Overview and Potential of Digital Decision Support Tools in Promoting Agroecological Irrigation

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Summary

- Introduction/Background
- Research Questions or Objectives
- Assumptions
- Literature review
- Methodology
- Results and Discussion
- Conclusion
- Limitations
- Future Research
- Contribution to the Field
- Acknowledgments

Introduction/Background

- Increasing irrigation demand with scarce water resources exacerbated by climate change with increasing irrigation demand.

- How to promote water efficiency and reduce water wastage in agriculture.

- The transition to agroecological irrigation and sustainable agricultural practices.

- The use of new technology?

Research Questions or Objectives

- To characterize the existing DSTs in France.

- Identify motivations, utilization issues, potential benefits, agroecological features, user engagement and communication, and needed improvements.

- Determine how DSTs perform on a plot level.
  - Identify tools’ response to different soil types and maize varieties.
  - Assess inter-tool variability in terms of irrigation recommendation.
  - Compare tools’ irrigation recommendation to actual irrigation consumption.

Assumptions

- DSTs in France are evolving.

- Motivations is aligned with agroecological principles.
  - Utilization and level of communication is improving.
  - There are still needed improvements.

- DSTs will respond differently to various soil types and maize varieties when tested.

- Comparable irrigation recommendation to the actual irrigation consumption.

Literature Review (pic about the climate)

- The impact of climate change on water resources in France is significant (Azhari and Loudyi, 2021; Schilling et al., 2020; Erraioui et al., 2022; Ougougdal et al., 2020).

- Despite uncertainties in predictions and models used (Schewe et al., 2013).

- Future Projection :
  - Increase in temperature by several degrees, more frequent and intense heatwaves
  (Wasimi, increasing precipitation in certain areas (Ribes et al., 2029) = effects on crop
  yields and productivity (Ceglar et al., 2020).

- Effect water scarcity and high water stress to plants (Oliveria et al., 2012; Volaire et al., 2023).

- Significant economic impact (Neufeld, 2020), although quantification is challenging.

Literature Review (pic about the climate)

- Irrigation demand is projected to increase: 32 - 70 M has. expansion by 2050 of irrigated agriculture (Rosa et al., 2020).
- In France: highest consumption of irrigation demand based S3 and S4 carbon neutrality scenarios (ADEME, 2022).
- Agroecological Transition (AT) in the mitigation and adaptation strategies (EU and France policy).
- Benefits, still, there are hurdles to AT: cost (Schaible and Aillery, 2012), technical & technological issues (Pradipta et al., 2022) (expertise), and policies (Grafton et al., 2018).

Literature Review (pic about the climate)

- Achieving AT through technology

- Digital DSTs
  - Optimize irrigation management and enhance efficient (Imbernon-Mulero et al., 2023; Ososanya et al., 2015)
  - Potential to address water scarcity, food security, and environmental sustainability (Lima et al., 2020; Fernandez, 2017; Karunathilake et al., 2023)
  - Use of machine learning algorithms (Chaterji et al., 2020).

- Successful use cases of DSTs in irrigation.

- Also, cases where DST failed to deliver
  - Gaps in the system: complexity and difficulty in analyzing these data (Zaman and Swaminathan, 2018), integration of factors affecting irrigation management (Neupane and Guo, 2019), stakeholders involvement (Arsene et al., 2020)
  - Cost (Meyer, no date)
  - Accuracy (Shah and Das, 2012)

- DST Characterization
  - Inventory, initial work of Leroux (2023) and AgroTIC (no date).
  - Online snowballing (Ghent University, 2023; Wohlin, 2014).
  - Inclusion and exclusion criteria.
  - DST defined on model and data used, the inputs, interface, outputs, spatial and temporal scale of recommendation, targeted crops and the year that the DSTs launched in the market.

- Motivation of DST Conception and Other Features
  - Interview those who responded favorably.
  - Structured set of questions.
  - AI transcriber.
  - Insight-lab by data IQ (no date) for knowledge graphs.

- Desk Testing – Simulation of the DSTs

  - 3 DSTs: Irre-LIS, NetIrrig, Pixagri Wago
  - Real plot.
  - 3 soil types and maize varieties.
  - Parameterized for every simulation.
  - 27 plot configurations: 9 plot each,1 configuration = 1 simulation.
  - Common reference period.
  - Pre-optimal and optimal simulation.
  - Sensitivity analysis.

Methodology

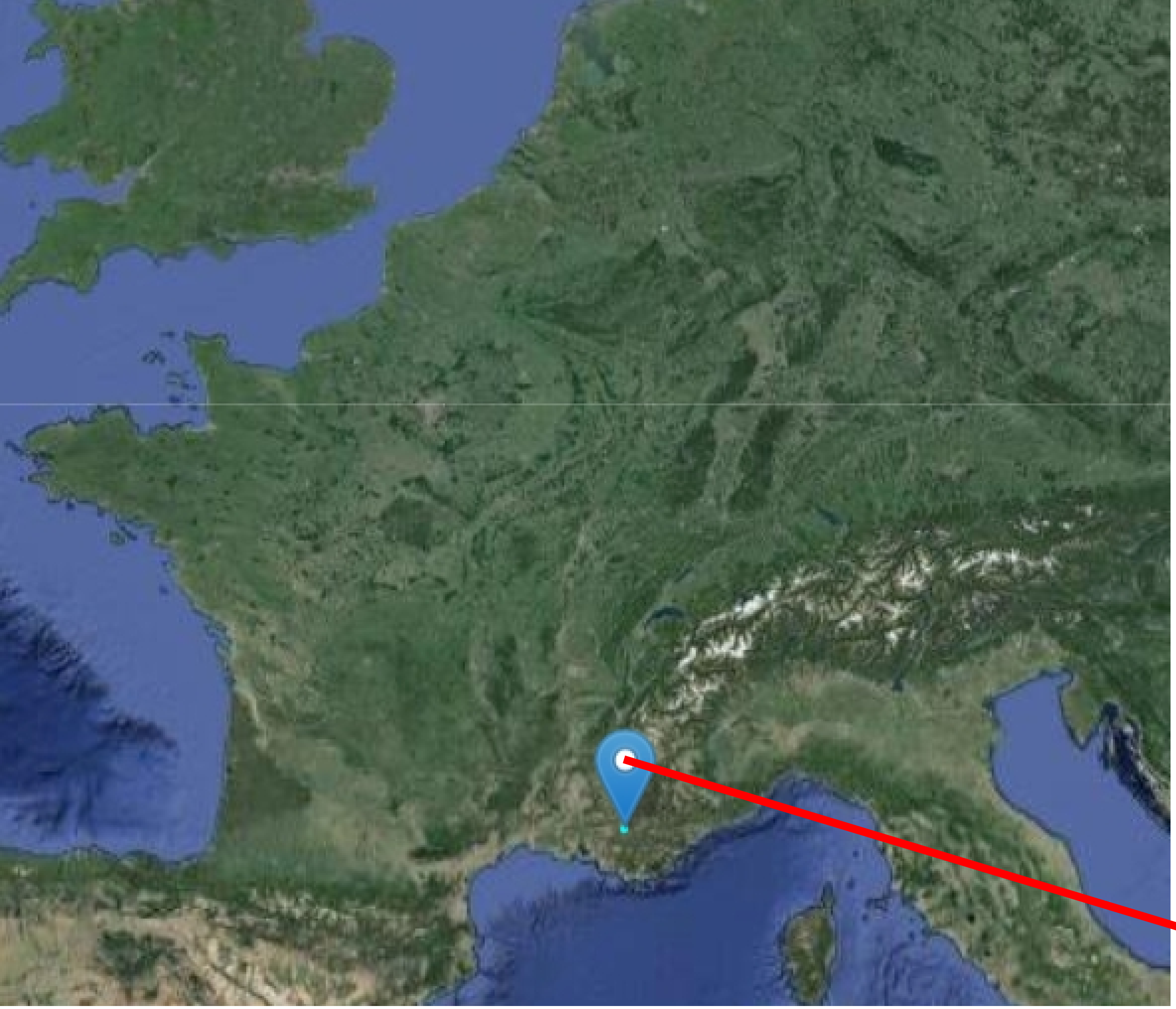
- # Desk Testing – Simulation of the DSTs

