CLEM: the Crop Livestock Enterprise Model

Farming systems modelling: enabling researchers to examine the 'butterfly effect' of their research

Whole-farm models, like CLEM, simulate **complex interactions** between different components (e.g. crops, livestock, horticulture, labour, economics, etc) of a farming system, often revealing important connections and linkages between farm components. They can be used to understand the **farm-wide effects of changing one component**, or a sub-component of the farming system – the 'butterfly effect' of any researcher's science – and to examine the **effect of any limited resources** (such as labour or farm finances) on the timing and scope of available management options.

Additionally, whole-farm models can be used to **quantify the risk and variability** over the medium to long term of different management practices, and to understand the likely effects of **climate change** on a farming system, its components and their interactions. These models can be used to examine an **extensive range of potential research options** before testing the most likely (in the field or laboratory) in order to identify the most effective interventions in which to invest further resources. Whole-farm models can be used: to inform decisions made by agribusinesses and smallholder farmers; for the development of sustainable state and national agronomic and environmental policies; and to increase national and international food security.

Since its release in July 2019, CLEM has increased CSIRO's international reputation as a leading contributor to farming systems analysis at a range of scales. Researchers are using CLEM in a range of contexts including in Australia and in emerging-economy countries spanning a wide range of production systems from smallholder subsistence farmers to larger dairy, extensive beef and mixed-farming agribusinesses. The inclusion of CLEM in research proposals has already proved to be attractive to funders including the Australian, Western Australian and Queensland governments; Bill & Melinda Gates Foundation; the United Nations; Columbia State University (USDF); and the Australian Centre for International Agricultural Research.

What's innovative about CLEM?

- **Scenario based model**: CLEM users develop experimental scenarios which are compared to baseline business-as-usual scenarios. This facilitated the comparison of many "very good" farm management strategies to understand the risks, benefits and trade-offs of each. CLEM is not an optimisation model.

- **Scalable**: CLEM can be used to model a range of farms from subsistence smallholder farms in low- and middle-income countries to large-scale extensive agribusinesses in advanced-economy countries. As well, CLEM is scalable in its functionality: the user need include only the model components required to address specific research questions.

- **User-defined simulation focus:** CLEM views the world in terms of resources (crops, livestock, labour, economics) and the activities (or tasks) with which these resources are managed. CLEM allows the user to consider any resource important (or not) and to define the order in which tasks are undertaken for each farm component. CLEM's conceptualisation of the farming system, and many of its processes, are unique.

- **Easily incorporates new functionality:** CLEM is flexible, dynamic and designed to be able to address research questions not yet envisaged. Recent changes to CLEM have introduced new management options in terms of greenhouse gas accounting, human nutrition and food security, detailed herd management, and communities of farms interacting with each other (i.e. villages).

- **Free and open-source:** CLEM is free for researchers to use and is provided within the APSIM Next Generation framework. No prior knowledge of APSIM is required to use CLEM. CLEM is open-source for those wishing to understand and/or further develop aspects of the model.

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Is CLEM hard to use?

No, not at all. CLEM has been designed for the broad researcher community, including those with little or no previous modelling experience but for whom a simulation model would add value to their current research. When building CLEM the common challenges researchers face when using simulation models were considered and avoided.

CLEM uses a graphical user interface; comes with extensive online resources; provides for full parameter validation; has comprehensive error and warning checks presented in plain English; and provides visual tools (e.g. a full descriptive summary of the farming simulation set-up) to enable to user to understand any simulation; as well as handy templates to get new users started. Of course, any researcher needs to be given time to become accustomed to CLEM, as with any new research tool.

CLEM is currently being tested across different farm environments. The model has undergone extensive and rigorous sensibility testing (i.e. all the functionality works) and we are working with researchers to complete the next stage in model validation using real world data. As part of this process the CLEM team is committed to continually and rapidly addressing any bugs identified and to ongoing improvement of the model.

How is CLEM different to other CSIRO agronomic modelling tools?

CLEM examines different research questions to APSIM (the **A**gricultural **P**roduction **S**ystems s**IM**ulator), which is primarily a cropping systems model. Users wishing to investigate cropping systems are recommended to use APSIM.

CLEM is a vast, iterative improvement on its two, CSIRO-developed, precursor models, the Integrated Analysis Tool (IAT) and the North Australian Beef Systems Analyser (NABSA), which are highly regarded and which were used on numerous research projects internationally and within Australia over the last 10 years. Both IAT and NABSA were more limited in scope and functionality than CLEM and have now been retired following the release of CLEM.

Researchers who currently examine changes in farming systems using either a number of currently-available models or combining one or more modelling tools with post-simulation spreadsheet analyses may find CLEM is able to simplify their workflow. For example, a project considering the economic impact of available machinery on farm profit by combining APSIM (cropping system productivity) with Excel-based post-simulation analyses (economics) could combine this research into one CLEM simulation which also included labour and any financial limits influencing machinery maintenance.

Okay, CLEM sounds interesting and I'd like to know more

Got a research idea? Not sure if what you'd like to investigate is possible with CLEM but want to explore more? We know that it can be hard to know where to start with a new research tool, and we're here to help! Please email the CLEM Initiative team at clem@csiro.au

For more information we have a website: www.apsim.info/clem, which is also where our reference materials and user guides can be found. A paper introducing CLEM to the world is currently under review; once published it will be available for researchers to cite when publishing their own research findings.