Review report

A review of modelling decision support tools for integrated farming systems in the ASEAN

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1 Background

The study evaluates the primary uses and significance of computer simulation decision support tools (DSTs) in assisting users and practitioners in selecting appropriate tools for integrated farming systems. Since the 1950s, computational models of agricultural phenomena—incorporating data analysis, modeling, and visualization—have helped stakeholders make informed decisions in economics, agronomy, environmental management, and social systems (Ahmed et al., 2022; Jones et al., 2017). DSTs simulate a series of activities that mimic real-world processes, enabling users to describe system structures and functions, predict interactions between components and external drivers, and identify key leverage points for optimization. By using DSTs, stakeholders gain insights into agricultural phenomena, addressing questions such as: (i) what happened and how? (ii) why did it happen? (iii) what is likely to happen next? and (iv) what is the best possible outcome? These tools are especially valuable when the cost and time required to observe real-world agricultural processes are prohibitive.

To advance sustainable farming practices, particularly in resource-constrained family farming systems, transdisciplinary and multi-stakeholder DSTs are increasingly employed. These tools integrate participatory and interdisciplinary approaches to tackle challenges such as improving productivity, managing natural resources, enhancing climate resilience, and ensuring food security. DSTs vary in scale and complexity, ranging from software-based models used at the field level to participatory frameworks that actively involve farmers in decision-making and land-use planning. By bridging the gap between scientific knowledge and practical application, DSTs empower farmers and agricultural practitioners to make informed choices that align with both economic and environmental sustainability goals.

Family farming systems, characterized by their small-scale, limited resources, and reliance on family labor, play a crucial role in global food production and rural livelihoods. However, these systems often face significant challenges, including restricted access to inputs, markets, and technical expertise. To effectively support family farms, agricultural tools and decision support mechanisms must be tailored to their specific needs while promoting inclusivity, scalability, and environmental sustainability. A well-designed DST can help address these constraints by providing accessible, context-specific solutions that enhance productivity and resilience, ensuring that farmers remain competitive and sustainable in an evolving agricultural landscape.

2 Review and synthesis

The purpose of the review was to synthesize the existing DSTs, provide an overview knowledge and support users in search for the appropriate tools. The study followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) approach to identify, select, appraise and synthesize the DSTs (Moher et al., 2009; Page et al., 2021). First, under work package 2 on methods and tools of the CGIAR initiative on mixed farming systems (MFS) (Hoeschle-Zeledon & López Ridaura, 2021), a compendium of modelling tools was developed through expert consultations and an online search. The focus was on tools for:

1. *describing farming system diversity in support of identification, prioritization, and targeting*
2. *conducting multi-criteria assessment to explain performance of farming systems using multiple sustainability indicators*

3. *exploring plausible scenarios of sustainable intensification of farming systems at different scales, and describe/assess the tradeoffs and synergies associated with those scenarios*
4. *designing pathways towards MFS that address several sustainability objectives in selected settings*

In second stage, an online scoping review (Paré & Kitsiou, 2016) of their usage in ASEAN was conducted using the Boolean string: *("tool abbreviation" AND "tool full name") AND ("country1" OR "country" 2 OR … OR "country")*. The initial search identified 3,428 documents. Exclusion criteria identified duplicates (versions of tools) and citations/mentions without explicit indication of usage in the ASEAN. Lastly, the uses – grouped into themes- of the tools were synthesised by reviewers: reading primary documents and the reports that explicitly indicate development or usage of DSTs in ASEAN.

3 Development and Usage of the tools in ASEAN

Our review shows that in the 10 ASEAN countries, most modelling tools have been used in Vietnam followed by Thailand, Indonesia, Cambodia and Laos PDR. The model CLUE (Conversion of Land Use and its Effects) has been widely used whereas D4R was only used in Lao PDR.

Tools like bio-economic models, nutrient flow simulations, and greenhouse gas calculators enable farmers and researchers to analyze farm systems and environmental impacts effectively.

