# Consortium Agreement

# “ALTOS”

## The following *Participants*:

**INSTITUT DE RECHERCHE POUR LE DEVELOPPEMENT**
Public body
180006025 00159, code APE 7219Z
Having its registered office at: 44, boulevard de Dunkerque, CS 90009,
13572 MARSEILLE Cedex 02
France
Represented by: Jean-Paul MOATTI
Function: Chairman
who has delegated his signature for the purposes hereof to Mrs Florence MORINEAU, regional representative of IRD Occitanie, Montpellier, France.

Hereafter referred to as "**IRD**"

Acting in its own name and on behalf of /

- JRU "LISAH", managed by its director, Jérôme MOLÉNAT
- JRU "CESBIO", managed by its director, Laurent POLIDORI

AND

**INSTITUT DE RECERCA I TECNOLOGIA AGROALIMENTARIES (IRTA)**
Public body According to Law 4/2009
Having its registered office at Torre Marimon. Cta. C-59, km 12,1.
08140 CALDES DE MONTBUI (Barcelona)
Spain
Represented by: Mrs. Silvia FERNANDEZ LOPEZ
Function: Coordinator of Projects Office
Hereafter referred to as "**IRTA**"

AND

**UNIVERSITÀ DEGLI STUDI DI CAGLIARI**
Public body
Having its registered office at: via Università 40
09124 Cagliari
Italy
Represented by: Prof. Luigi Raffo
Function: Delegate of the Rector for the purpose
Hereafter referred to as "**UNICA**"

AND

**NATIONAL COUNCIL FOR SCIENTIFIC RESEARCH**
Public body
Having its registered office at: 59, Zahia Salmane Street, Jnah
P.O. Box 11-8281, Beirut
Lebanon
Represented by: Mouïn Hamzé
Function: Secretary General of the CNRS-L
Hereafter referred to as "**CNRSL**"

AND

**LEBANESE AGRICULTURE RESEARCH INSTITUTE**
Public Body
Having its registered office at: 287 Tal Amara
Zahle
Lebanon
Represented by: Michel AFRAM
Function: Chairman
Hereafter referred to as "**LARI**"

AND

**CADI AYYAD UNIVERSITY**
Public body
SIREN number: 00216028300011
Having its registered office at: Boulevard Abdelkarim Khattabi
BP 511, Marrakech
Morocco
Represented by: Moulay Lhassan HBID
Function: President
Hereafter referred to as "**UCA**"

AND

**INSTITUT NATIONAL DE RECHERCHES EN GENIE RURAL EAUX ET FORETS**
[Public body]
Having its registered office at: Rue Hédi Karray, 2080 Ariana
BP 10, 2080 Ariana
Tunisia
Represented by: Zouhair Nasr
Function: General Director
Hereafter referred to as "**INRGREF**"

AND

**INSTITUT NATIONAL AGRONOMIQUE DE TUNISIE**
Public body
Having its registered office at: 43, Avenue Charles Nicolle
Cité Mahrajène, 1082- Tunis
Tunisia
Represented by: Faysal Benjeddi
Function: Director
Hereafter referred to as "**INAT**"

AND

**LE CENTRE DE RECHERCHES ET TECHNOLOGIES DES EAUX**
Public body
Having its registered office at: Route touristique de Soliman
BP 273, 8020 Soliman
Tunisia
Represented by: Ahmed GHRABI
Function: General Director
Hereafter referred to as "**CERTE**"

AND

**ECOLE SUPERIEURE DES COMMUNICATIONS DE TUNIS**
Public body
Having its registered office at: Cité technologique des communications
Km 3,5 Route de Raouèd, 2083 – Cité El Ghazala
Tunisia
Represented by: Sofiane CHERIF
Function: Director
Hereafter referred to as "**SUPCOM**"

Hereafter IRD, IRTA, UNICA, CNRSL, LARI, UCA, INRGREF, INAT, CERTE, SUPCOM, is individually referred to as a "Participant" and collectively as the "Participants".

**Whereas**

The research contemplated herein has arisen under the auspices of the PRIMA call PRIMA Section 2 "multi-topics" 2018 - Thematic area 1 "Sustainable water management for arid and semi-arid Mediterranean area" - Topic 1.1.1 "Water resources availability and quality within catchments and aquifers" and Topic 1.1.2 "Sustainable, integrated water management", which is a network of ministries and funding organisations from Euro-Mediterranean countries with the ambition to strengthen the Euro-Mediterranean research in the area and develop a common Euro-Mediterranean research agenda concerning sustainable water management.

The Participants established, in reply to a call for proposals by PRIMA call PRIMA Section 2 "multi-topics" 2018 - Thematic area 1 "Sustainable water management for arid and semi-arid Mediterranean area" - Topic 1.1.1 "Water resources availability and quality within catchments and aquifers" and Topic 1.1.2 "Sustainable, integrated water management", a Project called **: Managing water resources within Mediterranean agrosystems by accounting for spatial structures and connectivities. "ALTOS"**;

And as this Project has been selected for funding;

The Project participants now wish to set the terms and conditions for the implementation of their Project, and their respective rights and obligations resulting there from, by means of this Agreement.

**The following has been agreed upon:**

**Article 1: Definitions**

When used in this Agreement, the following words and expressions, beginning with a capital letter, have the following respective meanings:

**- Agreement**: means this Agreement and its Appendices, as well as any riders;

**- Committee:** means the management body for the Project, created by, and comprised of, Project Participants as listed in Appendix 2;

**- Confidential Information**: means any and all information and/or data, in any form and of any nature whatsoever, that is disclosed by a Participant to one or several other Participants under the Agreement, subject to the disclosing Participant having clearly and unambiguously stated its confidential nature or, in the event of oral disclosure, that the disclosing Participant states its confidential nature orally when it is disclosed and confirms such nature in writing within thirty (30) days;

- **Coordinator**: means the Project Coordinator; the lead Participant of the Project;

**- Field of Application**: means sustainable water management

**- New Knowledge**: means any and all technical and/or scientific information and knowledge, whether actually patented or not, and whether patentable or not, including know-how, software (in its source-code or object-code version), drawings, diagrams, designs, formulae or any and all other

type of information, in any form whatsoever, and all the related rights, that are developed by one or several Participants pursuant to the Agreement;

**- Own Knowledge**: means any and all technical and/or scientific information and knowledge and/or any and all other type of information, in any form whatsoever, whether patentable or not, and/or whether actually patented or not, and all the related rights, belonging to a Participant or held by the latter prior to the effective date of the Agreement.

The Participants' Own Knowledge at the effective date of the Agreement is specified in Appendix 3 hereto. During the performance of the Agreement, each Participant is responsible for advising the other Participants, in writing, of the creation of further Own Knowledge and for proving, where applicable, the latter's independence vis-à-vis the Project. In this case, Appendix 3 shall be supplemented;

**- Participant:** means a body (institution, organisation, enterprise) participating within this Project, here IRD, IRTA, , UNICA, CNRSL, LARI, UCA, INRGREF, INAT, CERTE, SUPCOM.

**- Project**: means the research project **Managing water resources within Mediterranean agrosystems by accounting for spatial structures and connectivities. "ALTOS"** described in Appendix 1 hereto;

**- Work**: means the Work carried-out by the Participants pursuant to the Project under this Agreement, as listed in Appendix 1 hereto.

**Article 2: Purpose**

The purpose of this Agreement is:

- to set forth the terms and conditions for implementing the Project;
- to set the rules for the transfer of the intellectual property attached to the New Knowledge;
- to set the general terms and conditions for industrial and commercial use and exploitation of the Own and New Knowledge.

**Article 3: Governance Structure**

**3.1 Coordinator**

**3.1.1 Appointment of the Coordinator**

With the Participants' joint agreement, Mr Frédéric Jacob, IRD is hereby appointed Project Coordinator of the ALTOS Project.

**3.1.2 Coordinator's Role**

The Coordinator has the following duties

- he sends correspondence of joint interest to the other Participants within a reasonable timeframe so as to ensure the Project's due and proper progress;
- he centralises the Participants interim reports and produce a mid-project report at 18 months and a final report to the PRIMA Office (Marco ORLANDO);

- within two months of the Project's expiry date, he shall send a single final report listing all the results achieved to PRIMA Office;
- he sends requests for changes to the Project to PRIMA Office;
- he advises PRIMA Office of any problems in implementing the Project, in particular, when a Participant decides to terminate their share of the Work for which it is responsible for or when the Participants request another Participant's involvement in the Project.

**3.1.3 Participants' obligations vis-à-vis the Coordinator**

Within the lead-times provided for, each Participant has the following obligations:

- to provide elements enabling the Coordinator to reply to any requests from PRIMA Office;
- to advise the Coordinator of the progress of the work that it is carrying-out, at a frequency that shall be decided upon by joint agreement within the Committee;
- to send the interim reports destined for PRIMA Office to the Coordinator and the elements required to draw-up the single final report;
- to immediately inform the Coordinator of any problem that may compromise the normal implementation of the Project.

**3.2 Committee's Role**

The Committee will be in charge of taking all measures, in addition to the contractual provisions already stipulated, necessary for the development of the present collaboration and the implementation of the Project. The Committee is responsible for the political and strategic orientation of the Work. It makes sure that the strategy adopted for the Project is preserved. The Committee acts by decisions or advices.

In particular, the decision power of the Committee concerns:
- the political and strategic orientation of the Work. The Committee cannot decide to extend or cancel the Project,
- the progress of the Work Packages in accordance with the Project defined in Appendix 2,
- the publication and dissemination policy : the Committee cannot delay a publication without fair reason as set forth in Article 7,
- the arbitration, in case of a deadlock situation within a Work Package, upon consultation of the corresponding of the Work Package Leader(s);

The Committee formulates proposals to the Parties, which will take decisions, among other about:

- Extension or reorientation of the Project or the budget. In that event, the Coordinator will submit a proposal to PRIMA Office and this proposal should be agreed by PRIMA Office and the National Agencies funding the Project.
- Measures towards defaulting Party, following rules as provided in Article 10,
- Intellectual property rights,
- Use and exploitation of the Results,
- Dispute of technical nature, upon request of the Parties.

**Article 4: Financial Terms and Conditions**

Each Participant receives funding relating to its share of the Work directly from the National Agency responsible for that Participant and according to the provisions of that Agency's decision to award aid. By accepting national aid, each Participant is required to abide with the rules and regulations concerning project funding in its own country. The articles set down in this Agreement do not replace, impinge, impede or otherwise impact the national rules and regulations which apply to each Participant.

The Participants shall, if necessary, individually provide the additional funding required in order to carry-out their share of the Work.

**Article 5: Intellectual Property**

**5.1 Own Knowledge**

Each Participant retains full and total ownership of its Own Knowledge.

**5.2 New Knowledge belonging to one Participant**

New Knowledge created alone by a single Participant belongs to that Participant and any resulting new patents shall only be registered in the name, and at the expense, of said Participant and at its sole initiative.

**5.3 Joint New Knowledge**

**5.3.1 Ownership principle**

In the event of New Knowledge being created by the staff of two or more Participants without being able to assess the individual contributions of these in obtaining such knowledge, this New Knowledge, hereafter referred to as "Joint New Knowledge", shall be jointly owned by these Participants (who are in turn hereafter referred to as the "Co-Owner Participants") proportionally to their intellectual, human, material and financial contributions, unless said Participants contractually agree to having the related property rights being transferred to one of them.

In the event of New Knowledge being created solely by a laboratory which is a joint research structure without corporate status, constituted by several Participants, the latter shall be deemed as being the owners of this New Knowledge, in accordance with the agreements executed between them.

In the event of Joint New Knowledge being created by the staff of at least two laboratories, each of which is a joint research structure, constituted by different Participants, ownership of the Joint New Knowledge shall be shared between the Participants which are the trustees of said joint research structures proportionally to their intellectual, human, material and financial contributions, it being hereby stipulated that, within each joint research structure, the Participants constituting said joint research structure shall be personally responsible for the breakdown of the proportion of ownership between them, in accordance with the agreements executed between them.

Any and all Joint New Knowledge consisting of a new patent, software or other knowledge protected by an intellectual property right, shall be subject to rules of co-ownership, that shall be drawn-up between the Co-Owner Participants as soon as necessary and, in all cases, prior to any and all industrial and/or commercial use.

**5.3.2 Patentable Joint New Knowledge**

The Co-Owner Participants of the patentable Joint New Knowledge shall decide whether the latter shall be subject to patent applications filed/registered in their joint names and shall designate the Participant from amongst them which shall be responsible for accomplishing the filing/registration formalities and for maintaining the patent in force.

The expenses relating to filing/registration, obtaining and maintaining the new patents in force under co-ownership arrangements shall be borne by the Co-Owner Participants according to their share of ownership as set forth in Article 5.3.1 hereinabove.

Should a Co-Owner Participant waive its entitlement to file/register, continue with a registration procedure or maintain one or several new patents in force, it shall inform the other Co-Owner Participants in due time so that the latter may file/register in their own names, and continue with the procedure for registering or maintaining said new patents in force, at their own expense and for their own benefit. The desisting Participant undertakes to sign, or have signed, any and all documents required to enable the other Co-Owner Participants to become sole co-owners of the new patent(s) in question for the relevant country or countries.

A Co-Owner Participant shall be deemed to have relinquished its rights over a new patent sixty (60) days following receipt of a registered letter with acknowledgement of receipt requesting it to give its decision in this respect, sent by the Co-Owner Participant responsible for accomplishing the formalities relating to filing/registration and maintaining the patents in force, as referred to in the first paragraph of this Article.

It is hereby stipulated that the waiving Participant shall not be able to claim any compensation as regards the use of the new patent(s) in question in the relevant country or countries.

Each Co-Owner Participant shall be personally responsible for any compensation for its inventors.

**Article 6: Principe of Use and Usage**

**6.1 Use and Usage of Own Knowledge**

Rules related to ownership and protection of Knowledge described under Article 5 shall apply. The following rules are complementary to these.

**6.1.1** Each Participant shall dispose freely of its Own Knowledge.

**6.1.2 Use for Carrying-out the Work**

In order to carry-out the Work, and for this sole purpose, each Participant grants a non-exclusive, non-assignable right, which may not be sub-licensed, and without financial consideration, to each of the other Participants, to use its Own Knowledge, provided said Own Knowledge is required for carrying-out its share of the Work.

Such Own Knowledge is provided by the Participant holding it at the express request of the other Participant and shall be considered as Confidential Information under the terms and conditions of Article 7.1 of the Agreement.

More specifically, when this Own Knowledge is software, unless there are provisions to the contrary in a licensing agreement executed between the relevant Participants, the Participant receiving such Own Knowledge may only use it on its own equipment and shall only be authorised to carry-out the reproduction that is strictly required by the loading, displaying, running, transferring and storing of this software for the sole purpose of its use to carry-out its share of the Work, and for making a back-up copy. The Participant receiving such Own Knowledge undertakes to refrain from using this software in any other manner and, in particular, from lending or disclosing it to third participants, unless it has the prior authorisation of the owner Participant, and from any and all use. The right of use thus granted shall not provide access to the source codes of the software in question without the prior, written authorisation of the Participant holding the rights over said software.

**6.1.3 Use for Commercial Purposes**

Each of the Participants undertakes to grant to the other Participants, following an express request from the latter and subject to third participant rights, a non-exclusive, non-assignable right that may not be sub-licensed, to use its Own Knowledge as required to enhance the New Knowledge, under the commercial market conditions for the Field of Application in question. Said commercial conditions and the terms of this licence shall be negotiated prior to any and all industrial and/or commercial use and shall be subject to a licensing agreement executed between the relevant Participants.

More specifically, when this Own Knowledge is software, the Participant receiving it may only use it on its own equipment and shall only be authorised to carry-out the reproduction that is strictly required by the loading, displaying, running, transferring and storing of this software for the sole purpose of using it to use its New Knowledge, and for making a back-up.

**6.2 Use and Usage of the New Knowledge and the Joint New Knowledge**

**6.2.1 General Principles**

Subject to the provisions of Article 6.2.5 hereinafter, each Participant may freely use, exploit and/or have exploited, the New Knowledge that it owns under Article 5 hereof.

The Participants undertake to take all appropriate measures, in particular, vis-à-vis their staff and/or any subcontractors, to enable them to grant the other Participants the rights of use and usage of the New Knowledge or the Joint New Knowledge, under the terms and conditions provided for in the Agreement.

**6.2.2 Use for Carrying-out the Work**

Each Participant grants a non-exclusive, non-assignable right, that may not be sub-licensed, and without financial consideration, to the other Participants, to use its New Knowledge for the sole purpose of carrying-out their share of the Works. The conditions for exercising this right of use are the same as those provided for in Article 6.1.2 hereinabove relating to the use of Own Knowledge.

In the case of software, the Participant receiving such New Knowledge may only use it on its own equipment and shall only be authorised to carry-out the reproduction that is strictly required by the loading, displaying, running, transferring and storing of this software for the sole purpose of its use to carry-out its share of the Work, and for making a back-up copy.

**6.2.3 Use for Research**

Each Participant may use, freely and free-of-charge, at its request, the New Knowledge belonging to the other Participants solely for its own research requirements and pursuant to research collaboration with third participants, to the exclusion of any and all direct and/or indirect use for commercial purposes.

If the New Knowledge thus requested is constituted of software, its furnishing shall be subject to a written agreement between the Participants in question that shall specify the terms and conditions of use, it being hereby stipulated that the rights of use granted in this manner shall not provide access to the source codes without the express agreement of the owner Participant or the Co-Owner.

**6.2.4 Use of the Joint New Knowledge**

The Co-Owner Participants of the Joint New Knowledge shall specify the terms and conditions for its use pursuant to an enhancement agreement prior to any and all industrial and commercial use or, for new patents subject to joint ownership, pursuant to rules of co-ownership as referred to in Article 5.3.1 hereinabove and in compliance with the principles set forth in Article 6.2.5.

As of now, the Participants agree that any direct and/or indirect use by a Co-Owner Participant of the Joint New Knowledge shall be subject to financial compensation being paid to the other Co-Owner Participants according to terms and conditions set forth subsequently in the abovementioned enhancement agreement or in the rules of co-ownership, without prejudice to Article 6.2.5 hereinafter.

When the Joint New Knowledge consists of software, the prior agreement of the other Co-Owner Participants shall be required if the planned use shall lead to communication of the source codes.

**6.2.5 Use of the New Knowledge and the Joint New Knowledge by another Participant**

**6.2.5.1** For a term of eighteen (18) months as from the Agreement's expiry or termination date, each owner Participant or Co-Owner Participant undertakes to grant a non-exclusive, non-assignable right, without entitlement to sub-licence, for use of its New Knowledge within a Field of Application to any other Participant that may so request, provided such is required by the Participant making the request in order to use its own New Knowledge. Said right shall be granted under preferential terms (i.e. more favourable than the commercial market conditions for the Field of Application in question) or under any and all other conditions jointly agreed to by the Participants. The preferential terms and the terms and conditions of the licence shall be negotiated prior to any and all industrial and/or commercial use and shall be subject to a licensing agreement executed between the relevant Participants.

In the case of software, the Participant receiving such New Knowledge may only use it on its own equipment and shall only be authorised to carry-out the reproduction that is strictly required by the loading, displaying, running, transferring and storing of this software for the sole purpose of using it to use New Knowledge, and for making a back-up.

In the event that no licensing agreement is executed between the Participants under the foregoing terms and conditions within eighteen (18) months of the Agreement's expiry or termination date, the abovementioned commitment shall lapse and the owner Participant or Co-Owner Participant shall again be free to use the New Knowledge and/or have it used exclusively, subject to the agreement of the other Co-Owner Participants for Joint New Knowledge.

**Article 7: Confidentiality - Publications**

**7.1 Confidentiality**

**7.1.1** Each Participant shall only provide the other Participants with the Confidential Information that it deems to be required for implementation of the Project, subject to third participant rights.

**7.1.2** No provision of the Agreement may be construed as obliging any Participant to disclose Confidential Information to another Participant, with the exception of the information required for implementation of the Project.

**7.1.3** The Participant which receives Confidential Information from one of the other Participants undertakes, for the term of the Agreement and for five (5) years following its termination or expiry, to ensure that the Confidential Information originating from the Participant disclosing it:

- is kept strictly confidential and is protected in the same manner as its own Confidential Information;
- is only provided to the members of its staff or subcontractors which have to be familiar therewith and is only used for the purposes set forth in the Agreement.

Any and all other disclosure or use of the Confidential Information shall require the prior, written agreement of the Participant disclosing it.

**7.1.4** All the Confidential Information and its reproductions, sent by a Participant to another pursuant to the Agreement shall remain the property of the Participant disclosing it, subject to third participant rights, and shall be immediately returned to the latter at its request.

**7.1.5** The Participant receiving the Confidential Information may disclose Confidential Information for which it is able to provide proof:

- that it was in the public domain prior or subsequent to its disclosure to it, and without any negligence being attributable to it;
- that use or disclosure was authorised in writing by the Participant from which it originated;
- that it was developed independently and in good faith by the staff of the Participant receiving it without such staff having access to said Confidential Information.
- that it was already in its possession prior the execution of the Agreement;
- that it was legally received from a third participant.

**7.1.6** No provision of this Agreement implies:

- a waiver of protection of Confidential Information by a patent or by any and all other intellectual property right by the Participant disclosing it;
- a transfer of any right over this information by the Participant disclosing it in favour of the other Participants.

**7.2 Publications - Communications**

**7.2.1** Any publication or communication as authorised in application of Article 7.1 must acknowledge the receipt of funding under the auspices of PRIMA such as: "These results have been achieved within the framework of the PRIMA, with funding from …*the National Agencies concerned…*".

**7.2.2** Each Participant undertakes not to publish, in any manner whatsoever, the Own Knowledge and the New Knowledge of other Participants with which it may have familiarised itself, provided such information is not in the public domain or if said Participant has not obtained the prior agreement of the Participant owning that Own or New Knowledge in question.

**7.2.3** Any planned publication or communication of information relating to the Work by one of the Participants shall be subject, during the term of the Agreement and for two (2) years following its expiry or termination date, to the prior and written agreement of the other Participants.

The Participants shall announce their decision within a maximum timeframe of one (1) month as from the request-notification date; said decision may consist of:

- unreserved acceptance of the planned publication or communication; or
- a request for changes, in particular if some of the information contained in the planned publication or communication may compromise the industrial and commercial use of the Own and/or New Knowledge, or a request that the publication or communication be postponed if such would seem to be dictated by actual and serious reasons, in particular if the information contained in the planned publication or communication needs to be protected as industrial property.

Should a Participant fail to reply within this timeframe, it shall be deemed to have given its agreement. Nevertheless, eighteen (18) months after the initial submission of the planned publication or communication in question, none of the Participants may refuse to agree to publication or communication, unless the information that shall be subject to said publication or communication has strategic scientific, industrial or commercial interest for the business activities of one of the Participants.

Such publications and communications shall mention the contribution of each Participant in implementing the Project.

**7.2.4** The provisions of this Article 7.2 shall not remove or prevent:

- either the obligation binding upon all persons involved in the Project to present an activity report to the organisation to which they report. In this respect, the publication of Confidential Information is limited to those bodies which need to be familiar therewith, provided they undertake to comply with the provisions relating to confidentiality;
- or the defence of theses by researchers involved in the Project. Such defence is organised in compliance with university regulations and the provisions relating to confidentiality. Where applicable, it may take place in camera and each member of the examining board shall be bound by a non-disclosure commitment.

**7.2.5** The publications and communications authorised in application of Article 7.1 will be sent, once published or communicated, to PRIMA Office.

**Article 8: Liability - Insurance**

**8.1 General Provisions**

**8.1.1** Each Participant undertakes to carry-out its share of the Work in accordance with the obligation of due care binding upon it.

**8.1.2** The Participants mutually waive entitlement to claim compensation from each other for consequential loss (loss of production, opportunity cost, etc.) that may occur pursuant to the Agreement.

**8.2 Participants' Staff**

Each Participant shall pay for covering its own staff in accordance with applicable legislation in respect of social security, industrial accident and industrial disease schemes to which it is affiliated, and shall carry-out the formalities for which is it responsible.

**8.3 Damage/Loss Caused to Participants' Property**

Under the conditions of ordinary law, each Participant is responsible for the damage/loss caused by it to another Participant's moveable or immoveable property, owing to, or during the performance of, the Agreement.