	Irre-LIS	NetIrrig	Pixagri Wago
Soil			
S1	Silty clayey (silty alluvium) with an RU Max of 80mm	Clayey silt under silty textures	Silt loam
S2	Clayey under other with an RU Max of 125mm	Sandy clay under clay-sand textures	Sandy clay
S3	Silt sand under other (silt sand) with an RU Max of 80mm	Medium silt sandy under silt sand textures	Sandy loam
Maize Variety			
V1	P7326 (Early variety)	Low water requirement ETM grain corn (reference)	Grain Corn (Early)
V2	P0725 (Medium maturity maize variety)	Grain corn 0.8 ETM Allier department	Grain Corn (Semi-early)
V3	P0937 (Late variety)	But late grain G4 420-460 Drome department	Grain Corn (Late)

Table 1 shows the comparable soil type and maize variety used in the testing for the 3 DSTs.

Tool	S1 constant	S2 constant	S3 constant	
Irre-LIS	S1V1	S2V1	S3V1	V1 constant
	S1V2	S2V2	S3V2	V2 constant
	S1V3	S2V3	S3V3	V3 constant
NetIrrig	S1V1	S2V1	S3V1	V1 constant
	S1V2	S2V2	S3V2	V2 constant
	S1V3	S2V3	S3V3	V3 constant
Pixagri Wago	S1V1	S2V1	S3V1	V1 constant
	S1V2	S2V2	S3V2	V2 constant
	S1V3	S2V3	S3V3	V3 constant

Table 2 details a total 27 plot configurations .



Location of the Real Plot (Nicolas Gassier)

- Coordinates: 43.732734184179999, 5.803116291785647.
- located near Vinon-sur-Verdon in the southeast of France.
- Area: about 147,620 m2 m^2 (perimeter of 1,575.38m).
- Using a conventional tillage management system
- Maize is the crop being cultivated in the said plot (0725).
- Soil: silt loam.

Figure 1 shows the test plot and its location in Vinon-sur-Verdon named as Nicolas Gassier plot with an area of about 14.7 hectares (https://earth.google.com and NetIrrig).

Results and Discussion

• DST Characterization

- Emerging DSTs using advanced technologies.
- Majority plot level (45); least at territory level (5).
- With overlaps.

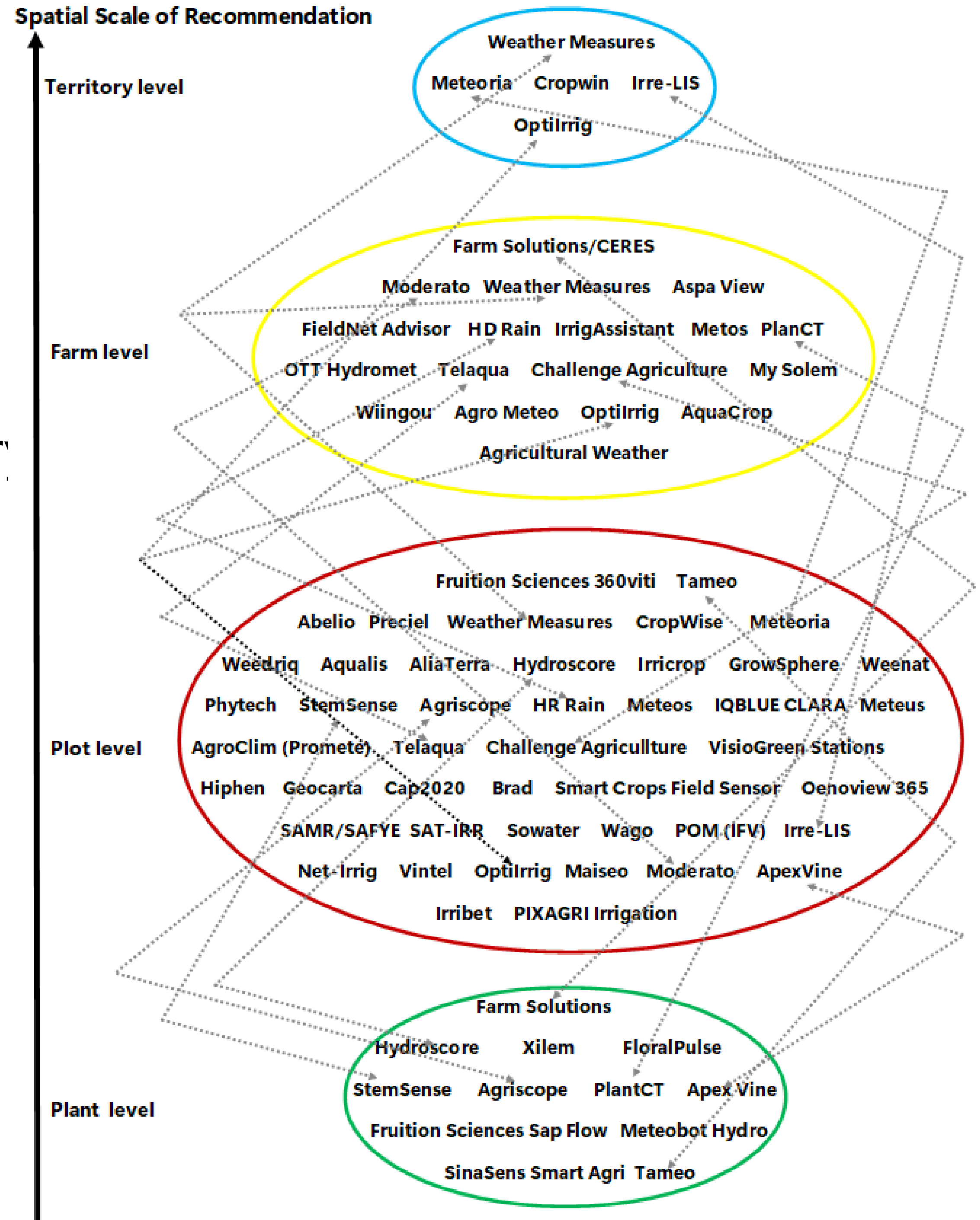


Figure 2 indicates that the plot-level spatial scale of recommendation is where most of the DSTs are concentrated.

Results and Discussion

- **DST Characterization**

- Real-time (15).

- Daily (11).