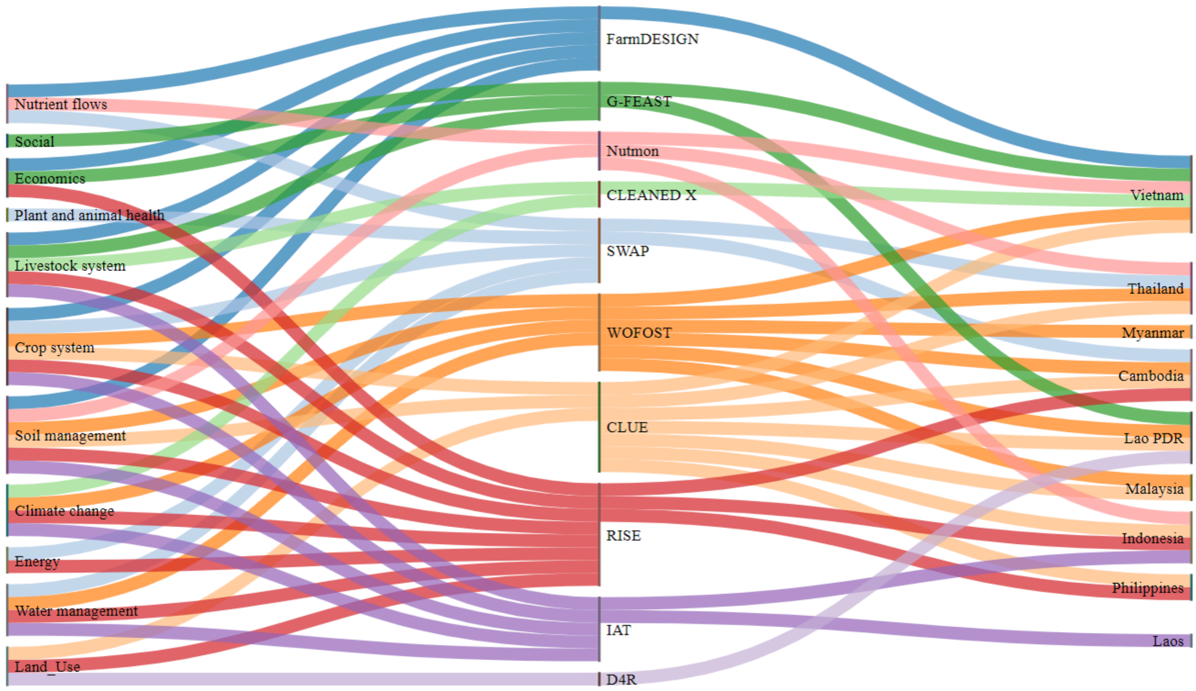

Figure 1 Farming systems decision support tools developed/adapted and/or used in ASEAN member states

3.1 CLEANED

The Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and Sustainable Development along livestock value chains (CLEANED) tool, is an ex-ante tool that assesses environmental impacts of livestock systems and value chains in terms of land requirements, productivity, economics, soil impacts (e.g., erosion, N balance), greenhouse gas emissions (GHGe) and water impacts (Notenbaert et al., 2021).

This tool focuses on livestock management and feed production practices, identified as the primary stages in the value chain contributing to environmental impacts. Since its launch a decade ago, CLEANED has been used globally in numerous projects and assessments (Notenbaert et al., 2025). In Asia, the CLEANED tool has been applied for environmental assessments in Vietnam (Dao et al., 2024; Mwema et al., 2022), Nepal (Giles et al., 2023) and Mongolia.

CLEANED is one of the decision support tools reviewed in this study and was applied as a case study in the Northern uplands of Lao PDR. The case study aimed to quantify the environmental impacts of different livestock production systems in Nonghet district, Xiengkhouang Province. A typology-based approach was applied to classify farms into distinct categories, and CLEANED used to analyze their environmental footprints, and identify high-risk areas for degradation. The key environmental metrics assessed included land requirements and land use efficiency, greenhouse gas (GHG) emissions and emission intensity, water usage, and water use efficiency. The ultimate goal is to provide actionable recommendations for mitigating environmental impacts while improving productivity and livelihoods.

3.2 FarmDESIGN

FarmDESIGN was developed by coupling a bio-economical farm model that evaluates the productive, economic and environmental farm performance, to a multi-objective optimization algorithm that generates a large set of Pareto-optimal alternative farm configurations (Groot et al., 2012). The model was implemented on a relatively large (96 ha) mixed organic farm in the Netherlands that represents an example with relevant complexity, comprising various crop rotations, permanent grasslands and dairy cattle. It has been modified and widely used in smallholder diversified farming systems across the tropics. Adapting to northwestern Vietnamese farms, Ditzler et al (Ditzler et al., 2019) expanded the capacity of farmDESIGN model by adding the modules on ‘Household budget’, ‘Household labor’, and ‘Household nutrition’, capture trade-offs and synergies between performance indicators at the farm–household level. Considering resources and nutrition was a critical improvement for resource constrained environments. It has been used to explained the trade-offs between leisure time and household free budget and explore synergies between environmental and human nutrition indicators (Estrada-Carmona et al., 2020).