**8.4 Damage/Loss Caused to Third Parties**
For that which concerns it, each Participant shall bear all the financial consequences of the civil liability that it incurs under ordinary law, owing to any and all bodily injury or physical damage caused to third parties during the Work carried-out pursuant to the Agreement.

**8.5 Insurance**

As an when required, each Participant shall take-out, and maintain effective, the insurance policies providing cover for any damage/loss to property or persons which may occur pursuant to the performance of the Agreement.

**8.6 Exclusion of Liability Attributable to Own and New Knowledge**

The Own or New Knowledge and/or other information disclosed by one of the Participants to any other Participant pursuant to performance of the Agreement is provided "as is", without any guarantee of any nature whatsoever.

Such knowledge and information is used by the Participants pursuant to the Agreement at their sole expense and respective risk and, consequently, no Participant may institute legal proceedings against another, in any capacity and on any grounds whatsoever, owing to the use of said knowledge and information.

**Article 9: Term**

The Agreement is executed for a 41 months term and shall take effect as from February 1$^{st}$ , 2020

The provisions of Articles 5, 6 and 7 hereinabove shall survive for their own term, notwithstanding the expiry or termination of the Agreement.

**Article 10: Termination**

In the event that a Participant were to breach its obligations hereunder, the other Participants may, subject to the agreement of PRIMA Office and the National Agencies funding the Project, terminate

the Agreement vis-à-vis the defaulting Participant if, within 30 days of a registered letter with acknowledgment of receipt having been sent to the Participant and the corresponding National Funding Agency, the defaulting Participant has still failed to comply with its obligations. The termination decision must be adopted by a unanimous vote from the non-defaulting Participants within the Committee, and has to be validated by PRIMA Office and all the National Agencies funding the project.

In the event of a Participant failing to meet its obligations to the National Agency supplying the funding for its Work, the National Agency reserves the right to terminate the defaulting participant according to the rules and regulations in place in that Participant's country. In such a case, the National Agency will inform PRIMA Office of its decision who in turn will inform the Coordinator.

In either case, the remaining Participants may elect either to assume the Work of the defaulting Participant themselves or to entrust a third participant with all or part of the Work to be carried-out. In both situations, this can only be undertaken with the explicit consent of PRIMA Office and the National Agencies funding the project.

The defaulting Participant undertakes to provide, free-of-charge, the other Participants or the substitute third participant with all the information required to continue with implementation of the Project in its stead.

The exercising of this termination right shall not discharge the defaulting Participant from complying with its contractual obligations until the effective termination date, subject to any damage/loss that may be suffered by the other Participants owing to the partial termination of the Agreement.

**Article 11: Force Majeure**

**11.1** "Force majeure" means any unforeseeable and exceptional event affecting performance of the Agreement, which is outside the control of the Participants, and which cannot be avoided in spite of the efforts which the Participants may reasonably make.

**11.2** The Participant invoking an event of force majeure shall advise the other Participants thereof within seven (7) days of the occurrence of the said event. The Coordinator shall then inform PRIMA Office immediately.

**11.3** Where applicable, the lead-times for carrying-out the Work may be extended by joint agreement between the Participants and PRIMA Office and the National Agencies funding the Project.

**Article 12: *Intuitu personae***

The Agreement is executed intuitu personae. Consequently, no Participant is authorised to transfer all or part of the rights and obligations hereunder to a third participant without the prior and written agreement of the other Participants and of the Consortium.

**Article 13: Governing Law – Disputes**

**13.1** The Agreement is governed by European rules and laws and the National Contracts and decisions signed concerning each participant's national funding.

**13.2** In the event of a disagreement as regards the interpretation or performance of the Agreement, the Participants shall endeavour to settle their dispute out-of-court through the Committee, and subsequently through their respective direction.

Should the disagreement persist, the matter shall be referred to the European Courts having jurisdiction.

**Appendices:**

The following documents are appended to the Agreement and form an integral part thereof:

- **Appendix 1: brief description of the project (summary and implementation)**
- **Appendix 2 : Committee Representatives**
- **Appendix 3: Participants' Own Knowledge**
- **Appendix 4: complete description of the project (proposal accepted for granting).**

In the event of a conflict or difference between the body of the Agreement and one of its Appendices, the body of the Agreement shall take precedence.

In 10 originals

Executed in Montpellier, France
On ...03/02/2020...

For IRD (LISAH and CESBIO)

Florence MORINEAU
regional representative of IRD Occitanie

Executed in Caldes de Montbui, Spain

On ....24/01/2020

For IRTA

Mrs. Silvia FERNANDEZ LOPEZ
Coordinator of Projects Office

IRTA INSTITUT DE RECERCA I TECNOLOGIES AGROALIMENTÀRIES
Torre Marimon
E-08140 Caldes de Montbui (Barcelona)

Executed in Cagliari, Italy

On ..05/02/20.....

For UNICA

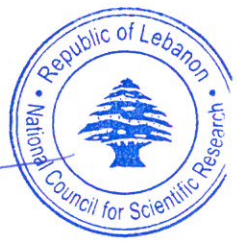
Professor Luigi Raffo
Delegate of the Rector for International research projects

Executed in Beirut, Lebanon

On 4/2/2020

For CNRSL

Dr. Mouïn Hamzé
Secretary General of CNRS-L



Executed in Tal Amara, Lebanon

On 27 January 2020

For LARI

Michel AFRAM
Chairman of LARI

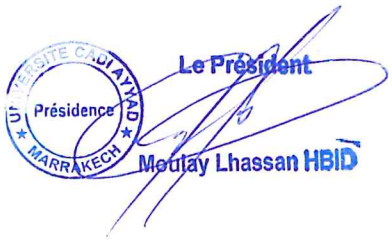
LEBANESE REPUBLIC
President
Director
General
Agricultural Research Institute

Executed in Marrakech, Morocco

On ..February..,7th 2020

For UCA

Moulay Lhassan HBID
President



Executed in Tunis, Tunisia

On ..... 03 FEV. 2020

For INRGREF

Zouhair Nasr
General Director

Executed in Tunis, Tunisia

On .....07 FEV 2020

For INAT

Faysal Benjeddi
Director

Executed in Tunis, Tunisia

On ....Tunis, 28 JAN 2020

For CERTE

Ahmed GHRABI
General Director

Le Directeur Général
Ahmed GHRABI

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR ET DE LA RECHERCHE SCIENTIFIQUE
Centre de Recherches Et des Technologies des Eaux -1-
TECHNOPOLE DE BORJ CEDRIA

Executed in Tunis, Tunisia

On 31/01/2020

For SUPCOM

Sofiane CHERIF
Director

**Appendix 1: brief project description**

**PRIMA Call Section 2 – Multi-topics 2018, under the thematic area 1: "Sustainable water management for arid and semi-arid Mediterranean area" - Topic 1.1.1 "Water resources availability and quality within catchments and aquifers" and Topic 1.1.2 "Sustainable, integrated water management".**

**Title of Proposal: Managing water resources within Mediterranean agrosystems by accounting for spatial structures and connectivities.**

**Acronym: ALTOS**

## Project Summary

The ALTOS project aims to improve water management models for rainfed and irrigated agriculture, by considering the modulation of spatial structures and connectivities induced by hydro-agricultural infrastructures and practices (e.g., modulating regional land use to drive upstream / downstream water repartition). Four study sites are considered for integrated analysis in Morocco, Lebanon and Tunisia; and two study sites are considered for methodological developments in Spain and Italy. WP1 deals with monitoring and modelling tools for characterizing spatial structures. It includes the use of innovative sensors for structure observations, and of innovative methods for data processing. WP2 addresses innovative monitoring tools for characterizing processes induced by spatial structures (.e.g, water flows). It includes several protocols relying on complementary measurements. WP3 addresses innovative modelling for simulating individual (e.g., evapotranspiration) and combined (e.g., hydrological cycle) processes. It includes multi-objectives / multi-criteria calibration procedures relying on distributed / nested measurements. WP4 simulates matter fluxes and storages for possible structure modulations, to next conduct an integrated analysis with end-users on the basis of participative seminars. It also cross-analyses irrigated and rainfed agrosystems, by addressing vulnerabilities and adaptation margins. WP5 deals with (1) the sharing of data and methods within the ALTOS consortium, and (2) the results dissemination and exploitation. For this latter item, we rely on long-term collaborations with several stakeholders (farmer associations, resource managers, engineering offices). Expected outcomes are related to SDG #2 (sustainable agriculture), #6 (water supply services), and #12 (responsible consumption and production). ALTOS contributes to PRIMA outcome indicators, including (1) newly modelling routines, (2) new irrigation technologies, and (3) innovative farming system.

## Project implementation

The ALTOS activities cover a three-year period and are structured into six interconnected work packages (Figure below), including WP6 on management and communication. The methodological framework was elaborated by the consortium toward the best approach to address the impact of spatial structures and connectivities on matter fluxes and storages. Below are summary descriptions of the work packages.

- **WP1 "Characterizing spatial structures"** deals with innovative monitoring and modelling tools for characterizing spatial structures. It includes the use of innovative sensors with high spatial resolution and of innovative methodologies for data processing.
- **WP2 "Monitoring fluxes and storages"** addresses innovative monitoring tools for characterizing matter fluxes and storage driven by spatial structures. It includes innovative experimental protocols that rely on the joint use of complementary measurements.
- **WP3 "Modelling fluxes and storages"** uses outcomes from WP1 and WP2 to address innovative modelling for simulating individual (e.g., evapotranspiration) and combined processes (e.g., combined hydrological cycle and crop functioning). It includes calibration procedures that rely on distributed and nested measurements to simultaneously calibrate several model parameters.
- **WP4 "Simulating fluxes and storages for structures modulations"** combines outcomes from WP1 and WP3 to simulate matter fluxes and storages for possible structure modulations. Obtained simulations are translated into indicators for integrated analysis with stakeholders during participative seminars. WP4 also includes a cross-analysis for irrigated and rainfed agrosystems, by comparing vulnerabilities and adaptabilities on the basis of indicators related to water availability and agricultural yield.
- **WP5 "Pooling, dissemination and exploitation"** conducts pooling of data and methodologies between project partners and throughout project duration, by using several means such as dedicated platforms, workshops, mobilities. WP5 is also in charge of the dissemination and exploitation of the project results according to the type of outcome and target audiences.

Figure: Interactions between work packages (WP numbers within black circles).

The ALTOS project goes beyond the transfer of research results among stakeholders, by involving them in the co-construction of management methods. In this sense, interactions with stakeholders are not addressed within a dedicated WP as they are part of (1) WP4 when setting evolutions scenarios and analysing impacts of structure modulations on matter fluxes and storages, and (2) WP5 when disseminating innovative results related to monitoring, modelling and integrated analysis.

Table: List of work packages

| Work package No | Work Package Title | Lead Participant No | Lead Participant Short Name | Person-Months | Start Month | End Month |
|---|---|---|---|---|---|---|
| 1 | Characterising spatial structures | 3 & 6 | IRTA & LARI | 230 | 1 | 21 |
| 2 | Monitoring fluxes & storages | 2 & 11 | CESBIO & CERTE | 214.5 | 1 | 21 |
| 3 | Modelling fluxes and storages | 4 & 8 | UNICA & INAT | 282.5 | 7 | 33 |
| 4 | Simulating fluxes & storages for structures modulations | 7 & 9 | UCAM & INRGREF | 192 | 12 | 36 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | Pooling, dissemination and exploitation | 5 & 9 | CNRS-L & INRGREF | 89.5 | 1 | 36 |
| 6 | Management and communication | 1 | LISAH | 45 | 1 | 36 |
| | | | | 1053.5 | | |

## Project partnership

The ALTOS partnership is equilibrated between southern shore (Tunisia, Morocco, Lebanon) and northern shore (France, Italy, Spain) of the Mediterranean Basin. Its organisation relies on transversal collaboration between partners, since each WP is co-leaded by a binational pair to avoid both a focus on a given study site and a country-based compartmentalization of activities. The ALTOS partnership mobilises complementary skills towards achieving collective objectives (Table below). Thus, ALTOS can address landscaping evolution and resulting impacts by involving skills in monitoring, modelling and integrated analysis based. The ALTOS partnership brings together higher education institutions, university laboratories, and applied research institutes. This makes the consortium acting on research, knowledge transfer activities towards professional sectors, an research results towards undergraduate and undergraduate students during capacity building / training activities. The ALTOS partnership merges several collaborations that took place at the intra-national and inter-national scales over the last 15 years. This historical dimension has allowed for the creation of community facilities such as international laboratories, observatories and modelling platforms, but also for the development of close interactions with a large panel of stakeholders: farmer associations, resource managers, and engineer offices.

| Table: complementary skills toward common objectives. | | |
|---|---|---|
| Country | Partner | Skills. |
| Morocco | UCA | Remote sensing, isotopy, crop functioning, hydrogeology. |
| Tunisia | INRGREF | Hydrology, bioclimatology, participatory seminars integrated analysis. |
| | INAT | Agronomy, remote sensing, hydrology. |
| | SUPCOM | Signal and image processing, statistics. |
| | CERTE | Hydrogeology, geochemistry. |
| Lebanon | CNRS-L LARI | Quantitative and qualitative hydrology. |
| | | Agrosystem management, remote sensing, outreach. |
| France | LISAH | Remote sensing, photogrammetry, hydrology, bioclimatology, geochemistry, agronomy, climatology, statistics. |
| | CESBIO | Remote sensing, hydrology, bioclimatology, crop functioning. |
| Spain | IRTA | Remote sensing, bioclimatology, participative seminars. |
| Italy | UNICA | Hydrology, hydrogeology, geochemistry. |

**Appendix 2: Committee Representatives**

| **Name** | **Partner** | **Country** |
|---|---|---|
| JACOB Frédéric | IRD / LISAH | France |
| BOULET Gilles | IRD / CESBIO | France |
| BELLVERT RIOS Joaquim | IRTA | Spain |
| MONTALDO Nicola | UNICA | Italy |
| FADEL Ali | CNRS-L | Lebanon |
| JOMAA Ihab | LARI | Lebanon |
| KHABBA Saïd | UCA | Morocco |
| AOUISSI Jalel | INAT | Tunisia |
| ZITOUNA - CHEBBI Rim | INRGREF | Tunisia |
| ABDELFATTAH Riadh | SUPCOM | Tunisia |
| LACHAAL Fethi | CERTE | Tunisia |

**Appendix 3: Participants' Own Knowledge**

**Partner name : IRD, UMR LISAH**

The partner IRD (UMR LISAH) has specific knowledge, skills and means in hydrology, contaminant transfer and soil erosion in highly developed cultivated landscapes, and on the spatial properties and evolution of these landscapes, especially :

- OpenFLUID modelling platform under GPL license.
- Modelling modules that can be used in the OpenFLUID platform, under GPL or proprietary license.
- Hydrological modelling using different models (e.g. SWAT, MHYDAS).
- Modeling of erosion processes using different models (e.g. STREAM, MHYDAS-erosion).
- GrooveScape tool for landscape numerical representation.

- Databases from previous contract research programs.
- Databases from previous thesis work.
- Databases from ORE OMERE.

- Methodological knowledge in remote sensing, pedology, geostatistics, surface hydrology, sub-surface hydrology, erosion, bioclimatology.
- Methodological knowledge in agronomy, including
    - methodologies for collecting and processing data on the functioning of agricultural holdings, agricultural practices, the dynamics of changes in holdings and agricultural practices at plot and territory level;
    - modelling of technical decisions taken by farmers.
- Methodological knowledge in landscape modelling, including spatial dynamics and temporal evolutions.
- Methodological and technical knowledge of observation systems, modelling systems, software engineering.

- All data, proprietary and non-proprietary software, methods, information and know-how not generated by direct participation in the project.

**Partner name : IRD, UMR CESBIO**

"The partner IRD (UMR CESBIO) has specific knowledge, skills and means in the modelling and in the observations of eco-hydrological functioning of the anthropized catchments in semi-arid areas, especially :

- Remote sensing of land surface
- Crop surfaces fluxes modelling
- Meteorological, vegetation, soil and micro-meteorological measurements
- Soil-Vegetation-Atmosphere-Transfer Modelling"

**Partner name : IRTA**

The partner IRTA has specific knowledge, skills and means in remote sensing for evapotranspiration, agronomy, crop physiology and modelling, and precision irrigation, especially:

- The TSEB model will be applied from the pyTSEB code, which IPR belongs to Hector Nieto and collaborators (https://github.com/hectornieto/pyTSEB). However, the pyTSEB code is provided under the GNU General Public License version 3. Therefore, this program is free software and it could be redistributed and/or modified under the terms of the GNU General Public License and published by the Free Software Foundation, either version 3 of the License, or any later version.
- The Data Mining sharpening (DMS) approach will be applied from the pyDMS code, which belongs to Radoslaw Gusinzki and collaborators (https://github.com/radosuav/pyDMS). However, the pyDMS is also a free software and could be redistributed and/or modified under the terms of the GNU General Public License and Published by the Free Software Foundation, either version 3 of the License, or any later version.
- Time-series of ET products for the period 2017-2019 in the Ebro basin obtained with the TSEB model and using Sentinel 2 and Sentinel 3 imagery.
- Algorithms and methodology to calculate the Crop Water Stress Index (CWSI) and to estimate the leaf water potential in different woody crops by using high-resolution thermal imagery.
- Databases of actual evapotranspiration in an almond and apple orchard, measured from an eddy-covariance and a weighing lysimeters, respectively.
- Methodological knowledge in remote sensing and development of codes to automate the mosaicking and atmospheric corrections of high-resolution thermal and optical imagery.
- Crop simulation models to estimate actual evapotranspiration and to conduct irrigation prescriptions.
- Methodological knowledge in agronomy and irrigation, including:
    - Methodologies for conducting physiological measurements in crops (woody and annual).
    - Methodologies for measuring LAI and daily fraction of canopy intercepted radiation (fiPAR).
    - Methodologies for installing soil moisture sensors and validation of the volumetric soil water content.
    - Knowledge about the seasonal sensitivity of crops to water stress and its response to yield and fruit quality.
- All data, proprietary and non-proprietary software, methods, information and know-how not generated by direct participation in the project.

**Partner name : UNICA**

The partner UNICA has specific knowledge, skills and means in hydrology, especially:

- spatially distributed hydrologic modelling
- ecohydrological modelling for land surface and vegetation dynamic interactions
- methodological knowledge for evapotranspiration, energy balance, carbon assimilation monitoring using eddy covariance based micrometeorological towers
- methodological knowledge for water balance monitoring at multiple spatial scales
- Databases from previous contract research programs
- Databases from previous thesis work
- Methodological knowledge in remote sensing, surface hydrology, sub-surface hydrology, geophysics, bioclimatology
- Methodological and technical knowledge of observation systems, modelling systems, software engineering.
- All data, proprietary and non-proprietary software, methods, information and know-how not generated by direct participation in the project.

**Partner name : CNRSL**

The partner CNRSL has specific knowledge, skills and means in hydrology, environmental monitoring, land use change, especially:

- Quantitative hydrology and snow monitoring (Automatic snow weather stations) and snow web application to monitor snow cover using MODIS
- Land use and land cover mapping (production of very high resolution (VHR) land cover maps using VHR satellite imageries from GeoEye, Ikonos, Spot
- Hydrodynamic ecological modelling using General Lake Model
- Environmental monitoring and mapping using satellite imageries (water quality using Landsat and Sentinel, coastal bathymetry, wheat mapping using Sentinel, etc.)
- Soil erosion and land degradation estimation using FAO soil map and GIS

**Partner name : LARI**

The partner LARI has specific knowledge, skills and means in Irrigation and Agro-Meteorology , especially :

- Department of Irrigation and Agro-Meteorology (DIAM) of LARI has a main mission to provide plant water requirement overall Lebanon.
- Managing crop water requirement, the DIAM collects field information of soil characteristics, crop rotation, and climate data over the country. DIAM owns 60 Automated Weather Stations distributed over the Lebanese Territory. Climate data is manipulated for computing potential evapotranspiration, using crop modelling techniques.
- LARI holds laboratories of soil, chemical, fertilizers, water, food, oil, honeybee, heavy metals, etc. Departments are Irrigation & Agrometeorology, Plant Protection, Tissue Culture, Seed improvement, Seed Bank, Olive Dept. Mushroom, etc.

**Partner name : UCA**

The partner UCA has specific knowledge, skills and means in hydrological and crop functioning modelling and observations, especially :

- Micro-meteorological and physiological processes observations of plant functioning;
- Crop surfaces fluxes modelling
- Modeling of crop growth development and yield;
- Observations of snowpack and wadis streamflow;
- Drought modelling;
- Irrigation scheduling;
- Hydrological modelling of mountainous basin and groundwater dynamic;

**Partner name : INAT**

The partner INAT has specific knowledge, skills and means in remote sensing, hydrology, hydrogeology, Chemical pollutants monitoring, soil erosion and soil and water conservation works, climate variability, integrated water management and irrigation, especially:

- Hydrometeorological data analysis (e.g rainfall variability, hydrometric data)
- Hydrological modelling (e.g SWAT, GR4J, HEC-RAS, SWIM)
- Modelling erosion processes and evaluation of the impact of soil and water conservation measures on hydrological processes and sediment loads
- Monitoring and modelling hydrological fluxes and biogeochemical fluxes
- Databases from previous research programs

- Database from Merguellil observatory
- Methodological knowledge in remote sensing, irrigation, surface hydrology, sub-surface hydrology, erosion, hydrometeorology.
- Integrated water management modelling (WEAP)
- Remote sensing (image processing, physical modelling, data assimilation, multispectral analysis, etc)
- Methodological knowledge in watershed, including
    - methodologies for collecting and processing data on the functioning of watershed system
    - Stakeholder involvement and empowerment in water management

- Construction and modelling scenarios (Best Management Practices (BMP)) for water resources management.

**Partner name : INRGREF**

The partner INRGREF has specific knowledge, skills and means in agricultural water management in the Mediterranean environment, especially :

- In Hydrology observation and modelling
- In irrigation management
- The team has a long experience on field observations and modelling of soil water content, surface energy and water productivity
- In collaborative activities with stockholders.
- INRGREF is co-managing OMERE observatory and is co-directing LMI NAILA.
- All data, proprietary and non-proprietary software, methods, information and know-how not generated by direct participation in the project.

**Partner name : SUPCOM**

The partner SUPCOM (COSIM Lab) has specific knowledge, skills and means in stochastic modelling, deep learning, data and image processing and analysis. The main thematic applications by this knowledge concern environmental problematic related to water and soil. Particularly we can enumerate the following specific expertise:Stochastic spatial generator of weather conditions

- Validation of simulated stochastic data with respect to observations from hydrometeorological variables (including univariate, multivariate and spatio-temporal aspects)
- Data transforming spaces (Fourier, Mellin, Wavelet, PCA, DCT, ...) for adapting each set of data to an adapted model,
- Supervised and unsupervised Image classification
- Remote sensing data, both optical and SAR (Synthetic Aperture Radar), pre-processing and processing, including:
    - Spatial filtering, data calibration, geometric and atmospheric correction, registration and ortho-rectification.
    - Polarimetric SAR image analysis
    - InSAR technique exploitation for environmental (desertification, flooding, soil salinity, ...) parameters computation
- Remotely collection of in-situ data using IoT sensors,
- Wireless sensor network implementation, and management

**Partner name : CERTE**

The partner CERTE has specific knowledge, skills and means in water research, especially: the development and dissemination of science and water-related technologies. It is composed of a supporting research and 5 research laboratories space: Georesources, Processing of natural waters, Wastewater and Environment, Water Membrane and Environmental Biotechnology, and Treatment and Valorization of wastewater. The CERTE contributes to the main research themes are:

- Hydrogeology, hydrology, geochemistry and modelling of surface and subsurface waters;
- Study of artificial refilling of water tables;
- Characterization of Dam - aquifer transfers and upstream - downstream surface / subsurface transfers;
- Characterization and Mapping of Deep Reservoir aquifers;
- Follow - up and assessment of Dams and great hydraulic shells;
- Geographic information systems and decision-making tools;
- Investigation of interaction between waters, soil and water tables.

