D5.1 Inception report

Project	OPERA
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OPERA consortium members

	OPERA Consortium partners	Short name
1	Wageningen Environmental Research (Alterra), The Netherlands	WEnR
2	Stellenbosch University (SU), South Africa	SU
3	Evenor Tech (Evenor), Spain	Evenor
4	Instituto de Recursos Naturales y Agrobiologia de Sevilla (IRNAS – CSIC), Spain	IRNAS
5	French National Institute for Agricultural Research (INRA – EMMAH), France	INRA
6	University of Florence (UNIFI – DISPAA), Italy	UNIFI
7	Council for Agricultural Research and Economics (CREA) – Research Centre for Policies and Bioeconomy (CREA-PB), Italy	CREA
8	Institute of Technology and Life Sciences (ITP), Poland	ITP

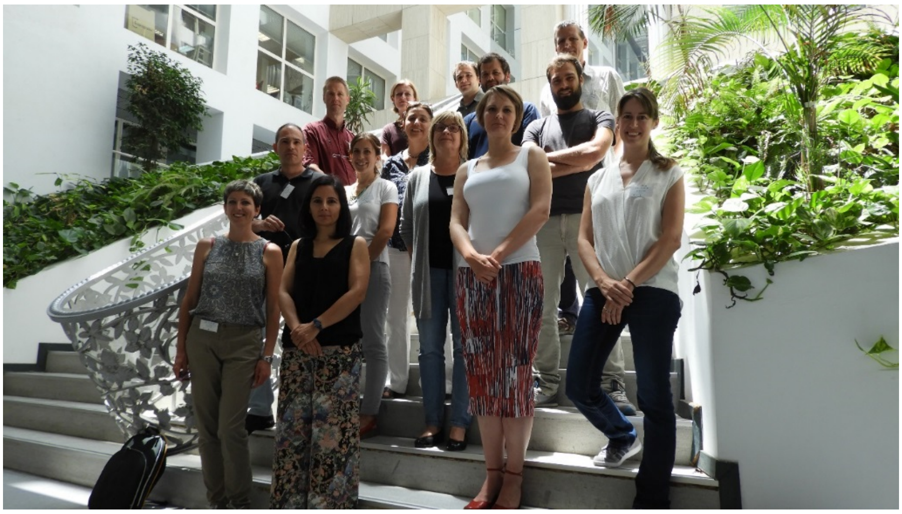
Contents

Summary

This report presents an update of the OPERA activities as planned in the project proposal and describes in more detail the approaches used for the project. The report clarifies in more detail:

-What each work package will deliver;
-How to organise stakeholder engagement across the work packages, and involvement of stakeholders in workshops and field activities;
-How to proceed with integration of case study results.

The report is based on discussions held at the kick-off meeting (Seville, June 2017) and follow-up discussions with the various work package leaders between May and August 2017.



The OPERA project team at the kick-off meeting in Seville, June, 2017

1 Introduction

The OPERA project will focus on making use of newly available information such as weather forecasts and sensor information, so that irrigation can involve a better anticipation of climate variability and critical moments of water scarcity. OPERA will advance the field of precision irrigation in two domains:
- By identifying ways on how farmers and irrigation organizations can react more flexible with their crop selection and production to market available opportunities and the predicted climate variability.
- By providing operational ICT technologies that allow the soil water depended identification and upscaling of crop water demands at field and territorial scale.

The project is organised in 5 work packages which are closely interlinked:

- *WP1 Identifying sector needs to increase resource use efficiency (lead IRNAS Spain).* WP1 is dedicated to the involvement of stakeholders, both in the case studies and at national/European level. Stakeholder involvement will play a key role to identify market driven needs and to increase water use efficiency. The WP1 will work closely together with other WPs: with WP2, stakeholders will be closely involved in the evaluation of the (innovative) management strategies; with WP3, stakeholders will actively participate in the monitoring and demonstration activities at the sites; with WP4, stakeholders will be involved in defining and fine tuning OPERA's services to the irrigation sector.
- *WP2 Forecasting water availability and critical water demand (lead INRA France).* WP2 will develop innovative methods to assess water availability, irrigation needs and the impact of water stress on production. Methods must be suitable for water management and implementable in operational context (see WP3). Innovation will take profit of technical progresses as provided by the Sentinel satellite mission, progress in low cost sensors, weather forecast and data assimilation in crop models.
- *WP3 Guidance for optimal irrigation water strategies (lead ITP Poland).* This WP will synthesize results and testing of practical guidance in the field as proof-of-principle (case studies).
- *WP4 Conceptualization of practical service models (lead CREA Italy).* This WP aims to investigating the roles, institutions and potential markets for operationalizing services to the irrigation sector capable of providing benefits to the user community.
- *WP5 Project management and dissemination (Wageningen Environmental Research The Netherlands).* This WP involves project management, the organization of transdisciplinary approach, co-learning and evaluation during the project period, and dissemination of project results to a wider audience.

Because of the dependencies between the work packages the focus in the first months of the project was on clarifying the linkages and outputs of the WPs and organising the involvement of stakeholders. In addition, the approach to integrate the different case study activities into common guidance for irrigation was elaborated. This has been discussed during and after the kick-off meeting with partners and WP leaders and is described in this report.

2 Organising stakeholder involvement

Stakeholder involvement will play a key role in OPERA, based on a transdisciplinary approach that will ensure joint learning and co-development with all relevant stakeholders. Stakeholders will actively participate in the monitoring and demonstration activities at the sites, and they will be involved in defining and fine tuning OPERA's irrigation services to the sector. Their involvement is represented in the various work packages. During and after the kick-off meeting (Seville, June 2017), it was discussed how to best organise the involvement of stakeholders. Two elements were discussed and further elaborated: i) identification of key stakeholders for involvement and ii) organising the workshops.

2.1 Identification of stakeholders

Stakeholders will be involved during the project lifetime as final users of the proposed methodology. A group of end users is represented by farmers, technicians or advisors of agricultural extension services and research units, who will be supplied with high quality information for supporting short- and long-term decision making processes. As the first step, the relevant key stakeholders for involvement are to be identified. It was decided during the kick-off meeting that some common guidance should be developed for this. Each case study builds on pre-existing experience with previous engagement with stakeholders and social science research methods. Most of the case study partners have already long- or medium-term collaboration with stakeholders in their areas. The guidelines should help to support a systematic selection of key stakeholders to be involved throughout the project, and how to disseminate information about the OPERA project.

After the kick-off meeting guidelines were developed by WP1 (Evenor Tech) to identify and characterize which actors and organisations hold a stake in the case study area in relation with the project objectives, what the role/stake is and how the different stakeholders are related to each other. Since each case study in the OPERA project is developed in a local context (geographical location, language, cultural and socioeconomic characteristics), the guidelines provide a flexible protocol to be implemented by the case study partner according to their own needs and capabilities, but ensuring a certain degree of harmonisation between case study sites by providing key principles to follow in each site.