- Also, with overlaps.

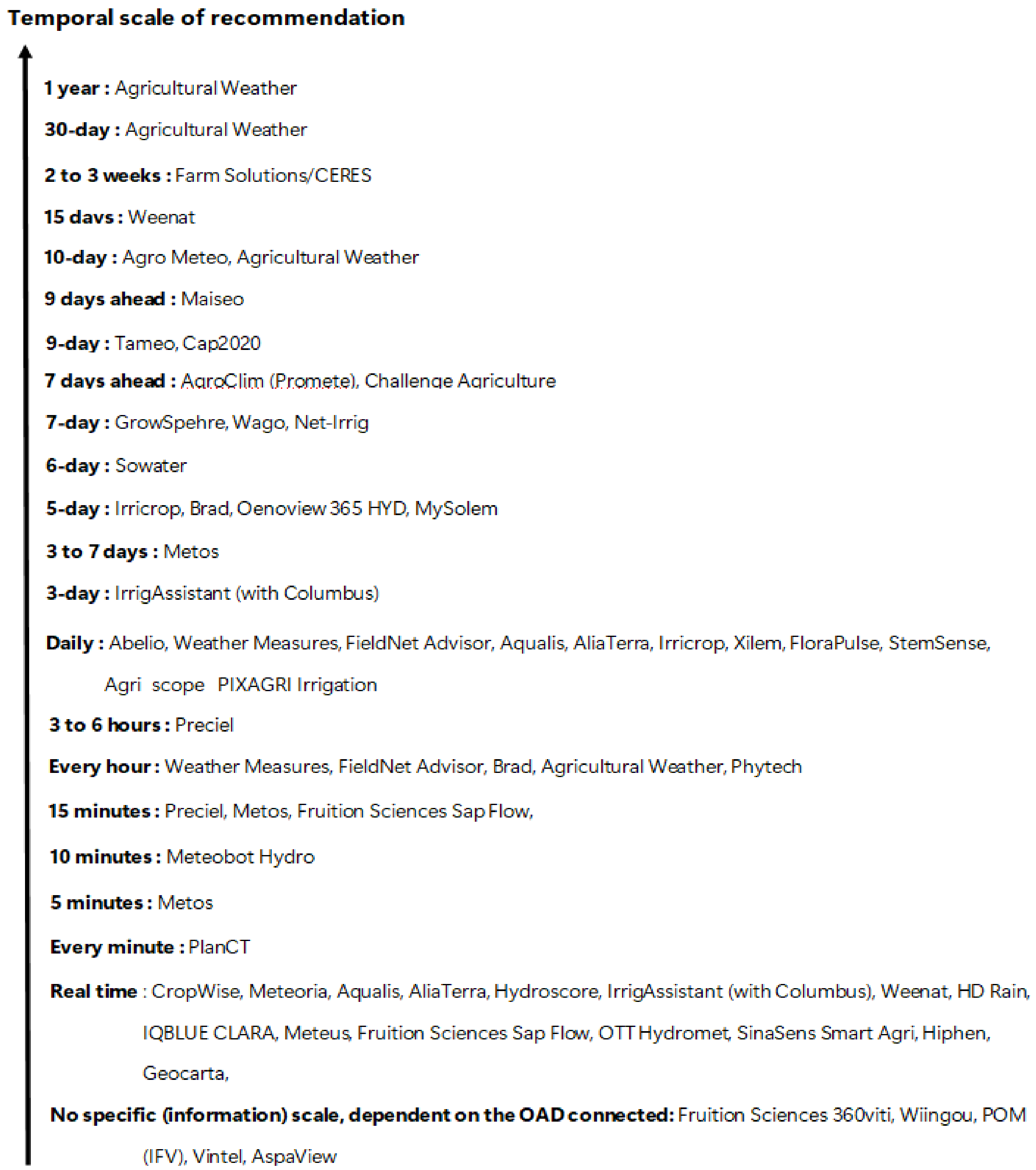


Figure 3 illustrates the wide-ranging temporal scales of recommendations provided by the DSTs, with majority having a real-time recommendation

Results and Discussion

- **DST Characterization**

- Sensors as widely used.

- About half either stan-alone or with crop model and satellite data.

- Crop model + in-situ sensors, +satellite data, or used alone.

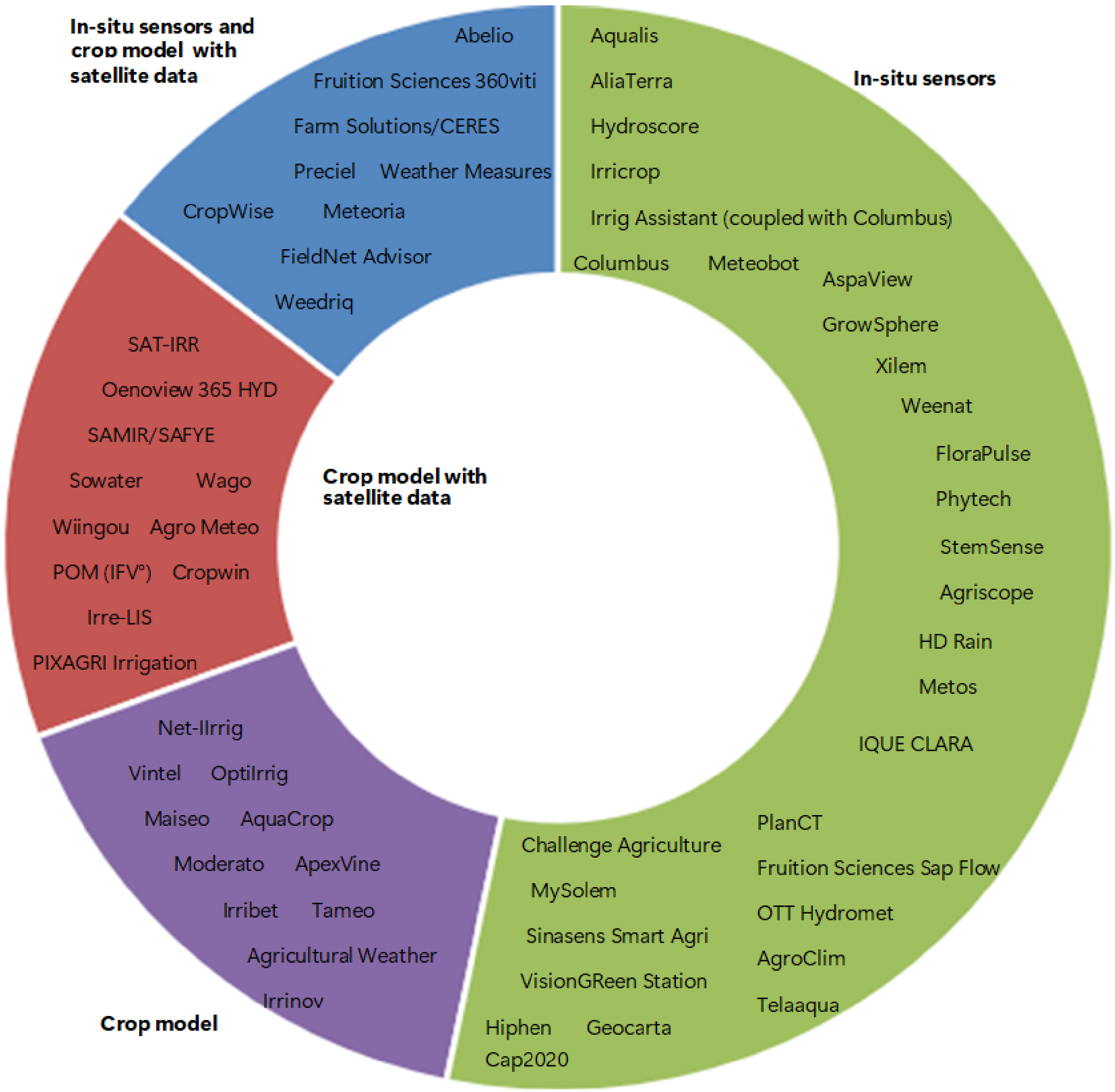


Figure 4 classifies the DSTs according to different vectors, with majority of them using sensors.

