

ESTIMATING IRRIGATION DEMAND AT TERRITORIAL SCALE: AN OPEN-DATA BASED APPROACH

ESTIMATION DE LA DEMANDE EN EAU IRRIGATION A L'ECHELLE TERRITORIALE: UNE APPROCHE BASEE SUR DES DONNEES OUVERTES

P. Rouault¹, D. Dorchies¹, C. Richert², G. Belaud¹

ABSTRACT

Against the backdrop of climate change, the agricultural sector is facing a significant squeeze between dwindling resources and increasing crop requirements. To make the best possible use of increasingly scarce water resources, changes in agricultural practices must be implemented. However, to have a significant impact, these practices must be considered at a regional level. However, in order to make these decisions and assess in advance the impact of a change in practice on consumption, it is necessary to rely on quantitative simulations. These simulations require taking into account numerous factors specific to the region, such as soil characteristics, crop types and climatic conditions. This study illustrates the method on a territory with lavender cultivation in the south of France. This crop is increasingly irrigated. This study uses CAWET (Calculation of Agricultural Water needs and Evapotranspiration) to model a territory with and without irrigation water to meet the needs of lavender. This tool enables the collection of agro-pedo-climatic data and the simulation of crops' irrigation water requirements. This comparison, with the generation of graphs and maps, makes it easy to visualise the significance of the decision to irrigate this crop.

Keywords: climate change; soil characteristics; crop types; climatic conditions; agricultural Water needs; Evapotranspiration.

RESUME

Dans le contexte du changement climatique, le secteur agricole fait face à une pression importante qui existe entre la diminution des ressources et l'augmentation des besoins en cultures. Pour optimiser l'usage s ressources en eau de plus en plus rares, il est constaté de modifier les pratiques agricoles. Cependant, pour avoir un impact significatif, ces pratiques doivent être considérées au niveau régional. Cependant, afin de prendre ces décisions et d'évaluer à l'avance l'impact d'un changement de pratique sur la consommation, il est nécessaire de s'appuyer sur des simulations quantitatives. Ces simulations nécessitent de prendre en compte de nombreux facteurs spécifiques à la région, tels que les caractéristiques des sols, les types de cultures et les conditions climatiques. Cette étude illustre la méthode appliquée sur un territoire consacrée à la culture de lavande au sud de la France, une culture de plus en plus irriguée. Cette étude utilise le CAWET (Calculation of Agricultural Water needs and Evapotranspiration) pour modéliser le territoire dans le cadre de deux scénarios : avec et sans eau d'irrigation afin de répondre aux besoins en lavande. Cet outil permet de recueillir des données agro-pédoclimatiques et de simuler les besoins en eau d'irrigation des cultures. Cette comparaison, avec la génération de graphiques et de cartes, permet de visualiser facilement l'importance de prise de décision d'irriguer cette culture.

Mots-clés: Changement climatique; Caractéristiques des sols; Types de cultures; Conditions climatiques; Besoins en eau agricole; Evapotranspiration.

¹ UMR G-Eau, Univ. Montpellier, AgroParisTech, BRGM, CIRAD, INRAE, Institut Agro, IRD, Montpellier, France

² UMR MIA Paris-Saclay, Université Paris-Saclay, AgroParisTech, Palaiseau, France

1. Introduction

In the context of climate change, rainfall patterns are changing. In many regions, such as in southern France, less rain is expected during irrigation seasons while higher temperatures should lead to an increase in evapotranspirational demand (Xue et al. 2025) and crop water requirement. This scissor effect (increasing demand and decreasing water availability) is observed in various climates, notably in Mediterranean climates (Duarte et al. 2021).

A common adaptation strategy is the use of irrigation (Balasubramanya et al. 2022), which raises the issue of water availability at the territorial scale, as well as the efficiency of various levers, such as crop rotations, the conversion to resilient varieties that require less or no irrigation supply, mulching, shading, watering using alternative methods, etc. (Ingrao et al. 2023).

Prospective scenarios must therefore include the evaluation of the potential of such strategies to decrease the overall water abstraction. In order to engage in dialogue at the regional level with stakeholders (farmers as well as various water users) and collectively reflect on the changes in practices desired locally, it is important to be able to inform the discussion with quantitative estimates of the prospective impact of a given change (Von Korff et al. 2010). Furthermore, visual tools can greatly support constructive debates by enriching discussions, particularly in the context of territorial conflict management (Swaab et al. 2002).

