Focus

Irré-LIS®, an example of an irrigation decision-support tool

Designed by the ARVALIS-Institut du Végétal, Irré-LIS® is a simple water balance model that can be used to control irrigation based on weather conditions and plot data provided by the farmer. The online tool was used to manage thirty-five thousand hectares of irrigated crops in 2019. It is currently operational for potatoes, grain and fodder maize, seed maize, soft wheat, durum wheat, spring barley, tobacco and soya.

Water is a major production factor in France. Agriculture draws about four billion m³ of water per year, i.e. between 10 and 15% of total water withdrawals, but of that consumes truly three billion m³, i.e. 50% of total water consumption (Roy, 2013). The increase in average temperatures and the stagnation of rainfall are resulting in more and more crisis situations. All forecasters agree that plant water needs will continue to grow in the near future (Gendre et al., 2019). Climate change will also affect the distribution of rainwater with future projections predicting wetter winters and drier summers in France (Boé et al., 2008; Terray and Boé, 2013; Vidal et al., 2012). This will be combined with the irrigation water requirements resulting from increased food needs linked to world population growth (Gerland et al., 2014).

It, therefore, becomes a matter of paramount importance for farmers to manage water to approximate the needs of the plant as closely as possible. When to bring water and in what quantity?

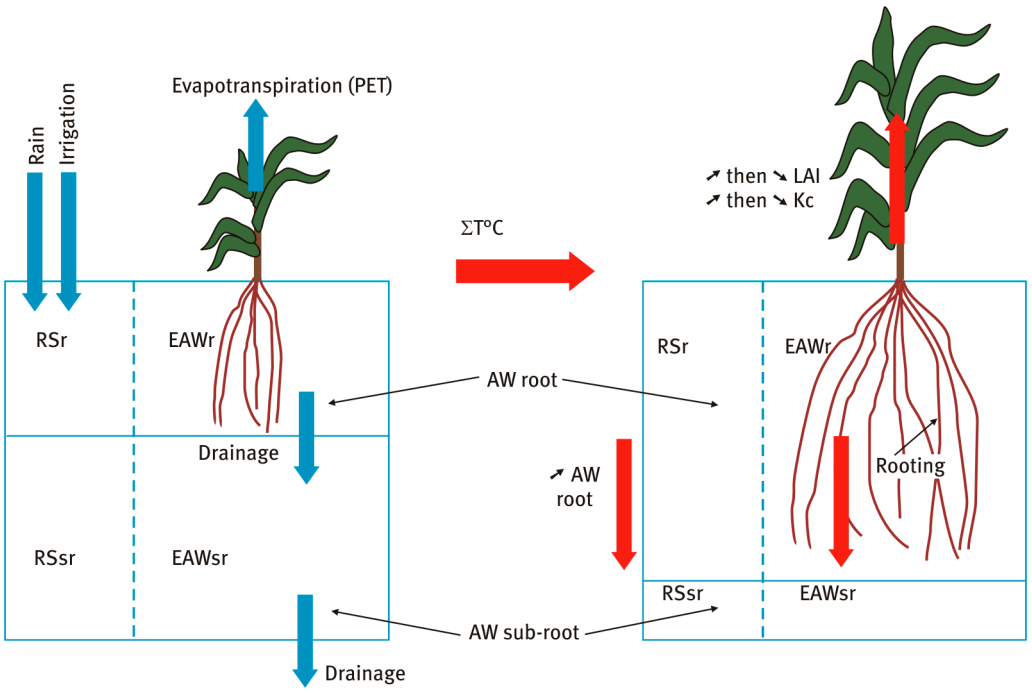
One of the tools for meeting this challenge is irrigation management. There are decision-making tools that allow farmers to plan their irrigation on a plot-by-plot basis according to precise agricultural and pedoclimatic criteria. Two main families of tools exist: tools based on modelling or water balance and tools based on plot-based measurements. The two main families of tools each have their advantages and disadvantages, as summarised in Table 1.

