Sustainable Irrigation water management and River-basin governance: Implementing User-driven Services
SIRIUS

SIRIUS Final Report

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Executive Summary

This document provides an overview of the main elements that determine the sustainable implementation of SIRIUS services beyond the project lifetime and beyond the pilot areas.

SIRIUS has followed a twofold mission strategy. On one hand, it has sought from the very beginning to develop tools and services of pan-European policy relevance, with the aim to provide a GMES Service for agricultural water management. On the other hand, it has continued work on the ground (initiated in previous projects) to provide decision support for water managers in irrigation user associations, river-basin organizations, and at farm level. The vision of the SIRIUS service environment goes beyond the merely technical definition, well aware that any technical system needs an enabling environment for implementation to be successful.

The SIRIUS Irrigation Water Management Service (IWMS) addresses water managers mainly at irrigation scheme level (main focus of the project), but also at river-basin up to national level (uplink). Its central purpose is exploitation planning, monitoring, and control. The SIRIUS Integrated Drought Management Service (IDMS) addresses water managers at regional or river-basin level and National Irrigation Plan Monitoring Offices. It provides decision-support in a multi-annual process, based on an EO-assisted spatially distributed water balance and coupling with a river-basin decision support system. The SIRIUS Integrated Farm Advisory Service (IFAS) addresses water managers at farm level. Its central purpose is irrigation advisory (near-real-time irrigation scheduling, irrigation efficiency monitoring, precision farming support). The technical core of all SIRIUS Services is the webGIS SPIDER (System of Participatory Information, Decision-support, and Expert knowledge for River-basin management), powered by EO imagery, non-EO data, and multi-media. Its intuitive ease of use makes it a powerful tool for stakeholder participation, collaboration and transparent governance.

The implementation of the SIRIUS services in eight pilot areas on four continents was effected through pilot campaigns during at least one growing season in each pilot area. The implementation has been prepared and accompanied by an intensive participatory process of collaboration with Core Users and active involvement of further stakeholders. In parallel, the key aspects of sustainable water management in pilot areas have been assessed.

The SIRIUS legacy is based on two pillars: Firstly, a set of business cases responding to the requirements of local and regional users on the ground. The degree of maturity of these cases is directly correlated to the length of prior involvement in and/or exposure to services similar to SIRIUS. Secondly, a conceptual design of a pan-European GMES/Copernicus service for agricultural water management, addressing both the nation-wide and the river-basin scale. Both the business cases and the pan-European service concept are firmly grounded in the demonstrated operative capacity of the SIRIUS Service Providers (covering a synergy of centralized basic production and local advanced production and user support). They are equally grounded in the local and regional user communities that have been created and strengthened during the participatory development and service validation process.

The foundation of the SIRIUS services is an integrated package around SPIDER as the central hub that connects the Earth observation (EO) and non-EO input data and production line with the participatory stakeholder process and the sustainability analysis toolset. A key feature of the technical level is the multi-sensor multi-temporal sequence of EO coverages that provide the users with maps of irrigated areas, irrigation water consumption/abstraction, crop water requirements, and further advanced products.

One major outcome of the SIRIUS process is a joint ownership of SIRIUS services among users and other stakeholders in all pilot areas. They all have contributed to the development and implementation of the services and are now in conditions to reap the benefits that give them tools for collaborative sharing of information, joint decision-making, transparcence in governance and a general sense of empowerment of the user community.

In most pilot areas users have confirmed their readiness to pay for SIRIUS services and regional/national authorities have indicated support for the potential extension of SIRIUS service implementation to larger areas.

Project consortium

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1	UNIVERSIDAD DE CASTILLA - LA MANCHA	UCLM	Spain
2	INTEGRATED RESOURCES MANAGEMENT (IRM) COMPANY LIMITED	IRMCo	Malta
3	FUNDACAO DA FACULDADE DE CIENCIAS E TECNOLOGIA DA UNIVERSIDADE NOVA DE LISBOA.	FFCT/UNL	Portugal
4	INFOTERRA LIMITED	ITUK	United Kingdom
5	ISTITUTO NAZIONALE DI ECONOMIA AGRA RIA	INEA	Italy
6	ARIESPACE SRL	Ariespace	Italy
7	UNIVERSIDAD POLITECNICA DE VALENCIA	UPVLC	Spain
8	DIPUTACION DE ALICANTE	DPA-DCH	Spain
9	INSTITUT DE RECHERCHE POUR LE DEVELOPPEMENT	IRD-Cesbio	France
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15	COLEGIO DE POSTGRADUADOS	ColPos	Mexico
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1. Introduction and scope

SIRIUS has developed and implemented satellite-assisted services for efficient water resources management in support of food production in water-scarce environments. This includes tools and intruments for effective water resources governance.

The purpose of this document is to recall the mission, approach, and elements of SIRIUS and to summarize the current state of service implementation in pilot areas, in particular in view of the consolidation of business cases. It pulls together the threads from all Workpackages and all pilot areas and thus provides an overview of the main elements that determine sustainable service implementation beyond the project lifetime and beyond the pilot areas. Details of this process are being reported in the set of complementary deliverables on service assessment (D6.5), business cases (D5.6), pilot area and technical sustanability (D7.2, D7.5).

The document draws on and acknowledges contents from D1.1, D1.5, D1.7, D5.3, D5.6, D6.5, D7.5, D7.2, and the WP6 Integrated data collection tables.

2. The SIRIUS mission and corresponding user requirements

SIRIUS has followed a **twofold mission strategy**. On one hand, it has sought from the very beginning to develop tools and **services of pan-European policy relevance**, with the aim to provide a **GMES Service for agricultural water management**. On the other hand, it has continued work on the ground (initiated in previous projects) to provide **decision support for water managers in irrigation user associations, river-basin organizations, and at farm level**. Not surprisingly, the basic user requirements for both are the same. As a result, the SIRIUS services serve both purposes.

The challenge of a pan-European GMES service for water resources management lies in the fact that water resources management has a very pronounced local component and needs functioning links between all scales in order to be efficient and effective. It also requires tools and instruments that foster integrated thinking and acting and that encourage information sharing between all stakeholders in a transparent collaborative environment. A collaboration process between farmers, WUA and authorities is a major pre-requisite for good management and governance.

However, there is a clear large-area monitoring, control, and management component that is common to all Member States and that needs to be addressed at pan-European level. This component is comprised of the monitoring and control (mapping) of irrigated areas, the monitoring and control of irrigation water consumption, and the mapping of irrigation water requirements, soil water balance, and water footprint for hydrological planning in the context of river-basin governance. The capabilities for the first two elements are based on time-series of high-resolution EO images (with appropriate ground-truthing), while the soil water balance and water footprint requires the integration of EO time-series with a range of models. The technical capability needs to be complemented with the appropriate participatory tools in order to effective, both as a policy instrument and a management and governance tool.

The Water Framework Directive (WFD) establishes water resources management based on river-basins as the natural geographical and hydrological units. It addresses surface and groundwater and establishes innovative principles for water management, including public participation in planning, and economic approaches, including the cost recovery of water services. Its implementation is supported by the Communication on Water scarcity and droughts (COM/2007/0414) and the recent Blueprint to Safeguard Europe's water resources (COM/2012/673). The Blueprint Communication puts the spotlight on the second most common pressure on EU ecological status (in 16 Member States), which stems from over-abstraction of water, in particular for agricultural use.

Water for food production (irrigated and rainfed agriculture) represents by far the largest share among all water uses (in particular in water-scarce environments) and its demand keeps growing. Irrigation water management happens in a complex web of institutional settings and private initiatives, which differ greatly from one country or region to another. There is, however, a common denominator among the major actors, farmers, water users associations and river basin authorities, their tasks and interests in water management:

The key for irrigation water management is the planning in annual cycles. The Annual Exploitation Plan (AEP, in some areas called by a different term, or simply hydrological plan) is the main tool for water management in an irrigation scheme, but also used on larger spatial scales (aquifer, river basin). It defines the upper limit of the amount of water to be consumed for irrigation in a given irrigation season for the area covered by this plan. The AEP establishes for each farm or for each Water Management Unit (WMU, farms or groups of farms drawing from the same source of water) the maximum amount of water (from groundwater or from channels) to be abstracted or diverted for irrigation purposes in a given year. The amount of water established in the AEP is related directly with the crops and the area they occupy, because the amount of irrigation water consumed per unit area for each crop in a given environment is well known.

The AEP is developed before the beginning of each irrigation season by the corresponding water management authority (e.g. Irrigation Water Users Association in the case of irrigation schemes or aquifers), normally based on the allocation of water amounts authorized by the River-Basin Organization for the given year. It is agreed by and legally binding for all members of the Water Users Associations (through voting in the general assembly). On the basis of the AEP, each farmer or producer decides which crops to plant on which plot in the given growing season.

Earth observation (EO) can provide, together with other, non-EO data, a set of products and services that support the compliance with and/or enforcement of the AEP. Moreover, EO-assisted products and services can also foster the required collaboration between all users and to make the enforcement process transparent.