Results and Discussion

- **DST Characterization**

- Majority targeting field crops and market gardening.

Name of DST	Targeted crops				Others
	viticulture	field crops/market gardening	arboriculture	horticulture	
Hydroscore, Wilem, Fruition Sciences Sap Flow, Geocarta, Oenoview 365 HYD, POM (IFV) ApexVine, Vintel					
FloraPluse			orchards		
PlantCT			apple and stone fruit		
StemSense	includes wine grapes		orchard	apple, peach, citrus, avocado, cherries, nuts, and more).	
Meteus			tree crops		
AgroClim (Promete)		potato, onion			
SinaSens Smart Agri			walnuts, olives, etc.		green spaces
Net-Irrig		cereals, corn, peas, sunflowers, soybeans, sugar beets, sorghum		canned vegetables (beans, peas, flageolets, salsify, carrots, vegetables (beetroot, asparagus, potatoes, onion	
Meteobot Hydro			tree crops		
Condititons)					
Farm Solutions/ CERES			orchards, tree nuts, grapes, citrus crops,		
Agriscope (Dendrometer)			tree crops, i.e. apple, apricot, etc.		
AspaView				production	big cultures
Irribet				beet	
Sowater			orchards, i.e. citrus, pomegrate, etc.		
Phytech			tree cops		
Challenge Agriculture		cereals, corn	fruits, i.e. melon, etc.	vegetable, seeds	other irrigated crops
MySolem					
Abelio		corn, soybean, sunflower, wheat, green bean and potato			
Preciel		corn and wheat			
CropWise		large crops			specialty crops
SAMIR/SAFYE		wheat)			
Cropwin		soybean			
Maiseo		corn, popcorn and all types of waxy.			
Moderato		maize			
Tameo		soft winter wheat, corn, barley, other new species			
Irre-LIS		(straw) cereals, soya/soybean, wheat, durum wheat, corn (fodder), seed maize, potatoes, spring barley, tobacco,			
OptiIrrig					seasonal crops
Wago		corn and wheat			annual crops; large crops and industrial crops
PIXAGRI Irrigation		all types of corn, wheat, cotton, vegetables			

Figure 5 classifies crops targeted by the DSTs, with significant number focusing on field crops/market gardening. .

Results and Discussion

- **DST Characterization**

- Increasing presence for the last 10 years.

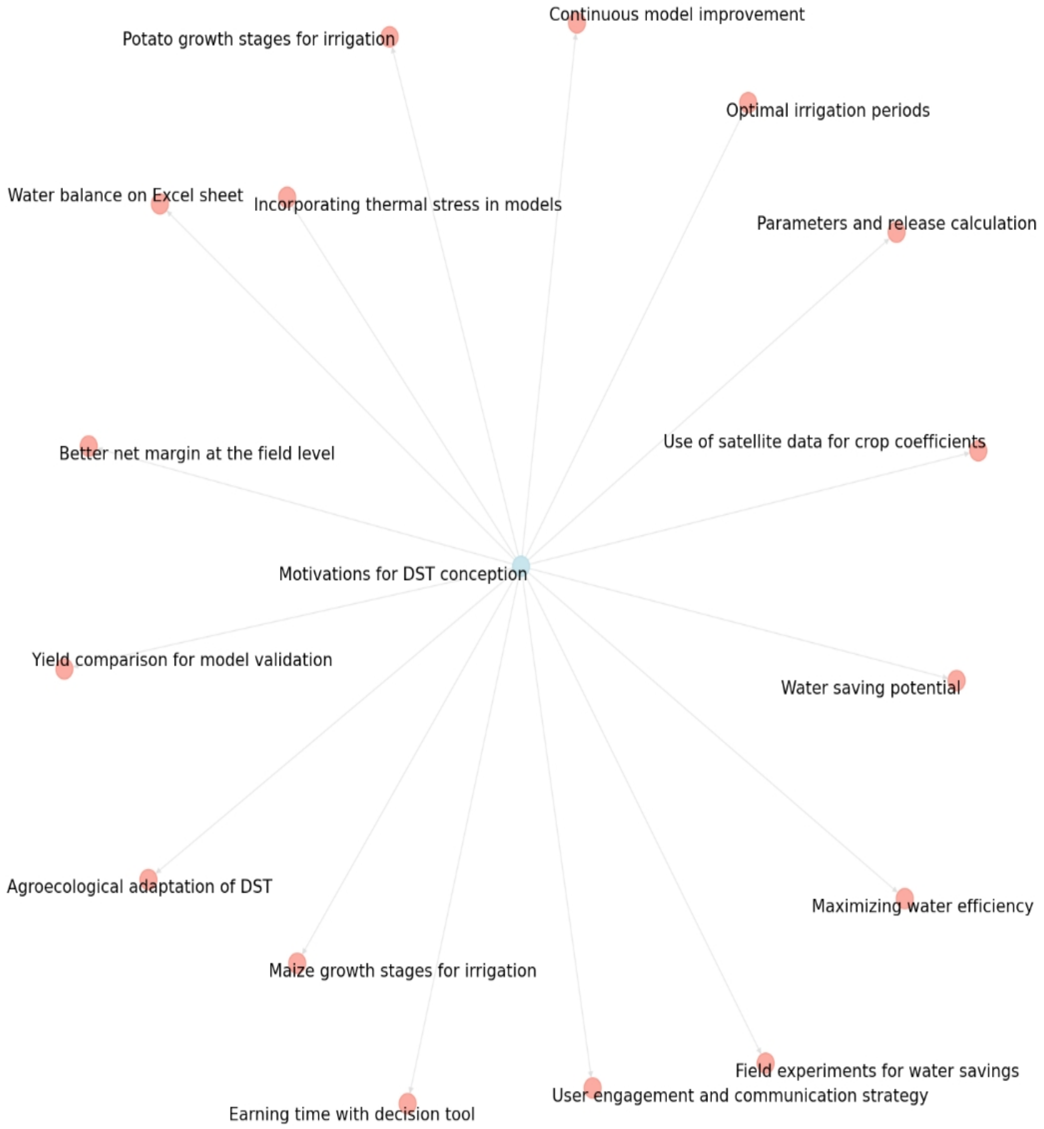
Figure 6 shows the chronology of market launch of DSTs in France, increasing their increasing presence for the last 10 years.