To estimate the irrigation water requirements of crops in a given area, crop water balance modelling is a widely used method that enables the quantification of the irrigation water requirements (Uniyal and Dietrich 2021). However, when estimating total irrigation water needs across the region, it is not sufficient to treat the region as a homogeneous whole (Ferreira et al. 2023). Factors such as crop diversity, irrigation practices, soil types and microclimatic variability must all be considered before aggregating the estimates at a regional level (Han et al. 2020; Rouault et al. 2026).

Such estimates require spatial databases. In mainland France, numerous previous studies have provided a wealth of information through national surveys and modelling of agronomically relevant parameters, and meteorological services provide data at a high spatial resolution. Similarly, current research now provides estimates of future local weather conditions. All this data is available online and can therefore be reused (Soutif-Bellenger et al. 2023).

However, this data is often overlooked, difficult to access and difficult to put into practice. Thus, whilst tools do exist in the literature to estimate regional water consumption for the irrigation of crops (Wriedt et al. 2009; Ruelle 2022; Balgabaev et al. 2025), these approaches are rather complex to use and require expert knowledge, making them non-accessible to non-specialist. However, for the debate of water sharing at territorial scale, there is a need to automate the production of indicators and visualisations of irrigation requirements in order to make it easier for water management stakeholders to explore and compare regional scenarios for future agricultural evolutions.

To do so, an open-data based tool has been developed to estimate irrigation demand at territorial scale. The open-source tool, CAWET (standing for Calculation of Agricultural Water needs and EvapoTranspiration), which enables the automated retrieval of relevant agro-pedo-climatic data, the modelling of each crop according to local conditions, and finally the creation of graphs and maps illustrating the water requirements of the territory. This article describes its principles and its application as a support for discussions about the trajectory of irrigated crops.

As an illustration, a case study is presented in the South of France, where large changes in irrigation demand are expected following the extension of lavender crops. The shift from irrigated cropping systems to no irrigation at all is a typical example of the challenges faced in a region subject to an increasingly harsh climate.

2. Methodology

2.1 Study area and evolution to the crop rotation system under investigation

2.1.1 Study area

The municipality of Oraison in southern France was chosen as a case study. This area is notable for its significant diversity of crops, with a predominance of lavender - a typical crop of the region - as well as arable crops (durum and soft wheat, soya, alfalfa, etc.) and typically Mediterranean crops such as olive groves and other fruit orchards. This area enjoys a typical Mediterranean climate, characterised by hot and dry summers, occasionally punctuated by thunderstorms.

As an illustration of the tool, prospective scenarios are analysed for a medium-range horizon (ca. 2050). To do so, the local DRIAS projections were used for the period of interest (2020 to 2022 as a simulated reference period, then 2045 to 2055 for projected scenarios), based on the RCP 8.5 scenario (Table 1). This table shows that the annual temperature is expected to rise by around 1 degree (°C) by the decade 2045-2055. Rainfall and the annual sum of potential evapotranspiration (PET) are highly variable both currently and in the future.

Table 1: Climatic characterisation in Oraison for following years from Drias simulation

	Sum of rains (mm)	Sum of PET (mm)	Average Temperature (°C)
2020	702	986	13.2
2021	591	1139	13.0
2022	670	1098	13.4
2045	785	1084	13.5
2046	642	1102	14.4
2047	835	1068	14.3
2048	517	1041	13.9
2049	777	1045	14.7
2050	759	1048	15.2
2051	703	1150	14.2
2052	571	1043	14.6
2053	892	1045	14.8
2054	567	1103	14.5
2055	878	1133	15.0

The proximity of the municipality to the Durance, a river with a substantial flow, currently ensures an adequate water supply. However, these Mediterranean regions are increasingly suffering from sporadic droughts during the summer months, leading to a shortage of water and coinciding with a rise in crop water requirements due to high temperatures. As a result, the region is often subject to directives from local authorities to reduce irrigation, putting potentially crop yields at risk.

Climate change will, in fact, lead to an increase in the frequency of such restrictions. The region therefore needs to review its crop rotation practices in light of climate change. Considering this potential in the context of a municipal level is a good compromise to visualise and simplify these processes.