Project partners are encouraged to include in their sample some stakeholders with whom they did not had previous contact. Stakeholder diversity is important for assessing how farmers and irrigation organizations can react more flexible in crop selection and production for markets, and for identifying potential customers for the OPERA outputs. As part of the guidelines, a questionnaire has been developed to map the stakeholders profile, role and activities, technologies and interests. The guidelines describe a step-by-step procedure to collect information about stakeholders. Three steps are followed in the stakeholder characterisation:

Step 1: Identification of stakeholders. Describe their field of activity, their form of interest or role and segment (private sector, government, public administration).

Step 2: Including new stakeholders. The aim is to make a selection of stakeholders that offer a diverse range of the irrigation market, with different roles, relevant for the particular case study.

Step 3. Selection of stakeholders and establishment of a stakeholder platform. Partners will be responsible for setting up stakeholder platforms for communication throughout the project in their respective national languages.

2.2 Organisation of workshops

After the stakeholders have been identified, workshops will be organised. Two rounds of stakeholder workshops are included in the project. The aim of the workshops is a joint identification of (i) demands of farmers, farmer associations, extension services and water management organizations, (ii) the best possible combinations of information technologies (sensors, models, remote sensing) to forecast drought and other climate critical events and, and (iii) scope for innovative service models to realize a practical transition towards an increased use of precision irrigation in practice.

The workshops will enable to disseminate information about the project, to motivate participation in the implementation process and to spark stakeholders interest as users of the resulting business models. The goals of the workshop have been discussed and are agreed as:

- Introduce the OPERA project and its expected results to key stakeholders and potential final users of the services finally developed.
- Identify the resources, capacities and preferences of the stakeholders to improve water use efficiency and resilience in irrigation into a background of climate change.
- Provide insights on opportunities for development and implementation of ICT tools and innovative service models to bring the information to the key final users.
- Identify the potential study fields of interest related with data required in WP2, monitoring and demonstration activities in WP3 and validation of the process developed in WP4.

The first round of workshops take place between November 2017 and January 2018. To ensure a certain level of uniformity in the case study workshops, guidelines have been prepared by WP1 (Evenor Tech) to support the organisation and implementation of the first workshops. The guidelines entail a level of flexibility, so that they can be partially adapted by partners for each case study where necessary. The guidelines involve:

- A suggested structure for the workshop.
- Dissemination material to introduce the project, role of stakeholder and benefits for participating.
- Sequence of communication with stakeholders, workshops and field trials.
- Possible exercises and set-up of roundtable discussion.
- Two surveys that have been developed:
  - Survey 1: Adoption of irrigation advisory services (developed by WP4, CREA). This involves a list of questions on data and information that stakeholders need to improve irrigation efficiency and the scope to adopt an Irrigation Advisory Service for this.
  - Survey 2: User requirements (online tool developed by WP1, Evenor Tech). Questions are focused on the joint identification of barriers and needs from the different groups of stakeholders to adopt improved irrigation strategies and behaviour as well as alternative crops or varieties to cope with present and predicted climate restrictions.

3 Case study activities and integration

3.1 Integration of case study experiments

The case study experiments are a major element of the project, and they are part of both work packages WP2 and WP3. The WP2 involves the development of methods for e.g. quantifying water availability and water demand, and WP3 includes testing of these methods in an operational context (case study experiments). During the kick-off meeting it was discussed on where to put the boundaries of the two work packages (which WP delivers what?) to ensure a solid framework for the case study activities and their evaluation, so that these can be integrated into practical guidance for irrigation strategies, related to:

- Which model to use and criteria for selection.
- Combination of tools and models.
- Upscaling.
- Reliability.

The table below summarises the discussions at the kick-off meeting on the outputs of the WP2 and WP3 activities and how to integrate case studies into guidance for irrigation (Table 1).

Table 1: Implementation of methods in case studies and evaluation.

Design and development of methods to improve irrigation (WP2)	⇨ Develop innovative methods to assess water availability, irrigation needs and the impact of water stress on production. ⇨ Provide a common evaluation procedure to be used for the demonstration in the different case study areas. ⇨ Design, test and evaluation of the methods (adding value with respect to conventional techniques and error assessment).
Case study experiments (WP3)	⇨ Implementation of the WP2 methods in operational context (evaluation of water saving with respect to usual practices). ⇨ Set-up of the case study experiments to provide relevant data sets (crop and management practices, Sentinel data, irrigation volumes, climate, yield, soil texture, soil moisture, transpiration, stress proxys). ⇨ Field activities in interaction with stakeholders (WP1, WP4).
Integration of case study results (WP1-4)	⇨ Guidance based on case study results: Irrigation decision support. Provide relevant information on e.g.: • Use of model (which kind of model, value of using model to make decision, are model able to address limited irrigation). • Additional value of using measure together with model. • Scaling up: how to pass from local measurement to field recommendation. • Remote sensing strength and limit of sentinel 2 images. • At which terms irrigation need forecast can be reliable. ⇨ Limitations to be described as guidance will be based on 6 case studies only.

To start preparing and guiding the case study activities, templates have been prepared after the kick-off meeting for the identification of the methods (WP2) and the implementation of the methods (WP3), as described below.

3.2 Method Identification

A template was prepared by the WP2 Lead partner (INRA-EMMAH) to summarise the main features of the methods that will be used in the project and how these will be evaluated (Table 2). The table will be completed by each case study, and will be used to prepare the reference framework defining requirements, implementation condition and evaluation procedure for the project methods (Deliverable D2.1, due in month 9).

Table 2: Reference framework defining requirements, implementation condition and evaluation procedure

Objective of the method	Implementation context: decision to be taken, issue being addressed, purpose of the method, link with WP1 to identify user requirements. Irrigation system: (crop, irrigation techniques, limits) Users: actors being involved in the implementation of the method (service provider, farmer, …), as identified in the first phase (stakeholder identification).
Method description	Rationale of the method: description of main principle underlying the method to assess the water requirement. Main hypothesis, algorithm being used. Provide illustration showing principle scheme or main results. Innovation: identification of the current practices to address similar decision and highlight the innovation. Requirements: knowledge, data, sensors (illustration of equipment when needed, or data). Maturity: describe the level of maturity at the beginning of the project and expected maturity at the end: idea, proof of concept, prototype, operational service. Market identification: in relation with WP4.
Method Evaluation	Performance indicator: what will be the metric to quantity the benefit of the method. Benchmark: benchmark (current use) to be used to quantify the benefit offered by the proposed method. Evaluation framework implemented in OPERA: description of the use case implemented in OPERA (link with WP3 – evaluation in pilots).

3.3 Implementation of the methods in case studies

A template was prepared by the WP3 Lead partner (the Institute of Technology and Life Sciences, ITP) to describe in a uniform way the case study characteristics, which methods will be used and which data will be collected (Table 3). The tables have been completed by each case study; See Appendix 1 for a detailed description of the OPERA case study activities.

Table 3: Case study description.