Results and Discussion

•Motivation for the DST Conception

Questions: *Why did you come up with this DST? What are you trying to address with this DST? What needs or issues are you trying to meet and address at the microcosm (farm) and macro-cosm level (societal)? How this DST will be able to address those needs or issues? What are the specific and important features of the DST for it to be able to meet or address those needs and issues?*

-Maximize water efficiency.
-Water saving potential; assistance in field experiments.
-Better yield margin.
-Better decision-making process
-Agroecological adaptation.



motivations behind the creation of the
yield margin at the field level, and
balance model and other important

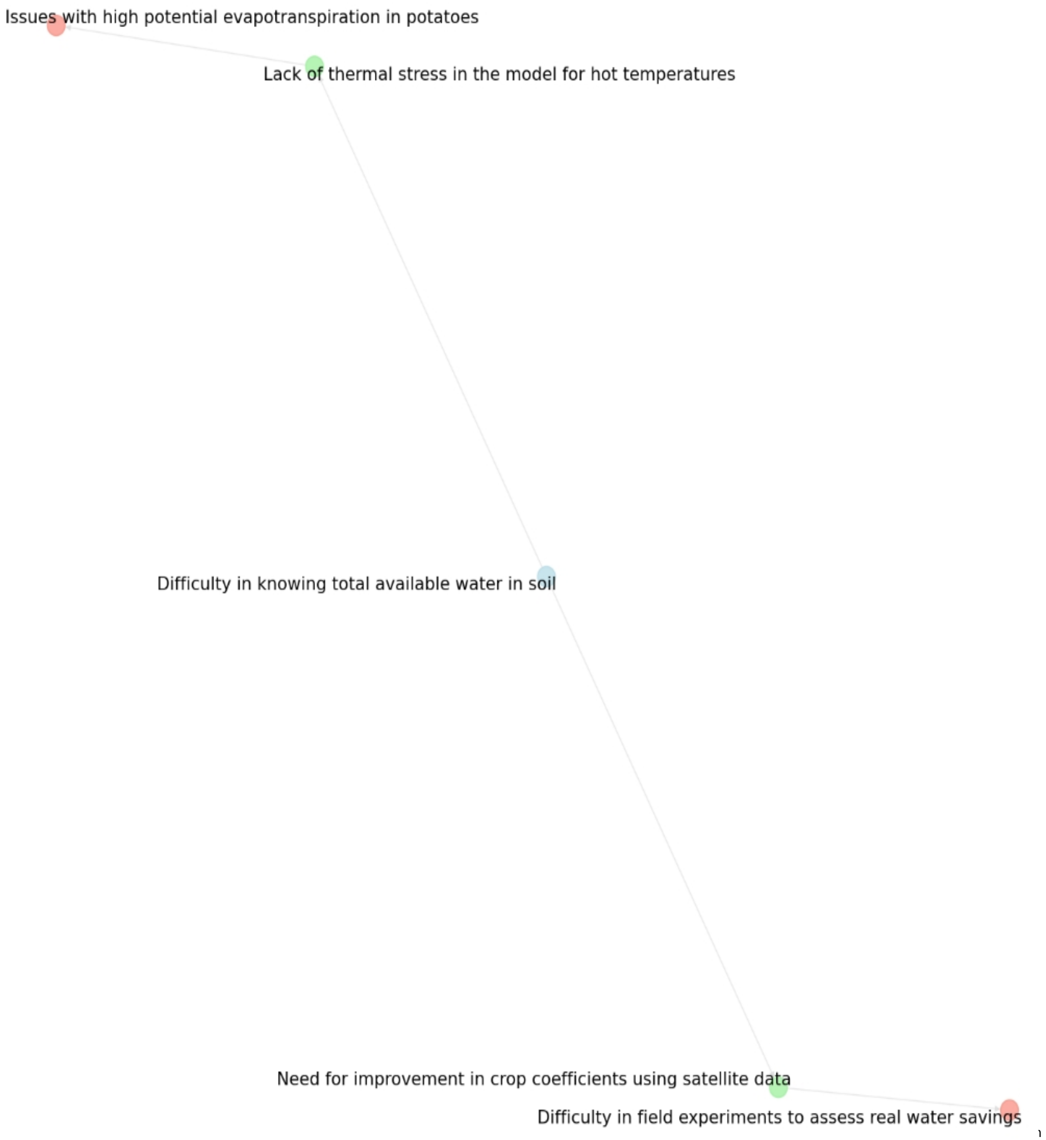
the
DSTs are to maximize water efficiency and water saving potential, while assisting as well field experiments in this area, better promote better decision-making process and agroecological adaptation through the use of satellite and crop data, water parameters

Results and Discussion

- **Ease of Use**

- Questions: *What feedback do you receive from your users in terms of the ease of use of the DST and the application (hardware and software)? In terms of DST features, what makes it easy to use for the farmers? Are there any features of the DST, both hardware and software, that you find or consider challenging for the users? At what length do you provide technical assistance to your user?*

-Users not knowing total available water in the soil.
-Issues on crop coefficients and evapotranspiration.
-Lack of thermal stress for hot temperatures in the model.
-Other difficulties: field experiments.



knowing total available water in the

soil, concerns on crop coefficients and evapotranspiration, and lack of thermal stress for hot temperatures in the model.

