

ASALEE, A TOOL FOR CO-DESIGNING WATER RESILIENT CROPPING SYSTEM UNDER CLIMATE CHANGE

ASALEE, UN OUTIL DE CO-CONCEPTION DE SYSTÈMES DE CULTURE RÉSILISTANTE À L'EAU FACE AU CHANGEMENT CLIMATIQUE

Gendre Sophie¹., Pasquier D.² and Marguerie M.³

ABSTRACT

Climate change is profoundly reshaping agricultural production systems worldwide by altering precipitation regimes, increasing the frequency and intensity of droughts, and aggravating crop water stress.

In this context, the decision-support tool ASALEE, developed by ARVALIS, provides an innovative framework for comparing crop rotation strategies in relation to water resource availability. ASALEE integrates a water balance model, plant phenology models, crop-specific water-response functions, irrigation rules, soil characteristics, and historical or projected climatic data (including scenarios from DRIAS), coupled with an economic assessment module enabling simulation of crop margins under 500 price scenarios.

Overall, the ASALEE tool represents a powerful platform for integrating biophysical modeling, economic analysis, and participatory design to support the co-development of water-resilient cropping systems in a context of accelerating climate change.

Keywords: Climate change; soil characteristics; historical climatic data; biophysical modeling; economic analysis.

RESUME

Le changement climatique transforme profondément les systèmes de production agricole à l'échelle mondiale en modifiant les régimes pluviométriques, en augmentant la fréquence et l'intensité des sécheresses et en aggravant le stress hydrique des cultures.

Dans ce contexte, l'outil d'aide à la décision ASALEE, développé par ARVALIS, offre un cadre innovant pour comparer les stratégies de rotation des cultures à l'égard de la disponibilité des ressources en eau. ASALEE intègre un modèle de bilan hydrique, des modèles de phénologie végétale, des fonctions de réponse à l'eau spécifiques aux cultures, des règles d'irrigation, des caractéristiques des sols et des données climatiques historiques ou projetées (y compris des scénarios issus de DRIAS), associés à un module d'évaluation économique assurant la simulation des marges des cultures selon 500 scénarios de prix. Dans l'ensemble, l'outil ASALEE constitue une plateforme puissante permettant d'intégrer la modélisation biophysique, l'analyse économique et la conception participative afin de soutenir le co-développement de systèmes de culture résistante à l'eau dans un contexte de changement climatique persistant.

Mots clés : Changement climatique; Caractéristiques des sols; Données climatiques historiques; Modélisation biophysique; Analyse économique.

¹ Arvalis, 110 chemin de la côte vieille 31450 Baziège, France Email: s.gendre@arvalis.fr

² Arvalis, Boigneville, France Email: d.pasquier@arvalis.fr

³ Arvalis, Gréoux-les-Bains, France Email: m.marguerie@arvalis.fr

Introduction

Climate change is profoundly reshaping agricultural systems worldwide, particularly in Mediterranean regions such as Southeastern France, which have been identified as climate change hotspots (IPCC, 2022). Increasing temperatures, decreasing precipitation, and rising evapotranspiration rates are already altering crop growth conditions and reducing water availability (Saadi et al., 2014; Del Pozo et al., 2019). These processes contribute to increased yield variability and heightened production risks (Alrteimei et al., 2022).

As a consequence, farmers are required to continuously adapt their practices and reconsider long-established technical and strategic choices in order to cope with a rapidly evolving environment (IPCC, 2022). In parallel, agricultural decision-making is becoming increasingly complex due to the combination of climatic uncertainty, market volatility, and evolving regulatory frameworks (Mir and Quadri, 2009). Farmers can no longer rely solely on historical references but must integrate uncertain projections and multiple constraints into their planning processes. This transformation highlights the need for advanced analytical tools, such as decision-support systems, capable of supporting decision-making under uncertainty (Sridevy and Djanaguiraman, 2023).

The length of the paper should not exceed 4,000 words (i.e. equivalent to 10 pages of A-4 size including tables and figures). The title of the paper should be in 'capital letters (uppercase)' (Font: Arial, Size: 12 points, all bold) in the centre of the page, and the author's name should be single line space below the last line of the title in the other language. If there are more than one author, these should be on the same line one after another.