**Appendix 4: complete description of the project (proposal accepted for granting).**

| **Title of Proposal:** Managing water resources within Mediterranean agrosystems by **a**ccounting for spatia**l** s**t**ructures and c**o**nnectivitie**s**. |
|---|
| **Acronym:** ALTOS |

## List of participants[1]

| Participant No * | PI name | Organisation | Country |
|---|---|---|---|
| 1 **Coordinator** | Frederic Jacob | IRD / LISAH | France |
| 2 **Partner 1** | Gilles Boulet | IRD / CESBIO | France |
| 3 **Partner 2** | Hector Nieto | Agri-food research and technology (IRTA) | Spain |
| 4 **Partner 3** | Nicola Montaldo | Cagliari University (UNICA) | Italy |
| 5 **Partner 4** | Ali Fadel | CNRS-L | Lebanon |
| 6 **Partner 5** | Ihab Jomaa | LARI | Lebanon |
| 7 **Partner 6** | Said Khabba | UCAM / FSS | Morocco |
| 8 **Partner 7** | Jalel Aouissi | Carthage University / INAT | Tunisia |
| 9 **Partner 8** | Rim Zitouna-Chebbi | Carthage University / INRGREF | Tunisia |
| 10 **Partner 9** | Riadh Abdelfattah | Carthage University / SUPCOM | Tunisia |
| 11 **Partner 10** | Fethi Lachaal | Carthage University / CERTE | Tunisia |

## 1. Excellence

The ALTOS project relates to the PRIMA Call Section 2 – Multi-topics 2018, under the thematic area 1: "Sustainable water management for arid and semi-arid Mediterranean area". It addresses issues primarily within the Topic 1.1.1 "Water resources availability and quality within catchments and aquifers" and secondarily within the Topic 1.1.2 "Sustainable, integrated water management". It addresses the role of spatial structures and their connectivities in Mediterranean cultivated landscapes with regard to integrated water management. It covers rainfed and irrigated crops and develops tools for assessing sustainable development scenarios in the framework of the UN Agenda 2030. It focusses on water resources management in Mediterranean agrosystems to achieve the interlinked Sustainable Development Goals (SDGs) by water issues.

Adaptation of water and land management is essential in the Mediterranean basin, which is already facing overexploitation of water / soil resources (Garcia-Ruiz et al., 2011[2]) and will experience important hazards due to change in climate forcing (IPCC, 2014[3]). Meeting the growing demand for food and water requires rationales for designing innovative solutions in agricultural land use planning and practices, so that stakeholders (e.g., public authorities including water and agricultural managers, farmer or water user associations) can setup trade-offs between various needs at different levels (e.g., agriculture versus other uses, farmers versus farmers). In the context of rainfed and irrigated agriculture, innovative solutions must aim to better collect, store, distribute and use water resources,

[1] Compared to stage 1, we removed HSM partner, as requested by French ANR for financial eligibility.

[2] García-Ruiz et al., 2011. Mediterranean water resources in a global change scenario. Earth-Science Reviews, 105, 121-139.

[3] M. Allen et al., 2014. IPCC fifth assessment synthesis report - Climate Change 2014 synthesis report. Intergovernmental Panel on Climate Change (IPCC), November 2014.

in order to manage current situations and design possible evolution pathways (Revolve Water, 2017[4]). Over the last two decades, most studies focused on either agricultural field or water management territory (Trolard et al, 2016[5]). However, water resource managers are looking for decision support system (DSS) tools based on the modulation of spatial structures and connectivities induced by hydro-agricultural practices (e.g., land use, inter-cropping, irrigation techniques) and infrastructures (e.g., reservoirs like dams, benches). Some examples in Morocco, Tunisia, and Lebanon are (1) the modulation of land use and reservoir / bench densities at regional scale for driving upstream / downstream water repartition, or (2) the modulation of crop rotation and irrigation techniques within irrigated perimeters for optimizing root-zone soil moisture and percolation-based refill of underlying aquifers exploited for irrigation.

Existing integrated water management frameworks include, inter alia, (1) integrated modelling schemes to simulate evolution impacts in terms of matter fluxes, and (3) stakeholder knowledges to design possible evolutions and to quantify their impacts (Iglesias & Garrote, 2018[6]). These integrated frameworks do not explicitly account for spatial structures and connectivities in relation to hydro-agricultural practices and infrastructures. Meanwhile, several progresses were made the last decade when addressing spatial structures and connectivities, i.e., (1) in characterizing their geometries and hydro-dynamical properties (e.g., Lagacherie et al., 2010[7]; Shabou et al., 2015[8]), (2) in quantifying their influences on matter fluxes (e.g., Séraphin et al., 2016[9]; Inoubli et al., 2017[10]), (3) in including them into integrated modelling schemes and mechanistic models (e.g., Fabre et al., 2010[11]; Amado et al., 2018[12]), and (4) in taking them into account when setting up possible evolutions of territorial water governance (Al-Faraj and Scholz, 2015[13]; Woodhouse & Muller 2017[14]). Nowadays, it is necessary to sustain efforts on these progresses and to capitalize on recent advances, by (1) designing new monitoring and modelling tools, (2) integrating new models within integrated schemes, (3) simulating processes with calibration procedures devoted to integrated modelling schemes, and (4)

[4] Revolve Water, 2017. Water Around the Mediterranean 2017 report, in partnership with the Union for the Mediterranean.
[5] F. Trolard et al., 2016. The PRECOS framework: Measuring the impacts of the global changes on soils, water, agriculture on territories to better anticipate the future. Journal of Environmental Management, 181, 590-601.
[6] A. Iglesias & L. Garrote, 2018. Local and Collective Actions for Adaptation to Use Less Water for Agriculture in the Mediterranean Region. In: Water Scarcity and Sustainable Agriculture in Semiarid Environment, 73-84, Academic Press.
[7] P. Lagacherie et al., 2010. Geo-MHYDAS: A landscape discretization tool for distributed hydrological modelling of cultivated areas. Computers & Geosciences, 36, 1021-1032.
[8] M. Shabou et al., 2015. Soil clay content mapping using a time series of Landsat TM data in semi-arid lands. Remote Sensing, 7, 6059-6078.
[9] P. Séraphin et al., 2016. Partitioning groundwater recharge between rainfall infiltration and irrigation return flow using stable isotopes: The Crau aquifer. Journal of Hydrology, 542, 241-253.
[10] N. Inoubli et al., 2016. Soil cracking effects on hydrological and erosive processes: a study case in Mediterranean cultivated vertisols. Hydrological Processes, 30, 4154–4167.
[11] J. Fabre et al., 2010. OpenFLUID: a software environment for modelling fluxes in landscapes. In: proceedings of LANDMOD2010, Montpellier, France.
[12] A. Amado et al., 2018. Investigating Hydrologic Connectivity of a Drained Prairie Pothole Region Wetland Complex using a Fully Integrated, Physically-Based Model, Wetlands, 38, 233-245.
[13] F. Al-Faraj & M. Scholz, 2015. Impact of upstream anthropogenic river regulation on downstream water availability in transboundary river watersheds. International Journal of Water Resources Development, 31, 28-49.
[14] P. Woodhouse & M. Muller, 2017. Water Governance - An Historical Perspective on Current Debates. World Development, 92, 225-241.

analysing the impacts of modulation scenarios on matter fluxes and storages, in the light of convergent / divergent stakeholder viewpoints.

The building of the above-discussed innovative means, their implementation in different physiographic or socio-economic conditions, and their co-construction with different stakeholders in rural catchments around the Mediterranean Basin, are likely to lead to a sustainable water and soil management as part of the implementation of SDGs. Indeed, these means will be helpful when rationalizing land development (e.g., land use, infrastructure setup for water harvesting and distribution) and farmer practices (e.g., crop location/rotation, irrigation techniques), for the benefit of water resources sustainability and related stakeholder activities.

## 1.1 Objectives

### 1.1.1. Overall objective

ALTOS overall objective is to improve water management models for rainfed and irrigated agriculture, by considering the modulation of spatial structures and connectivities induced by hydro-agricultural infrastructures and practices, as an innovative tool for rational use / protection of water resources.

- We address the modulation of structures related to (1) hydro-agricultural practices (land use, heterogeneous canopies such as inter-cropping and orchards, irrigation techniques) and (2) infrastructures (water-harvesting systems such as benches and reservoirs).
- Along with spatial structures, we consider connectivities through water fluxes, including (1) surface connectivities related to surface runoff, and (2) subsurface connectivities related to infiltration and percolation.
- We assess the impacts of spatial structure modulation on first-order matter fluxes and storages, including (1) blue water compartments for artificial and natural storages (depletion and recharge for reservoirs and aquifers), and (2) green water compartments for dependent agro-ecosystems (root zone water dynamics and related agricultural production).
- In a lesser extent, we study the modulation of farming inputs related to chemical treatments, and the resulting impacts on the water resources stored within surface reservoirs and aquifers.

To reach the above-discussed main goal, ALTOS considers two spatial scales and two temporal scales. The two spatial scales are:

- the agricultural catchment (tenths to hundreds of square-kilometres) related to water management;
- the sub-hectometric resolution related to agricultural practices.

The two temporal time scales are:

- the multi-decadal period to simulate possible evolutions on the basis of observed trends;
- the sub-hourly to daily period relevant to compute the dynamics of water fluxes at the field scale.

### 1.1.2. Specific objectives

To achieve the overall goal discussed above, ALTOS analyses the impacts of modulation scenarios on matter fluxes and storages. Therefore, the ALTOS project aims to pursue and achieve the following specific objectives.

- Designing innovative methodologies for monitoring, characterizing and digitally representing spatial structures and connectivities, as well as designing innovative methodologies for monitoring and understanding water flows and storages driven by spatial structures and connectivities.
- Modelling water flows and storages driven by spatial structures and connectivities. The goal is to (1) design innovative models that simulate matter fluxes and storages, with implicit descriptions through equivalent parameterizations, (2) include these innovative models within integrated modelling schemes, and (3) conduct model calibrations / validations using historical time series.
- Emphasizing the interest of updated modelling schemes by (1) designing modulations for spatial structures and connectivities, to be combined with changes in climate forcing, and (2) quantifying the resulting impacts on matter fluxes and storages within targeted compartments (blue and green water), on the basis of simulations from calibrated models.
- Quantifying benefits for water management by analysing scenario impacts with stakeholder having convergent / divergent viewpoints (water management authorities, agricultural development commissions, farmer associations within rainfed catchments and irrigated perimeters).

## 1.2 Relation to call and topic

The relations to topics 1.1.1 (primary level) and 1.1.2 (secondary level) are listed in Table 1.1.

Table 1.1: Relation with work program (ALTOS replies to bolded terms).

| Call Section 2 / Topic 1.1.1. | The ALTOS proposal |
|---|---|
| Challenge | |
| **The challenges now faced by water planners require a new generation of water management models that addresses the broad impacts of global changes on hydrological and hydraulic balance at catchment and aquifer level.** | • Improving water management models for rainfed / irrigated agriculture, by designing innovative solutions in agricultural practices and land use planning.<br>• Relying on historical and current collaborations with stakeholders to design modulations and analyse resulting impacts. |
| **Innovative options and technologies are required to ensure availability of groundwater resources for future generations and in particular to deal with storage and overexploitation, groundwater- dependent ecosystems,** seawater intrusion and salinization, **anthropogenic** and geogenic **contamination of the whole water cycle, and long-term sustainability.** | • Improving monitoring methodologies and numerical representations of spatial structures and connectivities, using recent sensors / data, such as Sentinel / Copernicus.<br>• Developing new process models to simulate matter fluxes driven by spatial structures and connectivities, and including them into existing integrated modelling schemes.<br>• Introducing water agricultural contamination for irrigated and rainfed crops into integrated management. |

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| **On the other hand, surface water bodies in the Mediterranean regions are characterized by intermittent streams. The lack of surface water during long periods of time constitutes a challenge to characterize their hydrological regime** and the geomorphological and ecological status**.** | • Addressing rainfed agriculture with water harvesting, and irrigated perimeters with groundwater abstraction.<br>• Using existing long-term observatories to include intermittent phenomena (low flows, flash-floods, droughts).<br>• Designing innovative methodologies for monitoring and understanding water flows and storages in intermittent streams and highly variable storages. |
| Scope | |
| **Quantitative analyses on ecosystem services require an in-depth understanding of their underlying processes. To meet this need, it is important not only to use adequate modelling methods, but also to apply effective monitoring tools and research on new methodologies to understand biogeochemical cycles. Particularly important is the development and demonstration of effective monitoring and modelling tools to gather appropriate data and provide forecasting capabilities** across the freshwater to marine salinity gradients**.** | • Proposing innovative monitoring methods using in-situ and remote sensing data.<br>• Analysing pluriannual time series provided by observatories, complementing historical data with punctual measurements.<br>• Proposing equivalent parameterizations based on parsimony for complex structures.<br>• Using time series to calibrate dedicated models (surface / subsurface hydrology, SVAT, crop functioning).<br>• Designing structure modulations and quantifying impacts on water storages and dependent agro-ecosystems. |
| **Developing efficient simulation models is necessary to analyse future scenarios at the spatial scales to be used for natural resource planning and management, and to identify cost- effective strategies and techniques for a rational use of water** and protection of land and soil**.** | • Improving integrated modelling schemes already mastered by the teams.<br>• Simulation-based assessment of structure modulation impacts to provide rationales in land use and practices.<br>• Identifying spatial structure modulations to increase the matching between water availability and needs.<br>• Evaluating innovative solutions at spatial scale ranging from field to catchment. |
| **There is a need for developing early-warning systems to detect potential pollution transport through the soils and deep vadose zone to groundwater**. This research should provide the needed information to support decisions on remediation strategies. | • Producing pesticides content data in a context of poor knowledge to (1) update recommendations to farmers for attenuating risks, and (2) provide knowledge to water resource managers for elaborating early warning systems.<br>• Monitoring and modelling pesticide transport, degradation and / or accumulation in the |

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| | vadose zone and groundwater. |
| **For surface water studies, new methods should be developed to characterise the hydro-geomorphological** and ecological **status** and degree of human affection **on ephemeral rivers. The methodology will address the hydrological regime, water and sediment connectivity, geomorphological conditions of river channels and river corridors,** biogeochemical functions and the spatial structure of the plant and animal communities**. In addition, in the semi-arid regions of the Mediterranean basins, floods are** not only natural hazards but also **renewable water resources.** | • Using methodological tools for the digital representation of spatial structures within catchments (e.g., Geo-MHYDAS [7]).<br>• Using integrated modelling platforms that account for connectivities (e.g., OpenFLUID).<br>• Addressing hydrological cycle components beyond runoff and rainfall: evapotranspiration, infiltration, reservoir / aquifer refills.<br>• Study areas typified by harvesting of renewable water resource (upstream production / downstream use). |
| **There is a need to understand the hydrological processes for the assessment, management and use of floodwaters. Proposals within this topic should allow to quantify a) the processes controlling this recharge, b) long-term recharge quantities (decade to multi-decadal scales) that determine the sustainability of these water resources and c) to translate these results into specific management strategies for alluvial aquifers of ephemeral rivers in Mediterranean regions.** | • Addressing rainfed agriculture with water harvesting techniques, and irrigated perimeters with groundwater use.<br>• Relying on long-term observatories to validate aquifer recharge modelling.<br>• Improving evapotranspiration estimates for better constraining water budget.<br>• Modulating spatial structures → resulting impacts on water storages & dependent agro-ecosystems yield.<br>• Relying on historical collaborations with stakeholders to design modulations and to analyse resulting impacts. |
| Call Section 2 / Topic 1.1.2. | The ALTOS proposal |
| Challenge | |
| **Water sustainability in the Mediterranean region should be ensured by improved technical tools** coupled with socio-economic studies able **to improve the efficiency of water** and energy **use in certain key regions under present and future global change scenarios. In this sense, recognizing the water-energy-food synergies** and balancing the potential trade-offs between water and energy use efficiency **is required.** | • Improving rainfed and irrigated water use by combining structure modulations and changes in climate forcing.<br>• Analysing impacts in the light of different user needs: storage of blue water in aquifers and reservoirs for irrigation and domestic uses, storage of green water within root-zone for agricultural production.<br>• Involving several stakeholders in multi-criteria assessment of scenarios. |
| Scope | |
| **A sustainable water management is crucial in the Mediterranean basin for ensuring efficient** | • Relying on close interactions with national, regional and local stakeholders (water |

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| **multiple water use in irrigation,** animal production systems, **drinking and industrial activities,** as well as the preservation of natural ecosystems**. This requires efficient governance at different levels: watersheds, districts, national. This call intends to improve water governance taking into consideration** both the socio- economic context and **the meteo-climatic trends of the Mediterranean basin, since both of them are considered as important drivers of current and future water resources management.** | management authorities, agricultural development commissions, water user associations), when (1) setting modulations for land use and practices, and (2) quantifying resulting impacts.<br>• Addressing water governance territories with infrastructures devoted to water harvesting / distribution. Providing stakeholders with decision support tools, to design infrastructure networks and anticipate degradations.<br>• Accounting for future changes in climate forcing when assessing impacts of land use changes. |
| **The development of innovative governance strategies, advanced planning methodologies,** appropriate and sustainable treatment technologies **and monitoring tools has to take into account the huge number of physical, technological and socio-economic variables in water management in order to address the ever-growing need for water and food. This implies the use of technologies and tools for water accounting systems, including new remote sensing capacities coupled with governance allocation structures** based on socio- economic rules for setting the limits for water and energy consumption**.** | • Valorising as far as possible remote sensing data for surface characterization.<br>• Improving monitoring methodologies by using recent spaceborne / airborne imagery, and innovative numerical representations for structures and connectivities.<br>• Relying on existing sites and observatories on which significant knowledge is already available regarding water issues.<br>• Evaluating the potential of modulating spatial structures, where (1) such modulations are an action lever for stakeholders, and (2) scenarios rely on former socio-economic studies with participative seminars.<br>• Setting structure modulations, and quantifying impacts on water storages and dependent agro-ecosystems. |

## 1.3. Concept and methodology

### (a) Concept

The modulation of spatial structures and connectivities, related to hydro-agricultural infrastructures and practices, has been long recognized as a promising lever by water resource managers and think-tanks (e.g., IAASTD, 2009[15]), because of its influence on matter fluxes and storages within agro-ecosystem compartments (e.g., root-zone, aquifers, reservoirs). However, this topic has received moderate attention due to the limited capacities of monitoring and modelling tools when analysing the impacts of modulation scenarios on matter fluxes and storages at both sub-hectometric resolution and

[15] International Assessment of Agricultural Knowledge, Science and Technology for Development, 2009. Agriculture at a Crossroads: Synthesis Report. Island Press, Washington, D.C. (2009).

catchment extent. Indeed, **several methodological challenges have to be tackled**, in relation to the specific objectives mentioned in Section 1.1.

- Innovative methodologies, devoted to the characterisation of spatial structures and connectivities, must be able to (1) process information provided by new sensing systems (e.g., photogrammetry, very high resolution spaceborne imagery), and (2) process geo-spatial information for digital representation (e.g., space discretisation including linear / areal / bulk elements, oriented topology for characterizing connectivities).
- Innovative monitoring tools, devoted to the characterisation of 2D- and 3D- fluxes driven by spatial structures and connectivities, should make most of complementary measurements. This is possible thanks to 30 years of (1) long-term observatories dedicated to integrated processes and (2) short-term observation campaigns dedicated to specific processes.
- Innovative models, that are devoted to simulating individual processes (e.g., evapotranspiration), and that are designed for inclusion into integrated modelling schemes (e.g., hydrological cycle), must (1) permit to describe complex spatial structures, (2) rely on a limited number of parameters, and (3) be generic enough to embrace a variety of conditions for the targeted processes.
- The inclusion of innovative modelling tools within integrated schemes requires paying attention to (1) the coupling variables between different process models, and (2) the setting up of irregular spatial grids / time steps.
- Calibrating model against existing datasets, for simulating fluxes and storages, requires setting procedures (1) with low density data as compared to model requirements, especially on southern and eastern shores of the Mediterranean Basin, and (2) for an ensemble of processes rather for individual processes thanks to integrated schemes, by using multi-objectives / multi-criteria procedures based on multi-local / nested measurements.
- Modulating first-order spatial structures and connectivities implies (1) addressing possible evolutions, by proposing realistic modulations for given structures (e.g., land use, benches), and (2) flagging new levers that are out of manager strategies, by evaluating exploratory modulations for a panel of spatial structures (e.g., reservoirs, land use).
- Quantifying benefits for sustainable water management implies (1) selecting acceptable modulations in view of simulated impacts through participative seminars, on the basis of trade-off between convergent / divergent stakeholder viewpoints, and (2) highlighting possible action levers that involve land use planning and farming practices (e.g., crop rotation and irrigation).

Thus, the modulation of spatial structures and connectivities is considered as a promising lever when rationalizing land development and farmer practices for the benefit of sustainable water resources within Mediterranean agrosystems, but it is also considered a development issue that raises several scientific challenges within different scientific disciplines (remote sensing, hydrology, plant agronomy, farm agronomy, resource management), through the design and implementation of methodologies for monitoring, modelling and integrated analysis. For integrated analysis, we rely on multiple actor approaches via participative seminars that involved several stakeholders (i.e., national and regional authorities for water management and agricultural development, farmer and water used associations) to design possible scenarios of spatial structure modulation (i.e., land use patterns, reservoir and bench networks) and next select acceptable scenarios on the basis of simulation-based impact assessment.

| Table 1.2: TRL for key activities with the ALTOS proposal. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Activities ↓ | TRL 1 | TRL 2 | TRL 3 | TRL 4 | TRL 5 | TRL 6 | TRL 7 | TRL 8 | TRL 9 |
| Innovative monitoring tools | | | | | | | | | |
| Innovative modelling tools | | | | | | | | | |
| Integrated modelling schemes | | | | | | | | | |
| Calibrated modelling tools / schemes | | | | | | | | | |
| Design of spatial structure modulation | | | | | | | | | |
| Simulated impacts of structure modulation | | | | | | | | | |
| Stakeholder concertation | | | | | | | | | |
| TRL nomenclature → | Research lab | | | | Simulations | | | Reality | |

The ALTOS project aims to improve water management models for rainfed and irrigated Mediterranean agrosystems, by considering the modulation of spatial structures and connectivities induced by hydro-agricultural infrastructures and practices. It provides methodological innovations for characterizing spatial structures and connectivities, methodological innovations for monitoring and modelling matter fluxes and storages, as well as new insights for designing management methods for water resources. **In terms of Technology readiness levels (TRL)**, ALTOS outcomes range from TRL 1 (basic principles observed and reported) to TRL 4 (lab technology validated), as detailed in Table 1.2.

