OPERA

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Operationalizing the increase of water use efficiency and resilience in irrigation

- Challenge-1) Increasing the efficiency and resilience of water uses
  - Sub-topic-1.a. Efficiency issues include the development of:
    - i. Innovative water use systems and practices, including precision irrigation technologies (e.g. models, sensors, ICT);
  - (Sub-topic-1.b. Resilience to climatic variability)

Focus

- Challenge-1) Increasing the efficiency and resilience of water uses
  - Sub-topic-1.a. Efficiency issues include the development of:
    - i. Innovative water use systems and practices, including precision irrigation technologies (e.g. models, sensors, ICT);
  - (Sub-topic-1.b. Resilience to climatic variability)

Consortium

WAGENINGEN
UNIVERSITY & RESEARCH

INRA
SCIENCE & IMPACT

IRNAS

ITP

UNIVERSITEIT
STELLENBOSCH
UNIVERSITY

crea
Consiglio per la ricerca in agricoltura
e l'analisi dell'economia agraria

UNIVERSITÀ
DEGLI STUDI
FIRENZE
DISPAA
DIPARTIMENTO DI SCIENZE DELLE
PRODUZIONI AGROALIMENTARI
E DELL'AMBIENTE

evenor tech™
Solutions for soil
use and protection

Funding : 920 k€ (Total 1236k€)

OPERA - Objectives

1) To identify specific market driven, farmer demands
2) To identify operational means to anticipate climate variability and critical moments of water scarcity.
3) To identify the most adequate combination of soil sensors, plant-based sensors, remote sensing, weather forecast and simulation models in irrigation scheduling.
4) To identify ways for operationalizing the upscaling at the territory scale information allowing a better management of water scarcity and drought.
5) To integrate experience in operationalizing precision irrigation from various climatic zones in Europe and South Africa to identify the best applicable service models.

Work Packages

Stakeholders oriented

WP1 - Identifying sector needs to increase resource use efficiency : **Needs**

lead: Evenor Tech, Spain

WP2 - Forecasting water availability and critical water demand : **Innovation**

lead: INRA – EMMAH, France

WP3 - Guidance for optimal irrigation water strategies (case studies) : **demonstration**

lead: ITP, Poland

WP4 - Conceptualization of practical service models for irrigation : **Transfer**

lead: CREA, Italy

Technical oriented

Demand from the farmers

- Assessment from users : 251 surveys, 2 local workshops, 6 pilots.

Strong water deficit

Moderate water deficit

External sources of water

Local source of water (pumping, local reservoir)

FR, SA

Maintain Agricultural system

IT
SP

NL
PL

Improve profitability

Issues linked to irrigation

	FR	SA	IT	SP	PL	NL
Cost (water price, Energy)			(x)	(x)	(x)	
Hydraulic infrastructure (water distribution, irrigation system, reservoirs)	x	x	x	x	x	
Regulation (water sharing between users, administration)	x	x	x	x	x	
Increase water use efficiency	(x)	(x)	x	x	x	x
Reduce labour cost	x		x			

limitations

Case Study	Water efficiency	Adopting alternative crops
Poland	**Economic:** - high investment costs (irrigation equipment, well drilling, water distribution), lack of available catalogue od the best technical and organizational solution **Administrative:** - complexity and time to obtaining water intake permit	- **uncertainty of prediction market demands** - advice on suitable crops -lack of specific information on water, fertilizer and cultivation requirements
France	**Economic:** - high cost of irrigation control system **Technical** - **Lack of trusts in the quality of the delivered information**	
Italy	Without preferences between the proposed factors, stakeholders given the same importance, fear of being more controlled Lack of trusts in the quality of the delivered information	- **costs** - uncertainty of prediction market demands
South Africa	The stakeholders considered themselves highly efficient. However, they mentioned that improving field infrastructure and adapting their irrigation strategies are the best way to improve efficiency	Crops according to the market demands
Spain	**Economic:** - **expensive products; investment costs** **Administrative:** - Lack of agility by the administration; Little promotion of advisory services by public administration **Technical :** fear in introducing new technologies	- costs - uncertainty of prediction market demands
Netherland	**Economic:** - High prices of good systems	- Costs - uncertainty of prediction market demands

Trust in innovation : the case of SA

Fruitlook – remote sensing

- Sophisticated tool :
  - Use satellite and weather information to monitor vineyards and orchards in terms of crop growth, crop water-use and leaf nitrogen content
  - Uses eLEAF's Pixel Intelligence technology (PiMapping®) which combines meteorological, biophysical and satellite data.
  - Data components are based on SEBAL
- Widely available : Open-access online platform, since January 2012 and covers approximately 200 000 hectares of crops

→ NOT USED, SOIL MOISTURE PROBES BEING PREFERED
  - → Why ?
  - → Increasing the trust by comparing results

Trust in innovation : the case of SA

Fruitlook – remote sensing

- Lack of trust
- Lack of understanding (interface, background)

Trust in innovation : the case of SA

m3 water for 943 hectares of plums in Robertson valley						
	FL ET_{actual}	FL ET_{ideal}	ET_0	ET_c	Soil factor	Applied
Sept	524712	544448	884534	536799	441015	1225900
Oct	857919	953181	1361423	1159652	968017	1414500
Nov	993845	1033797	1626675	1443171	1414745	1414500
Dec	1229122	1307843	1680480	1558812	1681583	1886000
Jan	1319411	1372615	1753187	1567457	1774085	1886000
Feb	1225361	1274235	1447586	1302827	1568672	1886000
Mrc	963384	1012558	1234990	1111491	1083280	848700
April	673302	729831	1058097	737902	822029	848700

Fruitlook (FL ET_{actual}, FL ET_{ideal}) — Weather station (ET_0, ET_c) — Soil Moisture (Soil factor)

Context

Innovation

Innovation support

Issues
Cost (water price, Energy)
Hydraulic infrastructure (water distribution, irrigation system, reservoirs)
Regulation (water sharing between users, administration)
Increase water use efficiency
Decrease labor cost