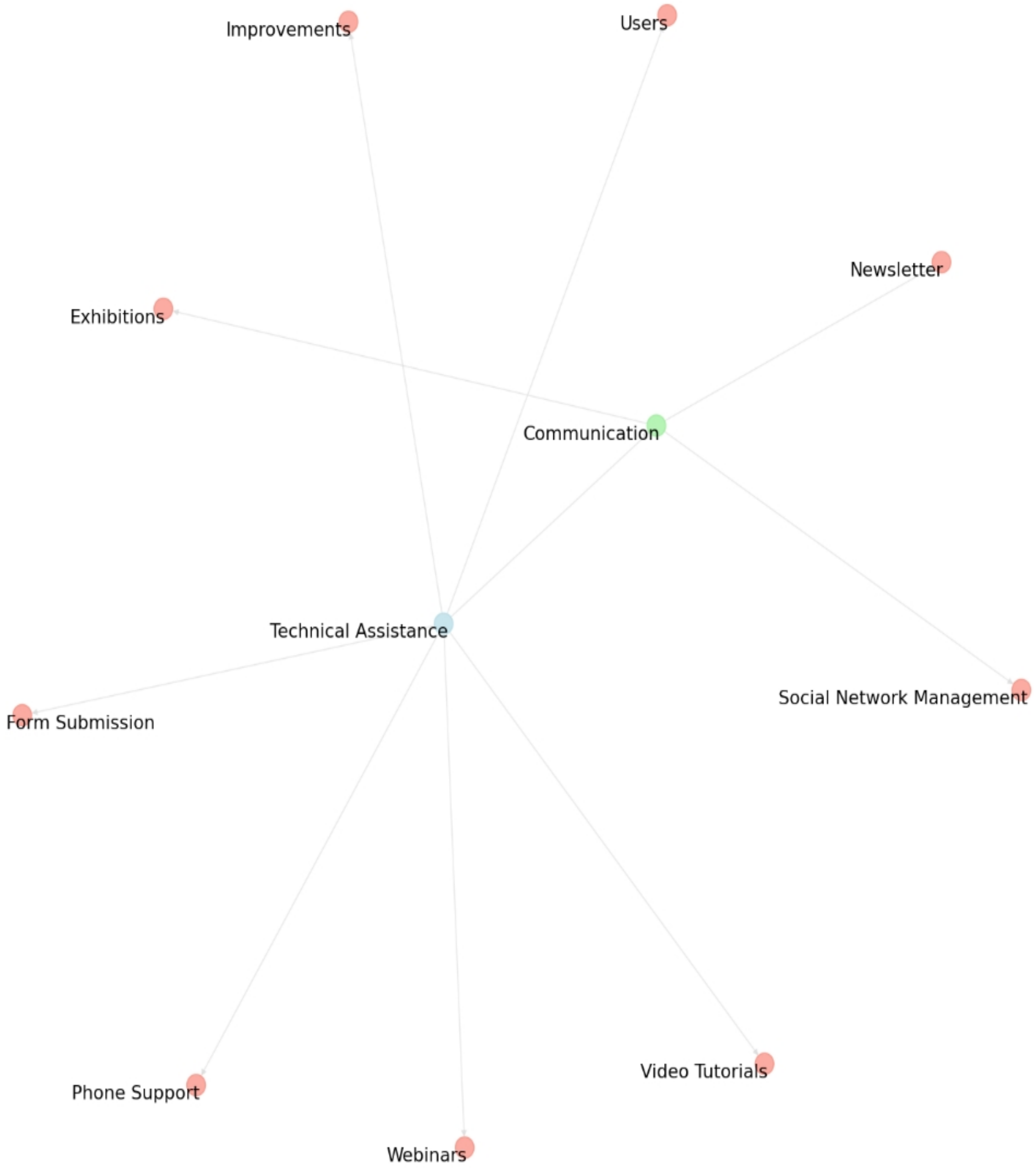
Results and Discussion

•Communication

•Questions: *How do you keep your users engaged with your product in terms of information accessibility and availability? Are the level of information about the DST and communication with your users sufficient?*

-Different modalities.

communication with their users by utilizing social network management.



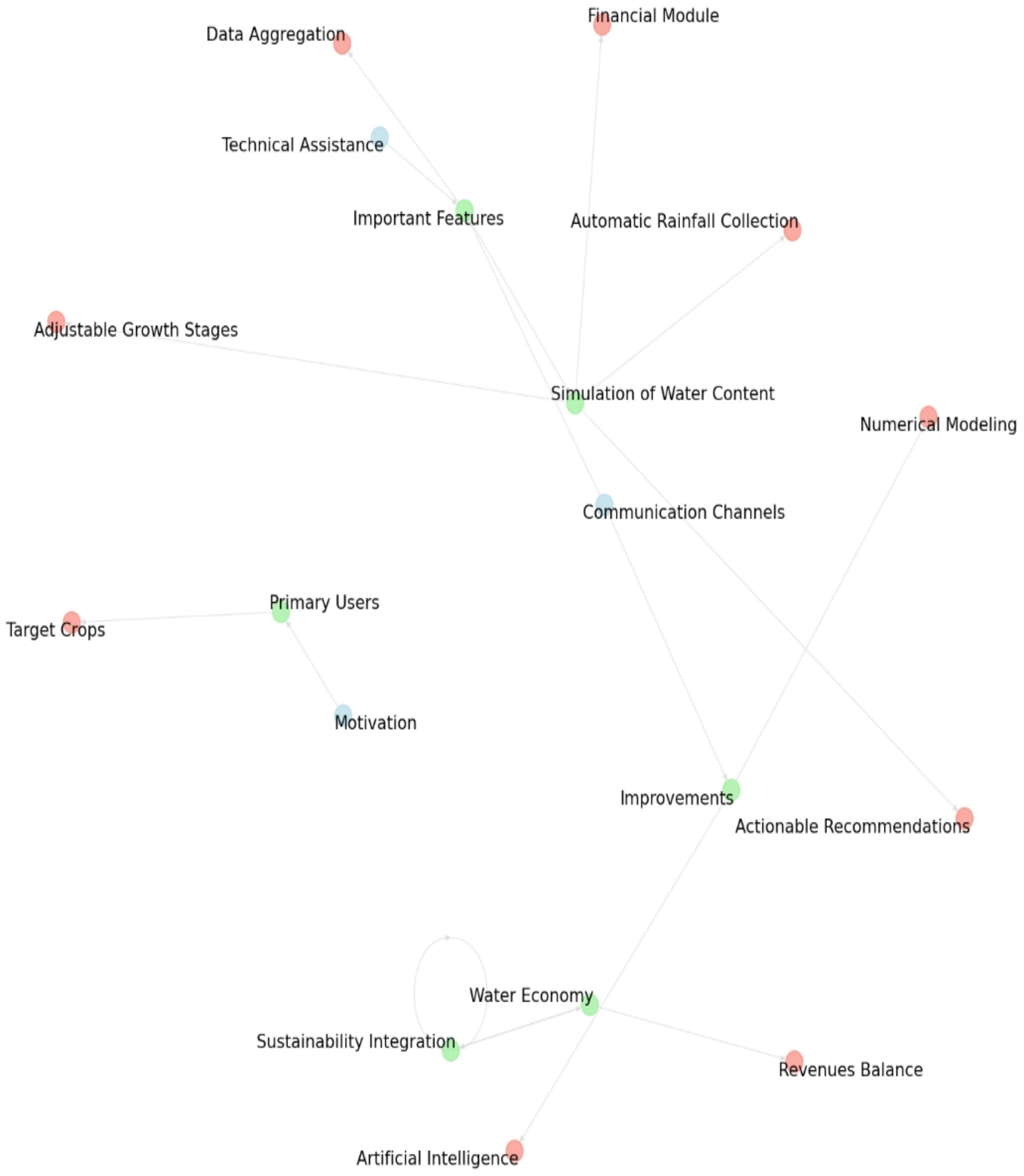
Results and Discussion

- **Improvements**

- Questions: *Are there any existing features of the DST you consider require further improvement or upgrade? What additional features or improvements would you like to do in order for the DST to perform better and better (i.e. numerical model/aspect, etc.)?*

-Numerical aspect of the model.
-Other modules and features.
-Climate change and irrigation constraints.
-Data integration in the model for better recommendations.