3.3 Nutmon/MonQ

Nutmon was developed in 1998 by Wageningen University group to monitor nutrient flows and economic performance of African farming systems (de Jager et al., 1998). It was parameterised for integrated farming systems in Kenya: tea/dairy, tea/coffee/dairy, coffee/maize, tobacco/food crops and livestock/shifting cultivation (Van den Bosch et al., 1998). The basic model used survey data and literature reviews to estimate 5 inflow and 5 outflow compartments of nutrients.

Considering the differences in the farming systems of Kenya and Mekong Delta in Vietnam, Phong et al. (2011), adapted NUTMON modules for rice-based, high and medium input fish systems, and to an orchard-based, low input fish system. Modified the atmospheric deposition module using measures from the region, parameterised N-fixation in rice fields by Azolla and other algae and green manure legumes, adjusted sedimentation with irrigation, fish ponding and dike systems, and parameterised leaching and gaseous losses instead of focusing on erosion. In 2018, Dao Trong et al (2018) applied to model in rice systems to explore rice residue management options and nutrient fluxes.

3.4 IAT (Integrated Analysis Tool)

Initially developed in ASEAN, the IAT simulation modelling tool's purpose was to assess the prospective impact of potential intervention strategies for increased beef cattle production by smallholders in the drier regions of eastern Indonesia (Lisson et al., 2010; McDonald et al., 2019). Although IAT is claimed to be widely used, our search could not find its further use or adaptation in the ASEAN.

The tool has been applied in Laos to evaluate pathways for transitioning from rice-cattle system towards a drought resistant, grazing type, dual purpose legume integration and small-scale irrigation. The analyses provides insights on climate mitigation and improved system productivity (Monjardino et al., 2020)

3.5 G-FEAST (Gendered Feed Assessment Tool)

The Feed Assessment Tool was originally developed by the International Livestock Research Institute (ILRI) and the International Centre for Tropical Agriculture (CIAT) (Duncan et al., 2012) and further refined under the CGIAR Research Program on Livestock (Livestock CRP). FEAST provides a rapid assessment of the availability and utilization of local feed resources which informs the design of site-specific intervention strategies to enhance feed supply and usage (ILRI, 2019). FEAST has been further developed into the Gendered Feed Assessment Tool (G-FEAST) which adds value to the existing FEAST approach by assessing how gender dynamics within households influence animal feeding practices and the adoption of feeding interventions; and identifying challenges and opportunities related to animal feeding across different household types (Lukuyu et al., 2019). GFEAST has been used as a diagnostic tool in livestock systems in several countries including Vietnam (Atieno et al., 2021; Tran et al., 2023) and Laos (Philp et al., 2024).

3.6 RISE (Response-Inducing Sustainability Evaluation)

RISE model was developed at the Swiss College of Agriculture (SHL) as a farmer- and measure-oriented sustainability evaluation method. The assessment covers agricultural production on a farm within one year and starts with the collection of comprehensive information on ecological, economic and social aspects through a questionnaire-based interview with the farmer. A computer model uses this information to calculate 57 sustainability parameters, condensed into twelve indicators consist of energy, water, soil, biodiversity, plant protection, waste, nitrogen and phosphorus emission potential. It has been identified as a potential model for Malaysia for assessment of nutrient flows, biodiversity, energy, water, soil health and finance (Shobri et al., 2016).

3.7 SWAP (Soil Water Atmosphere Plant)

SWAP uses Richard's water balance model to simulate vertical water flow in unsaturated soil for growing seasons. It is used in management of water, salinity, irrigation scheduling, drainage, plant growth, and pesticide leaching, accounting for soil heterogeneity (Kroes et al., 2017).

In Northeast Thailand, Kamthonkiat and others (2010) calibrated SWAP using soil moisture, water stress and yield data to simulate climate change impacts on ground water and rice yield at field scale. In 2022, SWAP was used in Upper Greater Mekong's Mae Klong and Tha Chin River Basins in western Thailand for the period 2000-2017 to guide the design of water use in the UGMMK Irrigation project (Phankamolsil et al., 2022).

3.8 CLUE (Conversion of Land Use and its Effects)

The CLUE model is a dynamic, geo-referenced, multi-scale tool developed to simulate the effects of changing demographic and biophysical driving forces on land use and land cover change, including feedback mechanisms between these forces. It was first applied in Costa Rica (Veldkamp & Fresco, 1996) and later in Ecuador (Verburg et al., 1999). It Europe, it has been used to model the natural regeneration of abandoned farmland (Verburg & Overmars, 2009).