The ALTOS project **mobilises a large panel of existing materials and partnerships for both research** (e.g., datasets, modelling schemes, integrated analysis with participative seminars), **and impact** (collaboration with water management authorities and engineering offices through community facilities such as observatories, joint laboratories, and modelling platforms). Table 1.3 below details the several past, recent and on-going initiatives on which relies ALTOS, by differentiating between long terms institutional programs (labelled LTI, lasting between 10 and 25 years) and medium-term contractual projects (labelled MTC, lasting between 3 and 5 years).

| Table 1.3 (to be continued): research and innovation initiatives whose outputs feed into ALTOS proposal. Letters between parenthesis (M: Morocco, T: Tunisia, L: Lebanon, F: France; S: Spain, I: Italy) indicate the country where any initiative take place (study area, numerical infrastructures or mobilities). We also indicate initiative durations for on-going ones. | | | |
|---|---|---|---|
| Initiative | LTI / MTC | Past / Current | Contribution to the ALTOS Proposal |
| Merguellil observatory (T, 2000 →) | LTI | C | Datasets about functioning / evolution of agrosystems and related water / soil resources at the catchment extent, including quantitative and qualitative observations. |
| OMERE observatory (T, 2002 →) | | C | |
| Tensift observatory (M, 2002 →) | | C | |
| O-LIFE observatory / LIA (L, 2014 - 2023) | | C | Datasets of farmer practices and underground water resources, including |

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| | | | quantitative and qualitative observations. |
| LMI TREMA<br>(M, 2012 - 2021) | | C | Monitoring and modelling tools for structures (e.g., pedological units), functioning (e.g., hydrological cycle) and evolutions (e.g., scenarios about anthropogenic and climate forcing). Collaborative structures including end-use committee. |
| LMI NAILA<br>(T, 2016-2025) | | C | |
| OpenFLUID project<br>(F, 2010 →) | | C | Software platform for modelling and simulation of landscapes functioning. Collaborative structure including end-use committee. |
| MISTRALS SICMED (M, T) | MTC | P | Monitoring and modelling tools for structures and functioning. |
| ANR DIGISOL-HYMED (T) | | P | Remote sensing methods for mapping soil properties. |
| EU RISE REC (M, F) | | P | Multi-sensor methods for monitoring soil moisture. |
| ANR AMETHYST<br>(M + T, 2014 - 2018) | | P | Integrated analysis: coevolutions of water uses and resources. |
| FP7-AFRICA-2010 EAU4Food<br>(M + T, 2011-2015). | | | Participative seminars about practices for increasing irrigated farming food production. |
| ANR ALMIRA<br>(M + T, 2014 - 2018) | | C | Integrated analysis: impacts of land use changes on yield & hydro-erosive fluxes. |
| AFB Projects<br>(F, 2016 - 2019) | | C | Methodologies for modelling hydrological and agronomical impacts of small reservoirs. |
| ARIMNet 2 MASCC<br>(M + T, 2016 - 2019) | | C | Integrated analysis: impacts of land use changes and agricultural practices on hydro-erosive fluxes. |
| SAGESSE<br>(M, 2016-2019) | | C | Design of decision support systems for water resource management. |
| Irrig-Bekaa<br>(L, 2016-2019) | | C | Methods for quantifying water use by irrigated crops. |
| CNES / THEIA Sentinel-2<br>(T, 2016 - 2020) | | C | Availability of Sentinel-2 data over Tunisia once pre-processed by French Space Agency. |
| MISTRALS HighLandDEM<br>(T, 2017 - 2018) | | C | Methodologies for producing high spatial resolution DEM. |
| H2020 VISCA<br>(S, 2017- 2019) | | C | Modelling vineyards phenological trend under climate change. |
| IFD MOIST<br>(I, 2017 - 2019) | | C | Monitoring crop water stress for water use management. |
| RIS3CAT LISA<br>(S, 2017 - 2020) | | C | Low input agricultural management basis on remote sensing and in-situ sensors. |

| | | | |
|---|---|---|---|
| ESA SEN-ET<br>(S, 2017 - 2020) | | C | Evapotranspiration monitoring with Sentinel imagery. |
| ARIMNet 2 VIANA<br>(T + L, 2018 - 2020) | | C | Land use related to adoption of agroecological solutions for small irrigated farming. |
| ERANET-MED CHAAMS<br>(T + M + L, 2019 - 2021) | | C | Past & current trends on land use & water governance. Process model calibration. |
| GMES - North Africa<br>(M + T, 2019 - 2021) | | C | Technology transfer towards engineering offices and national directorates for monitoring of agrosystems & water resources. |
| EU H2020 RISE ACCWA<br>(M + T, 2019 - 2022) | | C | Multi-sensor methods for monitoring soil moisture and evapotranspiration. |

The ALTOS project benefits from long-term institutional programs such as environmental research observatories, international joint laboratories, and modelling platforms, so called hereafter community facilities.

- The OMERE[16], Tensift, Merguellil and O-LIFE environmental research observatories are dedicated to the multi-decadal monitoring of water resources under climate / anthropogenic changes, including the gathering, processing and dissemination of data by following EU standards (e.g., INSPIRE). These observatories are included in either national networks (French IRD and CNRS for Tensift, OMERE and O-LIFE), EU networks (OMERE within the eLTER H2020 project), or international networks (JECAM for Merguellil and Tensift). Some of them have been operating for almost 25 years, thus providing unprecedented times series for the monitoring and modelling of matter fluxes.
- The IRD TREMA[17] & NAILA joint international laboratories (French label is LMI) and the CNRS O-LIFE associated laboratory (French label is LIA) are international collaborative structures that aim to gather complementary competences towards common objectives for research, training and knowledge transfer. These international laboratories address the functioning and fate of Mediterranean agrosystems in relation to soil and water resources, by designing innovative means for monitoring, modelling and integrated analysis. Beyond the structuring of national teams, LMI and LIA also aim to contribute to the structuring of the Research & Innovation Mediterranean community, by participating to international programs devoted to research (e.g., MISTRALS) or to environmental monitoring (e.g., GMES Africa). TREMA, NAILA, and O-LIFE are supported by research institutions / ministries from Morocco, Tunisia, Lebanon and France through minimal institutional budgets and competitive calls, and it is expected that these international laboratories become Mediterranean research centres. For instance, TREMA is involved in a matured national project of centre for renewable resource management that aims to develop international collaborations, especially with Africa. Then, TREMA will be a pillar of this centre, contributing for agricultural and integrated water management.

[16] J. Molénat et al., 2018. OMERE, a long-term observatory of soil and water resources, in interaction with agricultural and land management in Mediterranean hilly catchments. Vadoze Zone Journal, in press.

[17] L. Jarlan et al., 2015. Remote sensing of water resources in semi-arid Mediterranean areas: the joint international laboratory TREMA. International Journal of Remote Sensing, 36, 4879-4917.

- The OpenFLUID[18] project aims to develop and disseminate a software platform that provides a fully featured environment for spatial modelling of landscapes dynamics. The platform is based on a modular structure, which permits to implement modelling and simulation approaches from model development to executions and simulation analyses. The platform also permits to account for spatial connectivities thanks to graph theory, and to manage various spatial and times scales during simulations. The platform is also a collaborative tool for sharing models and data, as well as for building multidisciplinary coupled models. The GPL-licensed OpenFLUID platform has been identified as a major instrument by the French National Institute for Agricultural Research, and it has been transferred to private engineering offices for consulting activities.

Table 1.4: community facilities and involved partners on a country basis.

| Country | Community facilities | | Study sites | ALTOS partners |
|---|---|---|---|---|
| **Morocco** | LMI TREMA | Tensift observatory | Tensift | UCAM, CESBIO |
| **Tunisia** | LMI NAILA | OMERE observatory | Cap Bon | INRGREF, INAT, CERTE, SUPCOM, LISAH, CESBIO |
| | | Merguellil observatory | Merguellil | |
| **Lebanon** | O-LIFE observatory / LIA | | Litani | LARI, CNRS-L, CESBIO |
| **France** | OpenFLUID | | None - modelling platform | LISAH, INRGREF |

Amongst their institutional missions, the three above-discussed community facilities are in charge of disseminating activity outcomes (data, methods and knowledges) to academic and professional sectors. These outcomes are available in accordance to dissemination policies (e.g. observatory data policy to be discussed in section 2, GPL-licensed products for modelling platforms). These community facilities are overviewed in Table 1.4. on a country basis, along with the involved ALTOS partners and the study sites presented just after.

Within the framework of these community facilities developed from bilateral cooperation programmes between France and Morocco, Tunisia or Lebanon, many researchers from Mediterranean countries have contributed to the work as co-financed projects or on a personal basis. IRTA (Spain) and UNICA (Italy) have already made significant contributions. Having developed observatories and experimental fields on the same themes on the northern shore of the Mediterranean, they bring new data, methodological developments and models. They also provide training capacities and hosting capabilities for increasing mobility between the ALTOS community.

**(b) Methodology**

**The ALTOS project relies on two panels of study sites**, including (1) four study sites for integrated analysis about evolutions and impacts, as well as (2) two study sites for methodological developments. Articulation between both aims to provide methodological developments, to be included within modelling tools devoted to integrated analysis.

[18] Jean-Christophe Fabre et al., 2013. OpenFLUID: an open-source software environment for modelling fluxes in landscapes. *EGU General Assembly Conference Abstracts*. Vol. 15.

- For integrated analysis on evolutions and impacts, the four study sites depict relevant and complementary features to address the challenges discussed in Section 1.3.a (Table 1.5).
  - As a whole within the Mediterranean Basin, they depict a climate gradient, the main soils, the traditional and modern agricultures, and the main landscaping features for resource management.
  - They are typified by large diversities in rainfed and irrigated crops, and by agricultural conversions either locally driven (e.g., from grain to cash crops or reversely depending upon access to water), or regionally / nationally driven (e.g., public policies for extension of specific crops).
  - They are water governance territories typified by infrastructures devoted to water harvesting / distribution (Figure 1.1). The two Tunisian sites include rainfed crops within hilly upstream / irrigated crops within downstream plain, with an infill dam between. The Moroccan and Lebanese sites include small farming within mountainous upstream / irrigated crops within downstream plain. Local managers are looking for decision support tools to design infrastructures and to anticipate their degradations.

  These four study sites are part of long-term monitoring systems (Table 1.3 and 1.4), with subsequent availability of datasets about socioeconomic and biophysical processes that permit to conduct integrated analysis. They are also part of long-term collaborations between some of the ALTOS partners, since they are included within the aforementioned community facilities. Thus, data are collected, processed and disseminated in accordance to EU standards (e.g., INSPIRE nomenclature, geospatial databases).

- For methodological developments, the two study sites we select undergo innovative experiments related to ALTOS challenges such as water flows driven by heterogeneous media and agricultural practices, with expected impacts on hydrological flux modelling and water saving techniques. In Spain, managers are seeking decision support tools to design water supply systems focused on drip irrigation, as well as forecast tools for water allocation within catchments and irrigation districts. In Italy, managers are seeking knowledge on rangelands functioning and fate.

| Table 1.5 (to be continued): study areas and specificities related to ALTOS challenges.<br>Cap Bon study site includes upstream Lebna catchment and downstream Korba plain.<br>Tensift study area includes upstream Rheraya catchment and downstream Haouz plain. | | | | | | |
|---|---|---|---|---|---|---|
| | Study sites for integrated analysis: catchments as governance territories<br>(UP stands for upstream part, DW stands for downstream part). | | | | Study sites for methodological developments. | |
| | Merguellil, Centre-Eastern Tunisia. | Cap Bon, North-Eastern Tunisia. | Tensift, Central Morocco. | Litani, Eastern Lebanon. | Segre, Catalonia, Spain. | Orroli, Sardinia, Italy. |
| Climate | Semi-arid. | Sub-humid / Semi-arid. | | | Semi-arid. | |
| Soils | UP: immature, calcimagnesic & isohumic soils.<br>DW: sandy / silty-clay soils. | UP: regosols / vertisol with sandstone / marls outcrops.<br>DW: calcisols on Tyrrhenian deposits | UP: shallow mineral soils.<br>DW: loamy soils on alluvial deposits. | Thick / heavy soil sequence. | Calcisols with deep horizons. | Thin soils, silt loam. |
| Main vegetation covers | UP: mixed crops mosaic, olive trees orchards, forest, rangelands.<br>DW: cereals, orchards, gardening. | | UP & DW: cereals, orchards.<br>DW: olive trees. | Irrigated summer crops, fruit trees. | Orchards and vineyards. | Pastures (grass and wild olives) |

| Table 1.5 (continued): study areas and specificities related to ALTOS challenges.<br>Cap Bon study site includes upstream Lebna catchment and downstream Korba plain.<br>Tensift study area includes upstream Rheraya catchment and downstream Haouz plain. | | | | | | |
|---|---|---|---|---|---|---|
| | Study sites for integrated analysis: catchments as governance territories (UP stands for upstream part, DW stands for downstream part). | | | | Study sites for methodological developments. | |
| | Merguellil, Centre-Eastern Tunisia. | Cap Bon, North-Eastern Tunisia. | Tensift, Central Morocco. | Litani, Eastern Lebanon. | Segre, Catalonia, Spain. | Orroli, Sardinia, Italy. |
| Water supply & Infra-structures | Mainly rainfed on upstream and irrigated on downstream. | | | Rainfed / irrigated. | Rainfed / irrigated. | Rainfed. |
| | Infill dam.<br>Hilly upstream with network of surface reservoirs such as small dams.<br>Downstream irrigation networks and private groundwater drillings. | | UP: river-based irrigation, surface reservoirs such as small dams.<br>DW: Surface reservoirs, river irrigation, groundwater drillings. | River irrigation channels, groundwater drillings. | Irrigation channels branched out from river / surface reservoirs. | Surface reservoirs such as dams. |
| Hydrological regime | Upstream wadies, branched out network with tributaries, aquifer refills by reservoirs & irrigation. | | Upstream surface run-off and infiltration with of sub-surface flows towards downstream aquifer. | Limited surface water.<br>Private drilling for groundwater pumping. | Lower Ebro basin: mostly water inflow from snowmelt. | Winter rain harvested in large dams for domestic use. |
| | Reservoir drying, cracked aquifer under infill dam. | No dryness, porous aquifer under infill dam. | | | | |

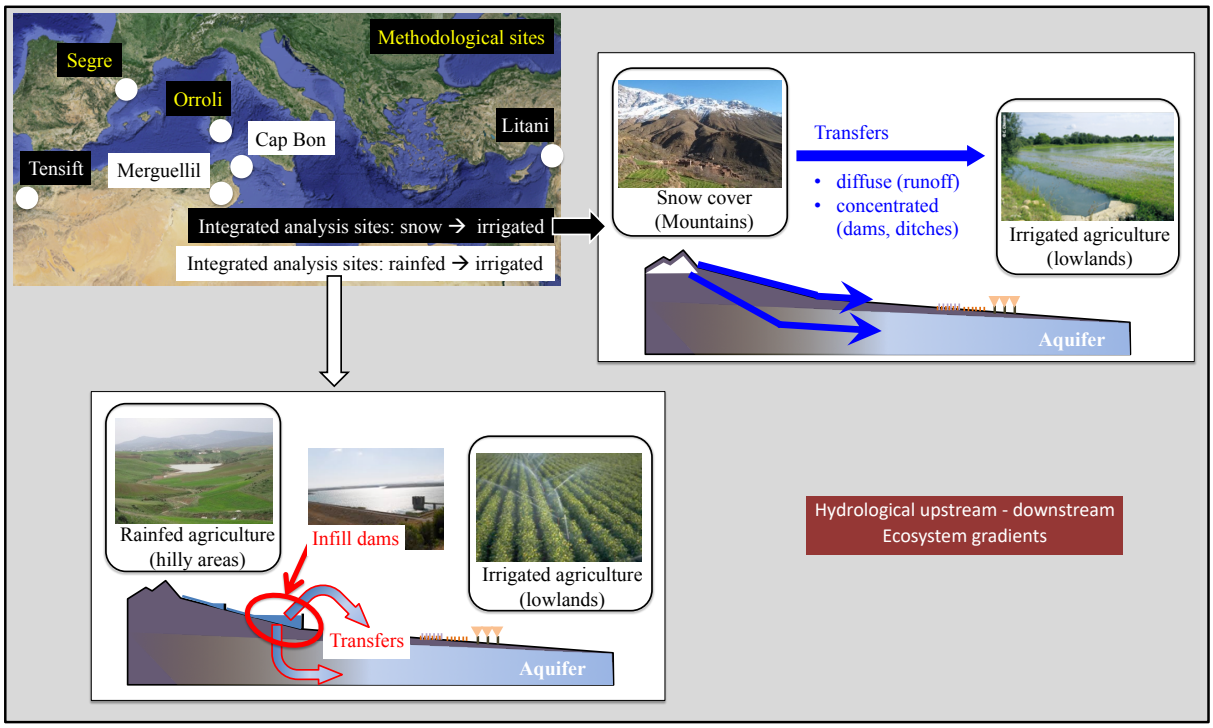


Figure 1.1: main features of the study sites (two study sites for methodological developments, four study sites for integrated analysis for integrated analysis). For integrated analysis sites, Cap Bon and Merguellil (respectively Tensift and Litani) sites are typified by upstream rainfed agriculture and downstream irrigated agriculture (respectively upstream snowed and downstream irrigated agriculture).

In relation to the features of the study sites above-discussed, **the ALTOS project addresses a panel of spatial structures to be modulated and of resulting impacts to be quantified.**

- The spatial structures of interest at local- and landscape- scales are
  - natural structures related to vegetation (canopy geometry), soils (depth / horizons / properties such as infiltrability), water resources (aquifer geometries) and climate (spatial organisation of climatic forcing), as well as
  - anthropogenic structures such as landscaping structures and agricultural practices (reservoir geometries, field delineations, land cover patterns).

- The hydrological connectivities of interest are (1) surface connections related to gravity-driven water flows, which corresponds to hydrologically conditioned topography, and (2) subsurface connections such as hydrological pathways between surface elements (e.g., reservoirs, root-zone) and underlying aquifers.

- The matter fluxes and storages to be considered include water fluxes (evapotranspiration and crop growth, soil & root zone moisture, reservoir - aquifer transfers, mountains - lowland surface / subsurface transfers), as well as chemical fluxes related to pest management. In a lesser extent, we address decrease in dam storage capacity by silting.

By addressing this panel of spatial structures to be modulated and of resulting impacts to be quantified, **the ALTOS project investigates several methodological innovations**.

- When characterising spatial structures (WP1), innovative methodologies rely on (1) the joint use of complementary observations with high spatiotemporal resolutions, either within one discipline (e.g., use of several satellite data over different spectral domain to characterize soil surface characteristics) or across several disciplines (e.g, use of electromagnetic sounding and isotopic tracing to characterize aquifer geometry; use of satellite data and agronomic field surveys to characterize land use and crop location / rotation), and (2) the use of data 3D processing methods (radiative transfer, photogrammetry). For numerical representations of hydrological connectivities (WP1), innovative methodologies rely on typology-based segmentations, as well as on deep learning-based processing of multisource information.

- To characterize matter fluxes and storages (WP2), methodological innovations involve the joint use of complementary observations with high spatiotemporal resolutions, across several disciplines (e.g, use of isotopic tracing, remote sensing, thermodynamics and micrometeorology to characterize evapotranspiration within row multistate canopy; use of agronomic surveys & chemical analysis to characterize pollutant transports and retention). Also, cognitive works aim to understand fluxes and storages under conditions of spatial heterogeneities induced by (1) row and multi-strata canopies at the local scale, and (2) soil, topography and vegetation pattern at the landscape scale.

- To model matter fluxes and storages (WP3), the ALTOS project addresses key improvements, including (1) individual processes such as evapotranspiration, vegetation growth, water balance within compartments (e.g., field root zone, reservoirs), and (2) combined processes such as catchment hydrological cycle and crop functioning. This relies on making the most of data obtained from innovative methodologies in WP1 and WP2, including distributed and nested in-situ / remote sensing measurements, to be combined with existing long-term time series.
  - For individual processes, innovations consist of developing parsimonious parameterizations for exchange coefficients of water flows within heterogeneous media, including (1) subsurface water exchanges within heterogeneous rooting systems or under drip-irrigated orchards, (2) surface - atmosphere exchanges for heterogeneous / multi-strata crops and hilly catchment crops, and (3) surface - aquifer exchanges below reservoirs in relation to hydraulic lift and watertable level.
  - For combined processes, innovations consist of including new parameterizations for individual processes within integrated modelling schemes, with attention to the coupling variables and to the articulation of different spatial grids / time steps. For this, we rely on several integrated modelling schemes (i.e., SAMIR-WEAP-MODFLOW[19], SAFRAN-ISBA-MODCOU[20], SWAT[21]) or to a dedicated modelling platform (i.e., OpenFLUID) for coupling distributed hydrological

[19] L. Jarlan et al., 2015. Remote sensing of water resources in semi-arid Mediterranean areas: the joint international laboratory TREMA. International Journal of Remote Sensing, 36, 4879-4917.

[20] T. Paris Anguela et al., 2008. Analysis of surface and root-zone soil moisture dynamics with ERS scatterometer and the hydrometeorological model SAFRAN-ISBA-MODCOU at Grand Morin watershed (France). Hydrology and Earth System Sciences, 12, 1415-1424.

[21] J. Aouissi et al., 2018. Valuing scarce observation of rainfall variability with flexible semi-distributed hydrological modelling–Mountainous Mediterranean context. Science of The Total Environment, 643, 346-356.

modelling (i.e., MHYDAS[22]) and crop growth modelling (i.e. SAFYE[23]). All these integrated modelling schemes are already implemented and mastered by the teams, which allows a quick move towards innovative tasks.

- For both individual and combined processes, innovative calibration procedures rely on multi-objectives / multi-criteria calibration (e.g. Pareto ranking) by using data from WP1 and WP2.
- The benefit of new parameterizations is highlighted through comparison exercises against former parameterizations, with a view to progress in trade-off between precision and complexity, in terms of both process and scale.

- To address the impacts of spatial structure modulation (WP4), the ALTOS project conducts an integrated analysis that includes (1) the design of modulation scenarios by using results from WP1, (2) the simulation of matter fluxes and storages for modulation scenarios by using the modelling tools calibrated in WP3, and (3) the ranking of modulation scenarios based on simulation-based indicators, via participative seminars with stakeholders. Table 1.6 provides an overview of scenarios, indicators and models used, along with study site and involved partners.
  - We focus on a panel of key structures related to agricultural practices (i.e., land use and crop types, irrigation techniques, pest management according to land use) and to hydro-agricultural facilities (i.e., reservoir and bench densities). Two types of structure modulations are foreseen. The first modulation corresponds to exploratory scenarios without any concertation with stakeholders, in order to flag promising configurations that are out of current manager strategies. The second modulation corresponds to realistic scenarios designed during participative seminars with the stakeholders mentioned in Section 2 (Table 2.2), in order to quantify potential impacts for possible evolutions.
  - On the basis of digital versions for the above-discussed scenarios, the impacts of structure modulations are simulated. We use a panel of integrated modelling schemes, either in current versions or after the improvements conducted during ALTOS (MHYDAS and SAFYE within OpenFLUID, SWAT, WEAP, SAFRAN-ISBA-MODCOU, SAMIR-WEAP-MODFLOW), and we consider a panel of fluxes and storages that can be viewed as services (yield & WUE, catchment outflow, aquifer refill, silting, chemical storage). We consider different integrated modelling schemes in order to highlight their own interests via comparison exercises.

- The ALTOS project also provides insights about vulnerabilities and adaptation margins for irrigated and rainfed agrosystems (WP4). For this, we conduct a cross-analysis between both agrosystems, by taking into account spatial modulations and climate change scenarios, and by considering several indicators related to water availability and agricultural production.

The ALTOS methodology presented above is dedicated to the development of innovative methodologies that draw on both new and existing materials. The existing materials are available from recent and ongoing project (Table 1.3). They include historical and recent datasets, recent

[22] F. Levavasseur et al., 2012. Simulating the effects of spatial configurations of agricultural ditch drainage networks on surface runoff from agricultural catchments. Hydrological Processes, 26, 3393-3404.

[23] A. Chahbi et al., 2014. Estimation of the dynamics and yields of cereals in a semi-arid area using remote sensing and the SAFY growth model. International journal of remote sensing, 35, 1004-1028.

methodological developments, several models and integrated modelling schemes, as well as scenarios of land use modulation. They provide a baseline to be improved and next used for integrated analysis during ALTOS. Thus, the ALTOS project permits to improve these achievements through collaboration between teams and sites.

Table 1.6: overview of scenario impacts along with the involved partners. WUE stands for water use efficiency.

| Site | Partners | Modelling schemes | Structures to be modulated | | | | | | Services | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Land use | Reservoirs | Benches | Irrigation | Pest management | Climate | Yield & WUE | Catchment outflow | Aquifer refill | Silting | Mitigating pollution |
| Cap Bon | INRGREF LISAH CERTE INAT | MHYDAS & SAFY (1) | X | X | | | | X | X | X | X | | |
| | | SWAT | X | | X | | X | X | X | X | X | X | X |
| Merguellil | CESBIO INAT CERTE | SWAT | X | | X | | | X | X | X | X | X | |
| | | WEAP | X | | | X | | X | X | X | X | X | |
| Tensift | UCAM CESBIO | SWM (2) SIM (3) | X | | | X | | | X | X | X | | |
| Litani | CNRS-L LARI CESBIO | WEAP SWAT | X | | | | | | X | X | X | X | |

(1) Refers to the coupling of MHYDAS and SAFY within the OpenFLUID platform.
(2) SWM stands for SAMIR-WEAP-MODFLOW.
(3) SIM stands for SAFRAN-ISBA-MODCOU.

To strengthen the Mediterranean partnership and to contribute to the structuration of a Mediterranean community, the ALTOS project implies three main action levers for pooling data and methodological developments between partners (WP5).