climate



•Desk Testing: Pre-Optimal Simulation

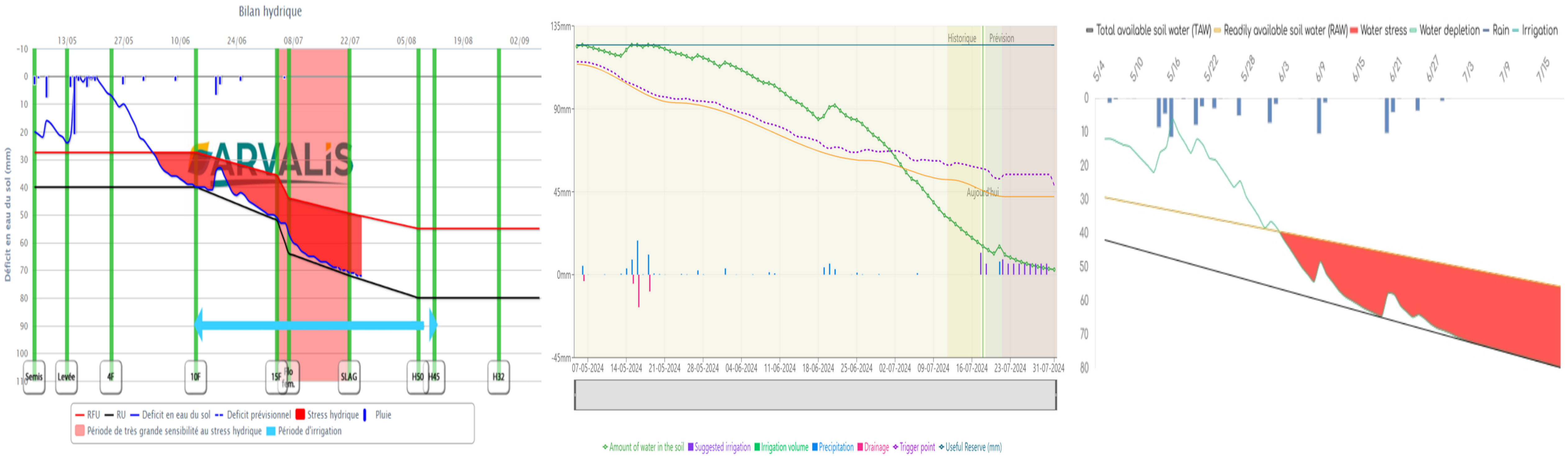


Figure 12 shows the S1V1 simulations for Irre-LIS, NetIrrig and Pixagri (top to bottom) when the readily available soil water or the minimum threshold of easily usable reserve curve was crossed, by the soil water deficit curve in Irre-LIS, the amount of water in the soil in NetIrrig, and the water depletion curve in Pixagri, indicating the **onset of water stress.**

Results and Discussion

•Desk Testing: Pre-Optimal Simulation

Plot Configuration	Irre-LIS		NetIrrig		Pixagri Wago	
S1V1	Blue line (soil water deficit) to red line (RFU)	05 June '24	Green line (amount of water in the soil) to yellow line (RFU)	04 July '24	Green line (water depletion) to Yellow line (RUF/ or total available water)	03 June '24
S1V2		04 June '24		12 June '24		03 June '24
S1V3		04 June '24		29 June '24		03 June '24
S2V1		08 June '24		03 July '24		26 May '24
S2V2		08 June '24		11 June '24		26 May '24
S2V3		08 June '24		28 June '24		26 May '24
S3V1		04 June '24		07 July '24		04 June '24
S3V2		04 June '24		03 July '24		04 June '24
S3V3		04 June '24		01 July '24		04 June '24

A

Plot Configuration	Irre-LIS	NetIrrig	Pixagri Wago
S1V1	04 July 2024	12 July 2024	18 June 2024
S1V2	27 June 2024	12 July 2024	18 July 2024
S1V3	27 June 2024	02 July 2024	19 July 2024
S2V1	04 July 2024	12 July 2024	19 July 2024
S2V2	27 June 2024	12 July 2024	19 July 2024
S2V3	27 June 2024	02 July 2024	19 July 2024
S3V1	04 July 2024	12 July 2024	19 July 2024
S3V2	27 June 2024	12 July 2024	19 July 2024
S3V3	27 June 2024	02 July 2024	19 July 2024

B

Table 3 shows shows the start date when RUF curve was crossed for each combination of all the DSTs indicating the onset of **water stress** (A), and start date of **high sensitivity to water stress** for each simulation in all of the DSTs (B).

•Desk Testing: Optimal Simulation

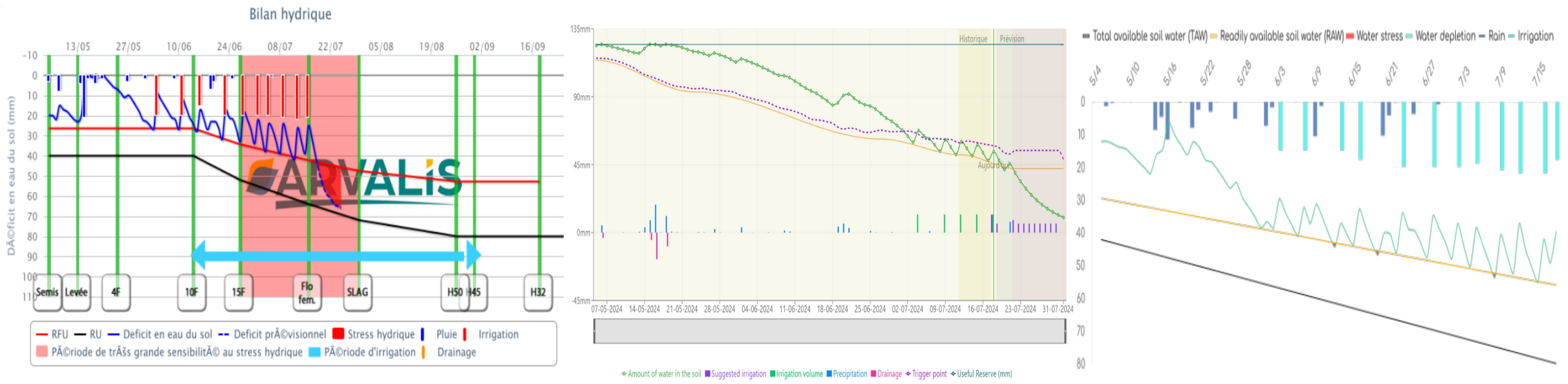


Figure 13 shows Irre-LIS, NetIrrig and Pixagri Wagi optimal simulations for S1V1.

•Desk Testing: Optimal Simulation

Plot configuration	Irre-LIS	NetIrrig	Pixagri Wago
S1V1	197	60	225
S1V2	197	132	220
S1V3	200	108	216
S2V1	175	60	246
S2V2	184	132	247
S2V3	183	120	255
S3V1	197	60	204
S3V2	200	57	206
S3V3	204	96	203

Table 4 the total irrigation performed per combination since sowing until July 18.

- Python code used to get the average irrigation for every soil type and maize variety per tool, and also to visualize.

```python
import pandas as pd
import matplotlib.pyplot as plt

# Your data
Irrigation_IrreLIS = [197, 197, 200, 175, 184, 183, 197, 200, 204]
Irrigation_NetIrrig = [60, 132, 108, 60, 132, 120, 60, 57, 96]
Irrigation_Pixagri = [225, 220, 216, 246, 247, 255, 204, 206, 203]
Soil_type = ['silt loam', 'silt loam', 'silt loam', 'Sandy clay', 'Sandy clay', 'Sandy clay', 'Sandy loam', 'Sandy loam', 'Sandy loam']
Maize_variety = ['Early', 'Med', 'Late', 'Early', 'Med', 'Late', 'Early', 'Med', 'Late']

# Create DataFrame for Soil_type
data_soil = pd.DataFrame({
    'Irrigation_IrreLIS': Irrigation_IrreLIS,
    'Irrigation_NetIrrig': Irrigation_NetIrrig,
    'Irrigation_Pixagri': Irrigation_Pixagri,
    'Soil_type': Soil_type
})

# Calculate means for each soil type
means_soil = data_soil.groupby('Soil_type').mean()
print(means_soil)

# Create DataFrame for Maize_variety
data_variety = pd.DataFrame({
    'Irrigation_IrreLIS': Irrigation_IrreLIS,
    'Irrigation_NetIrrig': Irrigation_NetIrrig,
    'Irrigation_Pixagri': Irrigation_Pixagri,
    'Maize_variety': Maize_variety
})

# Calculate means for each soil type
means_variety = data_variety.groupby('Maize_variety').mean()
print(means_variety)

########################## First two figures ####################################
```

