalisability. By reviewing the literature on digital twins in horticulture and agriculture, we found a notable gap persists between theoretically available assumption-tracking methodologies and their practical implementations in these studies.

Assumption tracking is not only a validation step but an ongoing process throughout the model lifecycle, which requires a structured framework. This review identifies an opportunity to embed a systematic, dynamic assumption-tracking framework by drawing on tools such as the ODD Protocol, Google Model Cards, Bayesian inference, and Monte Carlo simulation. We outline how such a framework can support ongoing validation, versioning, and transparency for different types of assumptions. We further map the usage assumption documentation and tracking tools in the model development and implementation lifecycle of a DT or ADT as an example. An adaptive framework that can be included into DTs and ADTs and can update assumptions based on real-time data is needed for capturing time-varying relationships, feedback loops, and emergent properties. Establishing this capability will allow DTs and ADTs to be more data-informed, and decision-relevant as conditions and data availability evolve.

Keywords: *Model assumptions, assumption tracking, iterative design, digital twin, horticulture and agriculture, model lifecycle*