Thus, the SIRIUS toolset and services can contribute to the implementation of the WFD in river basins in several combined ways:

- by providing decision support for river basin water management (including innovative policy instruments like water accounting and water and energy footprint);
- by enabling directly the joint management of surface and groundwater (essential basis for drought management);
- by facilitating active participation, commitment, and collaboration of all stakeholders in a transparent governance environment (which fosters compliance with regulations).

The following vision and definition of the **SIRIUS service environment** was developed in the initial project stage. It was intended to go beyond the merely technical definition. Our additional SIRIUS-specific elements (in magenta in the box below) emphasize the fact that **any technical system needs an enabling environment for implementation to be successful.**

SIRIUS has been executed following these guiding stars, which means that now, at the end of the project all necessary elements are in place. The following chapters give an overview of each element's realization in pilot areas.

A **SIRIUS service scenario** consists of

*** a **Service environment** (= a "real world" environment for which a service has been developed and in which that service has been implemented): a **pilot area** (with a task or challenge) & its physical & socio-economic-politial-cultural-technological context;

*** one or several defined **initial Core Users for this service**;

*** one or a set of **services** defined to address a specific task/area/issue and validated;

*** one or a team of **local service providers** (LSP) ;

*** a well-developed **production line** to provide that service, supported by sustainable data supply;

*** a **local community** that provides context, benefits from the services, & monitors its impact;

*** **local users** that take up the service;

*** **national policies** & their implementation process that support sustainable operation.

3. The SIRIUS pilot areas

The eight pilot areas have been selected according to the most promising precursor applications and implementation conditions on one hand (e.g., the Spanish and Italian sites as testbeds for optional service modules), and on the other hand for water-geo-strategic considerations (Romania as one of the new Member States with important new irrigation schemes; Turkey as an associated country with huge irrigated areas and the IPCC countries Egypt, Mexico, Brazil, India with enormous water-scarcity problems exacerbated by demographic and climate change).

Table 1 gives an overview of the main water-related challenges that exist in the different pilot areas. Figure 1 shows the location of all SIRIUS pilot areas, with different colors indicating the level of SIRIUS services developed and implemented (see explanation of service typology in Section 4).

Table 1. SIRIUS pilot areas and main water-related challenges.

Country	Pilot area	Main water challenge in pilot area
Spain	Mancha Oriental & Marina Baja in Júcar river-basin	Diminishing water levels in aquifer and in discharge to river leading to drought conditions; large groundwater aquifer threatened by overexploitation
Italy	Sannio Alifano, Campania Region	Increasing irrigation water demand; over- exploitation of groundwater resources
Romania	Casazu / Terasa Brăilei (lower Danube basin)	Water conflicts between old and new irrigation schemes and fast industrial development.
Turkey	Gediz (lower basin)	Water quality; Water scarcity; need for more efficient use of water for irrigation; Food quality and security
Egypt	Kafr al Shayk (part of Nile delta)	Decreasing water availability from the Nile. Increasing rural poverty and food insecurity. Coordination among users missing
Mexico	Yaqui-Mayo river basins	Providing control on water use during droughts. Ensuring an equitable and sustainable distribution of water within large irrigated zones
Brazil	Forquilha, Morada Nova, Jaguaribe Apodi (Ceará state)	Seasonal water scarcity and drought issues
India	Harangi Dam Command Area, in Cauvery Basin (Karnataka state)	Inter State water sharing conflicts. Water rotation, Monsoon dependence, over irrigation and low system efficiency. Poor yield.

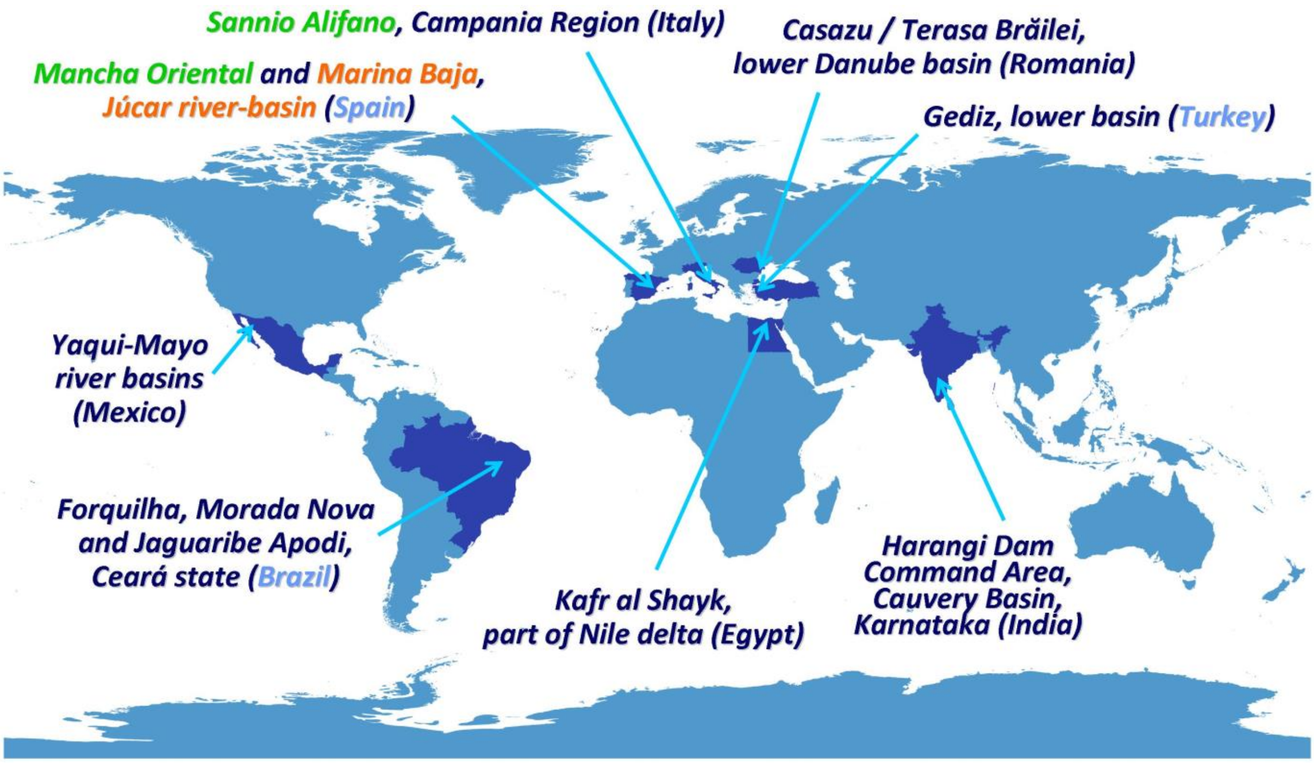


Figure 1. Location of SIRIUS pilot areas on a world map. Names in green (red) indicate areas where the Integrated Farm Advisory Service (Integrated Drought Management Service) has been implemented. Country names in light blue indicate that state- or nation-wide extension has begun.

4. Core Users in pilot areas

In line with the project's objectives, the SIRIUS Services have been developed mainly as a tool for water managers at irrigation scheme scale, but they also address the needs of water resources managers at river-basin level (uplink) and irrigation farmers (downlink).

Core Users of the SIRIUS Services are defined as the initial primary users during the project execution in a given pilot area. Therefore, the small group of Core Users was essentially composed of

- one water manager at irrigation scheme level in each pilot area; plus
- (optionally) one water resources manager /decision maker at river-basin level; plus
- (optionally) 3-5 irrigation farmers.

This group has been involved from the very beginning in the implementation, evaluation, dissemination and exploitation of SPIDER in each pilot area.

The main mission of **Irrigation Water Users Associations (and their water managers)** is water resources planning and management in their administrative territory (irrigation scheme, aquifer, province). Therefore, their main user requirement and purpose of using SIRIUS Services is the monitoring and control of the exploitation plan. Their secondary interest is a general decision-support and management tool. This type of user has been represented by the following institutions: Junta Central de Regantes La-Mancha Oriental (large aquifer, Spain), Diputación Provincial de Alicante, Hydrology Sector (coastal province, Spain), Consorzio di Bonifica del Sannio Alifano (large irrigation scheme, Italy), Casazu Water Users Association (irrigation scheme, Romania), Gediz Water User Association (irrigation scheme, Turkey), Kafr el Shaykh Regional Directorate (several irrigation schemes, Egypt), Río Mayo Water User Association (irrigation scheme, Mexico), Jaguaribe Apodi Water User Association (irrigation scheme, Brazil), and Harangi Command (several irrigation schemes fed by large dam, India). The basic **SIRIUS Irrigation Water Management Service (IWMS)** has been developed for and with them.