Results and Discussion

•Desk Testing: Optimal Simulation

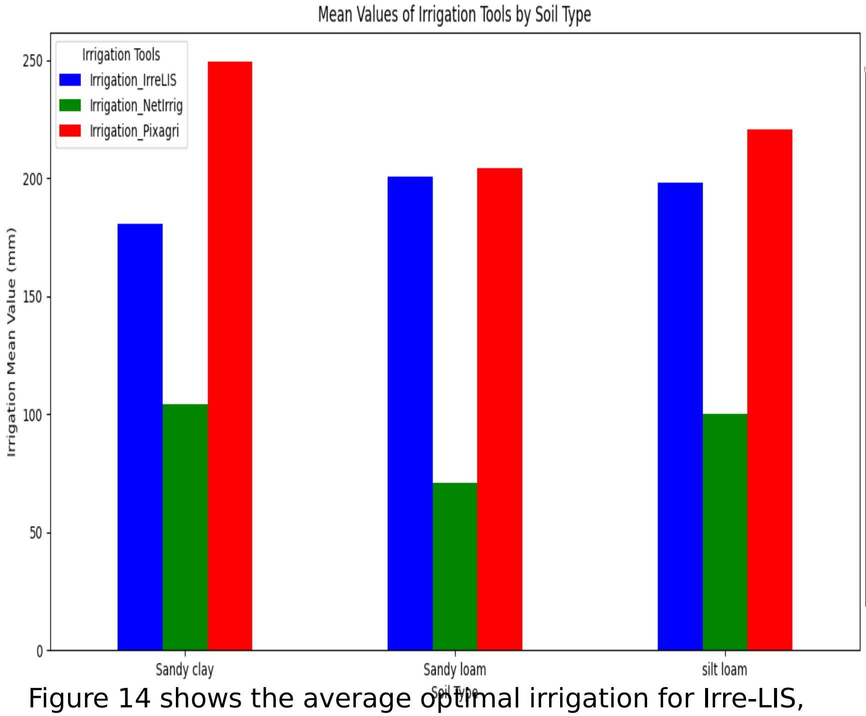


Figure 14 shows the average optimal irrigation for Irre-LIS, NetIrrig, and Pixagri Wago, suggesting that the tools are sensitive to soil types

Soil Type/Tool	Irre-LIS	NetIrrig	Pixagri Wago
Silt loam	198.0	100.0	220.3
Sandy clay	180.7	104.0	249.3
Sandy loam	200.3	71.0	204.3
Maize variety			
Early	189.7	60.00	225.0
Medium	193.7	107.0	224.3
Late	195.7	108.0	224.7

Table 5 shows the average recommended irrigation by tool, soil type,
and maize variety

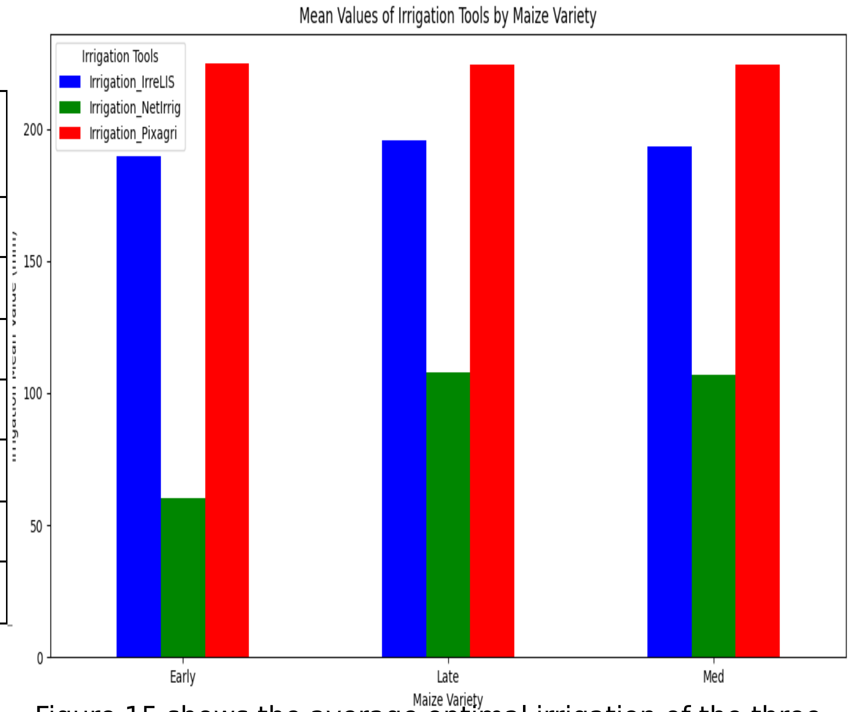


Figure 15 shows the average optimal irrigation of the three DSTs, suggesting that, except for Pixagri, the tools are sensitive in varying degrees to maize varieties.

Sandy Loam

Silt Loam

Sandy Clay

- Pattern not accurately followed.
- Only Irre-LIS providing least irrigation water for sandy clay (180.7mm).

Late

Medium

Early

- Pattern, except for Pixagri, followed.
- With Irre-LIS and NetIrrig
  - lowest for early grain corn.
  - highest for late grain corn.
  - In between for medium grain corn.

•Comparison of Irrigation Recommendation to Actual

Average Irrigation for May 5, 2024 – July 18, 2024 (in mm)				Difference from Actual Irrigation Consumption (in mm)		
Soil Type/Tool	Irre-LIS	NetIrrig	Pixagri	Irre-LIS	NetIrrig	Pixagri
Silt loam	**198.0**	**100.0**	**220.3**	**53.0**	**-45.0**	**75.3**
Maize variety						
Medium	**193.7**	**107.0**	**224.3**	**48.7**	**-79.3**	**79.3**

Table 6 shows that shows that **NetIrrig** is **underestimating** while **Irre-LIS** and **Pixagri** are **overestimating when compared to the actual irrigation consumption in 2023.**

Conclusion

- DST trajectory is increasing.
- Emphasis on agroecological and sustainable features.

    - Motivations and benefits promoting water efficiency, reduction

 of water use/wastage, and, importantly, on actionable advice.

    - Needed improvements: numerical aspect, data integration, easy of use.

- Sensitive to soil types and maize varieties.
- Underestimation/Overestimation when compared to actual irrigation consumption.

Limitations

- Length of period of simulations.
- Parameters/values only as close as possible.
- Use of 2024 actual irrigation consumption for comparison.

Future Research

- Tool comparison for 2024.
  - Many plots.
  - Different points in France.
  - With more crops and combinations.

Contribution to the Field

- Challenge the initial 2 major classifications of DSTs.
- Insights on the needed improvements of the DSTs.
- Re-validation of the different irrigation recommendations of the tools.

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QUESTIONS?