- First action lever relies on existing online information systems (1) from observatories (i.e., Tensift, O-LIFE, OMERE) and international programs (i.e., MISTRALS, THEIA) for sharing data, and (2) from code repositories sharing GPL-licensed codes (i.e., OpenFLUID shared repositories of models). The idea is to setup a cluster based infrastructure that includes
  - (1) the ALTOS project web site providing a listing of metadata / metamodels along with the corresponding URLs towards
  - (2) web sites of existing infrastructures (observatories, international programs, modelling platforms) for downloading data and models.

  In case the existing infrastructures cannot host ALTOS data and model, we use the ALTOS project website with logins / passwords, since such website infrastructures already exist at LISAH and CESBIO with ANR ALMIRA and AMETHYST projects.

- Second action lever is based on modelling workshops, a first one to draw up a state of the art, and two other ones to take stock of ALTOS innovations about modelling of individual processes (e.g., evapotranspiration) and of combined processes (e.g., integrated hydrological cycle).
- Third action lever is based on mobilities for researchers and students. The mobilities are mainly supported by the ACCWA proposal that was recently selected for funding by H2020-MSCA-RISE-2018 program (approximatively 30 months of mobility for ALTOS project partners), with supplemental support from ALTOS budget.

Alongside the strategy for pooling of data and methodological developments between academic partners, the ALTOS project also involves close connections with professional sector when co-constructing modulation scenarios and assessing the resulting impacts, but also when transferring project outcomes. This second item is specifically addressed within WP5 when dealing with dissemination and exploitation of project results, to be discussed later in Section 2.2 (measures to maximise impact) and 3.1 (WP5 presentation). It is worth recalling at this stage that the ALTOS project relies on community facilities for (1) long-term academic collaborations across the Mediterranean and (2) long-term collaborations with professional sector (section 1.3.a). Relying on these community facilities permits to benefit from knowledges on site features and functioning, whereas these knowledges are enriched by ALTOS innovative methodologies in monitoring and modelling, to next go further in integrated analysis.

## 1.4 Ambition

**Overall ambition** is to create strategic tools, valuable globally, for water and land management in a systemic approach, by considering all at once hydro-agricultural infrastructures and farming system practices along with their connectivities. Such decision-making support tools will help to adapt agriculture to water and land stresses likely to increase with CC. **First specific ambition** is to evaluate the potential of modulating spatial structures and connectivities, since (1) such modulation is identified by international think-tanks and water resource managers as a potential lever for the management of water resources, and (2) such modulation has received little attention up to now due to limited capabilities of monitoring and modelling tools. **Second specific ambition** is to sustain recent progresses on monitoring tools by strengthening our capabilities to address spatial structures / connectivities and resulting matter fluxes / storages, including (1) the joint use of recent observation technologies (e.g., high spatial resolution airborne / spaceborne imageries, remote sensing over all spectral domains, electromagnetic sounding, geochemical tracing, distributed piezometry, eddy covariance and sap-flow, chemical analysis within soil columns) and (2) the use of recent data processing methods (e.g., photogrammetry, radiative transfer modelling, learning machine, space segmentation, object-oriented classification, stochastic simulations, numerical inversions). **Third specific ambition** is to sustain recent progresses on modelling tools by strengthening our capabilities to address matter fluxes and storages driven by spatial structures and connectivities, including (1) the parameterization of exchange coefficients for hilly / mountainous topography and multi-strata crops, (2) the development of parsimonious models capable of addressing complex structures and heterogeneous landscapes, and (3) the integration of these newly developed parameterizations / models within integrated modelling schemes, and (4) the design of calibration protocols to cope with the mismatch between unknown parameters and low density data. **Fourth specific ambition** is to strengthen existing collaborations with stakeholders (farmer associations, water management authorities for rainfed catchment and irrigated perimeter), by **co-constructing integrated analysis** (potential impacts for expected evolutions, promising action levers), thanks to existing collaborations

between academics and stakeholders in the framework of long-term community facilities such as observatories or international joint laboratories. Therefore, the innovative tools we propose here will feed the technical and political decision making for the management of the Mediterranean rural areas and their water resources.

## 2. Impact

### 2.1 Expected impacts

ALTOS is interlinked with sustainable development goals (SDG) #2, #6, and #12 following the 2030 United Nations Agenda for Sustainable Development. By providing simulation-based indicators, the ALTOS project directly contributes to PRIMA Key Performance Indicators, including surface occurrence of productive and sustainable agriculture (SDG #2), water exploitation index (SDG #6), and global food loss index (SDG #12). The ALTOS project also contributes to PRIMA outcome indicators, including (1) newly modelling routines for water cycle, (2) new irrigation technologies with the modulation of irrigation techniques within irrigated perimeters, and (3) innovative farming system with improved crop water use efficiency and water resource quality.

With reference to the call PRIMA 1.1.1 (primary level) and 1.1.2 (secondary level), the expected impacts of the ALTOS project are listed in Table 2.1.

Table 2.1: expected impacts according to work program.

| Expected impacts | |
|---|---|
| Call Section 2 / Topic 1.1.1. | The ALTOS proposal |
| A more efficient water management, linked to studies devoted to understand the hydrological processes mediating ephemeral river flows, flooding events and aquifer overexploitation, recharge and salinization should have direct impacts on surface water bodies systems by increasing water flows and improve the water quality and reduce the underground water exploitation and salinity levels. In this sense, the proposals to successfully meet the impact of the call should promote some of the following expected impacts: | |
| Designing new modelling routines for determining the basic components of the water cycle, including economic, social and technical aspects (e.g. groundwater accumulation storage and recharge) and for forecasting droughts. | • Developing parsimonious models to simulate (1) evapotranspiration for complex structures (topography, multi-strata), (2) subsurface water flows induced by drip irrigation, (3) water flows between surface reservoirs and aquifers, and (4) vegetation growth within heterogeneous landscapes. |
| Mitigating pollution processes by better assessing water management policies and the impact of anthropogenic activities. | • Characterising south Mediterranean current practices about agricultural pesticide uses and resulting risks in terms of transport.<br>• Assessing land use modulation and resulting pest management to mitigate pollutant transport toward water. |
| Improved hydrological monitoring in | • Relying on current observatories by using their long- |

| | |
|---|---|
| ephemeral rivers, hydrological regime, water and sediment connectivity, geo-morphological conditions of river channels and river corridors. | term dataset for (1) understanding individual and integrated processes, and (2) quantifying impacts of spatial structure modulations. |
| A reduction in the risk of saline intrusion and improved management of salt accumulation in overexploited underground water bodies. | |
| Call Section 2 / Topic 1.1.2. | The ALTOS proposal |
| The water systems in the Mediterranean regions will benefit from the developed measures at different spatial levels in order to alleviate the existing pressure on water resources. By better defining the limits of water use and standardizing the water accountings procedures and methodologies, it will be possible to improve the analysis of the water footprints. More specifically some of the impacts expected by this call should be: | |
| Development of innovative tools and decision support systems for planning and adaptation to global change, including public and private stakeholders' involvement; | • Relying on close interactions with local and regional stakeholders when (1) setting modulations for land use and practices, to be combined with climate change scenarios, and (2) quantifying resulting impacts. |
| Improving evapotranspiration determinations by surface energy balance, in order to better assess the water and energy budgets, particularly in dry water basins. | • Developing innovative remote sensing approaches for ET estimates, especially exploiting the complementarity between sensors.<br>• Developing parsimonious parameterizations for surface - atmosphere heat / water exchange coefficients (1) within heterogeneous / multi-strata crops and (2) under conditions of hilly / mountainous topography. |
| Implementation of monitoring and forecasting systems to support the water management under scarce conditions, taking into account any anthropogenic effect on the integrated water cycle. | • Developing and testing advanced integrated modelling approaches for agricultural water and watershed management.<br>• Assessing the impact of spatial structures (e.g. land use and irrigation techniques for irrigated perimeters, land use and benches for rainfed catchments), and quantifying the resulting impacts on matter fluxes and storages within surface (reservoirs) / and subsurface (root zone, aquifers) compartments. |
| Development of innovative approaches for the proper management of water infrastructures, including small and multi-purpose reservoirs and water harvesting systems | |

In addition to scientific impacts and their consequences on a new vision of water and land management, the ALTOS project has an important component on capacity building, by involving numerous MSc, PhD students and post-docs, the latter benefiting from south - north co-supervisions, but also from mobilities with the support of the ACCWA projects that was recently selected for funding by the H2020-MSCA-RISE-2018 program.

Finally, we expect to strengthen the long-term collaborations between the project partners and the professional sector (water resource managers, commissioners for agricultural development, farmer and water user associations), thanks to community facilities such as observatories, international laboratories and modelling platforms. These long-term collaborations are useful to include stakeholder knowledge when (1) designing water management methods via participative seminars, or (2) benchmarking and transferring management tools toward farmer associations (e.g., irrigation scheduling). Thus, ALTOS innovations help to improve existing tools and to create new ones, to be next transferred on the basis of these existing collaborations that will continue beyond the end of ALTOS thanks to the aforementioned community facilities.

## 2.2 Measures to maximise impact

### a) Dissemination and exploitation of results

The ALTOS **strategy for result dissemination and exploitation relies on** (1) community facilities (i.e., international laboratories, observatories, and modelling platforms), (2) open access to project results, and (3) pro-active knowledge transfer to key target groups such as policy makers, academics and engineering offices. Through the community facilities presented in Section 1.3.a, most of which include statutory user committees, the project benefits from historical collaborations with several stakeholders involved in policy making about water / soil conservation and agricultural development (see Table 2.2). These community facilities, which will continue beyond the end of the ALTOS project, also permit to ensure that measures are effectively implemented after the project.

A specific task in WP5 is dedicated to setup a knowledge management strategy for result dissemination and exploitation, by involving close collaborations with stakeholders. In particular, this task uses outcomes of the participative seminars planned in WP4, amongst others. The knowledge management strategy, which draft plan is described below, is designed to facilitate the project implementation and to prepare the post-project period, by addressing the following items.

- To enable the further development of science-based management of water resources.
- To implement a suitable intellectual property right (IPR) strategy.
- To ensure high-level dissemination of several project results, including (1) innovations in monitoring and data processing, (2) innovations in modelling and simulation of land surface processes, (3) building and impact assessment of management methods, as well as (4) expertise about functioning and fate of rainfed and irrigated agrosystems within the Mediterranean Basin.
- To ensure high-level dissemination towards the stakeholders mentioned below, including (1) national and regional authorities, (2) professional associations in relation to farmer activities, as well as (3) engineering offices; and additional stakeholders such as academics, NGOs, think-tanks, and international organisations focused on development.

The ALTOS project aims to advance scientific knowledge for improving water resource management within rainfed and irrigated agrosystems. Consequently, stakeholders involved in this thematic are the end-users of the project, and they are the key targets for dissemination / exploitation activities. Seven main groups are identified, following instances in Table 2.2.

- *National and regional directorates* for agricultural development that are already involved in the community facilities in Tunisia (DG-RE, DG-BGTH, DG-PA, DG-ACTA and CRDA), in Morocco (ORMVAH, ABHT) and in Lebanon (Litani Authority).
- *Farmer, water user association and NGOs* in the field of rural development: GDAs and ADUTAR in Tunisia, Baalbeck NGO in Lebanon. The ALTOS project liaises with donors who support farmer associations and NGOs. Thus, it attends workshops organized by French Agency for Development who supports rural organizations and NGOs in Morocco, Tunisia and Lebanon.
- *Engineering offices*: NGI-MAGHREB, SCET Tunisia, ENVILYS**.**
- *Think tanks*: as indicated last May 10, at the opening of the second edition of the summit of African think tanks, Mediterranean countries pay particular attention to the development of think tanks as an integral component in the quest for sustainable development. Through IRD, ALTOS is connected with Institute for Sustainable Development and International Relations (IDDRI) and its Mediterranean program "Nature-based solutions in the Mediterranean region".
- *Regional and international organisations*: ALTOS is in line with the fourth priority of ICARDA (International Centre for Agricultural Research in the Dry Areas) 2017-2026 strategic plan "Develop innovative approaches to water, land, and soil resource management that address water scarcity, enhance soil health and productivity, and contribute to land degradation neutrality", and plans knowledge exchanges with ICARDA. Also, most partners of the ALTOS consortium work with an International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM).
- *Academics: scientific community and students*: each ALTOS partner is affiliated with a university and is involved in training and student mobility**.**

Table 2.2. Listing of partners from professional sector who are involved in the ALTOS project via the aforementioned community facilities. Labels for partners are PUB for public and PRI for private. OBS stands for observatory.

| **Country** | **Partner** | **Community facilities** | **Study sites** | **Status / missions** |
|---|---|---|---|---|
| **Morocco** | ORMVAH | LMI TREMA Tensift OBS | Tensift | PUB / infrastructure design, agricultural development |
| | ABHT | | | PUB / coordinating water management |
| **Lebanon** | Baalbeck NGO | O-LIFE observatory / LIA | Litani | PRI / farmer association |
| | Litani Authority | | | PUB / water resource management & exploitation |
| **Tunisia** | GDAs | OMERE OBS Merguellil OBS LMI NAILA | Cap Bon and Merguellil | PRI / management of irrigated perimeters |
| | CRDA | | | PUB / agricultural development and irrigation |
| | DG-RE | | | PUB / water resource exploitation & management |
| | DG-BGTH | | | PUB / dam management |
| | DG-PA | | | PUB / agricultural production |

| | | | | | |
|---|---|---|---|---|---|
| | DG-ACTA | Sol | | | PUB / soil resource management |
| | | CES | | | PUB / management of water harvesting infrastructures |
| | NGI-MAGHREB | | | | PRI / online services from remote sensing / digital mapping |

**French acronym significations.**

- **ORMVAH**: regional board for agricultural development within the Haouz plain
- **ABHT**: agency of Tensift hydraulic catchment
- **GDAs**: local syndicate for agricultural development (irrigation association)
- **CRDA**: regional commissioner for agricultural development
- **DG-RE**: national directorate for water resources
- **DG-BGTH**: national directorate for dams and large hydraulic shells
- **DG-PA**: national directorate for agricultural production
- **DG-ACTA**: national directorate for agricultural land development and conservation.
  - **/ Sol**: soil department.
  - **/ CES**: water and soil conservation.

Subsequently, the knowledge management strategy conducts a panel of specific actions to transfer the ALTOS results towards the targeted stakeholders. The panel of these specific actions includes (1) online data delivery through existing information systems, (2) publications, (3) training sessions, (4) methodological transfers though application programs, online dedicated hubs and user manuals, (5) reports from participative seminars, and (6) policy briefs. This panel of specific actions is overviewed in Table 2.3 that highlights the main lines. Details about the specific actions to be conducted are given Section 3.1 when presenting the dedicated workpackage (WP5). We note that Table 2.3 is not exhaustive and is refined at the time of producing deliverable D5.5.

As stated by the European Commission in the Guidelines on **open Access to scientific publications and research data** in Horizon 2020 "Modern research builds on extensive scientific dialogue and advances by improving earlier work". We are aware that full / wide access to scientific publications and data help to build on previous research results (improved result quality), to foster collaborations, to avoid effort duplications (improved transparency), to accelerate innovation, and to involve citizens (improved transparency of the scientific process). Thus, ALTOS scientists will make their best efforts to ensure that data are disseminated as far as possible, by following the main lines discussed below.

A consortium agreement is set up for regulating the ownership and access to key knowledge (IPR, data, etc.) and scientific foreground, among other things, after the approval of the project by the PRIMA-IS and, if possible, before the signature of the grant agreements with the national funding agencies. The consortium agreement, as far as IPR are concerned, helps to identify which knowledge is brought by each partner, and under which conditions access rights may be granted, together with a number of knowledge management procedures and exploitation rules.

The consortium delivers the data management plan integrated into the knowledge management strategy (D5.1 Month 6). This data management plan, is regularly updated under the supervision of the Coordination team (WP6) and Task 5.1 leader. This plan addresses how data are collected / generated, processed, presented, disseminated, protected and archived.

- For data storage, the idea is to setup a cluster based infrastructure that includes

- the ALTOS web site providing a listing of metadata with the corresponding URLs towards
- web sites of existing infrastructures (observatories, international programs such as MISTRALS or THEIA) for downloading data.

In case the existing infrastructures cannot host ALTOS data and model, we use the ALTOS project website with logins / passwords, since such website infrastructures already exist at LISAH and CESBIO for ANR ALMIRA and AMETHYST projects.

- For data dissemination, including quality check, nomenclature and accessibility, the ALTOS project relies on data policies currently applied within observatories, and which are compliant with the data policy of the eLTER H2020 project. This means that standard ALTOS data about fluxes and storage at the daily times scale are straight available; whereas research data, either collected or simulated, experience a 2-3 year embargo to secure the publication of research results for students and young researchers.

| Table 2.3 (to be continued). Panel of specific actions to be conducted for transferring ALTOS outcomes towards targeted stakeholders. | | | | | | | |
|---|---|---|---|---|---|---|---|
| Targeted audience→<br><br>Products ↓ | National directorates (link with ministries) | Regional directorates (link with governorates and farmers) | Farmer / water user associations. | Engineering offices | Academics | NGOs and think tanks | National and international organisations |
| Monitoring protocols (WP1 & WP2) | • Databases and technical reports about<br>  ○ infrastructures (reservoir geometries, soil maps);<br>  ○ fluxes and storages (aquifer levels, reservoir filling, chemical contents).<br>• Trainings on monitoring systems setup with observatories. | | | | • Publications.<br>• Online databases / user manuals & GITHUB platforms.<br>• Advanced trainings. | | Databases for country reports on climate change |
| Data processing algorithms (WP1 & WP2) | • Trainings.<br>• User manuals.<br>• GITHUB platforms.<br>• Support to get started. | | | • Trainings.<br>• User manuals.<br>• GITHUB platforms. | | | |
| Open source models (WP3) | | | | | | | |
| Simulation tools (WP3) | | | | | | | |

| Table 2.3 (continued). Panel of specific actions to be conducted for transferring ALTOS outcomes towards targeted stakeholders. | | | | | | | |
|---|---|---|---|---|---|---|---|
| Targeted audience→<br><br>Products ↓ | National directorates (link with ministries) | Regional directorates (link with governorates and farmers) | Farmer / water user associations. | Engineering offices | Academics | NGOs and think tanks | National and international organisations |
| Build and assessment of management methods (WP4) | • Database<br>• Technical reports from simulation analysis<br>• Policy briefs on catchment management from participative seminars. | | | | • Publications.<br>• Advanced trainings. | • Technical reports from simulation analysis<br>• Policy briefs on catchment management from participative seminars. | Policy brief on irrigated and rainfed systems |
| Expertise (WP4) | Tailored | | | | | | |

ALTOS scientists favour the Green Open Access option for publication, by disseminating version of accepted manuscript and proof prior to publication. For this, we use either the ALTOS project website, institutional repositories provided by the ALTOS partner institutes, or common infrastructures such as HAL (French acronym for hyper articles online), RG (research gate). The Golden Open Access is an expensive solution and is only considered as an additional option, by refereeing to the Directory of Open Access Journals.

**b) Communication activities**

The communication elements of the project involve all consortium partners and their respective staff, including researchers. Additionally, the project relies on ALTOS partner networks via community facilities (international laboratories, observatories…) and on existing infrastructures / resources (i.e. web presence, communication and public engagement officers) for multiplying the communication effects.

The communication activities during the ALTOS project encourage continuous interface between the consortium partners as well as between the project and the targeted groups. In the following we highlight the main elements. Communication between the consortium partners and external target groups mainly operates through the ALTOS website.

Targets are identified in table 2.3. Communication activities include the following items.

- Project web site. A specific, functional and attractive web site is created and regularly updated for communication and outreach services of the project. Specific efforts are made by european project manager to ensure rapid and continuous website feeding, for purposes of widespread project promotion for the beginning. For this, we rely on internal know-hows with ANR ALMIRA and AMETHYST project websites at LISAH and CESBIO.
- Peer-reviewed articles. Main outcomes from WP1 to WP4 are communicated to the scientific community through articles submitted in highly-ranked peer-reviewed journals. Articles also serve as the basis for communications in international scientific conferences.
- Policy briefs and policy report. Whenever ALTOS has results that can be useful to decision makers to feed debates, develop ideas, help in decision-making and when project partners are open to their dissemination, a policy brief is written. Easy-to-read and short, policy briefs convey a message to local, national or international decision-makers - institutional actors, political decision-makers, negotiators, NGOs, associations. They are freely accessible on the project web.
- Target meetings. The project annual seminars involve stakeholders and policy-makers, additionally to participative seminars in WP4 about evolution prospective and impact-based acceptability. One aim is to promote and facilitate the diffusion of the project impacts.
- Final conference. The goal is not to organize a classic scientific symposium over several days, but rather to present the main results of the project to a large audience among decision-makers, NGOs and scientists.
- Participation to conferences. ALTOS partners participate in academic conferences for disseminating scientific results and in non-scientific events dealing with general public themes, in order to disseminate the projects achievements.
- Project flyers. Flyers present the key objectives of ALTOS, its main concepts, partnership and geography, in order to create awareness about the start of the project. Flyers are translated in Arabic and English, and distributed during events dedicated to stakeholders (Table 2.3).

- Social and professional networks. The ALTOS project uses social networks, with a priority on Twitter, to regularly and interactively communicate to large groups. The impact of these activities is ensured by frequent contribution from partners and professional community.

The management coordination team (MCT, includes the coordinator and the european project manager) is intensively involved in the communication of the results, with the following actions (WP6).

- Providing periodic reports and summaries of such quality that the PRIMA-IS can publish them directly in the public domain. The texts are tailored to a large audience.
- Notifying main events (e.g. conferences) to PRIMA-IS who can help to amplify the message.
- Highlighting the financial support of the national funding agencies through PRIMA.

The coordinator also relies on the IRD in-house capabilities for science communication. This strategy comes from the experience of previous coordination of EU projects, where the coordinator and the communication teams must be very close and well connected.

## 3. Implementation

### 3.1 Work plan — Work packages, deliverables

The ALTOS activities cover a three-year period and are structured into six interconnected work packages (Figure 3.1), including WP6 on management and communication. The methodological framework was elaborated by the consortium toward the best approach to address the impact of spatial structures and connectivities on matter fluxes and storages. Below are summary descriptions of the work packages.

- **WP1 "Characterizing spatial structures"** deals with innovative monitoring and modelling tools for characterizing spatial structures. It includes the use of innovative sensors with high spatial resolution and of innovative methodologies for data processing.
- **WP2 "Monitoring fluxes and storages"** addresses innovative monitoring tools for characterizing matter fluxes and storage driven by spatial structures. It includes innovative experimental protocols that rely on the joint use of complementary measurements.
- **WP3 "Modelling fluxes and storages"** uses outcomes from WP1 and WP2 to address innovative modelling for simulating individual (e.g., evapotranspiration) and combined processes (e.g., combined hydrological cycle and crop functioning). It includes calibration procedures that rely on distributed and nested measurements to simultaneously calibrate several model parameters.
- **WP4 "Simulating fluxes and storages for structures modulations"** combines outcomes from WP1 and WP3 to simulate matter fluxes and storages for possible structure modulations. Obtained simulations are translated into indicators for integrated analysis with stakeholders during participative seminars. WP4 also includes a cross-analysis for irrigated and rainfed agrosystems, by comparing vulnerabilities and adaptabilities on the basis of indicators related to water availability and agricultural yield.
- **WP5 "Pooling, dissemination and exploitation"** conducts pooling of data and methodologies between project partners and throughout project duration, by using several means such as dedicated platforms, workshops, mobilities. WP5 is also in charge of the dissemination and

exploitation of the project results according to the type of outcome and target audiences (see Table 2.2 in Section 2).