2.1.2 Trends in crop production in the medium term

One of the most widespread crops in the region is lavender; it has medium water requirements but is very sensitive to extreme dry periods, and irrigation is being used more and more frequently due to the risks associated with severe droughts (Yetik and Şen 2025). Stakeholders could consider replacing it with a non-irrigated crop (such as non-irrigated grassland or vineyards without water supply or even return to lavender cultures but with more resilient varieties which could be non-irrigated) to reduce their dependence on irrigation water.

2.2 CAWET workflow and data sets

2.2.1 CAWET Workflow

For a period and area specified by the user, CAWET calculates a daily water balance for each crop. To do this, it follows three key steps illustrated in Figure 1.

- The retrieval of local spatial data: boundaries of agricultural parcels, crops recorded in the French LPIS (Land Parcel Identification System) , soil data (depth, usable reserves), as well as local daily weather records.
- Simulation, using a crop model, of evapotranspiration and potential irrigation water requirements for each of the crops identified within the area and parameterised in the model, for each relevant climate grid cell.
- The creation of visualisations (graphs and maps) illustrating the characteristics of the area and the modelling results obtained

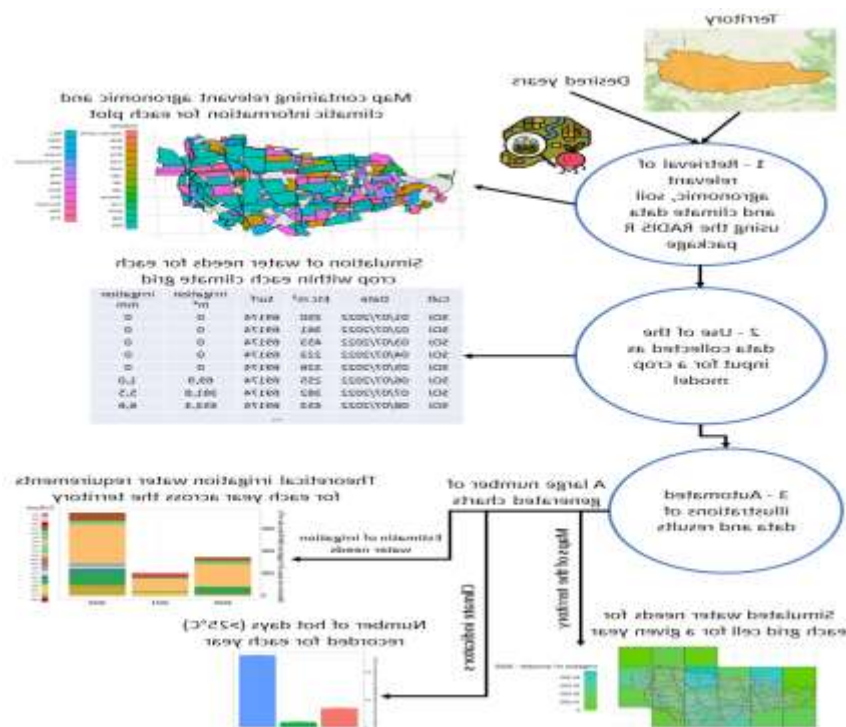


Figure 1: Flowchart of CAWET and illustration of the main processing stages

In the present version of CAWET, the standard FAO-56 approach ([Allen et al. 1998](#)) is chosen, as it is available for most crops (whether perennial or annual), and well evaluated and documented in various parts of the world. This approach is based on the use of a dynamic daily crop coefficient taken from a table, and a water balance in the soil taking account of evapotranspiration (with possible water stress), rain and irrigation (triggered according to user-defined rules). A wide range of crops are included, enabling the system to account for the great diversity of crops grown in the territory.

2.2.2 RADIS, a package for retrieving relevant agro-pedo-climatic data.

RADIS (Retrieve Agronomic Data In a Sector) is an open-access R library that facilitates the retrieval of public data for any area within mainland France (Figure 2). The databases used by RADIS enable the characterisation of past and future climate, soil, and land parcels. These data are standard inputs for models that estimate crop water requirements.