Case study description (what is the main problem that will be addressed, and what would be the expected improvement after OPERA?; objective of the case study)
Case study location and scale addressed (region, catchment, field).
Status of irrigation in the case study (current conditions): - Irrigated crops and area under cultivation (ha) - Irrigation techniques used - Irrigation / water management scheduling decision making methods currently used (e.g. sensors, meteorological, models, farmer appreciation, water turn) - Decision support services used - Current water saving practices applied in case study and how - Sources of water for irrigation (surface, ground) - Soil type - Water cost (water price, electric power, taxes)

- Legal basis for water use for irrigation - Any conflicts with other water users?
Data collection strategy and methods: - Methods being developed and tested in OPERA (in relation with WP2, see Method Identification) - Spatial design : define spatial entities on which data will be collected (field level, irrigation scheme level, watershed level, …) - Type of irrigated crops involved in the case study - Specify data being collected in each spatial entity : • Sensors (soil sensors, crops sensors): … • Remote sensing data: … • Other data (weather, weather forecast, climate, soil, water, other): … • Agricultural practices (irrigation calendar, …):…
Models that will be used in case study and for what (related to methods and data collection)
Starting date of data collection for OPERA: Already ongoing / historical data collection at the site:

4 Next steps

The project activities are on track and the time schedule for activities planned for 2018 remain unchanged.

Case studies
The case studies have all taken off since June 2017, and for some sites already ongoing / historical data collection was taking place at the site (milestone M3.1). Progress of the field experiments will be monitored on a monthly or bi-monthly basis in 2018 using skype meetings and regular progress reports will be provided.

Impression case study site Spain

The reference framework for integration and evaluation of case study results will be completed for all case studies and will be consolidated in a report (D2.1 Report: Reference framework defining requirements, implementation condition and evaluation procedure; month 9).

Stakeholder interaction and workshops
Contacts have been established with selected stakeholders in all case studies, and they have been invited to participate in the first round of workshops (milestones M1.1 and M1.2). Some of the workshops have been completed and some others will be held early 2018. After the workshops, WP1 will process the outcomes and share these with all WPs. A report will be prepared on this (D1.1 Report: Assessment of user requirements of the sector), due in month 8.

Service model development
For development of the irrigation service models, a survey was prepared which will be completed in the first round of workshops. These surveys form the basis for a socio economic assessment and willingness to pay analysis, which is used to develop a framework for business development and portfolio of business models established (M4.1 framework due in month 24).

Appendix 1 Description of OPERA Case Studies

Case studies
1 Andalusia, Spain
2a The Crau area, France
2b Ouvèze river basin, Entrechaux area, France
3 Volturno River catchment, Italy
4 The Netherlands
5 Upper Zglowiaczka River catchment, Poland
6 Breede river and Letaba river catchments, South Africa

Case study 1: Andalusia, Spain

1) Case study description Agriculture in the Mediterranean regions is facing serious problems related with present drought and the general scarcity of water resources, added to an increasing water demand[1]. Such difficulties are to be aggravated due to the future predicted severe water scarcity in the Mediterranean area[2]. Olive crop has been selected as case study since it is a strategic economic sector representing the 24% of the regional value of the agricultural production, covering a surface of around 1.5 mill. ha (about 17% of the region total surface, covering the 60% of the national surface dedicated to olive crops and 30% of the European surface), providing around 40% of the global olive oil production and around 20% of the global table olive production. It is, in addition, an important source of wealth and employment (it supports more than 22 mill. wages annually), element for social and territorial cohesion, a relevant agro-system of high environmental value and configurator of the Andalusian territory and culture[3]. This Case Study is focused on the Andalusian olive crop, covering a gradient of climate and crop management. Although some facilities and advice services are available in this area, the present solutions have been not properly brought into practice, thus desirable results continue to be reached. To this CS, OPERA will have **impact** the Andalusian olive sector by: i) Identifying the concrete local barriers that had prevented the transfer of research results into the farmer and water manager practice; ii) Defining, adapting and applying regulated deficit irrigation (RDI) in the Andalusian olive orchards, aiming a sustainable balance between water savings and olive production; ii) Using those methods upscaled to the territory (by the use of earth observation technologies, territorial analysis and modelling) and tested through OPERA to define goals and advice for policy makers; iii) Creating a self-updating, scalable computing tool to be friendly used by farmers, irrigation organizations and policy makers. The Institute of Natural Resources and Agrobiology together with the Technology Based Company Evenor-Tech will be the responsible of the present Case Study.
2) Case study location and scale addressed (region, catchment, field) Works will be conducted to both farm and territory (regional) scales. **At the farm level**, an experimental plot with different irrigation treatments will be used. It is well equipped with especialised sensors and other instruments. It is located at the Sanabria orchard (Sevilla, SW Spain; 37º 15' N, 5º 48' W), a hedgerow olive commercial orchard of about 10 ha, owned by Interoliva. Here, 'Arbequina' olive trees were planted in the spring of 2007, with a super-high density pattern of 1667 trees / ha. Other 6-10 experimental plots are being selected along the climate and management gradient across the Andalusian region, and will be equipped with essential instruments to validate the methods developed in the main Sanabria plot. **At the territory level, olive crops** comprises the about 17% of the region total surface, with different management and water use strategies and across a climate gradient from Dry warm Mediterranean to Continental Mediterranean climate, including crops under Oceanic Sub-humid Mediterranean climate.
3) Status of irrigation in the case study (current conditions): <u>Sources of water for irrigation (surface, ground):</u> rainfall water stored in a pool. <u>Irrigated crops and area under cultivation (ha):</u> Olive trees in 3 ha of experimental field. <u>Soil type:</u> Arenic Albaqualf, USDA2010 <u>Irrigation techniques used:</u> The irrigation system consists in one or two drip lines per tree row with a 2 L/h dripper every 0.5 m. Every tree receives the same amount of water, regardless of the number of drip lines, regulated through the irrigation time. The fertilization applied is enough to cover the needs of the crop and is injected to the irrigation. The distribution of the irrigation treatments is based on two factors: irrigation amount (Control and Stress) and the amount of drippers (One and Two drip line). This is a random design with four replicates (plots). Each experimental plot or replicate is composed of eight central trees, in which we conduct the measurements, surrounded by edge trees. <u>Irrigation / water management scheduling decision making methods currently used (e.g. sensors, meteorological data, models, farmer appreciation, water turn):</u> Irrigation treatments are controlled based on the estimated stomatal conductance (gs) estimated from sap flow related measurements so that the Control, both One and Two lines will receive water to maintain gs at values that do not imply more than 90% limitation of photosynthesis, and Stress treatment to maintain gs values around 30%. Sap flow gauges are installed in three representative trees of each irrigation treatment in three different plots. Only the most external thermocouple is monitored since previous works have shown that it represents the best the dynamics of stomatal conductance in the canopy. At the beginning of the growing season simultaneous measurements of stomatal conductance with the IRGA (Infra-Red Gas Analyzer) are taken in the canopy. These measurements help to calibrate the sap flow data and to infer stomatal conductance. <u>Decision support services used:</u> None, apart from scientific advice described above. <u>Current water saving practices applied in the case study and how:</u> Up to now, we have applied regulated deficit irrigation practices based on replacing ETc in the phases of the growing cycle when the crop is

[1] IPCC, 2014, Climate Change 2014: Impacts, Adaptation and Vulnerability, Vol. I Global and Sectoral Aspects.