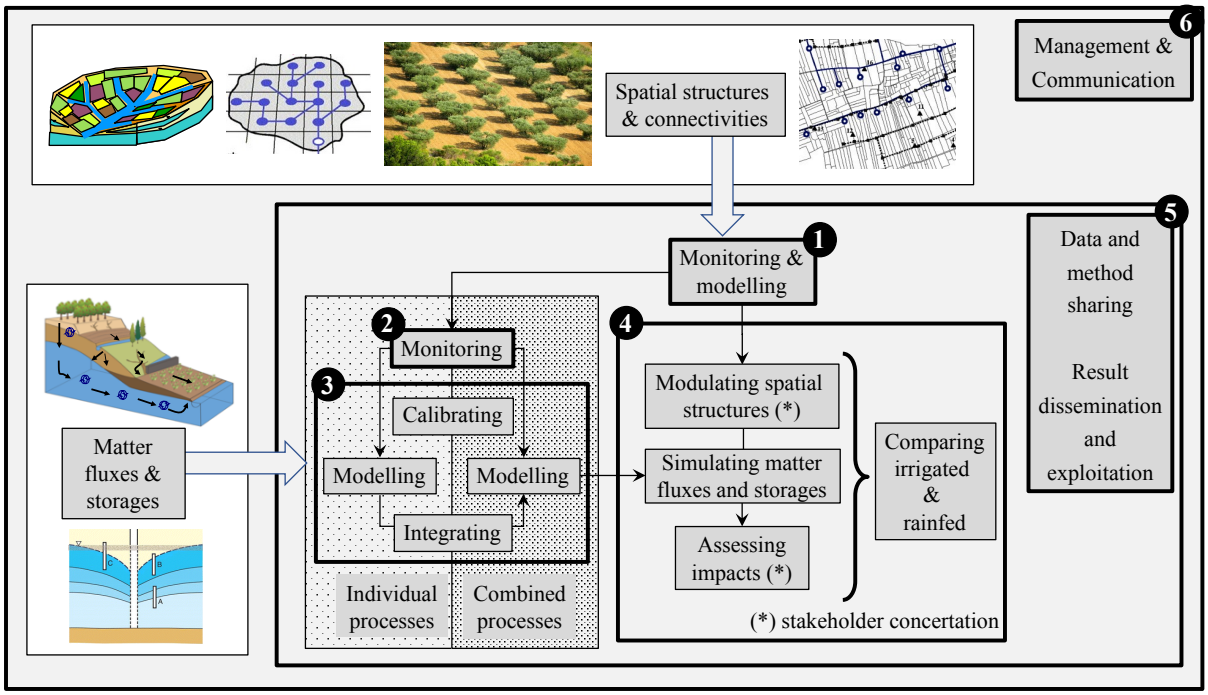


Figure 3.1: Interactions between work packages (WP numbers within black circles).

The ALTOS project goes beyond the transfer of research results among stakeholders, by involving them in the co-construction of management methods. In this sense, interactions with stakeholders are not addressed within a dedicated WP as they are part of (1) WP4 when setting evolutions scenarios and analysing impacts of structure modulations on matter fluxes and storages, and (2) WP5 when disseminating innovative results related to monitoring, modelling and integrated analysis.

Table 3.1a: List of work packages

| Work package No | Work Package Title | Lead Participant No | Lead Participant Short Name | Person-Months | Start Month | End Month |
|---|---|---|---|---|---|---|
| 1 | Characterising spatial structures | 3 & 6 | IRTA & LARI | 230 | 1 | 21 |
| 2 | Monitoring fluxes & storages | 2 & 11 | CESBIO & CERTE | 214.5 | 1 | 21 |
| 3 | Modelling fluxes and storages | 4 & 8 | UNICA & INAT | 282.5 | 7 | 33 |
| 4 | Simulating fluxes & storages for structures modulations | 7 & 9 | UCAM & INRGREF | 192 | 12 | 36 |
| 5 | Pooling, dissemination and exploitation | 5 & 9 | CNRS-L & INRGREF | 89.5 | 1 | 36 |
| 6 | Management and communication | 1 | LISAH | 45 | 1 | 36 |
| | | | | 1053.5 | | |

Table 3.1b: Work package description.

| Work package number | WP1 | | | Lead beneficiary | | | IRTA & LARI | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Work package title | Characterizing spatial structures and connectivities | | | | | | | | | | |
| Participant number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Short name of participant | LISAH | CESBIO | IRTA | UNICA | CNRS-L | LARI | UCAM | INAT | INRGREF | SUPCOM | CERTE |
| Person months per participant | 50 | 28 | 34.5 | 25 | 3.5 | 8 | 33 | 9 | 9.5 | 16.5 | 13 |
| Start month | 1 | | | End month | | | 21 | | | | |

**Objectives**

WP1 aims to characterize spatial structures and connectivities by developing innovating tools for observation and numerical representation.

- The spatial structures at local- and landscape- scales are (1) natural structures related to vegetation, soils, water resources and climate, as well as (2) anthropogenic structures such as landscaping features and agricultural practices. The hydrological connectivities are surface and subsurface connections between elements.
- Innovative methodologies rely on the joint use of complementary observations with high spatiotemporal resolutions, as well as on typology-based segmentations or deep learning-based processing of multisource information.

For both spatial structures and connectivities, the collected data (geospatial data, maps) are available for WP5 that conducts the pooling of ALTOS new data and integrate them with those issued by former / on-going projects (see Table 1.3) into the cluster based infrastructure. This collaborative sharing allows to improve data availability for (1) WP2 when using measurements to characterize matter fluxes and storages driven by spatial structures and connectivities, and (2) WP4 when setting modulation scenarios for spatial structures and connectivities.

**Description of work**

**Task 1.1: object geometries and landscape structures (leader: IRTA).**

- Tree geometry.
  - Targets: density, height and roughness, crown size, row spacing / direction, profiles of fraction cover and leaf area index.
  - Methodological innovations: 3D radiative transfer modelling with joint use of multispectral airborne data and Sentinel-1 & 2 satellite data, photogrammetric processing of multispectral airborne data.
  - Partners: UCAM, CESBIO, IRTA.
  - Study areas: Tensift, Merguellil, Segre.
- Aquifers.

- Targets: 3D description of aquifer structure and flow pathways.
- Methodological innovations: joint use of geo-electrical methods, electromagnetic sounding, and stable isotopes (δ18O and δ2H).
- Partners: CERTE, UNICA.
- Study areas: Cap Bon, Merguellil.

- Soils.
  - Targets: soil depth / horizon / texture / hydrodynamic properties.
  - Methodological innovations: joint use of geo-electrical methods, electromagnetic sounding, and optical / radar satellite data.
  - Partners: CERTE, UNICA, LARI.
  - Study areas: Cap Bon, Merguellil, Litani.
- Spatial variability in soil infiltrability.
  - Targets: mapping of soil surface characteristics related to soil infiltrability.
  - Methodological innovations: joint use of times series of optical and microwave remote sensing.
  - Partners: INRGREF, INAT, LISAH, CESBIO.
  - Study areas: Cap Bon, Merguellil.
- Climate variability.
  - Targets: climate spatiotemporal structures.
  - Methodological innovations: disaggregation of climate model simulations using multivariate statistics on various data (in-situ, remote sensing, high resolution meteorological model simulations) or using stochastic weather generator with SAR images.
  - Partners: INAT, INRGREF, SUPCOM, LISAH, CESBIO, UNICA.
  - Study areas: Cap Bon, Merguellil.

**Task 1.2: landscaping features, agricultural practices and connectivities (leader: LARI).**

- Reservoirs.
  - Targets: bathymetry and volume range.
  - Methodological innovations: photogrammetric processing of remotely sensed data by using algorithms based on point clouds and structure from motion.
  - Partners: LISAH, LARI, CNRS-L.
  - Study areas: Cap Bon, Litani.
- Land use.
  - Targets: field delineation, land use and land cover, crop rotation.
  - Methodological innovations: times series of Sentinel satellite data long with object-oriented classification methods, joint use of field surveys and high spatial optical remote sensing (e.g., Spot, Pléiades).
  - Partners: INAT, INRGREF, LISAH, UCAM, CESBIO, LARI.
  - Study areas: Cap Bon, Merguellil, Tensift, Litani.
- Crop biomass.
  - Targets: times series of biophysical variables along with final yield.
  - Methodological innovations: joint use of remote sensing data Sentinel-1 & 2 satellite data and TerraSAR-X satellite data along with statistical analysis.
  - Partners: SUPCOM, INRGREF.

- Study areas: Cap Bon
- Chemical treatments
  - Targets: pesticide practices.
  - Methodological innovations: field surveys according to land cover & crop rotation.
  - Partners: INAT, LISAH.
  - Study areas: Cap Bon.
- Surface hydrological connectivities.
  - Targets: numerical representations of surface / subsurface connectivities.
  - Methodological innovations: (1) pattern recognition based on deep learning and multisource and multiscale information, and (2) numerical space segmentation tools with oriented tree topology and inclusion of areal / bulk elements.
  - Partners: INRGREF, LISAH, IRTA, UNICA.
  - Study areas: Cap Bon, Segre, Orroli.

**Deliverables** (the task leaders are responsible for related deliverables).

- D1.1.1 [Task 1.1]: dataset @ Month 15 → to be included into project clustered database (WP5).
- D1.1.2 [Task 1.1]: 2 submitted publications for methodological innovations @ Month 21.
- D1.2.1 [Task 1.2]: dataset @ Month 15→ to be included into project clustered database (WP5).
- D1.2.2 [Task 1.2]: 2 submitted publications for methodological innovations @ Month 21.

**Associated milestone.**

- MS1: update of clustered database with collected data from monitoring systems. This milestone is associated with a presentation included in the agenda of the management board meeting @ Month 18, to review and validate the available data and their quality. If needed the project workplan will be reoriented accordingly.

| **Work package number** | **WP2** | | **Lead beneficiary** | | | **CESBIO & CERTE** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Work package title** | **Monitoring fluxes and storages** | | | | | | | | | |
| **Participant number** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| **Short name of participant** | **LISAH** | **CESBIO** | **IRTA** | **UNICA** | **CNRS-L** | **LARI** | **UCAM** | **INAT** | **INRGREF** | **SUPCOM** | **CERTE** |
| **Person months per participant** | **45** | **31** | **5** | **32** | **3** | **0** | **47** | **19.5** | **11** | **6** | **15** |
| **Start month** | **1** | | | **End month** | | | | **21** | | | |

**Objectives**

WP2 aims to monitor matter fluxes and storages driven by spatial structures and connectivities.

- This includes the characterization of matter fluxes (evapotranspiration and crop growth, runoff, infiltration and percolation, chemical transport) and storages within several compartments (root-zone, surface reservoirs such as small or large dams, aquifers).

- Methodological innovations involve the joint use of complementary observations with high spatiotemporal resolution, while cognitive works aim to understand fluxes and storages under conditions of spatial heterogeneities at canopy- and landscape- scales.

For both matter fluxes and storages, the collected data (time series of several flux, water budgets, chemical analysis) are available for WP5 that conducts the pooling of ALTOS new data and integrate them with those issued by former / on-going projects (see Table 1.3) into the cluster based infrastructure. This collaborative sharing allows to improve data availability for WP3 when modelling the processes of interest on the basis of available dataset and time series.

**Description of work**

**Task 2.1: water and chemical fluxes (leader: CERTE)**

- Evapotranspiration, soil moisture and crop growth.
  - Targets: vegetation water status across growth cycle, yield, water use efficiency.
  - Methodological innovations: joint use of eddy covariance / sap flow / isotopic measurements and optical / radar / thermal infrared remote sensing data, joint use of times series from in-situ and remote sensing data.
  - Partners: INRGREF, SUPCOM, CESBIO, LISAH, UCAM, UNICA, IRTA.
  - Study areas: Cap Bon, Merguellil, Tensift, Segre, Orroli.
- Dam - aquifer transfers and upstream - downstream surface / subsurface transfers.
  - Targets: dam water budget and underlying leaks towards aquifer; subsurface flows and soil hydrodynamics for slopping terrains that link mountains to lowlands.
  - Methodological innovations: joint use of (1) water budget calculation from hydrometric measurements (surface and subsurface inputs, water uses) and climate forcing data (rain, evaporation), (2) piezometric network data, (3) isotopic (stable δ18O and δ 2H) and geochemical tracing, and (4) geophysical measurements from WP1.
  - Partners: CERTE, LISAH, CNRS-L, UCAM, CESBIO, UNICA.
  - Study areas: Cap Bon, Tensift, Litani.
- Chemical pollutants: hydrological fluxes and retention processes.
  - Targets: chemical flows within surface water flows, reservoirs, soils, aquifers.
  - Methodological innovations: sampling protocols designed according to agricultural practices (WP1) and during hydrological events, joint use of in-situ soil passive samplers and laboratory soil column experiments.
  - Partners: INAT, LISAH, CNRS-L.
  - Study areas: Cap Bon, Litani.

**Task 2.2: characterization of spatial heterogeneities (leader: CESBIO).**

- Canopy scale heterogeneity induced by row and multi-strata structures and / or drip irrigation.
  - Targets: water fluxes in discontinuous canopies, subsurface hydraulic redistribution.
  - Methodological innovations: joint use of sap flow sensors (installed in both tree roots and trunks), isotopic tracers, eddy-covariance devices and in-situ remote-sensing to characterize the 3D functioning.
  - Partners: INAT, CESBIO, UNICA, IRTA.
  - Study areas: Merguellil, Segre, Orroli.

- Landscape scale heterogeneities induced by soil, topography and canopies.
  - Targets: water fluxes in heterogeneous landscapes.
  - Methodological innovations: joint use of eddy covariance data at sub-catchment scales (few tenths of hectares), of scintillometry data across field transects, and of remote sensing data with embedded metric to kilometric resolutions → analysis of spatiotemporal dynamics.
  - Partners: INRGREF, SUPCOM, CESBIO, LISAH, UCAM , UNICA, IRTA.
  - Study areas: Cap Bon, Merguellil, Tensift, Segre, Orroli.

**Deliverables** (the task leaders are responsible for related deliverables).

- D2.1.1 [Task 2.1]: dataset @ Month 15 → to be included into project clustered database (WP5).
- D2.1.2 [Task 2.1]: 2 submitted publications about data analysis @ Month 21.
- D2.2.1 [Task 2.2]: dataset @ Month 15→ to be included into project clustered database (WP5).
- D2.2.2 [Task 2.2]: 2 submitted publications about data analysis @ Month 21.

**Associated milestone.**

- MS2: update of databases with collected data from monitoring systems. This milestone is associated with a presentation included in the agenda of the management board meeting @ Month 18, to review and validate the available data and their quality. If needed the project workplan will be reoriented accordingly.

| **Work package number** | **WP3** | | **Lead beneficiary** | | | | **UNICA & INAT** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work package title** | **Modelling fluxes and storages** | | | | | | | | | | |
| **Participant number** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| **Short name of participant** | **LISAH** | **CESBIO** | **IRTA** | **UNICA** | **CNRS-L** | **LARI** | **UCAM** | **INAT** | **INRGREF** | **SUPCOM** | **CERTE** |
| **Person months per participant** | **90** | **42** | **28.5** | **47** | **0** | **0** | **28.5** | **17** | **19.5** | **0** | **10** |
| **Start month** | **7** | | | **End month** | | | | **36** | | | |

**Objectives**

WP3 aims to improve the modelling of matter fluxes and storages driven by spatial structures and connectivities.

- This includes (1) individual processes such as evapotranspiration and compartment water balance, and (2) combined processes such as catchment hydrological cycle along with vegetation functioning.
- Innovative methodologies include (1) the development of parsimonious parameterizations within heterogeneous media, (2) the inclusion of new parameterization within integrated modelling, and (3) calibration procedures that make the most of high spatiotemporal resolution data obtained from WP2.

The calibrated modelling tools are then available for WP4 when simulating matter fluxes and storages for scenarios of spatial structure modulations.

**Description of work**

**Task 3.1: modelling individual processes (leader: UNICA).**

- Water fluxes within heterogeneous rooting systems or under drip-irrigated orchards.
  - Targets: subsurface distribution of hydraulic redistribution and water flows.
  - Methodological innovations: hydraulic redistribution modelling with respect to root sap.
  - Partners: INAT, CESBIO, UNICA, IRTA.
  - Study areas: Merguellil, Segre, Orroli.
- Evapotranspiration.
  - Targets: surface - atmosphere exchanges within heterogeneous / multi-strata crops and above hilly crops.
  - Methodological innovations: modelling of exchange coefficients, including model development / parameterization / calibration. Comparing simulations from new parameterization against those from previous parameterizations to highlight benefits.
  - Partners: INRGREF, INAT, LISAH, UCAM, CESBIO, UNICA, IRTA.
  - Study areas: Merguellil, Cap Bon, Tensift, Segre, Orroli.
- Dam - aquifer exchanges.
  - Targets: water flows from dam leaks to underlying aquifer.
  - Methodological innovations: modelling of exchange coefficients, including model development / parameterization / calibration.
  - Partners: CERTE, LISAH, UNICA.
  - Study areas: Cap Bon.

**Task 3.2: modelling combined processes (leader: INAT).**

- Coupling distributed hydrology modelling along with crop growth modelling.
  - Targets: coupling of MHYDAS distributed hydrological modelling and SAFY crop growth model within the OpenFLUID platform.
  - Methodological innovations: accounting for combined processes about crop growth (evapotranspiration, yield) and hydrological connectivities (runoff, infiltration, percolation) at both agricultural field scale and catchment extent. Comparing MHYDAS - SAFY against SWAT to highlight the MHYDAS - SAFY interest.
  - Partners: CESBIO, LISAH, INRGREF.
  - Study areas: Cap Bon.
- Semi-distributed hydrology along with subsurface hydraulic redistribution.
  - Targets: improving subsurface hydraulic redistribution within the SWAT model.
  - Methodological innovations: improving the capabilities of the SWAT model by including subsurface water flows driven by hydraulic redistribution. Comparing SWAT simulations before and after improvement to highlight the interest of the approach.
  - Partners: INAT, UNICA.
  - Study areas: Merguellil.

- Hydrological modelling and climate forcing.
  - Targets: refining spatial variability in climate forcing for hydrological modelling.
  - Methodological innovations: comparing SAMIR-WEAP-MODFLOW simulations against SAFRAN-ISBA-MODCOU ones to highlight the impact of spatial variability in climate forcing at the catchment extent.
  - Partners: UCAM, CESBIO, UNICA.
  - Study areas: Tensift.

**Deliverables** (the task leaders are responsible for related deliverables).

- D3.1.1 [Task 3.1]: report on successes and progression margins for new parameterizations and calibration procedures @ Month 15, to be shared within modelling workshops in WP5 @ Month 18.
- D3.1.2 [Task 3.1]: 2 submitted publications for methodological developments of individual process modelling @ Month 27.
- D3.2.1 [Task 3.2]: report on modelling improvements via comparison exercises for integrated modelling schemes @ Month 33, to be shared within modelling workshops in WP5 @ Month 36.
- D3.2.2 [Task 3.2]: 2 submitted publications for methodological developments of integrated process modelling @ Month 36.

**Associated milestones.**

- MS3: improved versions of integrated modelling schemes are available for being used in WP4 @ Month 24. A risk-mitigation measure is setup, please refer to table 3.2b - penultimate item.

| **Work package number** | **WP4** | | **Lead beneficiary** | | **UCAM & INRGREF** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Work package title** | **Simulating fluxes and storages for different scenarios of structure modulations** | | | | | | | | | |
| **Participant number** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| **Short name of participant** | **LISAH** | **CESBIO** | **IRTA** | **UNICA** | **CNRS-L** | **LARI** | **UCAM** | **INAT** | **INRGREF** | **SUPCOM** | **CERTE** |
| **Person months per participant** | **80** | **9** | **0** | **0** | **8** | **4.5** | **15** | **32** | **35** | **0** | **8.5** |
| **Start month** | **12** | | | **End month** | | | | **36** | | | |

**Objectives**

WP4 aims to address the impacts of spatial structure modulations, by conducting an integrated analysis that includes (1) the design of modulation scenarios by using results from WP1, (2) the simulation of matter fluxes and storages for modulation scenarios by using the modelling tools calibrated in WP3, and (3) the ranking of modulation scenarios, on the basis of simulation-based indicators, via participative seminars with relevant stakeholders.

WP4 also addresses vulnerabilities and adaptation margins for irrigated and rainfed agrosystems, by conducting a cross-analysis between both agrosystems on the basis of several indicators related to

water availability and agricultural production, i.e. water stress occurrences, yield and water use efficiencies, spatial allocations between blue and green water.

WP4 results are available for dissemination and exploitation within WP5.

**Description of work**

**Strategy and exiting materials.**

- All partners except IRTA and UNICA contribute to Task 4.1. and 4.2. All sites for integrated analysis (Tensift, Merguellil, Cap Bon, Litani) are included.
- The approach relies on (1) a panel of structure modulations (land use, bench / reservoir density, irrigation techniques and pest management according to land use) combined with climate forcing, (2) a panel of simulated flux and storages that can be viewed as services (yield & WUE, catchment outflow, aquifer refill, silting, chemical storage), (3) a panel of integrated modelling schemes in most recent version or after improvements conducted during ALTOS (OpenFLUID, SWAT, WEAP, SAFRAN-ISBA-MODCOU, SAMIR-WEAP-MODFLOW). Table 1.6 in Section 1.3.b provides an overview of these panels, along with study sites and involved partners.
- In terms of evolution scenarios, we capitalise on existing materials.
  - Realistic scenarios about land use change within upstream Cap Bon for 2040, including three scenarios (agroforestry, forage crops, cereals / market gardening). These scenarios were designed during participative seminars with stakeholders (regional directorate for agricultural development, national directorate for soil and water conservation) in the framework of the ANR ALMIRA project (2014 – 2018).
  - Realistic scenarios about land use change within Merguellil for 2020-2050, with upstream reforestation and downstream irrigation extension in the context of conversion to olive growing. These scenarios were designed during participative seminars with stakeholders (farmer associations and regional directorate for agricultural development) in the framework of ANR AMETHYST project (2014 – 2018).
  - Realistic scenarios about land use change and conversion to drip irrigation within Tensift for 2020-2050, with upstream and downstream extension of irrigated annual crops and orchards. These scenarios were designed during participative seminars with stakeholders (farmer and irrigation associations, regional authority for agricultural development and water management) in the framework of the ANR AMETHYST project (2014 – 2018).

**Task 4.1: designing scenarios (leader: UCAM).**

- Exploratory scenarios about reservoir density within upstream Cap Bon subcatchment, to be setup on the basis of literature review.
- Realistic scenarios as following.
  - Chemical treatments for pest management within Cap Bon. Existing land use scenarios from ANR ALMIRA are used to estimate pesticide uses on the basis of (1) actual and present farmer practices for each land use (from WP1), (2) recommended form pesticide providers for each crop, and 3) glyphosate interdiction.
  - Bench modulation within upstream Cap Bon and Merguellil, to be designed via participative seminars with stakeholders (e.g., national directorate for soil and water

conservation).
  - Reforestation and conversion to irrigation within Litani, to be designed via participative seminars with stakeholders (forestry authorities, farmer associations, regional authority for water management).
- In order to provide larger insights in terms of structure modulation, and in accordance to simulation capabilities, we foresee various mixes (1) between different modulation scenarios, and (2) between modulation scenarios and climate scenarios. This issue is addressed during participative seminars for scenario design. We note that climate scenarios are already available from previous ANR projects, and are improved in WP1.
- Scenarios of spatial structure modulations have a numerical format. They correspond to superposing of various maps for different structures (land use, reservoirs, lakes, chemical treatments).

**Task 4.2: impact assessment and scenario ranking (leader: INRGREF).**

- Stage 1: selection of integrated modelling schemes (OpenFLUID including MHYDAS and SAFY, SWAT, SAMIR-WEAP-MODFLOW, SAFRAN-ISBA-MODCOU), including as much as possible the improved versions discussed in WP3.
- Stage 2: simulations with integrated modelling schemes over the above-discussed scenarios. When possible, runs of different schemes over a unique scenario for comparison purposes (e.g., benefit of OpenFLUID that explicitly accounts for spatial connectivities as compared to SWAT).
- Stage 3: production of indicators on the basis of integrated modelling simulations.
  - Panel of indicators (depends upon modelling schemes): yield and water use efficiency, catchment outflow, aquifer refill (assumed to be equal to percolation losses), dam silting-reduced storage capacity (suspended matter within catchment outflows), as well as contents in chemical pollutants within soils, aquifers and surface reservoirs.
  - Temporal scales: daily / monthly / annual values, harvest time values.
  - Spatial scales: catchment outlet with outflow values, agricultural field, land use class, aquifer scale.
- Stage 4: impact assessment of structure modulation scenarios. Ranking scenarios, on the basis of simulations-based indicators discussed above, during participative seminars with national / regional directorates (DG-ACTA, DG-BGTH, DGRE, CRDA, ABHT, ORMVAH, farmer associations).