In the ASEAN region, CLUE was first applied in the early 2000s to model land use transitions within forests, coconut farms, grasslands, and rice systems in the Philippines and Malaysia (Verburg et al., 2002). In Philippines, it has also been used to model the effects of tourism development on land-use and cover change (Pleisch, 2024) while In Malaysia, it has been used to model spatial-temporal dynamics of agricultural land use (Olawale, 2013).

In Thailand, CLUE has been widely used for various applications including modelling trends in deforestation and establishment of perennial crops due to conservation policies (Waiyasusri & Wetchayont, 2020), simulating potential impacts of rubber expansion on food crops and poverty (Sakayarote & Shrestha, 2019), and exploring impacts of land use change on water yield as indicator of environmental health (Ghimire et al., 2021; Shrestha et al., 2020) and on biodiversity (Trisurat et al., 2010). In transboundary conservation areas, Trisurat et al (2014) simulated the impact of agricultural and rubber expansion on the conservation areas for Thailand, Cambodia and Laos PDR.

In Vietnam, CLUE has been used to assess the effects of urbanisation on land use changes (Adhikari et al., 2020), explore the impacts of land use change on ecological health in terms of streamflow (Khoi et al., 2021), and to design strategies for mitigating habitat deterioration (Vu et al., 2022).

In Indonesia, CLUE has been applied to model effect of conservation and livelihood policies on community land use and management (Partoyo & Shrestha, 2017), simulate spatial change of mangrove habitat under coastal land use changes (Wang et al., 2021), assess sustainability of rice systems under land use and population pressures (Siagian et al., 2022), and monitor farmland loss due to urbanisation (Partoyo & Shrestha, 2013).

3.9 WOFOST (WOrld FOod Studies)

Originally developed in the 1980s to model crop yields in Europe, WOFOST estimates production potential and assesses the impact of meteorological and hydrological conditions on annual crops in the tropics (De Wit et al., 2019; Van Diepen et al., 1989).

In the ASEAN region, WOFOST has been applied to model production dynamics in rice systems. More recently, it has been used to simulate climate change-driven rice yields across Mainland Southeast Asia (MSEA) (Wanthanaporn et al., 2024). In the early 2020s, Hansawang et al (2021) utilized WOFOST to model rice production under the combined influences of environmental factors, soil conditions, agricultural management practices, and El Niño–Southern Oscillation (ENSO) climate variability.

4 DST choice considerations

The effectiveness of these tools is closely linked to their suitability for specific farming systems and contexts. For example, tools like CLEANED X and FEAST are particularly relevant for smallholder livestock systems, while others, such as CLUE, cater to broader, more generalized agricultural landscapes. Adapting these tools to address the diverse needs of smallholder farmers ensures they remain practical, flexible, and impactful at the local level.

Many tools require adaptation to accommodate varying scales of operation, ranging from individual farms to regional landscapes. They assess specific questions at the field, farm, village, landscape, or value chain level and are typically constrained to these scales by their design. Tools that allow movement between scales mostly fall under the category of approaches or are widely adapted tools, such as CLUE, which offers high flexibility due to the numerous adaptations it has undergone.

The amount of data required to enable this flexibility varies significantly between tools, but assessing these details was beyond the scope of this study. Where available, information on input data was compiled. In the Lao context, it must be assumed that more complex tools are less likely to be applicable, as many of the required parameters are unlikely to be readily available. Additionally, some stakeholder engagement-based tools may incur significant costs due to travel and staff time required for fieldwork. Tools such as IAT, Nutmon, RISE, WOFOST, and possibly FarmDESIGN require substantial data input.

Assessing tool limitations is challenging without detailed analysis. In a few cases, such analyses have been conducted, such as for WOFOST, FEAST, IAT, and certain approach- and survey-based tools. However, since no tool is perfect, understanding a tool's limitations is more relevant for planning its use and interpreting its outputs than for deciding whether to adopt it. This context highlights the importance of fostering innovation and collaboration to ensure that agricultural tools effectively support smallholders in achieving sustainable, resilient, and productive farming systems.

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ASEAN-CGIAR
Innovate for Food
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The **ASEAN-CGIAR Innovate for Food and Nutrition Security Regional Program** is a research collaboration among the ASEAN Member States, ASEAN Secretariat, and CGIAR Centers, with funding support from the government of Australia and the United Kingdom. The program's vision for the next 10 years is to scale up and out bold integrated innovations that will enhance the resilience of ASEAN's agri-food systems to climate change. This ambitious endeavor aims to deliver better livelihoods for food producers and other stakeholders along the value chain. It also seeks to ensure more affordable, nutritious, and healthy food for consumers while fostering a healthier natural environment for all.

For more information on the ASEAN-CGIAR Innovate for Food and Nutrition Security Regional Program, please contact:

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