Weather forecast

Crop model

Remote sensing

In situ sensors

Mature workflow giving access to ensemble forecast

Accessibility of spatial information layers

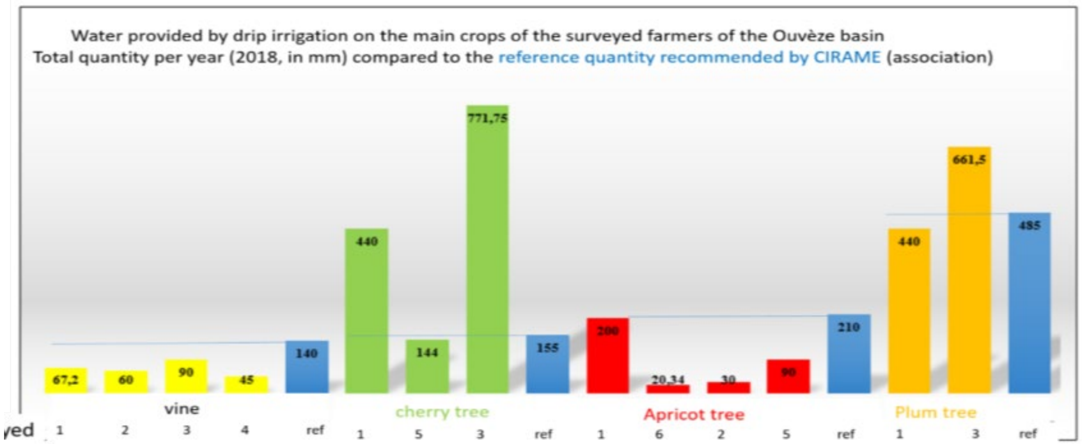
Sentinel mission : a breakthrough with a short revisit time and high spatial resolution

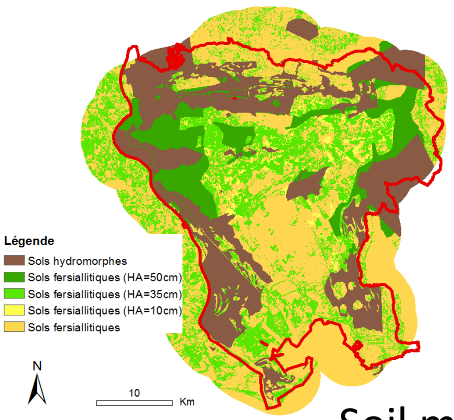
Developed Methods

Method ID	Users	Model	RS*	Field Sensors**	EF***	Crops in OPERA and limitation
M1 : Agroclimatic and remote sensing based Indice (EVENOR)	Farmers, public administration		X			**Olive** (OPERA) should be calibrated for other crops
M2 : Stomata conductance modelling (CSIC)	Farmers, public administration	X	X	X		**Olive** (OPERA) should be calibrated for other tree production
M3 : APSoMoCo based on crop modelling (WENR)	Farmers, water distributor	X		(X)	X	**Potatoes** (OPERA) all crops being modelled by SWAP-WOFOST
M4 : : CROPIRR based on crop modelling (ITP)	Farmers, advisory services	X				**Sugar beet, Parsley** (OPERA) Can be applied to any crops
M5 : – IRRICROP based on Remote sensing and a crop model (university of Florence)	Farmers, farmer's association, public administration	X	X		X	**Tomato** (OPERA) Limited to crop modelled by the Aquacrop model
M6 : Irrigation requirements at the territory level based on crop model and remote sensing INRA	Irrigation association, public administration	X	X		(X)	**Orchard, Grass land, gardening, Olive, Vineyard, field crop** (OPERA) can be applied to any crop simulated by STICS or Aquacrop models

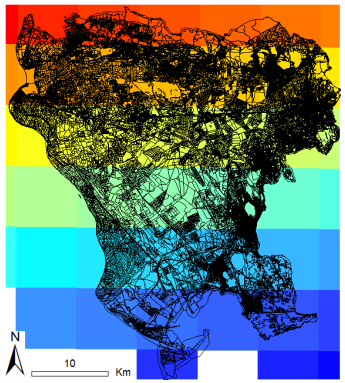
M6 Estimation of actual water need to manage water sharing during shortage period

farmers	Computed Volume m3	Declared Volume 2018 (ASA)	Difference
1	52712	22960	43%
2	45507	27484	60%
3	7811	1560	20%
4	6242,6	1087	17%





Soil map

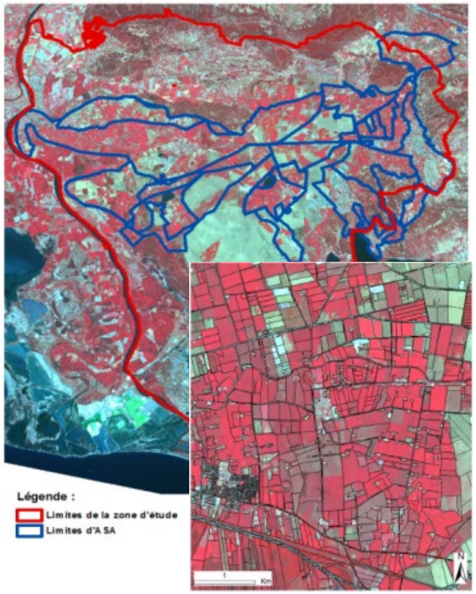


Climate

Model parameterization

Regional Modelling

Grassland Field Crop	Orchard Wetland, Forest	Dry Grass
	Modèle Kc – ET0 + Soil water balance	Empirical model + Soil water balance
Production		
Irrigation		
Recharge		

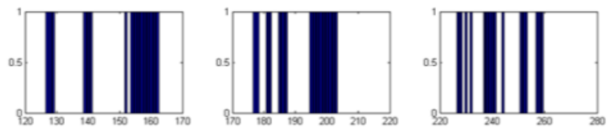


Irrigation [calendar, doses=f(soli, field topology)]

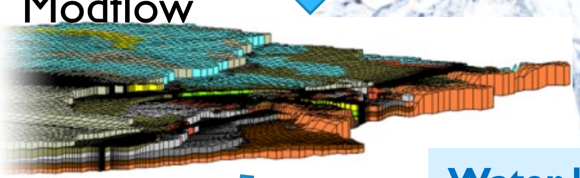
Crop practices

Hay harvest = f(requirements, biomass, precipitation)