**Task 4.3: comparing irrigated and rainfed agrosystems (leader: LISAH).**

- Cross-analysis for studying vulnerabilities and adaptation capabilities.
- Production and comparison of simulation-based indicators for the above-discussed scenarios.
  - Times series of water stress occurrences.
  - Yield and water use efficiencies.
  - Spatial allocations between blue and green water compartments.
  - Sectorial allocation of water.
- Spatial scales for indicators are farm / irrigated perimeter / land use class / catchment.

**Deliverables** (the task leaders are responsible for related deliverables).

- D4.1.1 [Task 4.1]: four new scenarios of structure modulation in the form of numerical representations @ Month 24 → to be included into project clustered database (WP5).

- D4.2.1 [Task 4.2]: scenario ranking from participative seminars on the basis of simulation-based indicators, in the form of report @ Month 33 → to be included into project website and disseminated to stakeholders (WP5).
- D4.2.2 [Task 4.2]: 2 submitted publications about scenario design / analysis / ranking from simulation-based indicators @ Month 36.
- D4.3.1 [Task 4.3]: comparative analysis of irrigated and rainfed agrosystems in the form of report @ Month 33 → to be included into project website and disseminated to stakeholders (WP5).

**Associated milestones.**

- MS4.1: four participative seminars about scenario design (one per study sites) @ Month 22.
- MS4.2: four participative seminars about scenario ranking (one per study sites) @ Month 31.
- MS4.3: update of clustered database with reports on scenario design, scenario ranking and comparative analysis of irrigated / rainfed agrosystems @ Month 35.

| **Work package number** | **WP5** | | **Lead beneficiary** | | | **CNRS-L & INRGREF** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Work package title** | **Pooling, dissemination and exploitation** | | | | | | | | | |
| **Participant number** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| **Short name of participant** | **LISAH** | **CESBIO** | **IRTA** | **UNICA** | **CNRS-L** | **LARI** | **UCAM** | **INAT** | **INRGREF** | **SUPCOM** | **CERTE** |
| **Person months per participant** | **22** | **8** | **1** | **4** | **4.5** | **0.5** | **4.5** | **15** | **26** | **1.5** | **2.5** |
| **Start month** | **1** | | | **End month** | | | | **36** | | | |

**Objectives** WP5 addresses pooling of data and methodological developments between project partners, as well as dissemination and exploitation of project results.

- We rely on three main levers of action to enhance the sharing of data and methodological developments among ALTOS partners: existing online information systems, modelling workshops, and mobilities for researchers and students.
- We rely on the knowledge management strategy presented in Section 2 for the dissemination and exploitation of the project results. We conduct a panel of specific actions to transfer ALTOS results towards targeted stakeholders, including (1) online data delivery through existing information systems, (2) publications, (3) training sessions, (4) methodological transfers though application programs, online dedicated hubs and user manuals, (5) reports from participative seminars, and (6) policy briefs.

**Description of work**

**Task 5.1: sharing of data and methods between ALTOS partners (leader: CNRS-L, all partners are involved).**

- Cluster based infrastructure for online-based sharing: metadata / metamodels for research

are listed and referenced on ALTOS project web site, with links for downloading via web sites of observatories, international programs, modelling platforms or ALTOS project.

- Sharing through modelling workshops. The first workshop draws up a state of the art and is held back-to-back with kick-off meeting. The second workshop takes stock of ALTOS innovations about modelling of individual processes (e.g., evapotranspiration), and is held back-to-back with midterm coordination meeting. The third workshop takes stock of ALTOS innovations about modelling of combined processes (e.g., integrated hydrology), and is held back-to-back with closure meeting. These workshops benefit from reports from WP3 (D3.1.1 & D3.2.1).
- Mobility-based sharing. We design the mobility plan for ALTOS partners in conjunction with the start of the H2020 RISE ACCWA project (currently in negotiation stage, next step is signature of consortium agreement). Since ACCWA project plans to allocate 30 months of mobility for some of the ALTOS project partners (UCAM, INAT, INRGREF, CESBIO, LISAH, IRTA, SUPCOM), priority is given to other ALTOS partners (UNICA, CERTE, LARI, CNRS-L) when granting mobilities on ALTOS budget.

**Task 5.2: dissemination and exploitation of project results (leader: INRGREF, all partners are involved).**

This task relies on the knowledge management strategy and the data management plan (Section 2.2.a). This strategy will be made available at Month 6 and updated at Month 18 and 36.

- The knowledge management strategy is a support to decision-making about the use of the foreground generated: identification of the results that can be disseminated by means of publication, conferences, workshops and technology transfers; identification of the results that should be protected (by copyright) and by whom they should be protected (partners reach agreement in the event of joint ownership).
- The data management plan included in the knowledge management strategy describes how (1) research data collected or generated are handled during ALTOS and beyond, (2) how data are shared and/or made open, and (3) how they are curated and preserved.

The knowledge management strategy includes the following actions for the dissemination and exploitation of results.

- Online availability of data for resource management (obtained from spatiotemporal aggregation of research data produced by TK1.1, TK1.2, TK2.1 & TK 2.2) for the benefit of national and regional directorates (DG-ACTA-CES & Sol, DGRE, CRDA, ABHT).
- Providing data processing methods and modelling tools for training session.
    - Data processing methods produced by TK1.1, TK1.2, TK2.1, TK2.2. Training sessions are organised by NAILA and TREMA international laboratories for the benefit of engineering offices (e.g., NGI-Maghreb) and national directorates (e.g., CNCT, ABHT, ORMVAH).
    - Modelling tools from TK 3.1. Training sessions are organised by GMES - North Africa project for the benefit of engineering offices (NGI-Maghreb), regional managers (ORMVAH) and national directorates (CNCT).
    - Integrated modelling tools from TK3.2. Training sessions are organised by:
        - the OpenFLUID user committee for the benefit of engineering offices (CEREG, ENVILYS) ;

- NAILA, TREMA and O-LIFE international laboratories for the benefit of regional managers (DG-ACTA, ABHT, Litani authority) ;
- agency of Catalonian Directorate of Agriculture for the benefit of irrigation district management and engineering offices (e.g. Canal Aragón y Cataluña).

- Technical reports on management methods for the benefit of managers, on the basis of the conclusions of the participative seminars (TK 4.2), to be disseminated among NGOs and think-tanks.
- Policy brief on vulnerabilities and adaptabilities of irrigated and rainfed systems (TK 3.3) to be disseminated among development organisations.

**Deliverables** (the task leaders are responsible for related deliverables)

- D5.1.1 [Task 5.1]: metadata and metamodels are available on ALTOS project web site @ Month 6, 18, 33.
- D5.1.2 [Task 5.1]: organisation of modelling workshops @ Month 2, 18, 36.
- D5.2.1 [Task 5.2]: knowledge management strategy along with data management plan in the form of report @ Month 6, 18, 36.
- D5.2.2 [Task 5.2]: technical reports for managers, based on the conclusions of the participative seminar (TK 4.2, 1 per study site) @ Month 33.
- D5.2.3 [Task 5.2]: policy brief on vulnerabilities and adaptabilities of irrigated and rainfed systems @ Month 35.

**Associated milestones.**

- MS5.1: mobility plan for ALTOS partners @ Month 4.
- MS5.2: availability of data for resource managers @ Month 24.
- MS5.3: availability of materials for training sessions @ Month 18 and 30.

| **Work package number** | **WP6** | | **Lead beneficiary** | | **LISAH** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Work package title** | **Coordination, management and communication** | | | | | | | | | |
| **Participant number** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| **Short name of participant** | **LISAH** | **CESBIO** | **IRTA** | **UNICA** | **CNRS-L** | **LARI** | **UCAM** | **INAT** | **INRGREF** | **SUPCOM** | **CERTE** |
| **Person months per participant** | **33** | **2** | **1** | **2** | **1** | **1** | **1** | **1** | **1** | **1** | **1** |
| **Start month** | **1** | | | **End month** | | | | **36** | | | |

**Objectives**

The main objective of WP6 is to implement proficient management and scientific coordination of the project, with four sub-objectives listed below.

- Monitor all project activities and ensure the quality of the work carried out in all WPs, including ensuring high standards for deliverables.
- Ensure that all actions are performed correctly and within the rules and regulations established by the consortium agreement, including financial and legal management.

- Communicate with all project partners as well as with PRIMA-IS and funding agencies with regard to the implementation and progress of the project, including reporting.
- Ensure dialogue with community facilities (International laboratories, observatories, modelling platforms).

**Description of work**

**Task 6.1: Coordination and Management (Leader: LISAH).**

- Entities and compositions.
  - The management and coordination team (MCT) includes the scientific coordinator with a european project manager (EPM).
  - The management board (MB) includes MCT, WP leaders, and partner representatives.
- Missions.
  - The MCT ensures communication with all partners to monitor tasks and deliverables, progress reports, and to organise project meetings. Relevant documentation related to project management (guidelines, standardized tools for reporting, PRIMA-IS funding rules) are provided to partners via the MB. The coordinator writes and reviews the mid-term and the final reports before sending them to the PRIMA-IS. The MCT is in charge of elaborating the consortium agreement and managing unforeseen issues (e.g., obstacles, conflicts).
  - The MB is responsible for the political and strategic steering of the project. It ensures that the project is conducted in accordance with the workplan and commitments. It is in charge of making arbitrations when consensus cannot be made, and of making final decisions when necessary. It verifies the work progresses and the deliverable productions with respect to time schedule. Within the MB, WP leaders take operational decisions regarding WP daily management, with respect to WP scope and expected results. They are in charge of progress reports on scientific results.
- Management meetings.
  - The MB meeting occurs every six months. First and last MB meetings are held back-to-back with ALTOS kick-off meeting (in Tunisia) and final conference (in Italy). The fourth meeting at project mid-term is held back-to-back with the second modelling workshop in Morocco. Other MB meetings are held by videoconference. Meetings are prepared by the MCT and the local partners.

**Task 6.2: Communication (Leader: LISAH).**

- In parallel with the dissemination and engagement strategies setup in WP5, WP6 coordinates internal communication within the project and between the project and the PRIMA-IS. Managerial staffs from IRD specialized in communication who are part of the project actively participate in the elaboration and implementation of the communication plan. A communication plan is designed at the beginning of the project, including web-site, flyers, social networks.
- The EPM is in charge of the update of ALTOS website, including the public part that displays project objectives, structure, partners, results. In close collaboration with Task 5.1 leader and participants (sharing of data and methodological development) the EPM collects the relevant

information among WPs, and organise the information on the website.

- Finally, this task focuses on the running of all internal communication efforts during the course of the project, and offers operational support to the WP5. External communication and dissemination activities include the outward-facing project website, all social media activities related to ALTOS, stakeholder and public engagement tools and activities (in close collaboration with WP5), and printed materials (e.g. flyers for conferences and participative seminars).

**Deliverables** (the task leaders are responsible for related deliverables)
D6.1.1 [Task 6.1]: PRIMA-IS mid-term report @ Month 18.
D6.1.2 [Task 6.1]: PRIMA-IS final report @ Month 36.
D6.2.1 [Task 6.2]: ALTOS communication plan @ Month 3.
D6.2.2 [Task 6.2]: ALTOS website online @ Month 4, updated on a monthly basis.

**Associated milestones.**
MS6.1: ALTOS kick-off meeting in Tunisia @ Month 2.
MS6.2: Monitoring Board meetings @ Month 2, 6, 12, 18, 24, 30, 36.
MS6.3: Final conference in Italy @ Month 36.

Table 3.1.c: list of deliverables across WP1 to WP6

| Deliverable (number) | Deliverable name | WP # | lead participant | Type | Dissemination level | Delivery date (in months) |
|---|---|---|---|---|---|---|
| D5.1.2 | Modelling workshops | 5 | CNRS-L | R | CO | Month 2, 18, 36 |
| D6.2.1 | Communication plan | 6 | LISAH | R | CO | Month 3 |
| D6.2.2 | Project web site | 6 | LISAH | DEC | PU | Month 4 |
| D5.2.1 | Knowledge management strategy including a data management plan to be updated | 5 | INRGREF | R | CO | Month 6, 18, 36 |
| D5.1.1 | Metadata and metamodels | 5 | CNRS-L | DEC | PU | Month 6, 18, 33 |
| D1.1.1 | Dataset from Task 1.1 | 1 | IRTA | OTHER | CO | Month 15 |
| D1.2.1 | Dataset from Task 1.2 | 1 | LARI | OTHER | CO | Month 15 |
| D2.1.1 | Dataset from Task 2.1 | 2 | CERTE | OTHER | CO | Month 15 |
| D2.2.1 | Dataset from Task 2.2 | 2 | CESBIO | OTHER | CO | Month 15 |
| D3.1.1 | Modeling progresses | 3 | UNICA | R | CO | Month 15 |
| D6.1.1 | Mid-term report | 6 | LISAH | R | CO | Month 18 |
| D1.1.2 | Submitted publications | 1 | IRTA | R | PU | Month 21 |
| D1.2.2 | Submitted publications | 1 | LARI | R | PU | Month 21 |
| D2.1.2 | Submitted publications | 2 | CERTE | R | PU | Month 21 |
| D2.2.2 | Submitted publications | 2 | CESBIO | R | PU | Month 21 |
| D4.1.1 | Designed scenarios | 4 | UCAM | DEM | CO | Month 24 |
| D3.1.2 | Submitted publications | 3 | UNICA | R | PU | Month 27 |
| D3.2.1 | Integrated modelling improvement | 3 | INAT | R | CO | Month 33 |

| | | | | | | |
|---|---|---|---|---|---|---|
| D4.2.1 | Scenario ranking | 4 | INRGREF | R | PU | Month 33 |
| D4.3.1 | Agrosystem comparison | 4 | LISAH | R | PU | Month 33 |
| D5.2.2 | Technical reports for managers | 5 | INRGREF | R | PU | Month 33 |
| D5.2.3 | Policy brief on adaptabilities | 5 | INRGREF | R | PU | Month 35 |
| D3.2.2 | Submitted publications | 3 | INAT | R | PU | Month 36 |
| D4.2.2 | Submitted publications | 4 | INRGREF | R | PU | Month 36 |
| D6.1.2 | Final report | 6 | LISAH | R | CO | Month 36 |

Table 3.1.d: Gantt chart.

| | | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WP 1 | TK1.1 | | | | | D1.1.1 | | D1.1.2 | | | | | |
| | TK1.2 | | | | | D1.2.1 | | D1.2.2 | | | | | |
| | | | | | | | MS1 | | | | | | |
| WP 2 | TK2.1 | | | | | D2.1.1 | | D2.1.2 | | | | | |
| | TK2.2 | | | | | D2.2.1 | | D2.2.2 | | | | | |
| | | | | | | | MS2 | | | | | | |
| WP 3 | TK3.1 | | | | | D3.1.1 | | | | D3.1.2 | | | |
| | TK3.2 | | | | | | | | | | | D3.2.1 | D3.2.2 |
| | | | | | | | | | MS3 | | | | |
| WP 4 | TK4.1 | | | | | | | | D4.1.1 | | | | |
| | TK4.2 | | | | | | | | | | | D4.2.1 | D4.2.2 |
| | TK4.3 | | | | | | | | | | | D4.3.1 | |
| | | | | | | | | | MS4.1 | | | MS4.2 | MS4.3 |
| WP 5 | TK5.1 | D5.1.2 | D5.1.1 | | | | D5.1.1 D5.1.2 | | | | | D5.1.1 | D5.1.2 |
| | TK5.2 | | D5.2.1 | | | | D5.2.1 | | | | | D5.2.2 | D5.2.1 D5.2.3 |
| | | | MS5.1 | | | | MS5.3 | | MS5.2 | | MS5.3 | | |
| WP 6 | TK6.1 | | | | | | D6.1.1 | | | | | | D6.1.2 |
| | TK6.2 | D6.2.1 | D6.2.2 | | | | | | | | | | D6.2.2 |
| | | MS6.1 MS6.2 | MS6.2 | | MS6.2 | | MS6.2 | | MS6.2 | | MS6.2 | | MS6.2 MS6.3 |

## 3.2 Management structure, milestones and procedures

The central management functions are led by the coordinating partner (IRD-LISAH) and handled by the management and coordination team (MCT) that includes the european project manager (EPM) and the IRD scientific coordinator. The governance structure is optimized in line with the size of ALTOS (11 partners), for the benefit of the consortium, and to ensure close liaison with the PRIMA-IS and national funding agencies at all stages of the project.

The **management structure** of ALTOS comprises two levels.

- Executive level is represented by the management and coordination team (MCT).
- Decision-making and operational level is represented by the monitoring board (MB) that includes partner representatives and WP leaders.

Knowledge management, intellectual property and other innovation-related activities pertaining to ALTOS project are steered by the scientific coordinator with the support of the WP5 leader who manage the exploitation and dissemination of results.

The rules and organization of the management structure are formulated in detailed contractual terms in the consortium agreement. The major aspects of ALTOS management processes are presented below.

**The management and coordination team (MCT)**

- The management and coordination team (MCT) is composed by the scientific coordinator and the european project manager (EPM). The MCT takes overall responsibility for managing the project, for reporting to PRIMA-IS (scientific and technical, financial and administrative), and for preparing and negotiating the consortium agreement.
- The EPM is strongly involved in the implementation of the project, and closely follows project management activities and procedures. He works half-time for the duration of the project, and he is located in Tunisia at INRGREF where the scientific coordinator is regularly present, 3-4 months a year. They are also in contact on a daily basis by email, phone and videoconference. The EPM (i) ensures overall administrative management of the project, keeping financial overview of effort allocation, follows up on the implementation of the consortium agreement, (ii) manages the consortium-level legal and ethical issues, (iii) prepares reporting to the PRIMA-IS, (iv) handles IPR with regards to research activities, (v) handles and mitigate potential conflicts and critical risks (jointly with the scientific coordinator and the monitoring board - MB), (vi) prepares the minutes of the monitoring board meetings and (vii) monitors any emerging issues (risk register), and establish contingency responses.
- The MCT is financially and administratively supported by IRD (financial & administrative support team), that has the necessary back-office support structure and capacities to adequately manage the financial and administrative dimension of the project. IRD is accustomed to manage large-scale European Commission funded projects and projects funded under the ERA-NET scheme. The administrative support unit of IRD has actively participated to the development of the ALTOS project, it is available to answer partner administrative questions, and it ensures obligations and reporting procedures are met in due time.

**The monitoring board (MB)**

- The MB includes the MCT, the partner representatives, and the WP leaders.
  - For efficiency in project management, we strongly recommend that each ALTOS partner is represented by its respective PI (see list of participants at the beginning of the proposal).
  - In order to strengthen the project transversal structure, each WP is co-leaded by a binational pair. Such co-leadership helps to avoid both a focus on a given study site and a country-based compartmentalization of activities.
- At the decision level, the MB is responsible for the political and strategic steering of the project. It makes sure that the strategy adopted for the project is respected. It discusses the project technical progress, as well as the use of resources. The MB is primarily in charge of the following tasks.

- Controlling project implementation in keeping with the project road map and monitoring corrective actions, including the review of deliverables.
- Contractual changes including technical roadmaps, measures for defaulting partners and changes to the consortium agreement.
- Arbitrating on deadlocks in WP, when a consensus cannot be found.
- Taking final decisions during the project, based on information provided by the coordinator, WP leaders, the national funding agencies, and PRIMA-IS.

- At the operational level, the MB implements the project strategy. It coordinates the WP and ensures their interactions. It analyses each step of the overall project. It monitors project progresses and can decide to call special technical meetings to redirect work. It is in charge of the following tasks.
  - Drafting scientific reports on work packages progress.
  - Controlling project deliverables.
  - Managing risks. This means anticipating any project changes and implementation of best solutions to project risks. Each risk and its repercussions are analysed and solutions found.
- MB meetings occur at least twice per year.
  - First and last MB meetings are held back to back with ALTOS kick-off meeting (in Tunisia) and final conference (in Italy). The fourth MB meeting is held at project mid-term back-to-back with the second modelling workshop in Morocco. Other MB meetings are held by videoconference.
  - Any partner who is unable to appoint may design a representative. Decisions are made by consensus, and, where this is not possible, by majority vote. Each MB member has one vote for decision-making. Experts and specialists may be invited to attend the MB meetings in the role of advisor, in particular members of the community facilities (LMI and related user committees, observatories, modelling platforms). The meeting agendas cover (1) strategic and technical matters and (2) the dissemination and exploitation of project results.

Table 3.2.a: list of milestones.

| Milestone number | Milestone name | Related WP | Due date (in month) | Means of verification |
|---|---|---|---|---|
| **MS1** | Database update | 1 | 18 | Data available and validated by the MB. |
| **MS2** | Database update | 2 | 18 | Data available and validated by the MB. |
| **MS3** | Improved modelling schemes | 3 | 24 | Models assessed and validated |
| **MS4.1** | 4 participative seminars on scenario design | 4 | 22 | Seminar reports |
| **MS4.2** | 4 participative seminars on scenario ranking | 4 | 31 | Seminar reports |
| **MS4.3** | Database update | 4 | 35 | Reports |
| **MS5.1** | Mobility plan | 5 | 6 | Plan validated by the monitoring board |
| **MS5.2** | Data for resource managers | 5 | 24 | Data repository available for managers |

| | | | | |
|---|---|---|---|---|
| **MS5.3** | Materials for training sessions | 5 | 18, 30 | Material repository available for trainers |
| **MS6.1** | Kick off meeting | 6 | 2 | KOM minutes |
| **MS6.2** | Monitoring board meetings | 6 | 2, 6, 12, 18, 24, 30, 36 | Meeting minutes |
| **MS6.3** | Final conference | 6 | 36 | Conference reports |

| Table 3.2b: Critical risks for implementation | | |
|---|---|---|
| **Description of risk (indicate level of likelihood: Low/Medium/High)** | **Work package(s) involved** | **Proposed risk-mitigation Measures** |
| Delays in financial and/or administrative procedures (M) | All | The project will start when all partners have received their first payment. The coordinator will be in contact with the funding agencies to fix the start date of the project well in advance and in line with the signature of the Consortium Agreement. The EPM will develop and update a regulatory road map including information on national agencies financial rules and payment schedules and will be in contact with the national funding agencies throughout the project. If problems persist, the PRIMA-IS will be informed. |
| Decision-making issues (L) | All | Appropriate decision-making / organisation structure has been set in concertation with partners and will be detailed in the Consortium Agreement. If problems persist, the PRIMA-IS will be informed. |
| A partner decides to drop out of project (L) | All | The issue will be discussed in the Monitoring Board which will decide if it is necessary to re-allocate work to other partners or suppress work without reducing the scientific quality of the project. |
| Departure of an individual researcher (L) | All | The team is large enough to be able to replace absent researchers. Replacements have been foreseen for WP leaders. |
| Political instability in study sites countries (L) | All | Very similar activities across 3 countries. |
| Difficulties in accessing study sites (L) | 1, 2 | Long-term observatories guaranty continuous access to study site. |
| Delay in delivery of data and models (L) | 1, 2, 3 | Baseline data / models are already available from other projects, and they can be used if ALTOS improvements are not timey available. |
| Set of indicators not user friendly (L) | 4 | Indicators are designed during participative seminars. |

## 3.3 Consortium as a whole

The Mediterranean partnership behind the composition of the ALTOS consortium is among the key features for the success of the project.

First, this Mediterranean partnership is **equilibrated** between southern shore (Tunisia, Morocco, Lebanon) and northern shore (France, Italy, Spain) of the Mediterranean Basin. Besides, its organisation relies on transversal collaboration between partners in order to strengthen the cooperation across the Mediterranean Basin. Indeed, each WP is co-leaded by a **binational pair** to avoid both a focus on a given study site and a country-based compartmentalization of activities. This co-leadership also allows for a balanced distribution of coordination responsibilities among all partners, since each partner is involved in WP leadership, apart from SUPCOM which provides specific key competences on statistics and signal processing.