[2] IPCC, 5th Assessment Report, 2013.

[3] Consejería de Agricultura y Pesca, Junta de Andalucía, 2010.

more sensitive to water stress, and reducing or even withholding irrigation for the rest of the cycle (Chalmers et al.1981). In this project we will determine the water stress of the trees using the modelled stomatal conductance values.
Water cost (water price, electric power, taxes): Annual costs: Electric energy associated to irrigation: 431 euros/ha; Irrigation programming: 157 euros /ha; Insurance/taxes: 100 euros/ha; Investment maintenance: 10.7 euros /ha. Irrigation water from own wells and rainfall pool (free).
Legal basis for water use for irrigation: Spanish Law 9/2010.
Any conflicts with other water users?: No.

4) Data collection strategy:
Methods being developed and tested in OPERA (in relation with WP2)**:** As described before, we will use stomatal conductance modelled with sap flow related measurements for the first time to schedule and quantify the amount of irrigation.
Spatial design: we will work at field level (farm) as described and upscale the results to region scale through the participation of invited stakeholders on other farms covering heterogeneity of key olive crop characteristics. Upscaling to the territory (regional scale) will be carried out by using other data sources according to soil properties, topography, drainage, land cover, Remote Sensing, and the application of prediction models. From the reclassification of this information and its intersection in GIS, land irrigation suitability maps will be obtained.
Type of irrigated crops involved in the case study: olive trees.
Specify data being collected in each spatial entity:
To the *farm level*, we will collect data from: ***i) Sensors***: Plant-based sensors (Sap flow gauges, trunk dendrometer, leaf turgor pressure sensors, fruit microdendrometers); Soil sensors (soil water content probes); other sensors (humidity/temperature, radiation); ***ii) Weather*****:** Standard meteorological stations already in use and specific meteorological station for micro-weather forecast to be purchased; ***iii) Weather forecast*****:** provided by ECMWF through the Spanish State Agency of Meteorology (*under revision*); ***iv) Remote sensing sources:*** drone imaginery and airborne thermal cameras; and ***v) Agricultural practices and other:*** irrigation calendar (irrigation starts between April-May and ends in October-November depending on the year), management type (crop density, soil type, applied irrigation strategies); regulations.
To the *territory level*, we will collect data from: ***i) Weather forecast*****:** provided by ECMWF through the Spanish State Agency of Meteorology (*under revision*); ***ii) Remote sensing sources:*** satellite imaginery; and ***iii) Agricultural practices and other:*** management type (crop density, soil type, applied irrigation strategies); regulations.

5) Models that will be used in case study and for what purpose (related to 4. data collection)
At the farm level, Micro-weather prediction based on MeteoGrid system wil, be used. The measurements will be collected with a micrometeorological station in the farm (Ranch-Systems). The control of irrigation will be based on the best combination of plant and soil measurements, process-based models and micrometeorological forecast for the farm. Data from farms additional to the experimental Sanabria orchard will be used to upscale the models.
At the territory level, irrigation will be estimated based on the potential maximum stomatal conductance of sunlit and shaded leaves, total leaf area of the plant and the microwether prediction. A protocol of irrigation scheduling will be developed and main troubles to apply it in practice will be identified. The protocol must be suitable to be applied twice per week and produce as output the hours of irrigation per day. This methodology will be implemented together with the adapted version of the USBR (United States Reclamation Bureau) land classification system, among other DSS and Remote Sensing Sources. The USBR recognizes 7 land classes. Subclasses indicate the reason for the land being downgraded to a lower class. These deficiencies are related to soil, topography and/or farm drainage.
Own models will be used in addition to: Farquhar for photosynthesis and MicroLEIS for land upscaling.

6) Starting date of data collection for OPERA:
Farm Level: 01 June 2017
Territory Level: 01 April 2017

Case study 2a: The Crau area, France

1) Case study description (what is the main problem that will be addressed, and what would be the expected improvement after OPERA) The Crau is a flat region located in South-Eastern France characterized by highly contrasted humid areas, with a high diversity of crops and agricultural practices. The Crau region is famous for irrigated meadows providing COP (Certified Origin Product) hay exported all over the world. The main source of water is collected from the Durance Valley hydraulic system. The Crau Aquifer is maintained by the flooding irrigation system, which provides 75% of the recharge. The aquifer is an alternative source of water. Main problems: Water tension induced by climate change is expected and restrictions on surface water are foreseen, which require to reconsider water sharing rule according to the actual needs and improve irrigation efficiency. For such purpose, heterogeneity brought by flooding irrigation has to be addressed. Expected improvements after OPERA: development of tools to better estimate water requirements and consumption (evapotranspiration); Mapping at different spatial scales (from the field scale to irrigation sector scale) water demand along the irrigation season for a better adjustment of water distribution between sectors, define infrastructure requirements to improve water irrigation efficiency
2) Case study location and scale addressed (region, catchment, field) Region "la Crau" a triangle of around 20x30x20 km between Arles-Salon de Provence-Fos /mer delimited by the following coordinates 43° 41'25.96N 4° 37' 2.86E, 43°40'12.19N 5°4'30.88E-43°25'28.22N 4° 51' 28.66E). This area corresponds also to the boundary of the shallow aquifer (between 4-10m). Studies will be conducted from field scale to the aquifer scale.
3) Status of irrigation in the case study (current conditions): Sources of water for irrigation (surface, ground): Mainly from channels from the Durance river coming from Alps and pumping from ground water table. This situation is representative of piedmont area. Irrigated crops and area under cultivation (ha):13500 ha of irrigated grasslands (8500ha COP) orchards Soil type: The soil of the Crau region is shallow (40–80 cm) and very stony (20% of stone at the surface and 90% below) inducing a very low water holding capacity. It is also generally poor except at surface layers of irrigated fields, which are rich in organic matter and mineral elements carried with time by irrigation water. Irrigation techniques used: mainly irrigation by flooding from March to September, drip irrigation on orchard. Irrigation / water management scheduling decision making methods currently used (e.g. sensors, meteorological data, models, farmer appreciation, water turn) Irrigation rounds are separated by 8 to 12 days (a round corresponds to the time between two irrigation events). Frequency is defined at the irrigation district level in order to ensure an equitable availability of water to each farm of the district. There are around 442 farms producing hay. More than 60% of these farms have an average area of 100–120 ha. Irrigation is managed by local association called ASA (Association Syndicale Autorisée). Drip irrigation on orchard is scheduled to follow the climatic demand and maintain the water bulb. Decision support services used: irrigation is driven by water availability defined by the water sharing rules. Current water saving practices applied in the case study and how: no water saving (restrictions sometimes these last summer due to droughts) Water cost (water price, electric power, taxes): 100 to 150 €/ha. Year for gravity irrigation. An annual fee fixed according to the volumes and requested debit Legal basis for water use for irrigation: managed by the ASA (local associations) and the water table by regional groups SYMCRAU (http://symcrau.com/) Any conflicts with other water users? In addition, as the ground water table is superficial (at about 10m from the surface), some farmers (~9% over the whole region?) use pumping to irrigate some of their fields. This pumping is not regulated by the ASA, and some interactions between wells may lead to conflict. Due to the flood irrigation technique and to the very stony soil type, about 60% of this water is lost by percolation and contributes significantly to the recharge of a superficial aquifer, which is the main source of water for domestic use in this area. 280000 inhabitants. The problem is then to share the cost of the hydraulic infrastructure that has strong externalities. At the present the maintenance is supported by farmers only.
4) Data collection strategy: Methods being developed and tested in OPERA (in relation with WP2)**:** Methods based on the combined use of remote sensing data acquired at high spatial and temporal resolutions (Sentinel 1 & 2 data) and models simulating water transfers between soil-plant and atmosphere. Use of assimilation methods of remote sensing data into crop models (STICS and simplified FAO approaches) to predict irrigation needs and the impacts of water shortage on vegetation productions and the aquifer. Spatial design: define spatial entities on which data will be collected (field level, irrigation scheme level, watershed level, …)