1ère coupe 2ème coupe 3ème coupe



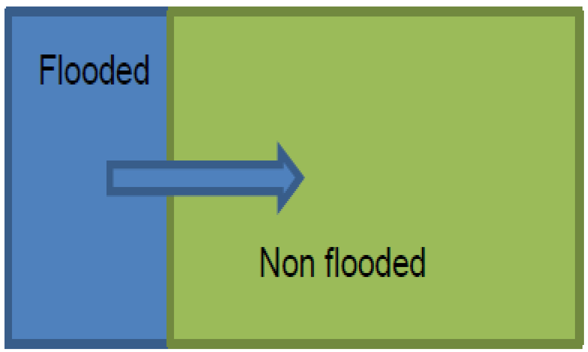
Modflow

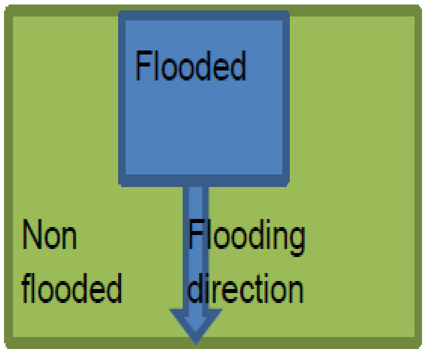


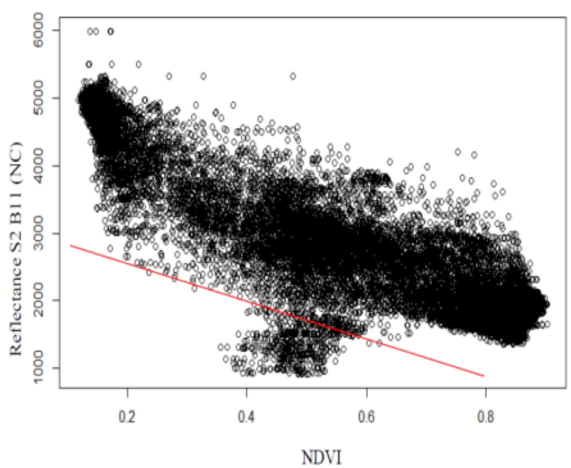
Water level

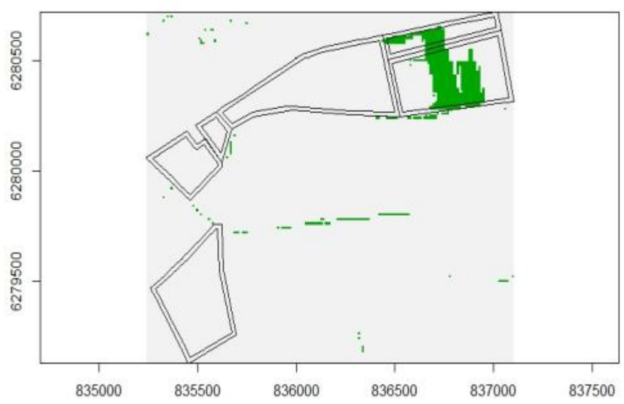
OPERA

Mapping crop practices and land use (Using Sentinel 2 data





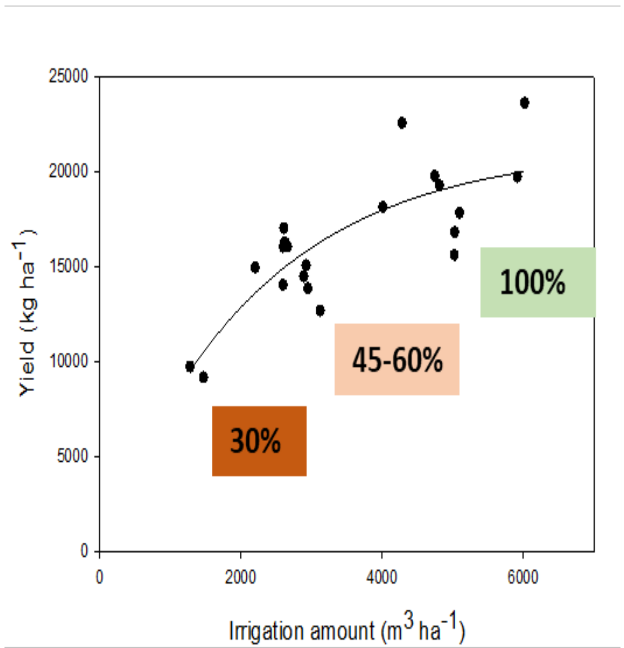




M6 evaluation

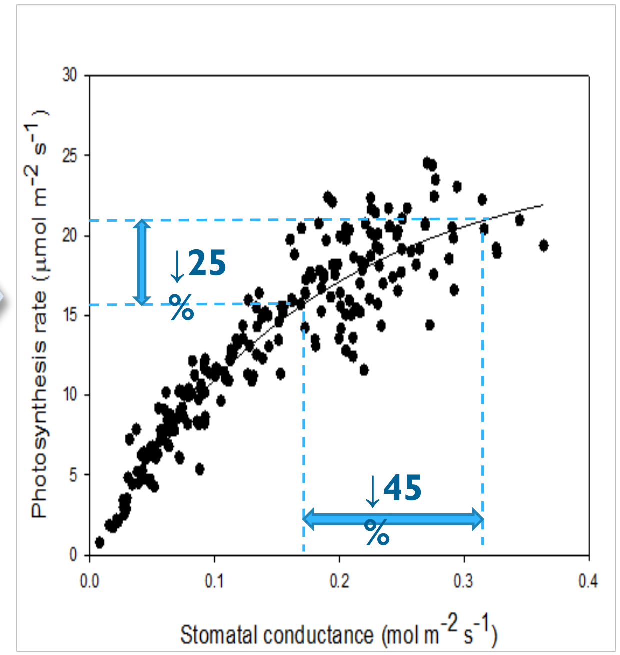
Farm	Nb of field	year	True positive	False positive	Rate of good determination
Boisvert	55	2016	6	0	100%
		2017	10	2	83%
Suffren	47	2016	5	0	100%
		2017	8	3	72%
Aqueduc	23	2016	3	0	100%
		2017	8	0	100%

M2 A novel plant-based method



Conceptual basis

Analogous??



How are we implementing it?

Combination of plant-based sensors and physiological process-based models

IRNAS

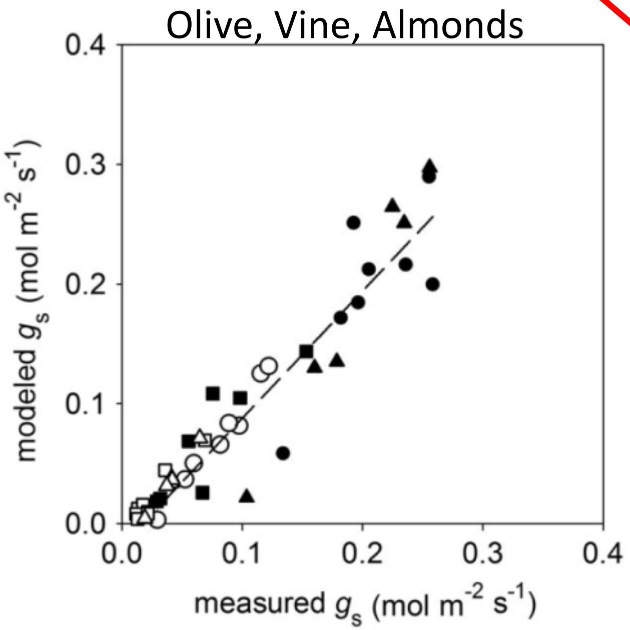
CSIC
Consejo Superior de Investigaciones Científicas

M2 : Stomatal conductance as a key information to evaluate plant status

Input variables
Soil water potential ($\approx\Psi_{pd}$)
VPD (air humidity)
PPFD (light)
[CO_2]
Temperature