The main mission of **water managers at the larger scale level (river-basin, state, country)** is state/national water resources planning, monitoring, and control. So they are primarily interested in the mapping of irrigated areas and the related water requirements, as well as the monitoring and control of irrgation water consumption (i.e. abstractions). This type of user has been represented by the following institutions: the Spanish Ministry of Agriculture, Food, and Environment (Rural Development Directorate General / Irrigation department), the Spanish Province Government of Alicante (Hydrology Sector), the Spanish Júcar River-Basin Authority, the Turkish Ministry of Forestry and Water Resources (Water Directorate General), the Egyptian National Water Research Center (part of the Ministry of Environment), FUNCEME (Ceará state meteorological service, part of the government of the Brazilian federal state of Ceará). The **SIRIUS Irrigation Water Management Service (IWMS)** has been developed also for and with them, in particular with a view to its extension to larger areas. The special module **SIRIUS Integrated Drought Management Service (IDMS)** has been developed in a pilot implementation for and with the Alicante province government and then extended to the Júcar river-basin (one of the WFD pilot basins).

The main mission of **water managers at farm level** is farm business management taking into account economic as well as environmental criteria. Their main interest is in irrigation scheduling (when to irrigate which crop and how much water to apply), as well as fertilizer and yield management. This type of user has been represented by groups of farmers in the Spanish and Italian pilot areas of La Mancha Oriental and Sannio Alifano, as well as the corresponding Irrigation Water Users Associations: Junta Central de Regantes La-Mancha Oriental (aquifer case, Spain) and Consorzio di Bonifica del Sannio Alifano (irrigation scheme case, Italy. They are benefiting from the **SIRIUS Irrigation Water Management Service (IWMS),** but in addition the special module **SIRIUS Integrated Farm Advisory Service (IFAS)** has been developed in a pilot implementation for and with them, both at Water User Association and individual farm level.

5. The SIRIUS services

In line with the SIRIUS mission and user requirements stated above, a set of three services has been developed, centered around the SIRIUS Irrigation Water Management Service (IWMS), considered as the basic general service, with additional modules SIRIUS Integrated Drought Management Service (IDMS) and SIRIUS Integrated Farm Advisory Service (IFAS).

The technical core of all SIRIUS services is the **webGIS SPIDER** (System of Participatory Information, Decision-support, and Expert knowledge for River-basin management) (Moreno-Rivera et al., 2009), developed in the FP6 project PLEIADeS (Participatory multi-Level EO-assisted Information and Agricultural Decision Support, www.pleiades.es). It implements GIS-web technology powered by EO imagery to provide online spatial analysis, dynamic interactive visualization, spatial aggregation, temporal accumulation, and customized pdf report generation. Its intuitive ease of use makes it a powerful tool for stakeholder participation, collaboration and transparent governance.

The **SIRIUS Irrigation Water Management Service (IWMS)** addresses water managers mainly at irrigation scheme level (main focus of the project), but also at river-basin up to national level (uplink). Its central purpose is irrigation water management (water exploitation planning, monitoring, and control).

It consists of a set of Core Products, delivered monthly, at 1ha resolution (which allows to capture the major part of European agricultural landscapes), during the growing season, as well as accumulated at the end of the growing season:

- Monthly maps of crop water consumption allow for the monitoring and control of the annual exploitation plan, including abstractions (per farm, per water management unit, per aquifer, per sub-river basin, per crop).

- Monthly maps of irrigation water requirements allow for monitoring the net water demand (from groundwater, reservoirs, etc.) for agriculture purposes.
- Maps of irrigated areas and a crop inventory serve as a basic planning aid. The final product can be delivered only after season end (the full time series of intermediate maps is needed to cover all crop stages of all crops in a given area), but intermediate maps are being delivered each month (containng only the crops active so far).

Several additional products have been implemented in some pilot areas (monthly during growing season), e.g., irrigation performance indicators; maps of crop water requirements; maps of fertilizer application; maps of yield; and statistics of all above products.

A more detailed description and explanation of the use of these products in the operational routine of Core Users is given in D6.5.

This service requires bi-weekly to monthly EO images from a high-resolution (HR) Virtual Constellation (multi-sensor time series), plus the following non-EO data: Vector maps of farms and water management units (e.g., from WUA exploitation plan; rural cadastre; orthophoto; public maps) for the purpose of verifying AEP compliance; daily agrometeorological station and rain gauge data for the calculation of crop water requirements; soil maps (texture and depth) and field data (water distribution; inputs (fertilization and pesticides) per crop) for the calculation of additional products.

The **SIRIUS Integrated Drought Management Service (IDMS)** addresses water managers at regional or river-basin level and National Irrigation Plan Monitoring Offices, but also water managers at irrigation scheme level. Its central purpose is drought management and decision-support in a multi-annual process. It provides an EO-assisted spatially distributed water balance and coupling with a river-basin decision support system (DSS).

It consists of a set of Core Products, delivered annually, at 1ha resolution, after the end of the growing season:

- Same 3 products as IWMS (same purpose).
- Distributed hydrological model of soil water balance components. This allows for monitoring diffuse recharge; crop water stress indicators; natural vegetation water stress indicators; drought vegetation indicators.

It requires the same high-resolution (HR) EO images as the IWMS, plus an additional sequence of medium resolution (MR) images (optional, to cover a larger area); a distributed GIS-based water balance model like HidroMore (Sánchez et al, 2010), and a river-basin DSS like Aquatool (Andreu et al., 1996). It also relies on the same delivery system as the basic IWMS, also using SPIDER to share distributed spatial information in order to facilitate technical analysis as well as participative processes and transparent governance.

Its primary testbed was the Spanish pilot area Marina Baja (Alicante, coastal province within the Júcar river-basin), later extended to cover the Júcar river basin (a WFD pilot basin).

The **SIRIUS Integrated Farm Advisory Service (IFAS)** addresses water managers at farm level. It ultimately serves all associated farmers (end-users of the information distributed by the Farm Advisory Service). Its central purpose is irrigation advisory (near-real-time irrigation scheduling, irrigation efficiency monitoring, precision farming support). This can happen either

- directly at farm holding (in particular at large commercial farm enterprises), or
- through existing extension services like Irrigation Advisory Services or Farm Advisory Services (to help them upgrade to a GMES-assisted service); or
- through WUA (to enable them to establish a new Farm Advisory Service); or
- any other (semi-)public entity in charge of irrigation scheduling advisory; or
- an Application Service Provider (to expand their own portfolio).

It consists of a set of Core Products, delivered in real-time (maximum 24h after satellite overpass), weekly or bi-weekly, at 1ha resolution (in some area with very smald fields, 0.1ha), during the growing season:

- Same 3 products as IWMS (same purpose) provide the context and basis for the detailed farm advisory.
- Maps of color combination provide an intuitive, qualitative measure of crop vigor and allow for detecting irregularities and heterogeneities within plots.
- Maps of Crop Water Requirements (CWR) and per-plot/crop CWR statistics provide numerical, quantitative information for irrigation scheduling (personalized for (sub-)plot).
- Maps of fertilizer and pesticide application and maps of yield estimates provide precision farming support.

It requires the same HR EO images as the IWMS, but in near-real-time image download and processing, delivery to user within 24 h of satellite overpass. In some areas, very-high-resolution (VHR) images may be needed, depending on field sizes.

Its testbeds were the Spanish Mancha-Oriental (focus on individual farms) and Italian Sannio Alifano (focus on whole area irrigation advisory) pilot areas.

6. SIRIUS Service Providers

The SIRIUS business strategies on the ground aim at stimulating operative and sustainable SIRIUS service activities capable of providing benefits to the user community of water resources management in each pilot and beyond. Local Service Providers (LSP) play a pivotal role here and networking is an essential tool to make them resilient and competitive.

As a first step, we have created the basis by having or establishing at least one Local Service Provider in each pilot area. In some pilot areas, there is an SME SIRIUS partner organization established as a clear LSP (Italy, Turkey, Egypt, Mexico). In all other pilot areas there are intermediate solutions (public administration or university institutes acting as LSP), some with spin-off companies pending to be established in the very near future.

In a second step, a Network of Local Service Providers has been launched, held together in a special Linkedin group. The associated LSPs have expressed interest in providing SIRIUS Services and have received some training.

Table 2 provides an overview of the Core SIRIUS Local Service Providers. They all have served and are serving further water-related users (in addition to Core Users, but of similar characterisitcs), like small and large individual farms; water managers of user association and regional river basin authority; national irrigation plan monitoring organisation, dam command area engineers, and private or public irrigation scheduling advisory.

All of the SIRIUS Service Providers in Table 2 are offering the basic products needed in order to provide the Irrigation Water Management Service (IWMS), as well as the basic irrigation scheduling component of the Integrated Farm Advisory Service (IFAS):

- Irrigated areas and crop inventory;
- Actual and total (accumulated) crop water consumption;
- Basic GIS layers;
- RGB color composites (maps);
- Crop water requirements (maps & text).

Many of them also offer statistics and time-series data, graphical information per plot, aggregation to district.

UCLM offers in addition the products needed to deliver the full Integrated Farm Advisory Service (IFAS) and the Integrated Drought Management Service (IDMS).

Table 2. SIRIUS Local Service Providers (LSP).