Field level up to the regional level to cover all the Crau area Type of irrigated crops involved in the case study: irrigated grasslands Specify data being collected in each spatial entity: Sensors (soil sensors, crops sensors): A flux station (eddy correlation, soil moisture) is installed on the Coussoul area (steppe ecosystem). Historical data were collected during five years including soil moisture and surface energy flux. Coussouls cover**s** about 30% of the area and then has a significant contribution to the aquifer recharge. Remote sensing data: mainly Sentinel 2 (completed at some periods by Landsat 8 and Sentinel 1 data) (Sentinel 2A delivers multi-spectral data every 5 days in 13 spectral bands in the optical and middle infrared ranges) Other data (weather, weather forecast, soil water properties, water, other): A functional soil map was established using the soil map and the analysis made on reference profiles. As part of the soils were constituted by loam sediments brought by irrigation, the surface layer was mapped according to starting date of the irrigation (several centuries in some case). The resulting soil layer depth may vary from 10 to 60 cm. Two meteorological stations are available, as well as the SAFRAN historical climatic data which is a gridded climatic product (meteorological reanalysis). Seasonal weather forecast will be available in the frame of the MEDSCOPE project Agricultural practices (irrigation calendar, …): Records of agricultural practices will be collected on different farms. (historical data are already available yet)
5) Models that will be used in case study and for what purpose (related to 4. data collection) Crop model STICS (http://www6.paca.inra.fr/stics_eng/) simulates grassland productions, water and nitrogen budgets, Models described in**:** Olioso A, Lecerf R, Baillieux A, Chanzy A, Ruget F, Banton O, Lecharpentier P, Trolard F & A-L Cognard-Plancq (2013)**.** Modelling of drainage and hay production over the Crau aquifer for analysing impact of global change on aquifer recharge. *Procedia Environmental Sciences, 19: 691–700.*
6) Starting date of data collection for OPERA: Already ongoing / historical data collection at the site: Sentinel 2 data already collected over our study sites from 1/2/2016 up to now. Corrected from atmospheric effects and georeferenced. Biophysical variables computed for each date (LAI, FCOVER, FAPAR) Meteorological data: two stations located on the study area: one on dry area (called coussoul), one on the irrigated part (Salon) Surveys on land use performed each year Surveys on irrigation practices planned in 2018

Case study 2b: Ouvèze river basin, Entrechaux area, France

1) Case study description (what is the main problem that will be addressed, and what would be the expected improvement after OPERA)
The Ouvèze basin: The challenge for agriculture is the reduction of the vulnerability of the farms to the access to the water. This requires the improvement of the management of the quantitative water on these watersheds taking into account the climatic demand and actual irrigation needs. Agriculture in this region is the only activity able to maintain and occupy the land while considering the stakes of landscape, fire fighting, flooding.
Main problem: The last years recurrent droughts and water shortage were met. Traditionally rainfed crops now (or in a very near future) demanding irrigation (cherries, table grape, wine grape). Water uptake rights will be renegotiated according to the water availability and new regulation to maintain a minimal flow in the river to maintain ecological quality (last water restrictions in summer 2017 see https://www.irrigation84.fr/actualites/secheresse/140-secheresse-arrete-prefectoral-25-08-2017)
Expected improvement after OPERA: Development of irrigation water needs maps at various scales. Identify sectors where water savings are possible and sectors where substitution water resources will be necessary (developing irrigation networks from the Rhône river).

2) Case study location and scale addressed (region, catchment, field)
The Entrechaux area represents a 480 km^2 sub-watershed of the Ouvèze river. It is located in the north of the Vaucluse department (centered on Entrechaux town :44° 13' 4.83N 5° 8' 18.88"E). Small watersheds (~3 x 3 km) are considered in the project.

3) Status of irrigation in the case study (current conditions):
Sources of water for irrigation (surface, ground): Irrigation from Ouvèze river
Irrigated crops and area under cultivation (ha): mainly orchards-vineyards (500 ha)
Soil type: shallow loamy soils with variable stone contents
Irrigation techniques used: drip irrigation and micro sprinklers (below canopy)
Irrigation / water management scheduling decision making methods currently used (e.g. sensors, meteorological data, models, farmer appreciation, water turn): Using expertise and climate data
Decision support services used: to be determined
Current water saving practices applied in the case study and how : To be determined
Water cost (water price, electric power, taxes): to be determined
Legal basis for water use for irrigation: managements by local associations ADIV84
Any conflicts with other water users?
A possible source of conflict may come from management of the Ouveze river flows and the water rights given to every irrigator associations.

4) Data collection strategy:
Methods being developed and tested in OPERA (in relation with WP2)**:** water needs will be evaluated by combining remote sensing (to locate fields and assess vegetation cover dynamic) and crop models. A modeling framework will be then implemented to provide irrigation needs at the fields scale over the whole irrigated area.
Spatial design: define spatial entities on which data will be collected (field level, irrigation scheme level, watershed level, …): studies conducted at field level and irrigation association (ASA) levels
Type of irrigated crops involved in the case study: orchards and vineyards
Specify data being collected in each spatial entity:
Sensors (soil sensors, crops sensors): …surveys on agricultural practices, crop heights, Crop developments from hemispheric photographs (LAI).
Remote sensing data: mainly Sentinel 2 (completed at some periods by Landsat 8 and Sentinel 1 data) (Sentinel 2A and B deliver multi-spectral data every 5 days in 13 spectral bands in the optical and middle infrared ranges)
Other data (weather, weather forecast, soil water properties, water, other):
4 weather stations located close the Ouvèze basin (<10km) from the INRA Meteo-France and CIRAME networks
Soil map at 1/50.000
Surveys among farmers to record agricultural practices : historical data on irrigation calendar and doses to calibrate/validate water needs estimates (link with the Territorial Project "Hauts de Provence Rhodanienne" conducted by the Chambre d'Agriculture du Vaucluse that aims at ensuring a stable water supply for the users of the territory, providing a survey among 350 farmers) + crop monitoring from March to September 2018

5) Models that will be used in case study and for what purpose (related to 4. data collection)
Similar models described in**:** Olioso A, Lecerf R, Baillieux A, Chanzy A, Ruget F, Banton O, Lecharpentier P, Trolard F & A-L Cognard-Plancq (2013). Modelling of drainage and hay production over the Crau aquifer for analysing impact of global change on aquifer recharge. *Procedia Environmental Sciences, 19: 691–700.* Simplified crops models (FAO Aqua**C**rop) and combined use of remote sensing data to estimate crop coefficients.