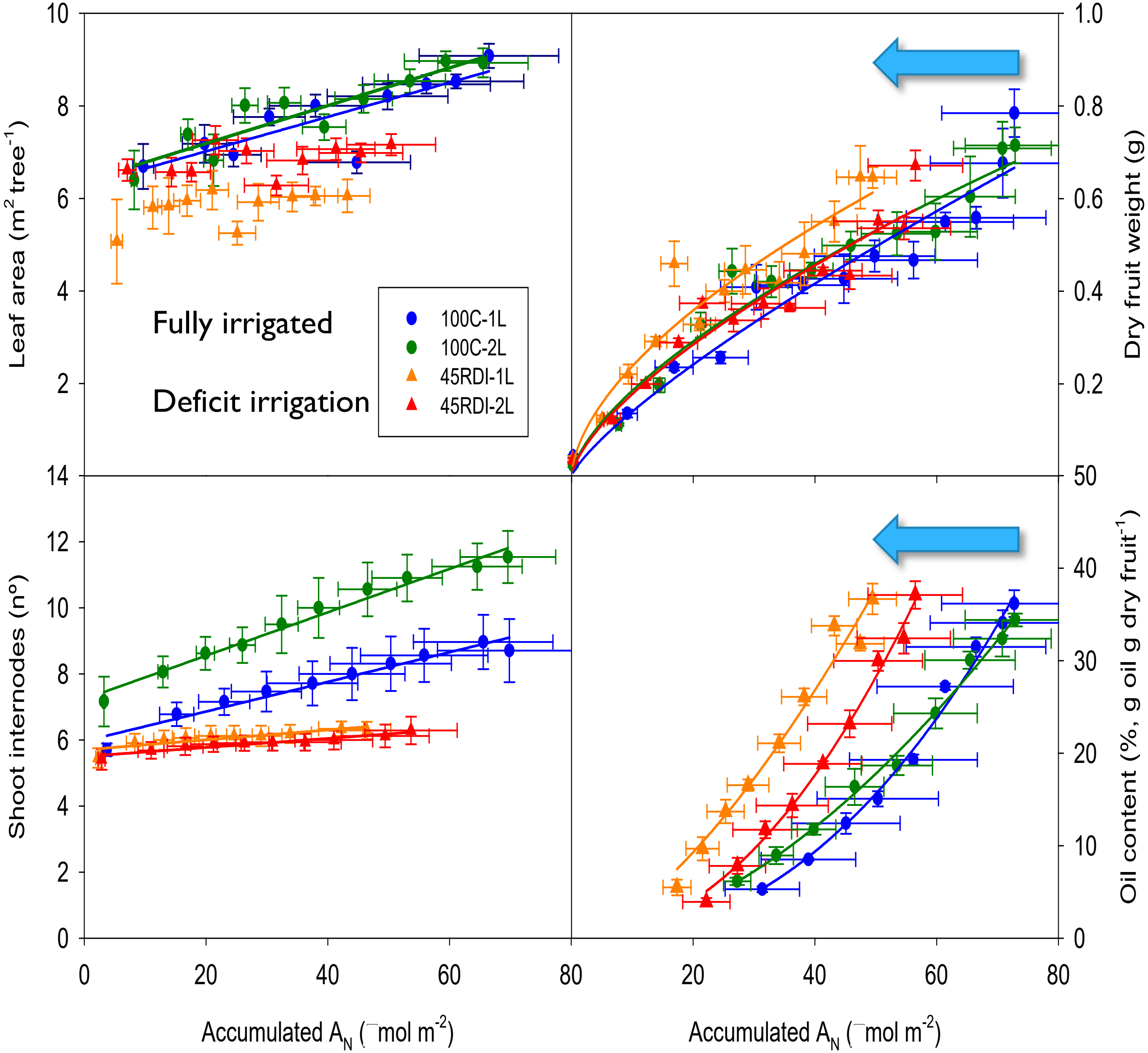
$$g_s = \frac{\chi\beta\tau(\Psi_s + \pi_e)}{1 + \chi\beta\tau R\,VPD}$$

Parameters
Plant hydraulic resistance
Guard cells sensitivity to turgor
Osmotic pressure