Country	Service Provider	Type of organisation
Spain	UCLM-IDR	Public application-oriented research institute (creation of spin-off imminent)
Italy	Ariespace	SME (university spin-off)
Romania	INCDIF-ISPIF	Public research and consulting institute
Turkey	EA-TEK	SME (university spin-off)
Egypt	IRMCo-Egypt	SME
Mexico	SEISSA	SME
Brazil	INPE	Public research institute (also image provider and applications provider)
India	BU-UVCE	Public research institute/university (creation of partnership with LSP SME imminent)

7. Technical infrastructure and operative capacity

The following steps and corresponding technical capacity are needed in order to provide the SIRIUS Services to users:

1. Data repository and web-GIS-based DSS (SPIDER, see D2.5);
2. EO image data procurement (see D3.1);
3. Non-EO data procurement (see D3.5);
4. Operational production line for processing and generation of products (see D3.2, D3.3, D4.3);
5. Quality control of products (D4.2);
6. Delivery of products to users (online via SPIDER, email, paper, media);
7. Dialogue with users.

Step 1 has been implemented in pilot areas in a centralized way by UCLM (the developer of SPIDER) hosting the global SIRIUS-SPIDER, offering either fully global navigation within and between pilot areas in its “global” access configuration (maintained and fed by UCLM centrally) or individual pilot area access in its local configuration (each limited to its wider pilot area territory), administrated and fed by each pilot area Service Provider.

For **step 2** (combination of Data Warehouse (DWH) and local procurement) and **step 3** (always local procurement), see the tables below.

Two different service models for **step 4** have been implemented and tested during the project lifetime, based on a centralized and a de-centralized processing and production line, respectively. Images procured from the DWH were centrally processed by ITUK and delivered on FTP to local Service Providers for four pilot areas (Romania, Turkey, Egypt, Brazil), while three pilot areas (Spain, Italy, Mexico) performed their own processing for those images. Image procurement capability of the DWH to the Indian pilot area is very limited. All images procured locally have been and are still being processed locally.

Step 5 goes through several levels of quality control, some included in the central production line (see D4.2) and some confined to the local level (see D3.3, D6.2).

Step 6 consists of uploading products to SPIDER and (optionally) providing output by email, SMS, or printout. This is a task of the Local Service Providers (see D4.4, D4.5).

Step 7 is one of the key tasks of the Local Service Providers (D5.3).

Table 3 specifies for each step who (which company/organization) has the required operative capacity and where the source of the required operational data procurement is. Table 4 summarizes the available infrastructure and operative capacity of Local Service Providers and Core Users uptake capacity by pilot areas. For more detail, see D7.5. Table 5 provides details on available EO (example 2012) data in pilot areas. "Core User uptake capability" is defined as the capability of the user to plug the SIRIUS Services into their existing operational routines. This requires both some technical capacity (e.g., GIS) and some previous experience with and/or exposition to SIRIUS-like concepts.

Table 3. Details of operative capacity for each element of SIRIUS Service provision line.

Element of Service provision line	***Who has operative capacity to provide / Source of data procurement***	***Current status (30/09/2013)***
SPIDER family	UCLM and spin-off	System operational in over 10 different projects
EO data procurement	DWH (now)	Short-term & GMES-projects only
	Landsat	Fully operational; high-quality; free
	Sentinel	coming (expected to be free)
	rest of multi-sensor constellation	Mostly fully operational; high cost
Vector data procurement	Local Water User Associations	mostly available; may need digitalization (including validation field work)
	Rural cadastre (in some countries)	
Agro-meteorological data procurement	National or local station networks	Operational access in most countries
	in case of need: new installation, to be maintained by LSP	Installation cost 2-3kEUR; some instrumentation skills
Production line for processing and generation of products	centralized: Astrium UK (ITUK)	Operational production line (NDVI & RGB color composite) demonstrated in SIRIUS
	local: Network of Local Service Providers (UCLM & spin-off, Ariespace, SEISSA leading the way)	Operational (including all additional products) at UCLM/spin-off, Ariespace, SEISSA; other LSP growing into it
Quality control of products	centralized: Astrium UK; local: Network of Local Service Providers (UCLM & spin-off, Ariespace, SEISSA leading the way)	same as in production line
Delivery of products to users (upload to SPIDER; further communication channels)	Network of Local Service Providers	Years of operational experience at some LSPs, others in learning process
Dialogue with users	Network of Local Service Providers	long standing record and excellent collaborative relationship in some areas (within and beyond pilot areas), growing in others (through active process, facilitated by SPIDER)

Table 4. Technical infrastructure and operative capacity in pilot areas. Y=Yes; F=fully equipped; VG=very good; G=good.

Pilot area	*Local Service Provider*			*Access to data*			*Core User uptake capability (see text)*
	software	*expertise*	*experience in EO-based services*	*EO*	*agromet station*	*vector (plot boundaries)*	
Spain	F	Y	long-standing	VG	Y	Y	very high
Italy	F	Y	long-standing	VG	Y	Y	high
Romania	F	Y	incipient	VG	Y	Y	incipient
Turkey	F	Y	incipient	VG	Y	Y	medium
Egypt	F	Y	incipient	G (no Formosat or Spot)*)	Y	Y	incipient
Mexico	F	Y	long-standing	VG	Y	Y	high
Brazil	F	Y	incipient	VG	Y	Y	high
India	F	Y	incipient	G (often cloudy)	Y	Y	incipient

*) overpass only at prohibilitvely slant view angles.

Table 5. Access to satelite images during operational campaign 2012. DWH = Data WareHouse.

Pilot area	*Satellites*	*Procurement*
Júcar river-basin (Spain)	Deimos, Landsat 7 ETM+, Landsat 5 TM, Formosat-2 (F-2)	USGS, Deimos (ERMOT project) locally procured, DWH (F-2)
Sannio Alifano (Italy)	Rapid-Eye	DWH
Casazu (Romania)	Formosat-2 Pleiades 1A	DWH (F-2) Pleiades 1A (Astrium GeoServices free of charge)
Gediz (Turkey)	Formosat-2 MS	DWH
Kafr Al-Shaykh (Egypt)	RapidEye, Landsat7, Deimos	DWH, GLOVIS, Deimos (courtesy)
Río Mayo (Mexico)	Landsat5, Landsat7, Deimos, RapidEye	Locally procured & DWH
Ceará (Brazil)	Landsat ETM+, Formosat	GLOVIS, DWH
Harangi (India)	IRS Resourcesat 2 L4MX, LISS3, IRS P6 LISS3, MODIS and Landsat	Locally procured (IRS) & USGS

8. Implementation and stakeholder process

The basic SIRIUS Irrigation Water Management Service (IWMS) has been implemented in all 8 pilot areas. The two additional modules have been implemented in Spain (Integrated Drought Manangement Service, IDMS, and Integrated Farm Advisory Service, IFAS, at farm level) and Italy (Integrated Farm Advisory Service, IFAS, at WUA level).

The **implementation of the SIRIUS services** was effected through preparatory campaigns (in 2011) and pilot campaigns (2012-2013) during at least one growing season in each pilot area (see D6.1). The objective and purpose of these campaigns was twofold:

(1) to provide the required datasets (field measurements, EO data, additional data, stakeholder data and perceptions) that are needed to generate the SIRIUS portfolio products for Core Users and stakeholder test groups;

(2) to provide the frame of reference, training, and guidance for the stakeholder evaluation process.

The implementation has been prepared and accompanied by an intensive **participatory process of collaboration with Core Users and active involvement of further stakeholders**. This process was based on the ppgis (public participatory GIS) framework and training manual (D1.1). Information on all relevant stakeholders has been compiled in this exercise, also based on information collection templates developed in D6.1. The results of this stakeholder analysis are described in detail for each pilot area in D1.5. A baseline description of each pilot area has been compiled in D6.3.

At the end of the participatory process, a Water Vision for each pilot area has been developed jointly by each Regional Team (D1.7). One major outcome of this process is a joint ownership of SIRIUS services among users and other stakeholders in all pilot areas. They all have contributed to the development and implementation of the services and are now in conditions to reap the benefits that give them tools for collaborative sharing of information, joint decision-making, transparcence in governance and a general sense of empowerment.

In parallel, and partly based on the same information, the **key aspects of sustainable water management in pilot areas** have been investigated. D7.2 describes the outcomes for each pilot area and visualizes them in a simple diagram that allows seeing at a glance where strong and weak points are. This supports the implementation of SIRIUS services by directing them and tailoring them to the specific needs of each pilot. For a summary, see below in section 10.

9. Service validation and business cases

The validation of the service modules was achieved at different levels. First, we performed a **verification of compliance to technical specification** based on the quality assurance protocol. This included for instance checking NDVI and crop coefficient maps were within the define range of values, the colour composites were correctly performed and data scaled for web visualization, a geometric match between the boundaries of parcels and raster data was achieved. The quality assurance was performed in each test site throughout the irrigation season as part of the data processing chain.

Successively and during the irrigation season, we assessed the service in a participatory approach with users based on a questionnaire and face-to-face meetings with core group of users. The results of this **qualitative evaluation** provided an indication of the efficiency and usefulness of the information in relation to the user needs and use cases. We identified two main groups of users: on one hand, in the public sector we find users who require irrigation water needs and who want to know the impact of certain measures and policies. On the other hand, we have the agribusiness sector with farmers that consider irrigation a key factor for yield.