Material and Methods

This study is based on the implementation of the ASALEE decision-support tool, designed to assist farmers and agricultural advisors in comparing crop allocation strategies under conditions of uncertainty. The methodological approach relies on an integrated modeling framework combining agronomic, economic, and climatic components. The objective is to simulate and compare alternative cropping strategies in order to identify robust solutions that balance profitability, risk exposure, and resource constraints.

The ASALEE tool operates at the farm scale and is structured to support strategic decision-making, particularly regarding the annual allocation of crops. The approach adopted in this study is scenario-based, allowing the exploration of multiple combinations of climate conditions, price levels, input costs and water disponibility evolution. The tool thus provides a framework for analyzing the sensitivity of cropping decisions to external drivers and for identifying strategies that perform consistently under varying conditions.

ASALEE tool is based on a modular architecture composed of three main components: (i) an agronomic module, (ii) an economic module, and (iii) a scenario module.

The agronomic module simulates crop performance as a function of environmental conditions. Estimation of water stress is based on a water balance which consider climate, soil water availability and crop-specific physiological parameters.

Yield estimation is based on simplified crop models that incorporate the effects of water stress and climatic constraints on biomass production and grain filling. The model accounts for interannual variability by applying different climatic sequences, allowing the representation of both average and extreme conditions.

A central element for improving ASALEE's predictive capacity is the refinement of crop water-response functions, especially for forage species that are increasingly considered in diversified rotations. Recent multi-site trials on alfalfa (*Medicago sativa*) led by Arvalis provide valuable insights into irrigation

responses, water-use efficiency, and root-system adjustments under contrasting water regimes. These experiments, conducted over several years in both research stations and farmers' fields, demonstrated significant impacts of irrigation strategies on plant population density, root profile, and irrigation water-use efficiency, which averaged around 22 kg DM ha⁻¹ mm⁻¹ but varied widely across sites and years. Such findings contribute to parameterizing more accurate water-response functions for alfalfa within ASALEE, improving simulation robustness for systems including forage crops (Larsonneau, 2025).

The economic module calculates the profitability of each simulated cropping system. For each crop, gross margin is computed as:

$$\text{Gross Margin} = \text{Revenue} - \text{Variable Costs}$$

where:

Revenue is derived from simulated yield multiplied by market price;

Variable costs include inputs (fertilizers, pesticides, seeds) and operational expenses.

The model incorporates variability in prices with 500 scenarios. This enables the evaluation of economic performance under different market conditions. Risk indicators, such as variability of gross margin or downside risk, are also computed to capture the uncertainty associated with each strategy. The variable costs come from SYSTERRE tool (<https://www.diverimpacts.net/service/videos/systerrr-by-arvalis-institut-du-vegetal.html>)

- The scenario module enables the generation of multiple combinations of climatic and economic conditions crossed with water disponibility
- These scenarios are combined to create a set of possible future states, representing uncertainty in the decision environment.
- The simulation protocol consists of evaluating a set of cropping strategies defined by farmers over a defined time horizon, typically one cropping season. For each strategy, the model is run across all defined scenarios.
- The evaluation of cropping strategies is based on multiple indicators reflecting different dimensions of farm performance:
 - Economic performance: average gross margin per hectare;
 - Risk exposure: variability of gross margin and probability of low-income outcomes;
 - Resource use: water requirements and input intensity;
 - Robustness: stability of results across scenarios.
- This multi-dimensional evaluation framework enables a comprehensive assessment of the trade-offs associated with different crop allocation strategies.