6) Starting date of data collection for OPERA:
Already ongoing / historical data collection at the site:

Sentinel 2 data already collected over our study sites from 1/2/2016 up to now. Corrected from atmospheric effects and georeferenced. Biophysical variables computed for each date (LAI, FCOVER, FAPAR) Meteorological data: 4 weather stations records near the area Surveys on irrigation practices : scheduled in 2018

Case study 3: Volturno River catchment, Italy

1) Case study description (what is the main problem that will be addressed, and what would be the expected improvement after OPERA)

Optimal approaches for dynamic forecasting of crop water requirements based on sequential assimilation of RS observations and numerical weather predictions in a crop growth model (AquaCrop).

The method for estimating crop water requirement through satellite imagery is already developed and applied (IRRISAT), while the dynamic forecasting based on sequential assimilation of RS observations and numerical weather predictions in a crop growth model is at experimental stage. Field testing and validation of data assimilation procedure will be carried on in the pilot area.

The Volturno Reclamation Consortium, located in Southern Italy, encompassing an irrigable surface of about 12,000 hectares divided in three districts: Sinistra Regi Lagni (7,600 Ha), Sinistra Volturno (2,450 Ha) and Destra Volturno (2,250 Ha). This region is shown in Figure above. The study area is characterized by irrigated agriculture in the period from April to September, with main crops grown corn, tomato, alfalfa, fruit trees and vegetables. The average size of each plot is about 2 hectares.

2) Case study location and scale addressed (region, catchment, field)

Land reclamation consortia, field level

3) Status of irrigation in the case study (current conditions):

<u>Sources of water for irrigation (surface, ground)</u>
Both
<u>Irrigated crops and area under cultivation (ha)</u>
Maize (ha), Tomato (ha), Potato (ha), Pepper (ha) Green Bean (ha).
<u>Soil type</u>
Under analysis (fertile)
<u>Irrigation techniques used</u>
Drip irrigation
Sprinkler (Maize, Green bean)
<u>Irrigation / water management scheduling decision making methods currently used (e.g. sensors, meteorological data, models, farmer appreciation, water turn)</u>
Farmer appreciation
<u>Decision support services used</u>
None
<u>Current water saving practices applied in the case study and how</u>
None
<u>Water cost (water price, electric power, taxes)</u>
Mc 0.07 euro (Energy cost excluded)
<u>Legal basis for water use for irrigation</u>

Farmers get water from Consortium pipe network. Most of outlets are equipped with water meters which allow a direct measurement of the water volumes consumed. The water fee is proportional to effective consumption. Despite this, many fields are still served with unchecked outlet and water is paid based on served surface. To this end, each farmer, every year, must state which parcels (and related surfaces) will be irrigated. The payment is based on the farmer's statement. Consortium managers, which are responsible for control of water resources, perform andom field inspection to confirm farmer declarations. They also use Earth Observations data to monitor the irrigated surfaces extensions, water rights and irrigated volume provided to each farmer. Any conflicts with other water users? Electricity generation (ENEL)
4) Data collection strategy: Methods being developed and tested in OPERA (in relation with WP2): Crop evapotranspiration under standard conditions (ETcrop) is calculated using a PM-FAO56 approach written in terms of albedo, LAI and meteorological data. Albedo or broadband (490–2160 nm) hemispherical-directional reflectance factor (HDRF) are retrieved from Satellite (Sentinel-2) at the time of the satellite overpass was calculated as a weighted sum of the Level-2A Sentinel-2 surface reflectance, with broadband weights representing the corresponding fraction of the solar irradiance in each sensor band. The broadband weights were adapted to take into account the spectral configuration of Sentinel-2. LAI are retrieved from Satellite (Sentinel-2) using ANN algorithms. Existing algorithms will be adapted to determine leaf chlorophyll content and leaf water content. The data will be used to monitor plant growth and health, for effective yield prediction and crop growth model. Numerical weather predictions of ensemble global circulation models are used for forecasting evapotranspiration. A Bayesian sequential procedure will be then applied in order to retrieve future crop water requirements by assimilating the crop states observed from the satellite images and the ensemble weather forecasts into AquaCrop model. Spatial design: define spatial entities on which data will be collected (field level, irrigation scheme level, watershed level, …) Data collected at field level, method upscale at land reclamation consortia level Type of irrigated crops involved in the case study Tomatoes, Maize (Potatoes , Green Beans, Pepper). Specify data being collected in each spatial entity: Sensors (soil sensors, crops sensors): Soil moisture Remote sensing data: Sentinel-2 Other data (weather, weather forecast, soil water properties, water, other): … Weather, weather forecast, soil and soil water properties, water volume Agricultural practices (irrigation calendar): Agronomic practices commonly used (ploughing, harrowing, weed management, fertilization, etc) Development of an Irrigation advisory service
5) Models that will be used in case study and for what purpose (related to 4. data collection) AquaCrop for soil water balance, crop yield, water productivity, Penman Monteith (Evapotranspiration)
6) Starting date of data collection for OPERA: Already ongoing / historical data collection at the site: Summer 2017, Summer 2016 (only EO data)

Case study 4: The Netherlands (NL)

1) Case study description (what is the main problem that will be addressed, and what would be the expected improvement after OPERA)
The case study in the NL will focus on the model prediction of the temporal changes in root zone water content (RZWC) for the coming days (1-15 d) based on the 50 ECMWF ensemble weather forecast predictions. The resulting average time pattern in RZWC, including the uncertainty band width resulting from the variation within the 50 ensemble weather predictions, can then be used by the farmer in his/hers irrigation management.

2) Case study location and scale addressed (region, catchment, field)
Due to delays in starting up of the project, obtaining ECMWF (contract negotiations) and receiving an automatic transmitting data logger, no field test could be started in 2017.

3) Status of irrigation in the case study (current conditions):
Sources of water for irrigation (surface, ground)
Irrigated crops and area under cultivation (ha)
Soil type
Irrigation techniques used
Irrigation / water management scheduling decision making methods currently used (e.g. sensors, meteorological data, models, farmer appreciation, water turn)
Decision support services used
Current water saving practices applied in the case study and how
Water cost (water price, electric power, taxes)
Legal basis for water use for irrigation
Any conflicts with other water users?
See under 2): no information available yet.