Rodriguez-Dominguez et al. 2016

Vegetative growth   Reproductive growth



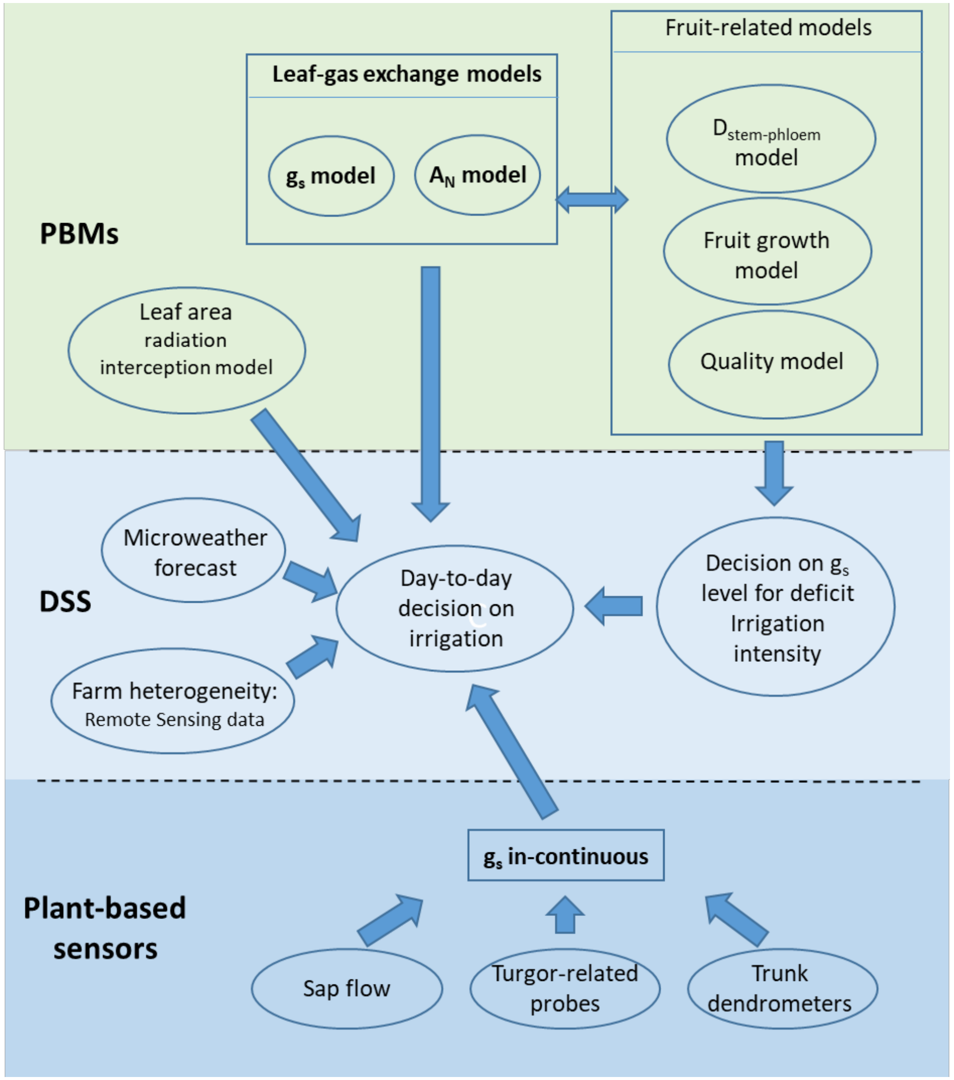
Hernandez-Santana et al. 2018

M2 : Overall scheme

Models

Decision

Sensors



IMPLEMENTATION

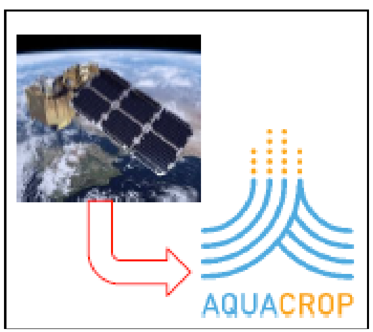
- Test method and quantify the performances
  - Define a Benchmark (what is done before OPERA)
  - Define metrics to assess the method performances
  - Provide a reference data set showing the interest of the method (difficult to obtain since it requires to manipulate irrigation).
- Provide guide lines
  - For the design Irrigation Advisory services based on the tested technologies (Context, issues, methods)

M5 irricrop (tested in Southern Italy)

1. AquaCrop model

2. IRRISAT, an irrigation advisory service based on Sentinel-2 imagery

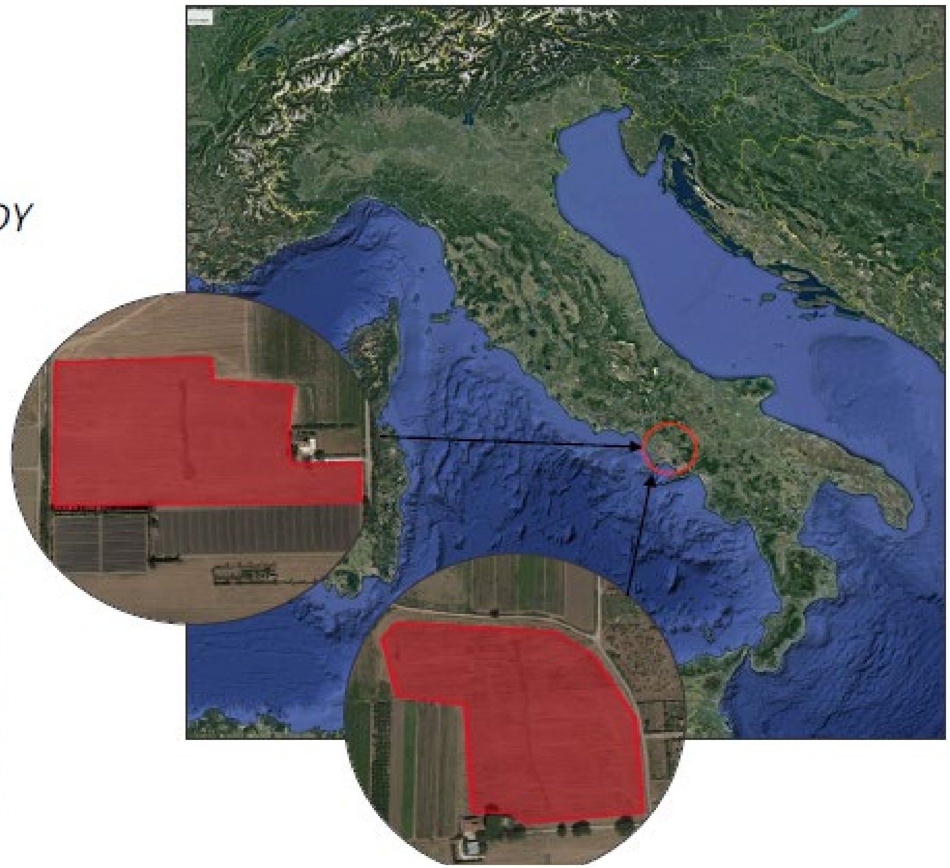
Benchmark



3. Assimilating the canopy cover (fc) estimated by Sentinel-2 imagery into AquaCrop

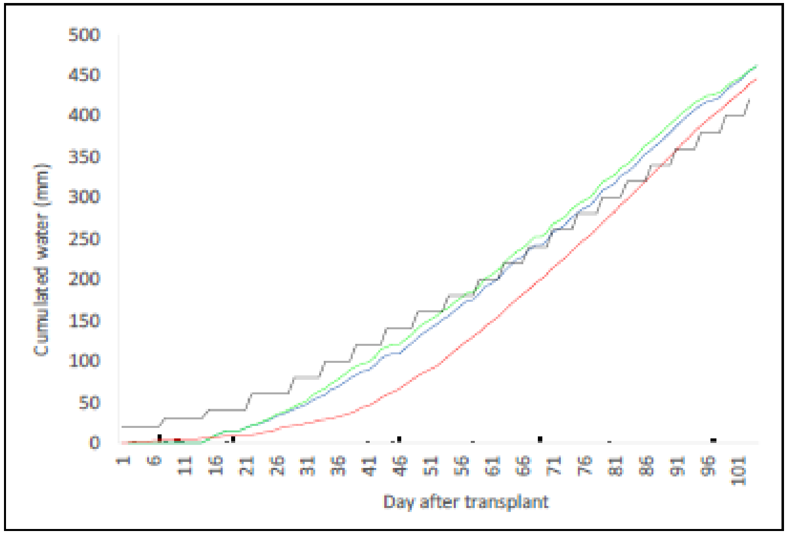
M5 irricrop (tested in Southern italy)