For the public sector, the need for knowledge of water use in irrigation is established by laws, national and international. They are usually regional government, national and international competent irrigation associations in cooperation with the administration. From the viewpoint of these customers' interest in products and services developed based SIRIUS is its reliability and cost compared to other traditional forms as field inspection.

The private agricultural sector is interested in crop yield and private profit by optimizing production and costs. For instance, cost savings are achieved via a reduction of the irrigation equipment runtime, that induces lower maintenance cost, extended lifetime, and the reduction of energy required for pumping. In our experience most farmers are not only interested in knowing the irrigation volumes but also the spatial and temporal distribution of the crop status (i.e. crop vigour) over the growing season for each of their fields and for multiple years (to compare performance between different years). This information can also be used for a better management of inputs other than water, e.g. the optimization of fertilizer needed.

Finally, as the last step of **service validation**, we developed a cost and benefit analysis for the different service scenarios and evaluated the readiness to pay. Based on this analysis, we estimated the a range of service cost for the three service modules with a summary provided in **Error! Reference source not found.**Table 6.

Table 6. Range of SIRIUS Service cost (based on data in D5.6). Higher costs apply to smaller services areas, lower cost to larger areas.

Service	***Geographical extension***	***Estimated Costs (incl. costs for work, computer, storage, backup, internet, etc.)***
Irrigation Water Mangement Service (IWMS)	Europe & global	1-10 €/ha/year (only in areas where irrigated agriculture is present)
Integrated Drought Management support Service (IDMS)	Europe & global	around 2 €/ha/year (depends on area to be served contiguously)
Integrated Farm Advisory Service (IFAS)	Europe & global	1-10 €/ha/year (only in areas where irrigated agriculture is present)

The results of the overall service validation exercise have been summarized in Table 7.

The **readiness to pay** of a user is here defined as "confirmed and demonstrated" if the user has already paid for SIRIUS Services in at least one occasion. "Confirmed" stands for a user that has expressed their firm commitment to pay (after receiving the information on cost and clarifying the financing mechanism). "Emerging" readiness to pay denotes a user that has expressed interest, based on the information on service cost for their area, and who is currently exploring the financing options. All entries in the corresponding column in Table 7 refer to Core Users. The readiness to pay of the wider user base in each pilot area is emerging or open.

Policy support and implications for the potential extension of SIRIUS service implementation to larger areas (state- or nation-wide) have been explored with authorities at that scale. "Strong" stands for the willingness to move resources for that purpose on behalf of the state of national authority (e.g. Ministry). "Incipient" policy support indicates interest expressed by the authority and first discussion about funding options.

Table 7. Service validation results and enabling environment for sustainable implementation. For details on evaluation and validation, see D6.5 and D5.6. "useful"=(according to user statements) reliable and makes their routine work easier; "plug-in"=can be directly inserted into operational user routine procedures. "open"=not yet defined.

Pilot area	***Local community support***	***SIRIUS Service assessed***	***Evaluation***	***Validation***	***Readiness to pay*** (see text)	***Policy support*** (see text)
Spain	strong	IWMS, IDMS, IFAS	very useful, plug-in	save water, energy, €€; improve governance	confirmed & demonstrated	very strong
Italy	strong	IWMS, IFAS	very useful, plug-in	save water, energy, €€	confirmed & demonstrated	strong
Romania	incipient	IWMS	potentially useful	save water, energy, €€	open	open
Turkey	strong	IWMS	useful	save water, energy, €€	confirmed	strong
Egypt	incipient	IWMS	potentially useful	improve governance	open	open
Mexico	strong	IWMS	very useful, plug-in	save water, energy, €€	confirmed & demonstrated	open
Brazil	incipient	IWMS	useful	save water, energy, €€	confirmed	strong at State level (Ceará)
India	incipient	IWMS	potentially useful	save water, energy, €€; improve governance	emerging	incipient at State level (Karnataka)

Each **business case** covered the financial, risk, pricing and marketing analysis of the service modules and provision. The experience gained and the lessons learned in SIRIUS indicate that local conditions have a great influence on the development of business cases. This mainly affects customers, but also needs to be taken into account by service providers and the services/products they offer. Different level of detail was therefore achieved in each pilot area. Detailed business cases were developed in Italy, Spain, Mexico, Turkey and Brazil. In the other areas, we found three different reasons and obstacles that need to be cleared before the SIRIUS Service can be implemented sustainably. In India, the user base is ready and highly interested, qualified service providers are also ready. However, cloudy weather conditions are often in the way of getting the necessary continuous time-series of images during the growing season. Two solutions are being pursued, but will take possibly another year to be incorporated: one is to replace cloudy images with FAO-56 estimates and the other is the fusion with (cloud-independent) microwave EO data. In Romania, the technical part and a service provider consortium are ready, several users are interested, but not yet fully motivated to commit themselves and policy support is not immediately evident. This is a natural part of the process (which did occur in the mature cases many years ago) which will be overcome with time and continued supportive user-collaboration. In Egypt, both the technical/service provider and the users parts are ready, but the current political situation does not allow medium or longer term predictions.

Overall the development of tasks and implementation in pilot areas has varied in speed and form, due to technical, socio-economic, environmental, political, and cultural factors. Yet, the major cause of these differences is due to the very different starting points in time. Figure 2 shows the history of SIRIUS precursor services developed and/or deployed in the eight pilot area. It shows clearly that those pilot areas with a longer history are now mature business cases, while those with no pre-SIRIUS experience are just emerging. However, the process is quicker for them since cross-learning from "older" pilot areas helps speed up the process.

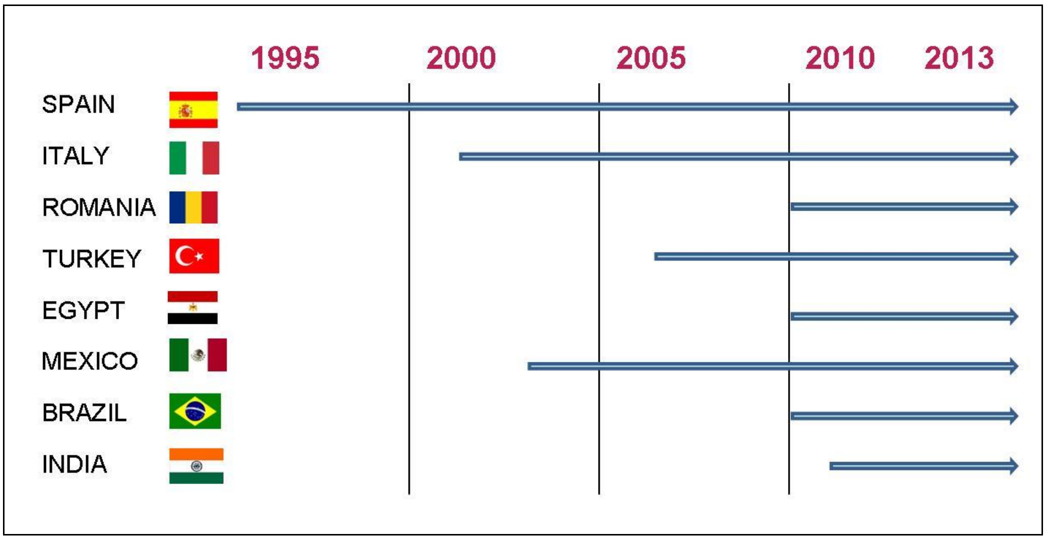


Figure 2. History of SIRIUS precursor services in pilot areas.

10. Wider sustainability context

One distinctive feature of the SIRIUS approach lies in the acknowledgement that the use of EO-based services for improved water management should be framed and designed taking into account the wider sustainability context of the regions where they are operating, considering environmental, economic, social and governance dimensions, and should be clearly grounded on active engagement of interested communities. Therefore, in order to pave the ground for the implementation of SIRIUS services, we performed an assessment of the ecological, social, political, cultural, and economic environment of pilot areas in a holistic and systemic perspective. For this purpose we developed a new framework for integrated sustainability assessment of SIRIUS pilot areas (D7.1) that considers 4 basic dimensions in sustainability assessment of irrigation areas: (1) environmental integrity; (2) economic profitability and resilience; (3) social well-being and (4) good governance. For each dimension a set of core issues were identified. Figure 3 summarizes the main elements of the SIRIUS sustainability assessment framework. For each of the 17 core issues the aspects to be evaluated and corresponding indicators were associated