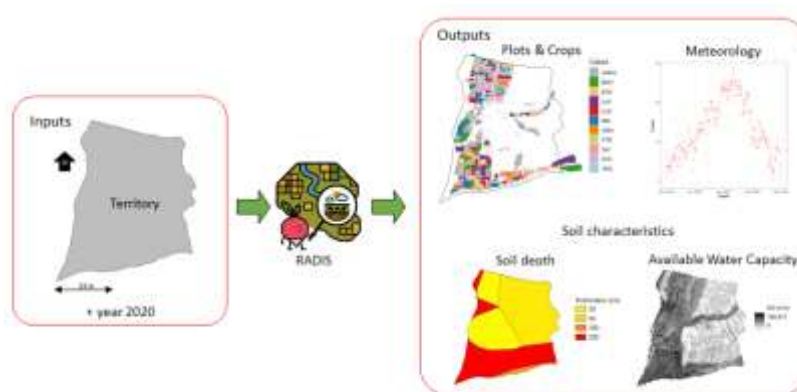


Figure 2: Diagram showing how the RADIS library works to retrieve different types of data.

RADIS thus enables the retrieval of gridded meteorological data with a spatial resolution of 8 km and a daily time step from three different databases:

- SIM2 data produced by Météo-France using the SAFRAN-ISBA model chain, available from 1958 up to the date of download ([Meteo-France 2025](#)).
- DRIAS/Explore2 climate projections are available for the RCP scenarios covering the periods 1950–2100 for RCPs 2.6, 4.5 and 8.5 ([Sauquet et al. 2025](#)).
- The FYRE Climate reanalyses characterising precipitation and temperature between 1871 and 2012 ([Devers et al. 2021](#)).
- The soil characteristics that can be retrieved using RADIS are:
- Soil depth, derived from the French Soil Geographic Database ([Le Bas 2021](#)).
- The Available Water Capacity (AWC), which may be sourced from the French Soil Geographic Database ([Le Bas 2018](#)) or a database modelised by INRAE's Info&Sols Research Unit ([Roman Dobarco et al. 2021](#)).
- The texture, which may be derived either from a database produced by the Info&Sols research unit ([Roman Dobarco et al. 2022](#)), or from the HWSO database ([Batjes 2016](#)), or from the SoilGrids database ([Poggio et al. 2021](#)).

Finally, RADIS facilitates access to data from the RPG (Registre Parcellaire Graphique) which involves making the French section of the LPIS (Land Parcel Identification System) freely available, derived from the declaration of agricultural parcels under the European Union's Common Agricultural Policy (CAP), and to the "RPG complété" (enhanced RPG), which identifies parcels not declared under the CAP and

their crop rotation patterns, drawing in particular on remote sensing data for mainland France ([Lardot et al. 2022](#)).

2.3 Parametrisation for the case studied

2.3.1 Data selection for CAWET parameterization

The tool used has a wealth of data available to simulate the area of interest. This study has chosen to simulate two scenarios: one in which irrigation of the lavender fields continues to fully satisfy the actual needs of lavender areas, and the other in which irrigation possibility of these areas is halted. The simulations were carried out for 3 years of the present period (2020 to 2022) and track this trend for future years around 2050 (from 2045 to 2055).

The locations of the fields were identified using the local LPIS directly by the tool. The climatic characteristics were derived from the Drais database projections (RCP 8.5) for future and past years. Finally, the soil AWC characteristics were extracted from the Info&Sol database.

The crop parameters (crop coefficients, key dates, etc.) required for the underlying operation of CroWat are based on the set of parameters provided within the tool. Among these, the parameterisation selected for lavender cultivation - which is particularly important in this study - is the "Lavande_lavandin_1". This setting assumes a crop with a crop coefficient that starts at 0.35 in mid-February, then rises gradually to a maximum of 0.95 in April, remains stable between April and July, and then falls gradually to 0.8 between July and September ([Pereira et al. 2024](#)).

In simulations with no restrictions on water supply between April and October, irrigation is set at 100% of the crop's water requirements. This period corresponds to the typical period of water availability in the southern regions of France. As for the scenario involving a ban on irrigation for lavender, the parameters remain as before, with the exception of the irrigation period, which is prohibited throughout the calendar year for lavenders.