1 Advantages and drawbacks of the two main families of decision-support tools for irrigation management.

Period	Calculated water balance	Field measurements: voltages (tension probes) or humidity (capacitive probes)
Winter to germination	Required initialisation of the water balance to assess the state of the easily available water storage capacity of the soil (EAW)* at the beginning of the season.	Direct assessment of the state of the RFU at the beginning of the crop cycle. The measurement incorporates previous effects: previous winter and evaporation in spring. Note the depth of measurement if there is a significant deficit.
Germination with complete ground cover by vegetation	Relevance of water balance calculation depending on cover growth and soil surface (texture, colour, structure).	Measurement directly incorporating the effects of soil evaporation and plant transpiration: period when the field measurement is the most relevant because it incorporates specific situations not taken into account by water balance tools (low crop growth, etc.).
Complete soil coverage to senescence	Most relevant calculation period assuming correct accuracy of input data (rainfall, irrigation, PET **) and normally developed cover (no nitrogen stress, or health problems).	Delicate interpretation of measurements in the case of limited rooting. In case of severe restriction, the tensiometric probes are not very suitable (ceiling of 150 cbars). Note the depth of measurements in deep soil. Check the representativeness of the site because of irrigation.
Accuracy and representativeness	Depends on the accuracy of the input data: PET, rainfall, irrigation, estimation of RFU and AW***.	Representativeness of the measurement site: soil, position in the water circuit, irrigation equipment (overlapping area). Local measurement of irrigation essential (rain gauge).
In case of thunderstorm or heavy rain	Need to estimate effective rainfall.	The measurement includes effective rainfall... locally

* EAW: Easily Available Water; ** PET: potential evapotranspiration; *** AW: Available Water.

❶ **Schematic operation of the Irré-LIS® tool (RSr = survival root water storage capacity, RSsr = survival sub-root water storage capacity, EAWr = easily available root water storage capacity, EAWsr = easily available sub-root water storage capacity, LAI = leaf area index, kc = crop coefficient).**



Within the family of modelling tools, several calculation mechanisms exist. The best known are:

- AquaCrop, a model developed by the FAO[1], free access available online for barley, cotton, dry beans, maize, rice, potato, quinoa, sorghum, soya, beet, sugar cane, sunflower, teff, tomato and wheat;
- Optirrig, a model developed by INRAE[2] (ex-Irstea) for large-scale cultivation and market gardening, as well as for the hay of the Crau plain;
- MOUSTICS, a model developed by INRAE (ex-INRA), free access available on request for soft wheat, durum wheat, maize, sunflower, rapeseed, spring peas, winter peas, spring barley, winter barley, sorghum, soya, alfalfa, rye-grass, mustard, vetch, vine, miscanthus grass, sugar cane, rice, sugar beet;
- AqYield, a model developed by INRAE (ex-INRA) free access available on request for soft wheat, rapeseed, maize, winter peas, spring peas, soya, sorghum, sunflower, meadow, intermediate crop, ryegrass;
- SAFYE, a model developed by CESBIO[3] free access available on request for maize, wheat, sunflower and soya;
- Irré-LIS® belongs to the first tool category. It is a simple water balance model. The model was designed by Arvalis-Institut du végétal. Arvalis is an agricultural technical institute specialising in field crops (straw cereals, maize, fodder, potatoes, tobacco, flax fibre), financed and managed by French farmers.

In the tool, the plant is simply modelled as an evapotranspiration unit (there is no evaporation/transpiration separation), unlike more complex biophysical models such as STICS, AquaCrop or Pilote. The aim of the model is to require not much configuration to make it user-friendly for farmers. It is a proprietary tool for which a fee is charged. Implemented in the field since 2008, it is a water balance model with two reservoirs. The soil is divided into a functional root reservoir and a functional sub-root reservoir. This means that it takes into account root growth as the cycle progresses and that the usable reservoir accessible to the plant at the beginning of the cycle is lower than that at the end of the cycle (Figure ❶).