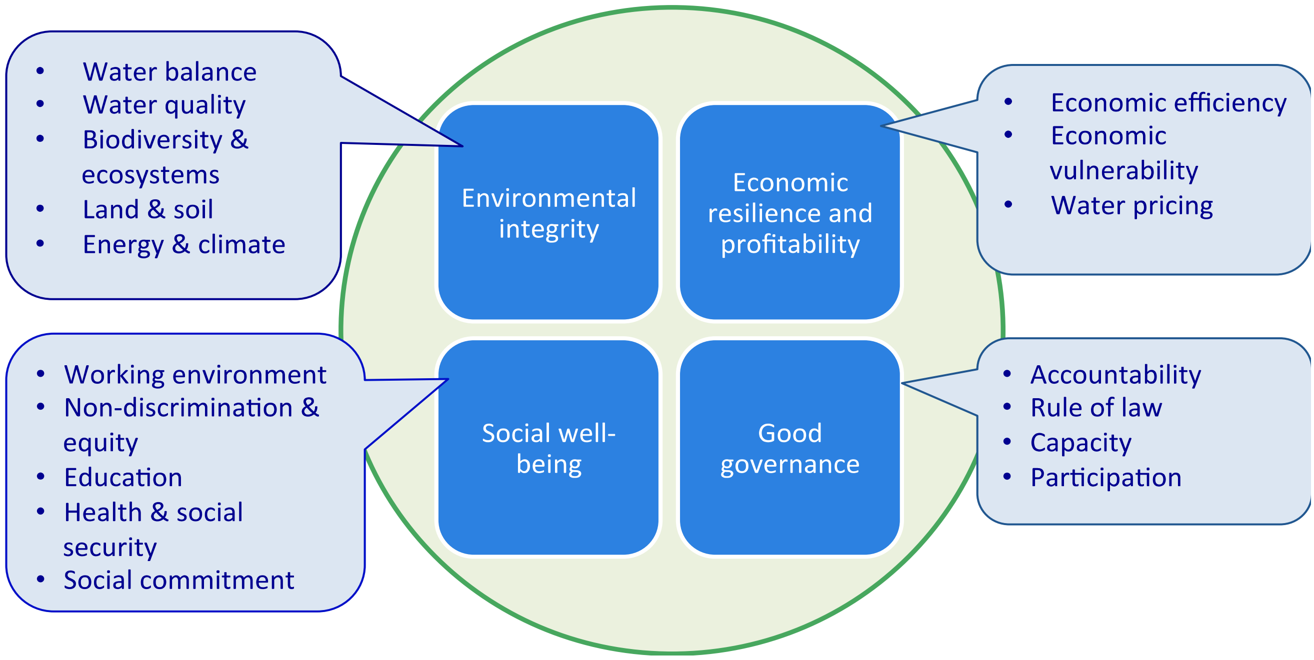


Figure 3. SIRIUS sustainability assessment framework: main dimensions and core issues.

A questionnaire was developed to support the data gathering process in pilot areas. This questionnaire was distributed to regional managers that undertook the responsibility of collecting the relevant information in appropriate sources. Regional meetings and ppgis (pubic participatory GIS) activities played a very relevant role to support data collection and validation of information with the main actors in the pilot area. For each area a 'sustainability profile' was prepared based on the data gathered by regional teams, adopting a 0-5 scale (0 - very poor to 5 - very good) to assess each of the core issues included in the SIRIUS sustainability assessment framework (D7.2) (Figure 4).

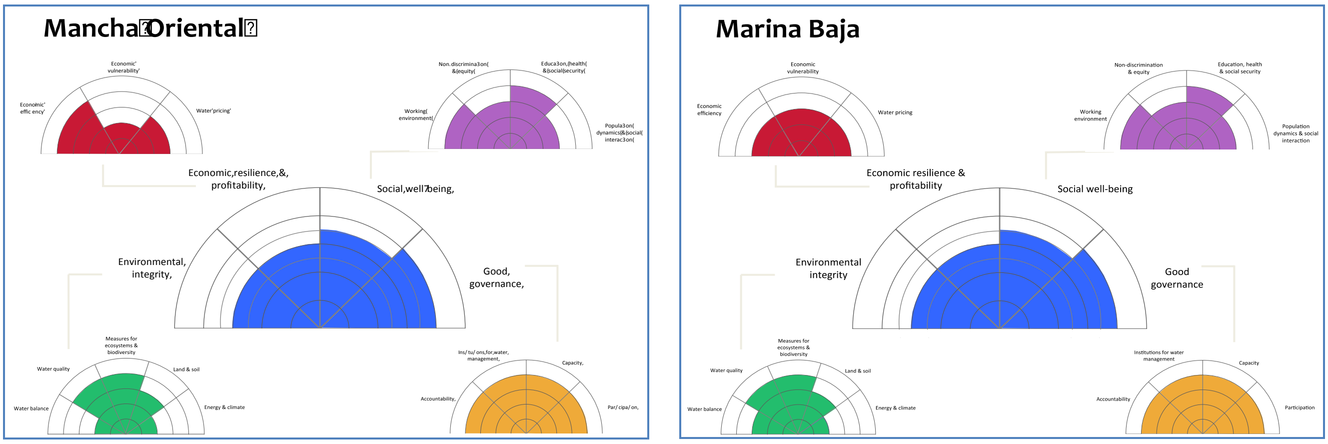
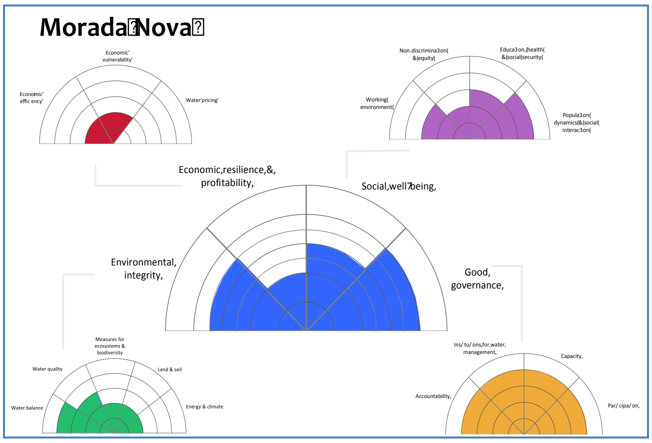