2.3.2 Comparison with actual data

The difficulty in using regional models lies in the lack of reliable comparative data. In France, the "Banque Nationale des Prélèvements d'Eau" (BNPE - National Water Withdrawal Database) provides a quantification of municipal water consumption linked to agricultural irrigation. This database is the only one available that provides a reasonably accurate figure for the amount of irrigation water used declared by farms whose headquarters are located in the municipality in question. This database does not reflect the actual water withdrawals of the plots within the area, but rather the figures reported by the farms listed in it. In the case of the municipality of Oraison, the water withdrawal reported for the farms is around 3 million cubic metres per year.

3. Results

3.1 Variation in total irrigation water consumption across the territory according to years and scenarios

Table 2 shows the trend in simulated water irrigation needs for lavender in the region in the context of climate change. It appears that the water requirements for this crop are relatively high (384 to 574mm). These data show significant year-on-year variability, particularly between 2020 and 2021 and between 2051 and 2052. These substantial gaps are linked to the variability of the climate simulations. The DRIAS estimations are not actual figures for a given year but illustrate the diversity and specific climatic variations between years over a period. As a result, crop water requirements fluctuate significantly from one year to the other, with an upward trend expected in the coming years, when these requirements will depend heavily on the actual rainfall patterns observed in the 2050s.

Table 2: Estimated average water requirement for lavender crops in the territory for the various climatic years (20XX) analysed

	20	21	22	45	46	47	48	49	50	51	52	53	54	55
Average water needs (mm)	388	574	553	492	493	503	432	488	448	538	384	427	542	471

A comparison of the irrigation water requirements estimated by CAWET (Figure 3) firstly illustrates the importance of considering the irrigation required to meet lavender's water needs in terms of total water consumption (approximately 25% of total water needs are attributable to this crop). This graph also illustrates, on the one hand, the variability in these requirements between the different years. In particular, wet years such as 2020 show relatively lower simulated water demand values than drier years (2021, 2022, etc.). However, the tool takes rainfall patterns into account; thus, certain climatically dry years (2048, for example) show lower simulated water requirements because rainfall was more evenly distributed across the growing season.

The difference between past and future years in this region is not immediately apparent, as the majority of crops grown here are well adapted to future climatic conditions. However, it is interesting to note from this diagram that a large inter-annual variability persists. Furthermore, comparing the scenario where irrigation of the main crop is maintained with one where it is discontinued highlights the effect of discontinuing a practice in a region such as the one presented here. This gap is all the more evident in the years ahead, when demand will be exacerbated by rising temperatures and increased evapotranspiration, even though, under the current settings, lavender is only slightly affected.

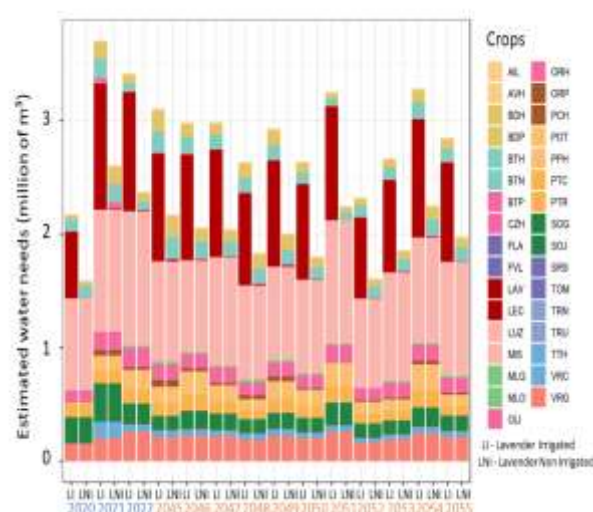


Figure 3: Chart comparing simulated water requirements for crops in the region by years and scenarios

3.2 Spatialisation of the simulation results on the different locations in the territory

The spatial representation of water consumption at a resolution of 1 km, as shown in Figure 4, allows for a quick visualisation of areas of high water consumption due to a concentration of cultural fields with water demand (the Center West) and areas of lower consumption (here, the North-Est part of the territory). These maps were generated for the year 2048, the climate scenario with the lowest cumulative rainfall (Table 1); this allows to visualise, in an extreme climate scenario, the variation in water consumption between two land-use management approaches. Comparing the maps showing the situation with and without a change in practice allows us to identify the areas most affected by a change in practice. It is interesting to note a difference in consumption particularly marked in the central part of the extensive agricultural area to the South of the municipality. This practical change could therefore

alleviate the pressure on resources more significantly in this area, allowing available resources to be reallocated to other parts of the region where demand remains high such as the North or the West part.