ITALIAN CASE STUDY

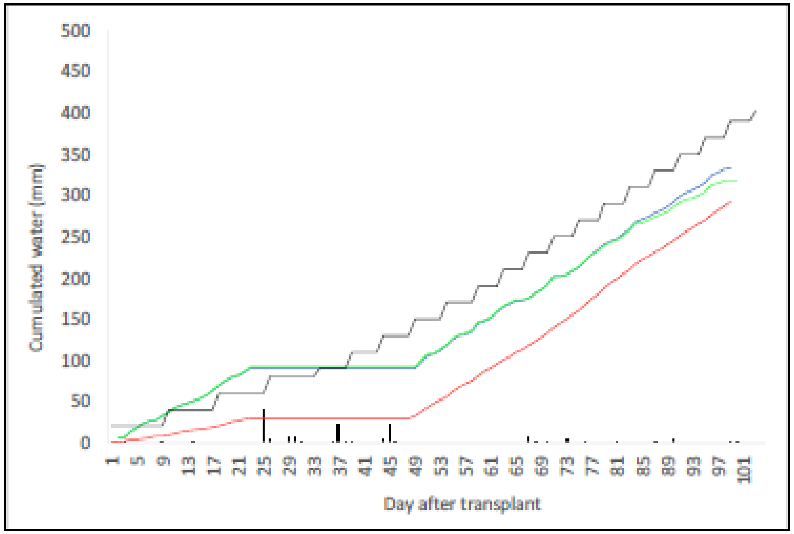


M5 :Evaluation

2017



2018



Cumulated irrigation water requirement (mm) estimated by:

- AquaCrop
- IRRISAT
- Assimilation of fc retrieved by Sentinel-2 imagery into AquaCrop
- Observed schedule

Dalla Marta et al. Agronomy 2019

M5 Irricrop evaluation

		Yield (t/ha)	Tr (mm)	E (mm)	ET (mm)	IWR (mm)	WP_{IWR} (kg/m^3)
2017	Observed	7.20				416	1.73
	IRRISAT				450	450	
	AquaCrop	7.23	345	192	537	461	1.57
	Assimilation	8.23	372	165	537	461	1.79
2018	Observed	7.35				402	1.82
	IRRISAT				349	298	
	AquaCrop	7.60	291	137	428	332	2.29
	Assimilation	7.34	273	139	412	317	2.31

Crop and water balance variables
(Tr: crop transpiration, E: soil evaporation, ET: evapotranspiration, IWR: irrigation water requirement, WP_{IWR}: irrigation water requirement productivity).

Conceptualization of practical service models in line with the farmers needs

- The aim was propose, define, optimize and customize irrigations advisory services, provided by OPERA.

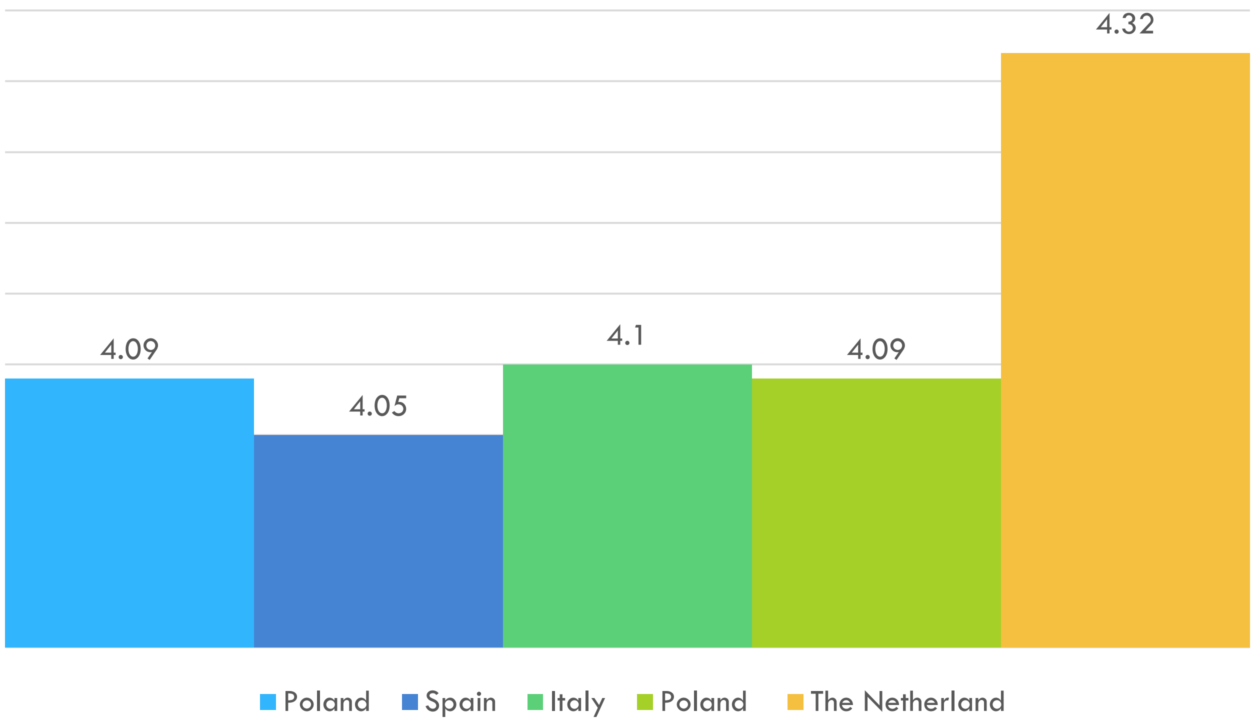
Two main approaches :

- The choice experiment to determine the preferences of farmers regarding the main characteristics and attributes of IASs. Among these, **price** allows an estimation of the trade-offs between attributes in monetary terms, thanks to marginal “willingness to pay” (WTP)
- SWOT analysis

Choice experiment

Attributes	Variants
Weather forecasts.	Weather forecasts with a time horizon of up to 5 days.
Contract. It indicates the adoption of IAS for a range of time and for each farm.	for entire crop cycle, one or three years
Crop Water Requirement. It indicates a range of forecasting.	range of forecasting for 1, 2 or 3 days
Crop monitoring. A satellite image (i.e. Vegetation response to environmental stresses) of your plots.	every per day, 10 ,15 days
Registration of irrigation. Indicates recording the dates and the volumetric water applied.	one time, two times or three per month
Price (/ha/y)	5 – 10 – 15 €

Choice experiment results



Wheather forecast : Willing to pay (€/d)

SWOT

Strengths

- Water saving
- Cost reduction
- …

Weakness

- They face a lack of funds
- Low levels of diffusion of the information at farm level
- …

Threats

- Social aspect and education
- lack of funding, institutional mechanisms to link rural communities

Opportunities

- improving agricultural production
- increase the water management troughs the ICT
- …

General Conclusions

- **Integration :** sharing methodology at both end of the process (needs and market analysis) => a broader vision of needs thanks to the different pilot area contexts.
- **Integration** in the way of describing the innovation and method to evaluate IAs.
- **Timely** to continue development using technological opportunities (Sentinel, ensemble forecast, crop models)
- **Diversity** of implementations but **similarities** in approaches ➔ strengthen conclusions
- **FACCE /Water** : Irrigation at the intersection of climate change (adaptation) and water management (water use efficiency, water resources)
- **Management** of the project satisfactory (2 steps, expected length of the document, link with national agencies). Improvements (format of the report known at the submission level).