Results

Beyond its technical components, ASALEE is embedded in participatory design processes with farmers. The tool has been actively used in co-construction workshops, bringing together farmers, advisors, and local institutions to collaboratively explore adaptation pathways and evaluate the impacts of future water stress at the cropping-system level. This approach is at the heart of initiatives such as DIVERSYCOLE in southeastern France, where diversified rotations, forage integration, and improved water management are jointly assessed with farmers to enhance resilience under tightening water-resource constraints. ASALEE supports these territorial dialogues by providing transparent, comparative simulations that help stakeholders reason about irrigation needs, economic risks, and trade-offs between cropping strategies. French South East region is particularly exposed to water scarcity, strong interannual variability in precipitation, and increasing frequency of extreme climatic events such as

droughts and heatwaves.

The dataset used to parameterize the model includes:

- Climatic data: historical weather series (temperature, precipitation, evapotranspiration) at a daily or monthly time step, representing a range of agro-climatic conditions;
- Soil data: soil texture, water holding capacity, and depth, influencing crop water availability and yield potential;
- Agronomic data: crop-specific parameters such as growth cycles, potential yields, and sensitivity to water stress;
- Economic data: crop prices, input costs (fertilizers, seeds, pesticides), and operational costs (machinery, irrigation);
- Regulatory constraints: crop diversification requirements, irrigation restrictions, and environmental policy conditions.

These data were sourced from a combination of regional databases, agronomic references, and advisory networks. The integration of locally relevant data ensures the consistency of simulations with real farming conditions.

The simulations conducted using ASALEE within the CASDAR-funded DIVERSYCOLE project highlight the substantial role of crop diversification as a lever for improving both economic performance and risk management at the farm level. The results indicate that more diversified cropping systems generally exhibit greater stability of gross margins across climatic and economic scenarios compared to specialized systems. Last analysis are still ongoing. ASALEE has been used in a lot of regional projects in all French regions.

Discussion

Several limitations must be acknowledged. First, the accuracy of the results depends on the quality and representativeness of input data. Second, the simplified nature of crop models may not capture all biophysical processes. Third, economic scenarios are based on assumptions that may not fully reflect future market dynamics.

REFERENCES

- IPCC (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.
- Del Pozo, A., Brunel-Saldias, N., Engler, A., Ortega-Farias, S., Acevedo-Opazo, C., Lobos, G.A., Jara-Rojas, R. and Molina-Montenegro, M.A. (2019). Climate Change Impacts and Adaptation Strategies of Agriculture in Mediterranean-Climate Regions (MCRs). *Sustainability*, 11(10), 2769.
- Alrteimei, H.A., Ash'aari, Z.H. and Muharram, F.M. (2022). Last Decade Assessment of the Impacts of Regional Climate Change on Crop Yield Variations in the Mediterranean Region. *Agriculture*, 12(11), 1787.
- Gutiérrez, F. (ed.) (2022). Application of Decision Support Systems in Agriculture. *Agriculture* (MDPI Special Issue).
- Raksha, Sharma, S., Dhankar, A., Rana, M., Shiksha, Kumar, K., & Thakur, A. (2024). Agronomic Interventions for Alleviating
- Water Stress and Optimizing Productivity of Field Crops: A Review . *International Journal of Environment & Climate Change*, 14(9), 669–680.
- [researchgate.net]
- Pérez, C., López, A. M., & Sánchez, L. (2025). Climate change impact on rice growth and agronomic practices: A comprehensive review . *International Journal of Research in Agronomy*, 8(8), 844–846. [agronomyjournals.com]

- Plant Science Review Editorial Team. (2025). The Role of Agronomic Interventions in Mitigating Climate Change Impacts on Crop Growth and Yield . Plant Science Review. [psr.crcjournals.org]
- ARVALIS – Institut du végétal. (2022). ASALEE : l'app créée par ARVALIS récompensée à l'international . [arvalis.fr]
- Chambres d'Agriculture France. (2024). Arvalis : l'outil ASALEE de comparaison des assolements vis-à-vis de la ressource en eau . Webinaire. [operaconn... culture.fr]
- CNIPT. (2025). ASALEE, comparateur d'assolement vis-à-vis de la ressource en eau . Pomme de terre hebdo , n°1439. [cnipt.fr]
- Larsonneau, P. (2025). Effects of Water Stress on Alfalfa and Impacts of Irrigation . Proceedings of the Alfalfa Symposium (UC Davis).