Figure 4. Results of sustainability assessment in SIRIUS pilot areas (continued on next page).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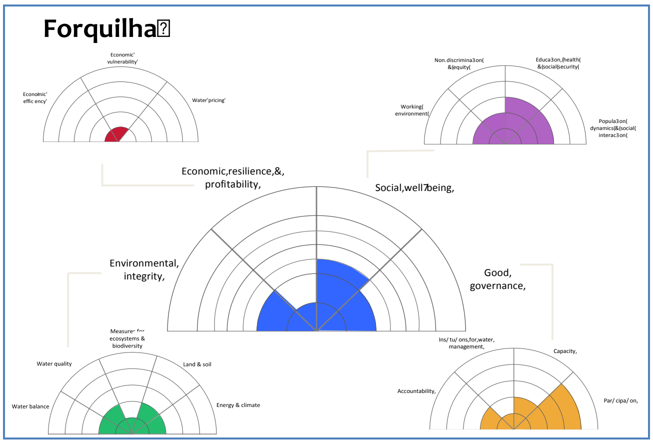
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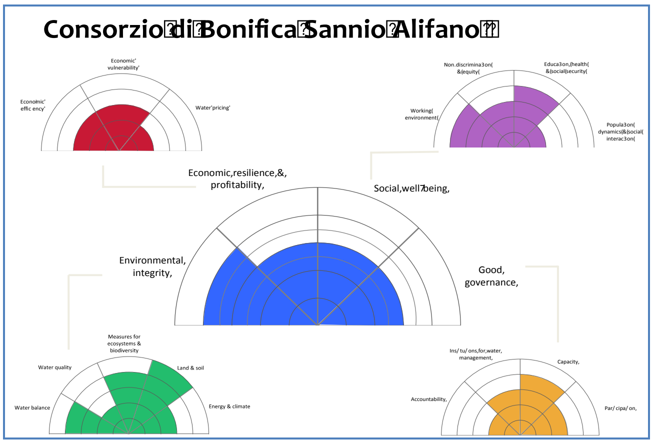
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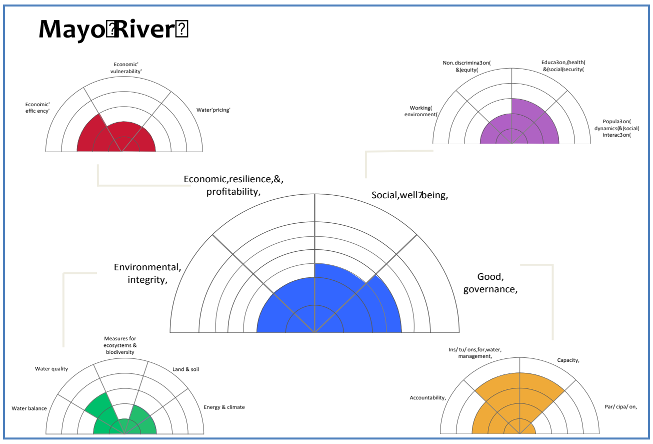
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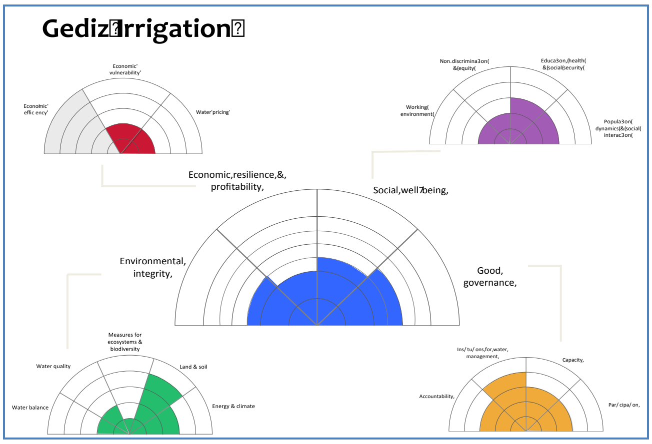
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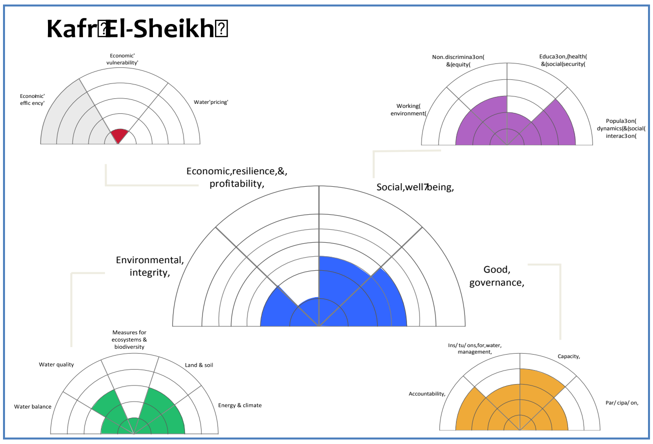
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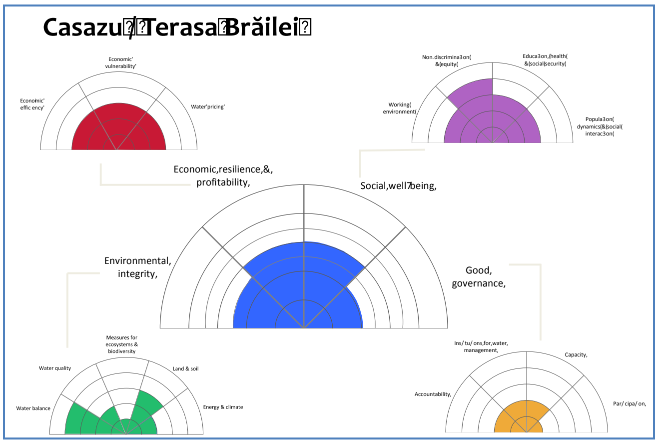
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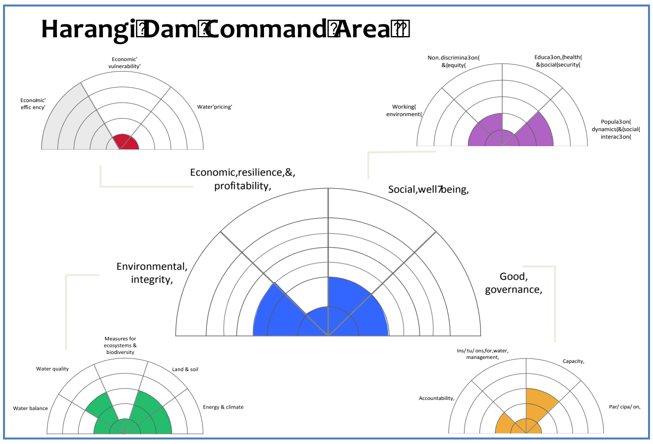
Harangi Dam Command Area
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Environmental, integrity,
Good, governance,

We have confronted the vision for each pilot area with the findings of this sustainability assessment exercise and identified the main actions that form the roadmap for sustainability in each pilot area (D7.9). Although the different pilot areas presented diverse sustainability concerns and associated actions required, it was possible to derive common 'ingredients' for a roadmap for sustainable agricultural areas, including:

- Environmental integrity is an underlying basic pillar for sustainability. In irrigated agricultural areas it is particularly relevant to develop plans for the future in order to ensure sustainable provision of water with good quality in the future and to balance current and future needs of the different uses within the carrying capacity of the environmental system.
- Vulnerability to climate change is a key aspect in all pilot areas and it is important to develop adaptation plans to ensure resilience of irrigated agriculture areas under climate change scenarios.
- Tailored water pricing schemes are an essential element of the policy toolbox to give appropriate incentives to water users, increasing water productivity and managing water scarcity in an efficient way. But they are also essential for the sustainable implementation of SIRIUS farm advisory services. If water prices gradually reflect the real costs of water services, as well as the environmental and scarcity costs associated with water use, then farmers will be also increasingly willing to pay for SIRIUS services in proportion to water savings and the corresponding reductions in the water bill.
- The dependence on public subsidies is common to almost all SIRIUS pilot areas, and in many agricultural areas around the world, as a condition for survival. It is important to condition the granting of public subsidies to the adoption of good/best water management practices (eco-conditionality). Also in the design and implementation of water pricing mechanisms it is important to consider the capacity to pay of farmers, developing integrated funding solutions to guarantee the provision of water services as well as of SIRIUS services.
- It is important to ensure a fair distribution of opportunities and income in society – this means, for instance, fairness in access to resources between small and large farmers, balance in salaries between agricultural workers and other economic sectors, fairness of opportunities across genders.
- Education of water users and managers, good working conditions, access to medical care and social security are important elements of the roadmap to sustainability. In all pilot areas there is room to improve in these regards and they are a fundamental element to support the implementation of improved water management practices supported by SIRIUS services.
- Clear and accepted water allocation rules, coupled with strong institutions and technical capacity are also fundamental governance elements of the roadmap. Without these ingredients it is impossible to promote sustainable water use, enforce decisions and handle water allocation conflicts.
- Finally, direct involvement of all interested parties and transparency in decision making processes regarding water management contributes to the development of better solutions to water resources problems, helps building a sense of ownership towards the decisions taken, fosters social learning and strengthens community relations.
- SIRIUS tools can be used as an entry point to promote improved water governance and increase water use efficiency in irrigated agriculture, having also the capacity to be used as a platform to organize information for water resources management, as a way to promote compliance with regulations and water allocation decisions (e.g. detect over-exploitation patterns). It may also be used as a platform around which participatory processes are organized. In summary, SIRIUS can play a very important role and contribute to the development of a shared understanding and a new mindset regarding water management problems and solutions among the different stakeholders.
- The diversity of problems and contexts in the different pilot areas show the impossibility of thinking in terms of 'one size fits all' approaches to the use of EO-based services for water management in agricultural areas. This supports the implementation of SIRIUS services by directing them and tailoring them to the specific needs of each area.
- On the other hand the analysis also shows that implementing services like SIRIUS without the underlying sustainability conditions is a useless effort.

11. The SIRIUS legacy

In accordance with the twofold SIRIUS mission strategy, the SIRIUS legacy is based on two pillars:

- a set of business cases responding to the requirements of local and regional users on the ground (water managers at Water User Associations and similar institutions, river basin authorities, and farmers). Some of these business cases are fully mature (Spain, Italy, Mexico), some are almost mature (Turkey, Brazil), and others are emerging (India, Romania, Egypt). Their degree of maturity is directly correlated to the length of prior (pre-SIRIUS) involvement in and/or exposure to services similar to SIRIUS.

- a conceptual design of a pan-European GMES/Copernicus service for agricultural water management, addressing both the nation-wide scale (Irrigation Water Management Service, including monitoring and control of abstractions) and the river-basin scale (idem, plus Integrated Drought Management Service).

Both the business cases and the pan-European service concept are firmly grounded in the **operative capacity of the SIRIUS Service Providers** (covering a synergy of centralized basic production and local advanced production and user support), demonstrated in eight pilot areas during 1-2 operational irrigation campaigns. They are equally grounded in the **local and regional user communities** that have been created and strengthened during the participatory development and service validation process.

The previous section provides the roadmap how to transition into a fully sustainable service implementation beyond the project lifetime and beyond the pilot areas.

The **foundation of the SIRIUS services is an integrated package** (see Figure 5) around SPIDER (the System for Participatory Information, Decision support, and Expert knowledge for River-basin governance), a leading-edge webGIS that serves a the service hub (either implemented centrally or as a network of SPIDERs). This hub connects on a technical level the Earth observation (EO) and non-EO input data and production line with the participatory stakeholder process (by means of the ppgis approach) and the sustainability analysis toolset. A key feature of the technical level is the multi-sensor multi-temporal sequence of EO coverages that provide the users with maps of irrigated areas, irrigation water consumption/abstraction, crop water requirements, and further advanced products. Another key feature is the merging of the classical ppgis (or community mapping) with SPIDER into the novel e-ppgis, which empowers users and enables active collaboration of all stakeholders.

In a nutshell, SPIDER is

- a powerful engine to integrate all data (digital and non-digital from all media) in a spatial context online and to visualize them in a dynamic interactive easy-to-use environment; and

- a powerful tool for active participation and collaboration of all stakeholders, and

- an effective policy instrument for efficient water use in irrigation and transparent water governance.