General Conclusions

For the future

Farmers trust in IAs remains the key issue : Need of dedicated experiment where advices are really tested in the field

→ need to focus effort on an experimental set up to analyse impacts on **both** water saving and the vegetation production and evaluate models in their ability to represent water/production interactions accurately

→ appropriate infrastructure, long term perspective → Format of the projects

Thank you

Acknowledgement

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Funding

- Total budget: € 1,236,613
- Requested funding: € 920,481
  - Own contribution: € 316,132 (Evenor, UniFI, CREA, INRA)

Partner	Funding Organisation	Budget	Funding
1 – Wageningen Environmental Research (Alterra)	EZ (NL)	149200	149200
2 – Stellenbosch University (SU)	WRC (SA)	50000	50000
3 – Evenor Tech	CDTI (ES)	194844	116906
4 – Instituto de Recursos Naturales y Agrobiologia de Sevilla (IRNAS – CSIC)	MINECO (ES)	130188	130188
5 – French National Institute for Agricultural Research (INRA – EMMAH)	ANR (FR)	259657	98142
6 – University of Florence (UNIFI – DISPAA)	MIUR (IT)	114599	80220
7 – Council for Agricultural Research and Analysis of Agricultural Economics (CREA)	MIUR (IT)	141000	98700
8 – Institute of Technology and Life Sciences (ITP)	NCBR (PL)	197125	197125

Choice experiment results

Attribute	Coef (μ)	std.err	t-stat	p-value
Price (euro / ha)	-0.089	0.022	-4.04	0
Time length of forecasts (per day)	0.360	0.054	6.72	0
Duration of the contract (per year)	-0.247	0.086	-2.86	0.004
Crop water requirement (per day)	-0.055	0.231	-0.24	0.813
Frequency of satellite monitoring availability (per day)	-0.034	0.013	-2.59	0.01
Registration (per month)	-0.314	0.128	-2.44	0.015
No choice	-0.541	0.411	-1.32	0.188

SWOT External parameters

Threats

- Social aspect and education
- lack of funding, institutional mechanisms to link rural communities

Opportunities

- improving agricultural production
- increase the water management troughs the ICT
- new markets and consumers
- reducing the environmental pollution.

SWOT Internal parameters

Strengths

- Water saving
- Cost reduction
- …Capacity and competence
- Good network of land reclamation and irrigation consortia
- Innovation development
- Provide water measurements

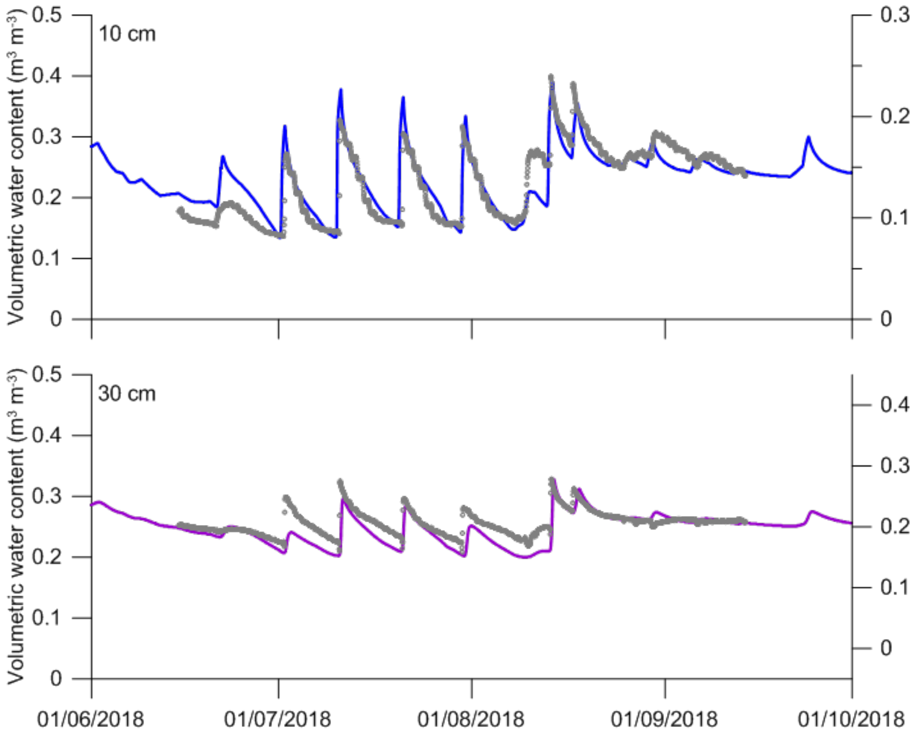
Weakness

- They face a lack of funds
- Low levels of diffusion of the information at farm level
- Negative perception of information provides by IASs
- Low use of electronic devices among farmers of sharing knowledge provide from IASs.