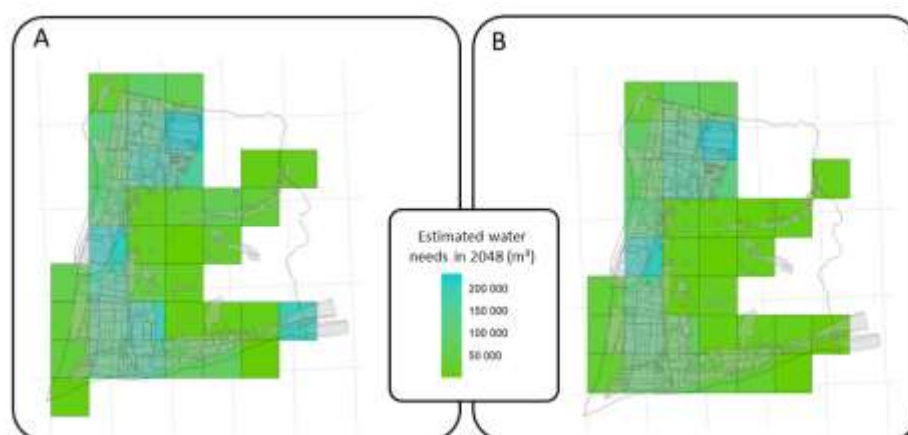


Figure 4: 1 km grid maps of the region showing the cumulative water requirements of crops for the scenario involving the continuation of current practices (A) and the scenario involving a shift away from irrigation on land currently planted with lavender (B) for 2048

4 Discussion

4.1 Discrepancies between practice and available validation data

The irrigation water withdrawal reported in to the BNPE (3 million m³) is indeed of a similar order of magnitude to the figures produced by the tool in the simulation of local crop water requirements (approximately 2.5 million m³). To explain the discrepancies between BNPE reports and water demand simulations, it is important to bear in mind several key factors in the simulation. Whilst the uncertainty in climate data associated with the use of DRIAS projections may appear to be the main cause of interannual variability, other factors also influence the discrepancy between CAWET simulations and reported data.

Firstly, it is important to note that the two sets of data are not strictly comparable. On the one hand, the BNPE declarations relate to water use by farms whose registered office is located within the municipality, whereas the simulations are based on plots of land situated within the municipal area. A plot of land located within the municipality but where the farm's registered office is outside the municipality will not be counted by the BNPE. Similarly, a farm whose registered office is located within the municipality may have plots outside its boundaries. On the other hand, BNPE declarations report the actual amount of water supplied to crops; however, these declarations may be inaccurate due to a lack of knowledge on the part of those involved (Chery et al. 2014).

Secondly, the simulations do not consider the actual amount of water supplied to the plots, but rather the crops' water theoretical requirements. Water supply practices that result in a deficit, notably when there are restrictions, or conversely, over-irrigation, are therefore not taken into account. These are, however, common practices, as crop irrigation depends on the farmer's habits and their subjective assessment of the crop's condition at a given time (Olivera-Guerra et al. 2023; Rouault et al. 2026). There are also different uncertainties in the modeling chain, such as soil characteristics, crops coefficients and phases, irrigation efficiency...

Such information is generally not accessible at the plot nor the farm scales, so that "standard" values have to be used. For example, drip irrigation is usually considered as highly efficient (van der Kooij et al. 2013). However, on the one hand, this is not always true (e.g. Benouniche et al. 2014) and, on the other hand, irrigation efficiency depends on many factors not reported in any database. Similarly, there

is no method that can reliably determine whether a plot of land is irrigated or not. Remote sensing methods have been explored in numerous studies, but they cannot be generalised to larger areas or various types of crops ([Bwambale et al. 2022](#); [Awais et al. 2023](#); [Rouault et al. 2024](#)).

One of the key factors that may also explain the discrepancies between reported data and simulations is the inclusion of the inherent variability in the tool's input data. In this case, the soil data in particular is based on a pre-existing model of soil AWC at a resolution of 90m ([Roman Dobarco et al. 2021](#)). This preliminary modelling itself involves inherent uncertainties regarding the results it produces ([Román Dobarco et al. 2019](#); [Styc and Lagacherie 2021](#)).