One of the main conclusions of SIRIUS (and precursor projects) is that the technical elements of SPIDER and the SIRIUS services always need to be embedded in the non-technical particpatory environment in order to be effective and bring true benefits to the user communities.

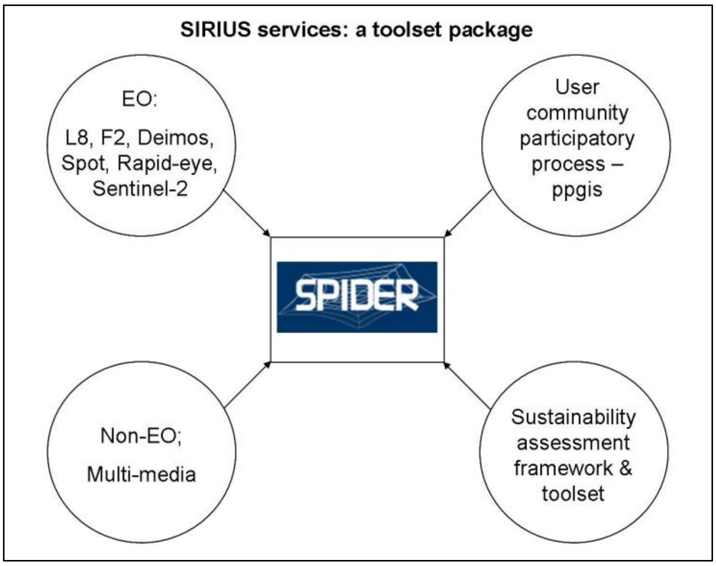

Figure 5. Elements of SIRIUS services package: SPIDER, EO, non-EO, participatory process, sustainability assessment tool.

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Annex A - The technical basis (SPIDER, EO summary overview)

SPIDER, the web-GIS based system for data sharing and participation

The SPIDER system simplifies the process of integrating multi-sourced maps, including EO data and non-EO data such as meteorological data and administrator boundaries, and the distribution of the data and the results. SPIDER is a centralized data server where different users can upload different kinds of layers (vector, raster, alphanumerical and multimedia files) and work together with them in a participatory and collaborative environment, as a support for the academic and research groups, as well as for the different stakeholder levels implicated on the water management issue. The information is provided to a wide range of stakeholders at their required space-time resolution in non-academic, non-technical, easy-to-use and intuitive form that encourages participation. SPIDER is based on the new Web 2.0 concept, where the web itself has become the platform. The user doesn't need to install any software in the client PCs since the service is provided through the most popular web-browsers.

During the SIRIUS project the data are uploaded in the system by the group administrator/s, which have necessary knowledge about formats, sources, data quality and system requirements. Each one of the pilot areas has created and managed its own SPIDER group. So there are a group for Ceará (Brazil), Kafr el Sheik (Egypt), Harangi (India), Sannio Alifano (Italy), Río Yaqui & Río Mayo (Mexico), Cazasu – North Braila Terrace (Romania), Jucar River Basin and Alicante Province inside Júcar District (Spain) and Gediz Irrigation Association in Gediz River Basin (Turkey). This list of groups is available from the project webpage http://www.sirius-gmes.es. Each group has uploaded the data available for its region, including a minimum time series of satellite images (including NDVI and RGB color composites). In all cases a multisensory data layer has been built and used for the different campaigns carried out during the project.

Useful, robust and innovative toolkits. The successive versions released during the project have included new functionalities and have improved previous developments.

One of the advances of the SPIDER system is the possibility to **chart the temporal evolution of the information** uploaded in the system. The temporal evolution is visualized in interactive charts that also allow to define the range of dates analyzed, the parameter plotted and the number of queries displayed; being possible the comparison of the time evolution of multiple points along time for a variety of spatial scales: into the same plot or in different pilot areas. Additional functionalities are the accumulation of the analyzed parameter along the time by dragging the mouse over the chart axis and interactive selection of the date displayed in the visor from the chart. The grid size for the calculation is defined by the user in the interface and the result is the average value of all the pixels in the grid. This way the error due to EO sensor resolution is reduced and each image has its corresponding point in chart. This tool is based on dynamic mosaic of images with a spatial and a temporal component, covering different areas on different dates.

To facilitate geographic searches by users and provide a spatial context for all SPIDER groups, the interface combines user defined layers (satellite images of NDVI and color composites and vector maps) **with the Google layers (Google Road Maps, Google Satellite and Google Terrain)**. This functionality requires the adoption of the Google reference system for data visualization, in spite of the original data can be uploaded in a variety of reference systems.

The multimedia support was added so that users can link the most common formats of multimedia content to the layers of the pilot areas. The idea was to improve the experience sharing information and offering reports to the different stakeholders. Also it improves the participatory tools to support the ppgis process carried out in each pilot area. Another minor improvement, but also significant for SIRIUS users, is adding the sensor information in images from time tiled layers. This is very useful for multi-sensor layers.

Beyond the technical features of SPIDER, it is also interesting to highlight the direct relation between the multimedia content supported in SPIDER and how users, and identify which users, use that content. It is summarized in Table 8 where the users considered are: Farmers, Water Managers, Advisory Service Managers, Consultants and Public Opinion.

Table 8. Multimedia tools offered by SPIDER to users

Multimedia Content	Purpose	Users
Photos	Report crops diseases	Farmers; Advisory Service Managers; Consultants
	Report water supply system failures	Farmers Water Managers
	Share crop farming techniques	Farmers
	Share ppgis activities and material to promote participation	Farmers Water Managers
PDFs	Share reports from models like HidroMORE or AquaTool.	Advisory Service Managers Water Managers
	Share reports from Advisory service managers to the farmers	Farmers
Vídeos	Dissemination of pilot area problems	Farmers General public
	Share ppgis activities and material to promote participation	Farmers Water Managers

EO data, towards operational and sustainable product lines.

Our guiding star has been the development of a production line to obtain useful and robust (not vulnerable) products. A complete compilation of EO data sources are given in the document EO image data procurement (see D3.1) and an in depth description of the product lines are described in the documents Operational production lines can be completed by the institutions involved, but in addition, we supported our EO data process lines on the figure of the **Data Warehouse**. This offered the possibility of a centralized processing line and provided the data necessary for the project objectives as needed.

The general idea is that two products are highly necessary and thus mandatory for the services. These products are spectral vegetation indices (SVI) and colour composites (CC).

- **Calculation of SVI.** SVI are quantitative descriptors of plant-crop development, and within the variety of indices proposed in the literature we selected the NDVI index. SVI are linear correlated with important biophysical parameters such as the crop coefficient. Thus SVI are in the core of the estimates of crop water requirements. Additionally, the temporal pattern of these indices is used to discriminate the type of crops in land uses-land cover maps. Other uses are related to the quantitative analysis of crop development and plot homogeneity.

  The procedure to obtain temporal series of SVI is designed to ensure the stability of the time series, avoiding effects not related to vegetation changes, such as changes in illumination geometry and atmospheric effects. SVI must be calculated through the combination of spectral reflectances derived from satellite images. The calculation of reflectance requires the knowledge of sensors-specific calibration coefficients and the estimation of sun illumination angles, these procedures are summarizes in the deliverables previously mentioned.

- Additional steps are the use **atmospheric correction methodologies**, conceived to minimize or compensate the effect of the atmosphere in the signal registered by the sensors. Absolute correction methods, using atmosphere properties at satellite acquisition time and radiance inversion models, are not implemented for all sensors in an operative manner. The alternative is the use of relative atmospheric correction methods. These methods normalize the signal obtained in each image to the signal of a reference. The reference could be one image adequately corrected or field measurement of canopy reflectance. This normalization is performed using the signal measured over target surfaces considered pseudo-invariant. The most recommended pseudo-invariant targets are the full dense vegetation and bare soil. The value of the SVI in these surfaces are known and allow to rescale the values of the SVI in the images using linear functions.

- **Color composites are helpful products** for the analysis and interpretation of EO data. No standard procedures are available but some aspects must be considered; studied elements must be easily identified and the composite must be stable and comparable in the time. Color composites based in the combination of Shortwave infrared band, SWIR, in the red channel, Near infrared band, NIR, in the green channel and Red band in the blue channel allows to identify natural surfaces, soil, vegetation, etc. Some of the sensors used in the project (i.e. DEIMOS, FORMOSAT and RapidEye) do not measure canopy reflectance on the SWIR band, thus the Green band was used in the red channel. In addition we developed several filters for an adequate visualization of the images in the SPDER system.

Most of the operational EO sensors and platforms are compatible in terms of the signal retrieved from the ground surface and the products derived from these sensors (i.e. reflectance and reflectance based vegetation indices) are comparable. Thus, we can combine the images provided by these sensors compounding virtual constellations of EO platforms. The use of virtual constellations instead of individual sensors ads robustness to the services since allow us to increase the temporal resolution of each individual platform, avoiding the undesirable problems of data availability. Several virtual constellations had provided dense temporal (high frequency) sequences of images within the context of the SIRIUS project, necessary for the services provided.