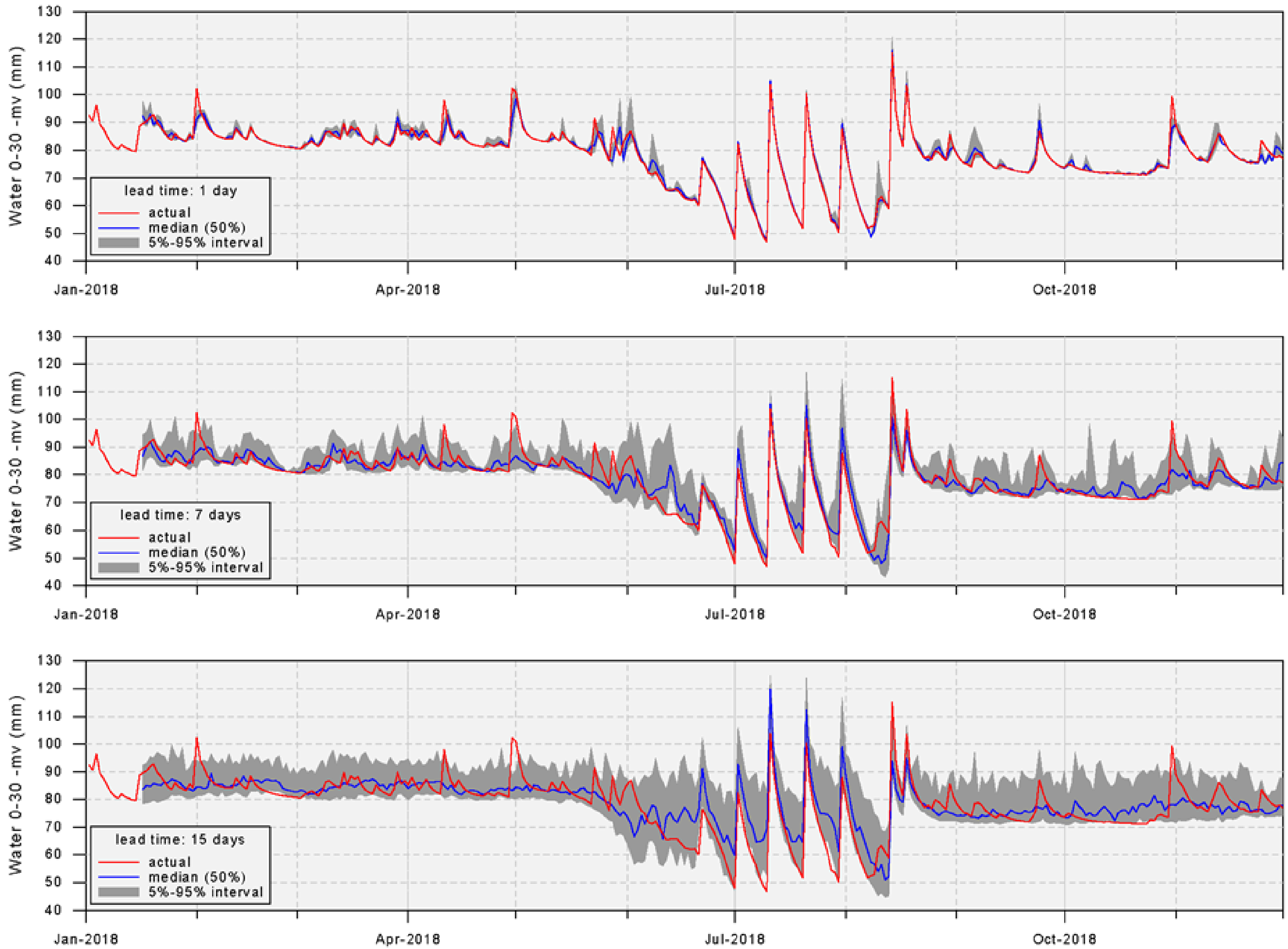
M3 :APSoMoCo modelling soil moisture with ensemble forecast

- Simulation model (SWAP-WOFOST)
  - history: true weather
  - future 15 d: ensemble (51) weather forecast
- Prediction + uncertainty of water content in root zone
- Automation
  - download ECMWF data, download historic KNMI weather data, download sensor data
  - run SWAP-WOFOST for all scenarios
  - Produce graphs (and send these by E-mail)

SWAP-WOFOST implementation evaluation

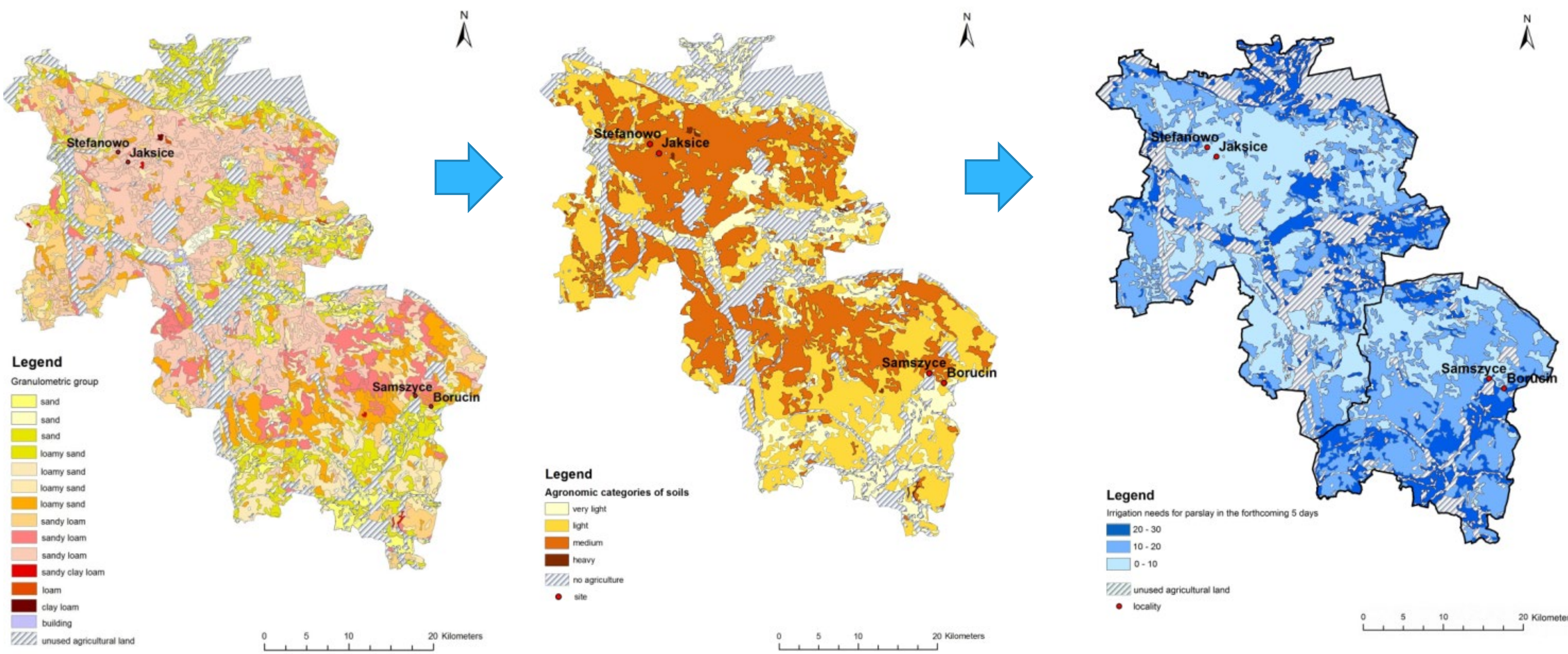


M3 Hindcast Analysis



M4 CropIrr : advisory given at the regional level

Upscaling from field scale to region scale based on soil-agricultural maps, modeling and GIS techniques.



Elaboration of maps: T. Bolewski, E. Kanecka-Geszke (ITP KOB)
based on the maps of the Institute of Soil Science and Plant Cultivation (IUNG)

OPERA

Conclusions

- Our results show that farmers are actually willing to pay to introduce an irrigation support system that results in an economic advantage over their current situation.
- It has been shown that farmers' willingness to pay varies according to the attributes that characterize the service offered based on the country of origin.
- Implicit prices estimates enabled us to measure the non-market benefits that would arise from an improvement in the water use efficiency and productivity.