1. Food and Agriculture Organization.
2. INRAE, French National Research Institute for Agriculture, Food and the Environment was born of the merger in 2020 between INRA, the National Institute for Agricultural Research, and IRSTEA, the National Institute for Research in Science and Technology for the Environment and Agriculture.
3. Biosphere Space Studies Centre.

The tool's configuration was based on Arvalis' field experiments in different French regions over more than ten years. The farmer accesses the tool via a web platform and enters information about his plot (location, crop, variety, sowing/planting date, presence of an intermediate crop, soil type or available water storage capacity of the soil). The location of the plot is used to spatialize the weather data. In fact, for the calculation of potential evapotranspiration (PET), the tool takes into account the five weather stations closest to the plot and estimates PET in proportion to the distance from each station. For rainfall, the five nearest weather stations are also taken into account, but an additional step is envisaged. Rain is taken into account only if it has rained on the nearest station. If this is the case, it is then calculated in proportion to the distance of the five stations in the same way as for the PET. Nevertheless, it is a complex task to estimate summer rains, which are often very localized. For this reason, it is possible for the farmer to modify the rains in the tool. From 2020, it has been possible for him to connect a linked weather station to his plot of land to take into account the actual rainfall. Based on the soil, weather conditions and crop, the tool calculates in real time:

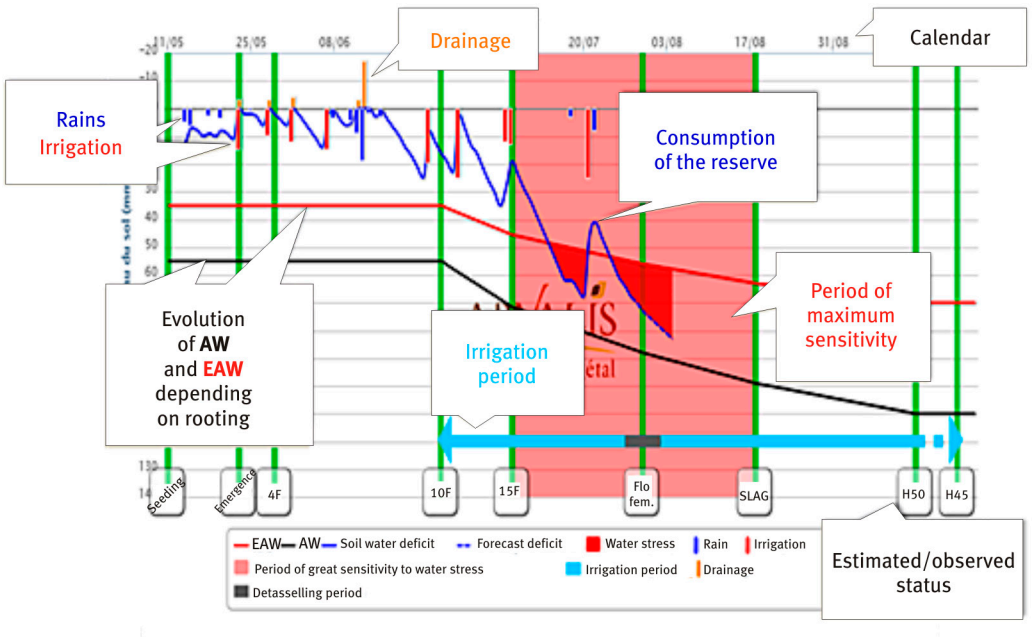
- the estimated dates of the physiological stages of the different species,
- the status of the soil water reserve and the seven-day forecast (excluding possible rainfall),
- the PET forecasts.

From all the information entered, the tool can generate a graph (Figure ❷) that facilitates the farmer's decision making. It follows the blue curve (calculated soil water deficit) and its objective is to keep it above the red line (the bottom of the reservoir that can easily be used by the plant). If its water deficit is 0 (moisture at field capacity), the tool calculates drainage (orange bar). The Irré-LIS tool does not decide when to irrigate; the decision as to whether or not to launch the irrigation system is always up to the farmer who has to take into account the results of the tool but also the rainfall forecast and the capacity of his irrigation equipment.