4) Data collection strategy:
<u>Methods being developed and tested in OPERA (in relation with WP2)</u>**:**
Model (SWAP) predicted temporal changes in root zone water content (RZWC) for the coming days (1-15 d) based on the 50 ECMWF ensemble weather forecast predictions. The 50 ECMWF ensemble predictions result in different meteorological input data for the SWAP model, such that 50 realizations of predicted RZWC become available for the coming 1 to 15 days. The average + band-width graphs can then be used to look in the future whether or not additional irrigation might be needed by the farmer (his/hers own decision; not governed by the model).
This exercise will be repeated each day. At the beginning of each day the model will be updated with actual weather data from the day before. Every now and then (e.g. weekly) the model can be calibrated based on locally measured water contents in the soil. These data will become available via an automated sensor-datalogger system.
<u>Spatial design: define spatial entities on which data will be collected (field level, irrigation scheme level, watershed level, …)</u>
This case study focusses at the field level. Irrigation itself will not be controlled by the system developed. The resulting RZWC predictions should be used by the farmer in his/hers irrigation management decisions.
<u>Type of irrigated crops involved in the case study</u>
Either potatoes or grass.
<u>Specify data being collected in each spatial entity:</u>
Sensors (soil sensors, crops sensors): soil water content (soil temperature and rainfall optionally)
Remote sensing data: no
Other data (weather, weather forecast, soil water properties, water, other): daily new 50 ECMWF ensemble 15-days weather forecasts (including rainfall, radiation, temperature, dew-point temperature, wind speed, cloud cover); daily actual climate parameters of previous day (KNMI)
Agricultural practices (irrigation calendar, …): crop management, irrigation management (data to be provided by the farmer)

5) Models that will be used in case study and for what purpose (related to 4. data collection)
SWAP-WOFOST: <u>SWAP</u> simulates the dynamics of water in the soil, and <u>WOFOST</u> is a crop growth model. Both models are fully integrated, so that water demand by the crop is fully integrated in the soil water balance. Crop growth may be limited via drought, oxygen stress (too wet conditions in root zone), and salinity. Further information: http://swap.wur.nl/

6) Starting date of data collection for OPERA:
Already ongoing / historical data collection at the site:
See under 2): no information available yet.

Case study 5: Upper Zglowiaczka River catchment, Poland

1) Case study description (what is the main problem that will be addressed, and what would be the expected improvement after OPERA)

The upper Zgłowiączka River catchment is situated in the Kujawy region, that belongs to one of the driest in Poland. In the growing season (April-September) the long term average precipitation is about 300 mm. The catchment area is characterised by very large temporal variability of pluvial and hydrological conditions.

The catchment area amounts to 78 km^2. The upper and middle part of the river (7.6 km long) is an intermittent stream, fed by water flowing from the drainage system in periods when soil water content exceeds field capacity. Surface water resources are insufficient to use them for irrigation.

Dominant soil types are Phaeozems (about 85% of the watershed area). Field water capacity (for profile with depth of 150 cm) varies between 160–200 mm, depending on the soil texture. Arable lands prevail in the watershed (90% of the area) due to high quality of soils.

The main cultivated crops are: cereals, maize, winter oilseed rape and sugar beet. In the growing season crop water deficits with probability of occurrence p = 50% (every second year) in the Kujawy region amounts to: 0–40 mm for winter oilseed rape, 40–80 mm for winter wheat and maize, 80–120 mm for sugar beet.

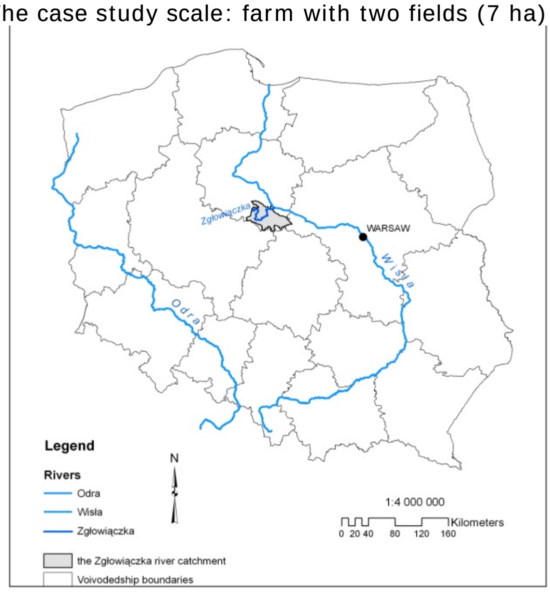
In the time of intensive crops growth and the highest water needs (April–August) potential evapotranspiration significantly exceeds monthly precipitation totals in the Kujawy region.

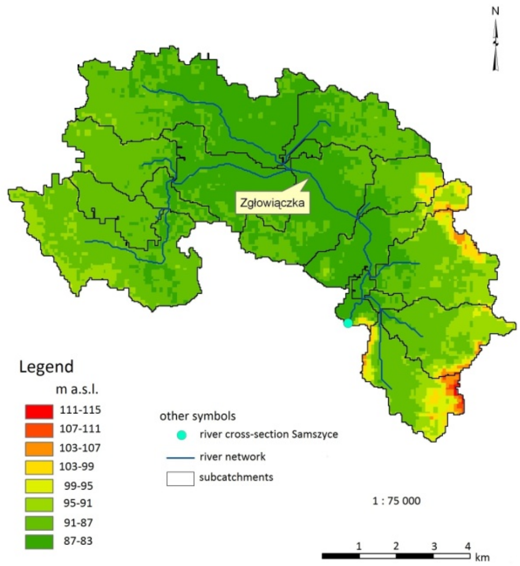
The main problems: water scarcity in the growing season, use of clean long-renewable deep groundwater resources for irrigation, low efficiency of water use for irrigation, lack of irrigation decision support system for farmers based on current crop water needs and weather forecasts.

The expected improvement: to improve the methods for identifying water demands and improve efficiency of irrigation water use in field and catchment scale.

2) Case study location and scale addressed (region, catchment, field)

The case study scale: farm with two fields (7 ha) and the catchment scale (7800 ha).





3) Status of irrigation in the case study (current conditions):

Sources of water for irrigation (surface, ground): mainly ground water

Irrigated crops and area under cultivation (ha): in 2017 in the farm – parsley (3 ha), in the catchment – vegetables; the irrigated area is about 1-2% of arable land but >30% of vegetables and orchards are irrigated, the precise area will be recognized within the project duration

Soil type: clay soils

Irrigation techniques used: mainly sprinkler irrigation

Irrigation/water management scheduling decision making methods currently used (e.g. sensors, meteorological data, models, farmer appreciation, water turn): commonly available weather forecast and farmer appreciation