Finally, the last adjustable parameter that could introduce uncertainty into the simulation is the estimation of the crop's water requirement using the FAO56 method itself. This method is based on crop coefficient parameters for each crop type; these parameters were established in various studies and do not necessarily correspond to the specific variety actually present to which the general coefficient is applied. Consequently, varietal variations are not considered ([Pereira et al. 2021](#); [Andreu-Coll et al. 2024](#)). Whilst various methods have been explored to adjust these coefficients in line with the actual growth of existing crops from Remote-Sensing analysis ([Saadi et al. 2015](#); [Rouault et al. 2025](#)), they are relatively cumbersome to implement and have not yet been made available or studied for all crops across the regions.

4.2 Evaluation of the scenario-building process and discussion of the results generated by the CAWET tool

This relatively simple simulation of a scenario in which the region transitions to a different practice makes it easy to see the impact of this change on estimated irrigation water consumption. It thus makes it possible, on the one hand, to better identify the order of magnitude of the volumes involved (Figure 3) and, on the other hand, to visualise spatially the impact this will have on water consumption within the region (Figure 4). In this study, simulating this practice thus makes it possible to identify areas that are affected to varying degrees by changes in the practice. This visualisation could enable stakeholders on the ground to consider their water management plans in order to concentrate water supplies in areas of high demand, but also to consider future water supplies in light of the practices envisaged by agricultural stakeholders and what they will implement.

4.3 CAWET tool usability

CAWET is a functional tool released under an open-source licence, enabling the simple and quick estimation of the theoretical water needs for a range of crops across a given area. The main benefit of this approach lies in the automated extraction of soil, crop and climate data, which are essential for calculating water balances. A number of evolutions are currently being considered with a view to improving certain aspects of this tool and expanding its scope.

One area for improvement concerns the agronomic parameters used by the model. The set of coefficients currently incorporated, drawn from the FAO database, covers a large proportion of the crops commonly found. However, these coefficients may depend on local soil and climate conditions or on specific characteristics of the crop variety or cultivation practices ([Guerra et al. 2016](#)). The database can be expanded to adapt these coefficients to local conditions and extend their coverage to new crops or production systems.

However, other approaches could also improve the use of these tables. In particular, the use of fixed calendar dates for changes in the crop coefficient within the models could be replaced and refined by calculating key phenological stages based on locally recorded degree-days. This approach would make it possible to account for variations in the timing of emergence, peak vegetation growth and senescence for crops under local conditions, including future conditions derived from Drias projections ([Paredes et al. 2025a, b](#)). Other crops models can also be plugged in place of Cropwat (eg. Aquacrop).

Similarly, various other data sources, such as remote-sensing, could be used to improve our understanding of the land and the diversity of farming practices. This improved understanding of farming practices would enable us to calculate the crop coefficient for each plot more accurately (Saadi et al. 2015; Rouault et al. 2024, 2025; Ahady et al. 2025).

Conclusion

Changing an agricultural practice such as crop irrigation has a major impact on the amount of water required in the region. The simulation of this water volume is significantly affected, and visualising it through graphs and grid-based maps helps to illustrate the impact of a particular practice on current and future water use patterns.

CAWET is therefore a tool that greatly facilitates the modelling of regional water demand. It should be noted, however, that this tool is based on a modelling principle that relies on data which, in turn, is based on datasets derived from modelling to determine local agro-pedo-climatic characteristics and which are therefore themselves subject to uncertainty. Consequently, the reliability of the tool cannot be guaranteed within a precise range of measurements. This tool is primarily intended to identify, assess and illustrate the dynamics at play in relation to a particular practice. It is not intended to be used as a decision-making tool for localised applications. The tool is, however, flexible and designed to be improved over time. Its open-source structure allows for the addition of new cropping patterns or the straightforward implementation of new practices that affect local water use.

The use of grid-based maps and simulations that generate easy-to-understand graphics makes it simple to get a sense of the scale of the changes involved in altering crop rotations or land-use practices. Furthermore, these maps allow the area to be visualised intuitively and highlight areas of high demand. All these features aim at facilitating local dialogue between stakeholders.

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