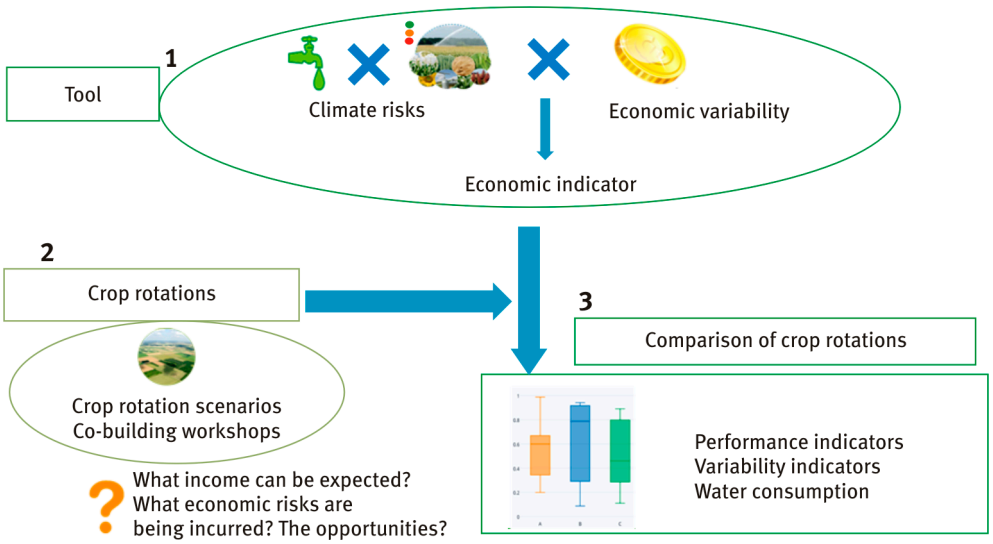
The tool now works with potatoes, grain and fodder maize, seed maize, soft wheat, durum wheat, spring barley, tobacco and soya (a crop implemented in partnership with Terres Inovia). In 2019, the tool enabled farmers to manage 35,000 ha of crops.

The model is also used on a scale larger than the plot. Indeed, beyond its use for irrigation management at the plot level, because quantitative water management is also relevant at the farm level, the Irré-LIS calculation engine has been integrated into the ASALEE tool, also designed by ARVALIS - Institut du végétal in partnership with Terres Inovia, INRAE, the Chambers of Agriculture of Charente-Maritime and Deux-Sèvres. ASALEE is a decision-support tool for comparing crop rotation strategies (Figure ❸), based on the emerging need to identify the impact of climatic hazards on the economic results of "field crop" type farms. The objective of ASALEE is to enable a farmer and/or advisor to compare different crop rotation choices by integrating various risk factors such as the variability of agricultural production prices, climate change and access to water resources. These choices, driven by the technical capacities of a given farm, will make it possible to determine the level of acceptable risk-taking so that each farmer can identify their own solutions.

❷ **Irré-LIS ® Farmer's visual water balance for a grain maize crop.**



❸ Schematic diagram of the functioning of ASALEE.



The ASALEE tool is mainly used in the context of the CLIMASSOL project in New Aquitaine (project funded by the Nouvelle Aquitaine Regional Council, 2020) to understand the effect of climate change on current crop rotation and to reflect on possible adaptations via the co-building of crop rotations that break with current practices.

Irré-LIS is a simple crop model (no simulation of the foliar index or intercepted rays, for example), which enables the integration of new low-cost crops in terms of initial inputs and it is a tool that is increasingly used at the plot level by farmers. The new uses of the model at the farm level allow farmers to get answers to their questions on crop rotation with regard to water availability. ■

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Further reading...

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