Decision support services used: no

Current water saving practices applied in the case study and how: no

Water cost (water price, electric power, taxes): cost for groundwater use for irrigation (in case of >5m^3

per day) equals 0.05 € per m^3, electric pumps power supply costs will be recognized Legal basis for water use for irrigation: Water Act. Legislated by the Polish Parliament on July 20, 2017. Any conflicts with other water users?: Yes, in local communities due to uptake of ground water for irrigation, domestic usage and animal watering.
4) Data collection strategy: Methods being developed and tested in OPERA (in relation with WP2): soil moisture and agro-meteorological parameters measurements in the demonstration farm, weather forecasts, mathematical modelling, upscaling method from field scale to river catchment scale using modelling and GIS techniques, adaptation and verification of selected crop growth model under irrigation conditions Spatial design: define spatial entities on which data will be collected (field level, irrigation scheme level, watershed level, ...): soil moisture, crop development current status, crop sensors – at field scale; modelling – field scale and catchment scale; remote sensing as a support. Type of irrigated crops involved in the case study: in the farm – parsley and sugar beet; in the catchment – cereals, grain maize, sugar beet and vegetables; Specify data being collected in each spatial entity: Sensors (soil sensors, crops sensors): soil moisture (sugar beet – 10 cm, 30 m, 50 cm, 70 cm and 90 cm; parsley – 10 cm, 20 cm, 30 cm, 40 cm and 50 cm), crop sensors – infrared thermometer and LAI sensor – in the farm Remote sensing data: will be supplementary for in situ and modeling investigations – in the farm and the catchment Other data (weather, weather forecast, soil water properties, water, other): automatic weather station: air temperature, air humidity, wind speed, solar radiation and precipitation – in the farm and the catchment; weather forecast is planned for 2018 and 2019 seasons; soil water-physical properties – in the farm; soil map of the catchment Agricultural practices (irrigation calendar, ...): information on terms and methods of tillage, sowing, plant protection activities, fertilizing, irrigation, harvesting, crop development and yield – in the farm and the catchment
5) Models that will be used in case study and for what purpose (related to 4. data collection) Own model of short-term prediction of sprinkler irrigation based on the FAO CROPWAT and AguaCrop models; WOFOST crop yield model.
6) Starting date of data collection for OPERA: current data in situ: from 18 May 2017 Already ongoing / historical data collection at the site: historical data: from weather station at Samszyce (distance from the examined fields: 2 km)

Case study 6: Breede river and Letaba river catchments, South Africa

1) Case study description (what is the main problem that will be addressed, and what would be the expected improvement after OPERA) South Africa is one of the most water-scarce countries in southern Africa, with climate change expected to contribute to even more infrequent rainfall patterns (DWA, 2013). Parts of the country are currently experiencing the worst drought in over a century. Agriculture accounts for 60% of all of South Africa's water use, and water is the most limiting factor for agricultural expansion (DAFF, 2015). Therefore, in order to stay productive, farmers will need to adopt ways of using their water more efficiently. Furthermore, the South African Government's National Development Plan requires 500 000 hectares of expanded irrigated agriculture for small and emerging farmers, which can only happen if current water use is drastically reduced (DAFF, 2015). Optimisation of irrigation practices through the OPERA project will result in a practical methodology/product that can be applied by farmers beyond the study group and make a meaningful impact on reduced water usage in agriculture in the country, freeing up much needed resources in drought-stricken areas and for new farmer development.
2) Case study location and scale addressed (region, catchment, field) Two locations have been identified for this case study: The Breede Catchment in the Western Cape Province, and the Letaba Catchment in the Limpopo Province. Both catchments are highly irrigated, but also severely water-stressed, due to agricultural, industrial and town expansion, population growth and destruction of natural environment impacting on surface water flow and quality (BGCMA, 2016; WRC, n.d.). The Breede Catchment is also currently experiencing a drought and since close to Stellenbosch, it may be our major focus area.
3) Status of irrigation in the case study (current conditions): Sources of water for irrigation (surface, ground): Both areas rely heavily on surface water and are mostly irrigated (BGCMA, 2016; DWA, 2013a, WRC, n.d.). Some boreholes are used by commercial farmers where possible (i.e. if not brackish), but small, emerging farmers generally do not have access to ground water. Approximately 103 million m^3 of groundwater is used in the Breede River area, while groundwater yields in the Letaba region are much lower (WRC, n.d.). Irrigated crops and area under cultivation (ha): Breede: wine grapes (~24000ha); table grapes (~6000ha); apples (~5000ha); pears (~5000) and smaller amounts vegetables and citrus (StatsSA2007). Soil type: Breede: clay, sand, limestone (Saayman, 2013). Letaba: sand (DWA, 2013a) Irrigation techniques used: Breede: micro jets, trickle, drip irrigation (Van Zyl & Van Huyssteen, 1998). Irrigation / water management scheduling decision making methods currently used (e.g. sensors, meteorological data, models, farmer appreciation, water turn): Irrigation scheduling and planning is mostly done based on planned irrigation amounts and supported through measurement. The irrigation schedule has mostly preference as large areas are serviced by one pump. Decision support services used: Most farmers accept the information provided by specialists but most farmers are also well trained in management of irrigation Current water saving practices applied in the case study and how: the only water saving practice currently is through optimization and this is caused by the cost of electricity. Water cost (water price, electric power, taxes): the cost of water is fairly low, but the cost of electricity is high. Legal basis for water use for irrigation: Water-use license and allowed allocation Any conflicts with other water users?: Not yet. Government is conducting water-use validation and verification which will allow them to re-allocate water to smaller farmers. When this happens, it will certainly cause conflict. Water theft is also a reality, although the existence and extent of this in the project sites have not been established.
4) Data collection strategy: Methods being developed and tested in OPERA (in relation with WP2)**:** the general attitude to accept change need to be tested. The principle of "water stewardship" need to be promoted. These are therefore elements of the model approach currently missing. A model and method does not necessarily imply water scheduling information but needs to address elements of a water-food-energy nexus. Spatial design: define spatial entities on which data will be collected (field level, irrigation scheme level, watershed level, …) Data will be collected at farm-level if resolution of remote sensing data allows. If resolution cannot be obtained, data will be collected over blocks of the same crops over multiple farms and/or at irrigation scheme level. Type of irrigated crops involved in the case study Breede: deciduous fruit, table grapes and wine grapes. Letaba: vegetables, fruit. Specify data being collected in each spatial entity: Sensors (soil sensors, crops sensors): Making use of existing Soil sensors at farm level Remote sensing data: Highest resolution data vs cost – to be determined through cost-benefit analysis Other data (weather, weather forecast, soil water properties, water, other): weather data, hydrological modelling Agricultural practices (irrigation calendar, …): … The suite of interventions will allow farmers, or groups of farmers, to make more informed decisions around irrigation based on their crop and location. This optimisation is expected to improve productivity

and reduce water and electricity usage. It will also in the long term allow farmers to expand their operations in spite of potential reallocations and further drought conditions. Data, results and approach for replicability will be made available publicly for other farmers to access. A market analysis will inform how/by whom payment for the remote sensing service could be absorbed to allow for the service being offered to small farmers. This is essential to ensure uptake of the model beyond the study period.
5) Models that will be used in case study and for what purpose (related to 4. data collection) The same models developed and tested in the other OPERA partners' case studies will be applied in South Africa. The results from the remote sensing-based models will be compared with field results to minimize the margin of error in predictions. A guideline will be produced which will allow other farmers to implement the model themselves, or for extension officers to use the information to support the small farmers.
6) Starting date of data collection for OPERA: Already ongoing / historical data collection at the site: Sites to be refined as quality of information is not always good.

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