Second, this Mediterranean partnership **mobilises complementary skills towards achieving collective objectives** (Table 3.3). Thus, ALTOS can address landscaping evolution and resulting impacts by involving skills in monitoring, modelling and integrated analysis based. Such ambition is ensured by involving teams that are **internationally recognized** for their scientific excellence, nine of them being part of international laboratories labelled by Mediterranean institutions / ministries. These teams are also in charge of environmental observatories dedicated to the multi-decadal monitoring of water resources under climate / anthropogenic changes, including the gathering, processing and dissemination of data by following international standards (e.g., eLTER network of EU observatories). Finally, most of these teams are involved in large scale project management and contribution, as listed in Table 1.3. Few instances are (1) LISAH management responsibilities for ANR projects DIGISOL-HYMED and ALMIRA, as well as for ARIMNet 2 project MASCC, (2) CESBIO management responsibilities for ANR Project AMETHYST, H2020-MSCA project REC, as well as for ERA-NET MED project CHAAMS, and (3) UCAM management responsibilities for SAGESSE Moroccan project.

Table 3.3: complementary skills toward common objectives.

| Country | Partner | Skills. |
|---|---|---|
| Morocco | UCAM | Remote sensing, isotopy, crop functioning, hydrogeology. |
| Tunisia | INRGREF | Hydrology, bioclimatology, participatory seminars integrated analysis. |
| | INAT | Agronomy, remote sensing, hydrology. |
| | SUPCOM | Signal and image processing, statistics. |
| | CERTE | Hydrogeology, geochemistry. |
| Lebanon | CNRS-L LARI | Quantitative and qualitative hydrology. |
| | | Agrosystem management, remote sensing, outreach. |
| France | LISAH | Remote sensing, photogrammetry, hydrology, bioclimatology, geochemistry, agronomy, climatology, statistics. |
| | CESBIO | Remote sensing, hydrology, bioclimatology, crop functioning. |
| Spain | IRTA | Remote sensing, bioclimatology, participative seminars. |
| Italy | UNICA | Hydrology, hydrogeology, geochemistry. |

Third, this Mediterranean partnership brings together university laboratories and applied research institutes, some of the latter being partly missioned for knowledge transfer activities towards the agricultural sector. This makes the consortium acting on both research and knowledge transfer activities. This Mediterranean partnership also brings together research and higher education institutions, which makes the consortium transferring research results towards undergraduate and

undergraduate students during capacity building / training activities. Obviously, each partner is involved in ALTOS according to his/her institutional missions and related resources, and in accordance with his/her own competences built on previous projects.

Fourth, this Mediterranean partnership merges several collaborations that took place at the intra-national and inter-national scales over the last 15 years. This historical dimension has allowed for the creation of community facilities such as international laboratories, observatories and modelling platforms, but also for the development of close interactions with a large panel of stakeholders: farmer associations, resource managers, and engineer offices. Thus, strong interactions with stakeholders are formalised through user committees within the aforementioned community facilities, such committees being missioned to monitor adequacy between user needs and scientific programs / activities. Few instances about close collaborations with engineering offices are the GMES Africa program and the OpenFLUID modelling platform. Stakeholders who are part of these user committees are involved not only in result dissemination / exploitation, but also in the design of modulation scenarios and in the analysis of impact assessment. In this sense, the ALTOS project does not aim to transfer research results towards stakeholders only, but also to co-construct management methods directly with stakeholders.

## 3.4 Resources to be committed

Table 3.4a: Summary of staff effort. Note: we set a WP co-leadership (apart from WP6 on coordination), and therefore two person-month are in bold for each WP.

| | WP1 | WP2 | WP3 | WP4 | WP5 | WP6 | Total Person-Months per Participant |
|---|---|---|---|---|---|---|---|
| **IRD / LISAH** | 50 | 45 | 90 | 80 | 22 | **33** | 320 |
| **IRD / CESBIO** | 28 | **31** | 42 | 9 | 8 | 2 | 120 |
| **IRTA** | **34.5** | 5 | 28.5 | 0 | 1 | 1 | 70 |
| **UNICA** | 25 | 32 | **47** | 0 | 4 | 2 | 110 |
| **CNRS-L** | 3.5 | 3 | 0 | 8 | **4.5** | 1 | 20 |
| **LARI** | **8** | 0 | 0 | 4.5 | 0.5 | 1 | 14 |
| **UCAM** | 33 | 47 | 28.5 | **15** | 4.5 | 1 | 129 |
| **INAT** | 9 | 19.5 | **17** | 32 | 15 | 1 | 93.5 |
| **INRGREF** | 9.5 | 11 | 19.5 | **35** | **26** | 1 | 102 |
| **SUPCOM** | 16.5 | 6 | 0 | 0 | 1.5 | 1 | 25 |
| **CERTE** | 13 | **15** | 10 | 8.5 | 2.5 | 1 | 50 |
| **Total Person Months** | 230 | 214.5 | 282.5 | 192 | 89.5 | 45 | 1053.5 |

ALTOS staff effort is significantly supported by PRIMA funding (40%) in addition with partner organization own funding. The combination of the two funding sources is key to ensure the achievements of ALTOS objectives and partner commitments.

Table 3.4b: 'Other direct cost' items (travel, equipment, other goods and services, large research infrastructure)

| 1/IRD-LISAH | Cost (€) | Justification |
|---|---|---|
| **Travel** | 11 000 | • Coordination meetings (kick-off, monitoring board, |

| | | |
|---|---|---|
| | | final conference) (WP6)<br>• Field campaigns (WP1, WP2) |
| **Other goods and Services** | 12 000 | • Organization of kick-off meeting in Tunisia (60 participants) |
| **Total** | 23 000 | |
| **2/IRD-CESBIO** | **Cost (€)** | **Justification** |
| **Travel** | 10 000 | • Coordination meetings (kick-off, monitoring board, final conference) (WP6)<br>• Field campaigns (WP1, WP2)<br>• Participative seminars (WP4) |
| **Equipment/Consumables** | 5000 | • Root sap flow measurements (Task 2.1 Task 2.2) |
| **Total** | 15 000 | |
| **3/IRTA** | **Cost (€)** | **Justification** |
| **Travel** | 3 000 | • Coordination meetings (kick-off, monitoring board, final conference) (WP6) |
| **Equipment/Consumables** | 20 000 | • Field campaigns (WP1, WP2)<br>• Workstation & storage (WP1, WP3)<br>• Photogrammetric software (WP1)<br>• Eddy Covariance Sensor Calibration (WP2)<br>• Equipment replacements, TDR probes (WP2)<br>• dGPS upgrade to centimetric resolution (WP2) |
| **Other goods and Services** | 15 000 | • Contracting flight hours (WP1, WP2)<br>• Participation to scientific congresses (WP5)<br>• Publications (WP1, WP2, WP3) |
| **Total** | 38 000 | |
| **4/UNICA** | **Cost (€)** | **Justification** |
| **Travel** | 35 000 | • Coordination meetings (kick-off, monitoring board, final conference) (WP6)<br>• Field campaigns (WP1, WP2)<br>• Participation to scientific congresses (WP5) |
| **Equipment/Consumables** | 10 000 | • Repairs and maintenance of scientific instruments (WP2) |
| **Other costs** | 20 000 | • Organization of final conference (WP6) and of one modelling workshop (WP5).<br>• Publications (WP1, WP2, WP3) |
| **Total** | 65 000 | |
| **5/CNRS-L** | **Cost (€)** | **Justification** |
| **Travel** | 8 000 | • Coordination meetings (kick-off, monitoring board, final conference) (WP6)<br>• Participation to scientific congresses (WP5) |
| **Equipment/Consumables** | 6 000 | • Field campaigns (WP1, WP2)<br>• Laboratory analysis (WP2) |
| **Other goods and Services** | 9 000 | • Organization of participative seminars (WP4) |

| | | |
|---|---|---|
| | | • Subcontracting (temporary expert/researcher) for participative seminars (WP4)<br>• Publications (WP1, WP4) |
| **Total** | 23 000 | |
| **6/LARI** | **Cost (€)** | **Justification** |
| **Travel** | 3750 | • Coordination meetings (kick-off, monitoring board, final conference) (WP6)<br>• Participation to scientific congresses (WP5) |
| **Equipment / Consumables** | 3000 | • Field campaigns (WP1, WP2) |
| **Other goods and Services** | 3 850 | • Organization of participative seminars (WP4)<br>• Publications (WP1) |
| **Total** | 13 000 | |
| **7/UCAM** | **Cost (€)** | **Justification** |
| **Travel** | 29 650 | • Coordination meetings (kick-off, monitoring board, final conference) (WP6)<br>• Participative seminars (WP4)<br>• Mobility of PHD (WP5)<br>• Participation to scientific congresses (WP5)<br>• Field campaigns (WP1, WP2) |
| **Equipment/Consumables** | 31 050 | • Measurement instruments: KH20 Krypton Hygrometer (tree evapotranspiration), 5 sap flow systems (tree sap flow), 5 TDR, soil Moisture Sensor Probe (WP2) |
| **Other goods and Services** | 3 000 | • Organization of participative seminars (WP4) |
| **Total** | 63 700 | |
| **8/INAT** | **Cost (€)** | **Justification** |
| **Travel** | 10 500 | • Coordination meetings (kick-off, monitoring board, final conference) (WP6)<br>• Modelling workshops (WP5)<br>• Field campaigns (WP1 WP2)<br>• Mobility of PhD (WP5)<br>• Participative seminars (WP4) |
| **Equipment/Consumables** | 9 000 | • Computer Equipment for numerical modelling (WP3) and numerical simulations (WP4)<br>• Software for hydrological modelling (WP3)<br>• TDR Probes (WP2) |
| **Other goods and Services** | 10 000 | • Chemical Analysis (WP1, WP2)<br>• Organization of Participative seminars (WP4)<br>• Publications (WP2, WP3, WP4) |
| **Total** | 29 500 | |
| **9/INRGREF** | **Cost (€)** | **Justification** |
| **Travel** | 13 000 | • Coordination meetings (kick-off, monitoring board, final conference) (WP6)<br>• Mobility of PhD (WP5) |

| | | |
|---|---|---|
| | | • Field campaigns (WP1, WP2) |
| **Equipment/Consumables** | 7 000 | • Computer for numerical modelling (WP3) and numerical simulations (WP4)<br>• Terra SAR-X (WP1) |
| **Other goods and Services** | 10 000 | • Organization of participative seminars (WP4)<br>• Publications (WP3, WP4) |
| **Total** | 23 000 | |
| **10/SUPCOM** | **Cost (€)** | **Justification** |
| **Travel** | 5000 | • Coordination meetings (kick-off, monitoring board, final conference) (WP6)<br>• Mobility of PhD (WP5) |
| **Equipment/Consumables** | 4000 | • Workstation (Xeon processor) for data processing and statistical analysis (WP1, WP2)<br>• Wireless sensor networks (moisture, luminosity, cameras …) acquisition and installation (WP2) |
| **Total** | 9 000 | |
| **11/CERTE** | **Cost (€)** | **Justification** |
| **Travel** | 6500 | • Coordination meetings (kick-off, monitoring board, final conference) (WP6)<br>• Mobility of PhD (WP5)<br>• Field campaigns (WP1, WP2) |
| **Equipment/Consumables** | 10 000 | • Geophysical cable (WP1, WP2)<br>• Hobo Water Level Logger Instruments (WP1, WP2)<br>• Hobo Conductivity Data Loggers; (WP1, WP2)<br>• Multi-parameter water quality meters for geochemical tracing (WP1, WP2)<br>• Visual MODFLOW Flex (WP3)<br>• Computers for numerical modelling (WP3) |
| **Other goods and Services** | 1000 | • Publications (WP1, WP2, WP3) |
| **Total** | 16 500 | |

Table 3.4c: declaring cost of large infrastructures

| **Participant Number/Short Name** | **Cost (€)** | **Justification** |
|---|---|---|
| **Large research Infrastructure** | **Non applicable** | |

## Section 4: Members of the consortium

Both LISAH and CESBIO are Laboratories under the supervision French Research Institute for Sustainable Development (IRD). IRD is a French multidisciplinary research institute dedicated to working on global development issues. Placed under the supervision of the French Ministry of Research and the Ministry of Foreign Affairs and International development, the IRD uses an original

approach on development research and expertise throughout its international network in over 90 countries. Emphasizing interdisciplinarity, the IRD has focused its research for over 65 years on the relationship between man and its environment, in Africa, Mediterranean, Latin America, Asia and the French territories. Its research, training and innovation activities are intended to contribute to the social, economic and cultural development of southern countries. In the coming years, the major issues of development research will focus on three interrelated areas: the consequences of climate change, demographic trends and globalisation. These areas need to be tackled by responding to the aspirations and singular priorities of states, who themselves are sensitive to exchanges between the economic, social, cultural and geographical areas. Beyond this new international context, including the diversity of situations in the South and the current crises, the IRD, with its academic partners, promote an ethic of partnership.

### 4.1. Participants (applicants)

**#1 LABORATORY FOR THE STUDY OF SOIL-AGROSYSTEM-HYDROSYSTEM INTERACTIONS (IRD / LISAH)**

**Description:**
LISAH Laboratory conducts research in hydrology, contaminant transfers and erosion in cultivated landscapes. Landscapes are studied as spatial properties with spatiotemporal changes, in order to integratively address the management of soil and water resources in cultivated landscapes. Main objective is to develop knowledges on mass transfers (water, erosive) and on eco-dynamics of contaminants (with a focus on agricultural pesticides) in relation to the organization (in time and space) of both natural (soils, landform) and anthropogenic (land use, management, agricultural practices) properties. The team involved in ALTOS gathers skills in subsurface and subsurface hydrology, bioclimatology and SVAT modelling, remote sensing and photogrammetry, digital soil mapping and landscape numerical modelling, geochemistry, land use and cropping systems, erosion, climatology, geostatistics and spatialization methods.

**Members:**

- **Frédéric Jacob** (Project coordinator; PI-IRD/LISAH) (M) is an IRD senior scientist (PhD) who conducts research / transfer activities in southern France and Tunisia. His background is the use of spectral, angular, spatial and temporal information collected from optical remote sensing for the retrieval of crop water consumption and related drivers. He now investigates the use of in-situ and remote sensing data for characterizing crop water consumption under complex situations such as hilly and heterogeneous landscapes and discontinuous crop canopies. At the collective scale through management of large projects (ANR ALMIRA, NAILA international joint laboratory), he studies the structuring, the functioning and the evolution of cultivated landscapes, as well as the modulation of landscape structures for the setting up of trade-off between different ecosystems services. He has served as an associate editor for IEEE-GRSL (IEEE senior member since 2015), as an evaluator for H2020 proposals, and as a scientific committee member of CNES / NASA / ISRO space missions. He has supervised 6 PhD students and 15 MSc students. He has published 57 peer-reviewed articles, 3 book chapters, 1 white book; and he has edited one special issue (Scopus h-index is 20). As part of his IRD professional assignments, he spent six years as an expatriate in Tunisia, where (1) he has coordinated the ANR ALMIRA project

which extends over France, Tunisia and Morocco, and (2) he has co-led the NAILA international laboratory.

- Laurent PRÉVOT (M) is an INRA senior scientist (PhD) who works on modelling and observing of crop water consumption under complex situations such as hilly and heterogeneous landscapes and discontinuous crop canopies. He focuses on assessing and tailoring existing methods based on eddy covariance techniques and SVAT modelling.
- Jean-Christophe FABRE (M) is an INRA research engineer (MSc) who works on the development of generic frameworks for the modelling of environmental processes, including conceptual frameworks for spatial connectivities and process modular description. He is currently in charge of the team that develops the OpenFLUID integrated modelling platform.
- Jérôme MOLÉNAT (M) is an INRA senior scientist (PhD) who works on surface and surface hydrology within cultivated landscapes, with a focus on agricultural infrastructures such as reservoirs. He is currently in charge co-managing the OMERE observatory, and he is director of UMR LISAH.
- Cécile DAGÈS (F) is an INRA research scientist (PhD) who investigates surface and subsurface flows of water and agricultural pollutants, along with the benefit of agricultural landscaping for mitigating pollutant effects. She serves as the scientific coordinator of the OpenFLUID integrated modelling platform, and thus chairs the OpenFLUID user committee.
- Damien RACLOT (M) is an IRD senior scientist (PhD) who works on observation and modelling of erosion processes, in view to propose mitigation solutions based on land use and landscaping.
- Olivier Grünberger (M) is an IRD senior scientist (PhD) who works on soil and water contamination processes by pesticides in southern Mediterranean countries. As part of his IRD professional assignments, he is currently assigned at INAT Tunis, and involved in (1) long-term field monitoring, and (2) management of OMERE site in Cap Bon. He is Deputy Head of UMR LISAH.
- Denis FEURER (M) is an IRD research scientist (PhD) who works on the characterization of landscape structures at very fine spatial resolutions, including the design of observation systems such as kite-borne sensors, and the design of photogrammetric processing for resulting data. As part of his IRD professional assignments, he spent four years as an expatriate in Tunisia, to co-manage the OMERE Tunisian site.
- Cécile Gomez (F) is an IRD senior scientist (PhD) who works on digital soil mapping from Vis-NIR remote sensing data at very fine spatial resolutions. As part of his professional assignments at IRD, she spent two years as an expatriate in Tunisia.
- Anne BIARNÈS (F) is an IRD senior scientist (MSc) who works on farmer strategies for agricultural practices such as land use conversion, crop rotation, tillage and chemical treatments.
- Bailly Jean-Stéphane (M) is an AgroParisTech senior scientist (PhD) who works on developing geostatistical methods for characterizing agricultural infrastructures within cultivated landscapes.
- Julie CARREAU (F) is an IRD research engineer (PhD) who works on the development of geostatistical methods for characterizing extremes events related to climate forcing.

**Relevant publications:**

- Carreau J., Naveau P., Neppel L. (2017). Partitioning into hazard subregions for regional peaks-over-threshold modelling of heavy precipitation. Water Resources Research, 53(5), 4407-4426.
- Galleguillos M. Jacob F., Prévot L., Faúndez C., Bsaibes A. (2017). Estimation of actual evapotranspiration over a rainfed vineyard using a 1-D water transfer model: A case study within a Mediterranean watershed. Agricultural water management, 184, 67-76.
- Gomez C., Adeline K., Bacha S., Driessen B., Gorretta N., Lagacherie P., Roger J.M., Briottet X., 2018. Sensitivity of clay content prediction to spectral configuration of VNIR/ SWIR imaging data, from multispectral to hyperspectral scenarios. Remote Sensing of Environment, 204, 18–30.
- Molénat J., Raclot D., Zitouna R., Andrieux P., Coulouma G., Feurer D., Grünberger O., Lamachère J.M., Bailly J.S., Belotti J.L., Ben Azzez K., Ben Mechlia N., Ben Younès Louati M., Biarnès A., Blanca Y., Carrière D., Chaabane H., Dagès C., Debabria A., Dubreuil A., Fabre J.C., Fagès D., Floure C., Garnier F., Geniez C., Gomez C., Hamdi R., Huttel O., Jacob F., Jenhaoui Z., Lagacherie P., Le Bissonnais Y., Louati R., Louchart X., Mekki I., Moussa R., Negro S., Pépin Y., Prévot L., Samouélian A., Seidel J.L., Trotoux G., Troiano S., Vinatier F., Zante P., Zrelli J., Albergel J., Voltz M., 2018. OMERE, a long-term observatory of soil and water resources in interaction with agricultural and land management in Mediterranean hilly catchments. Vadoze Zone Journal. In press.
- Mekki, I. Bailly, J.S., Jacob F., Chebbi H., Ajmi T., Blanca Y., Zairi, A., Biarnès A., 2018. Impact of farmland fragmentation on rainfed crop allocation in Mediterranean landscapes: A case study of the Lebna watershed in Cap Bon, Tunisia. Land Use Policy, 75, 772–783.


**Relevant projects:**

- ANR DIGISOL-HYMED (2009-2012). Digital hyperspectral imagery for environmental modelling Soil Mapping by in Mediterranean regions.
- ANR TRANSMED ALMIRA (2014-2018). Adapting landscape mosaics of Mediterranean rainfed agrosystems for a sustainable management of crop production, water and soil resources.
- FP7 ExpeER (2010-2015). ExpeER (Experimentation in Ecosystem Research) is a European project which aimed to bring together the major observational, experimental, analytical and modelling facilities in ecosystem science in Europe.
- ARIMNet 2 MASCC (2016-2019). Mediterranean Agricultural Soils Conservation under global Change.
- ERA-NET MED CHAAMS (2018-2021). Global Change: Assessment and Adaptation to Mediterranean Region Water Scarcity.

**Description of significant infrastructures and technical equipments:**

- LISAH co-manages with INRGREF (Tunisia) and INAT (Tunisia) the OMERE observatory in the Cap Bon study site.
- LISAH is co-leading with INRGREF (Tunisia) the NAILA ("Managing water resources in Tunisian rural areas") Joint International Laboratory.
- LISAH is leading the OpenFLUID integrated modelling platform which is labelled as a strategic instrument by the "Environment and Agriculture" Department of the French National Institute for Agricultural Research
- LISAH manage a micro-pollutant laboratory dedicated to the analysis and tracing of labelled molecules in soil columns.

## #2 CENTRE FOR THE STUDY OF THE BIOSPHERE FROM SPACE – (IRD/CESBIO)

**Description:**
CESBIO is a French public research laboratory dedicated to the study of continental surfaces using remote sensing. It is a Joint Research Unit from 5 public entities: the French centre for scientific research (CNRS), Toulouse University, the French Space Agency (CNES), the Research Institute for Development (IRD), and recently, the French institute for agronomic research (INRA). CESBIO research and academic activities cover the observation and modelling of the continental surfaces, address the interface between physical and biological sciences, and participate to the specification of space missions and the processing and applications of remotely sensed data. The team involved in this project gathers specialists in remote sensing and its applications to monitoring water-related biophysical variables (soil moisture, LAI, ET, irrigated area and LU mapping...), hydrological and soil-vegetation-atmosphere transfer modelling and integrated water resource management modelling through the development of the SAMIR software and its coupling with the water allocation model WEAP.

**Members**

- Gilles Boulet (PI-IRD/CESBIO) (M) is an IRD senior researcher (PhD). He has led several projects sponsored by the French Space Agency to develop and evaluate ET products based on VIS/NIR/TIR data. He has more than 20 years of experience in field experiments and research developments designed for semi-arid water resources sustainable management. He has published more than 80 papers in peer referred journals and his h-index is 23.
- Olivier Merlin (M) is a CNRS researcher (PhD) specialized in the joint use of multi-sensor (optical/TIR/active and passive microwave) remote sensing data for multi-scale monitoring of surface water fluxes and status.
- Lionel Jarlan (M) is an IRD senior researcher (PhD) specialized in water resources monitoring and vegetation functioning through remote sensing data assimilation into land surface models over semi-arid areas.
- Mehrez Zribi (M) is a CNRS senior researcher (PhD) specialised in microwave modelling for land surface parameters estimations and applied to land surfaces.
- Michel Le Page (M) is an IRD engineer specialized (MSc) in geo-computing including the development of GIS softwares, geoprocessing lines and web applications.
- Laurent Drapeau (M) is an IRD research engineer (MSc) in applied mathematics and spatial environmental information systems projects.
- Valérie Le Dantec (F) is a Toulouse University assistant professor (PhD) whose current research focuses on the application of remote sensing to detect and to monitor plant water stress.
- Vincent Simonneaux (M) is an IRD research engineer (PhD) specialised in operational approaches for the management of irrigated areas using satellite images and is currently co-manager of the TREMA mixed French-Moroccan laboratory based in Morocco.
- Ghani CHEHBOUNI (M) is an IRD senior researcher (PhD) in remote sensing with a focus on the monitoring of key processes related to evapotranspiration with finalized research oriented towards irrigation scheduling.

**Relevant publications:**

- Aouade, G., Ezzahar, J., Amenzou, N., Er-Raki, S., Benkaddour, A., Khabba, S., and Jarlan, L., 2016. Combining stable isotopes, Eddy Covariance system and meteorological measurements for partitioning evapotranspiration, of winter wheat, into soil evaporation and plant transpiration in a semi-arid region, Agricultural Water Management, 177, 181-192.
- Boulet, G., Mougenot, B., Lhomme, J.-P., Fanise, P., Lili-Chabaane, Z., Olioso, A., Bahir, M., Rivalland, V., Jarlan, L., Merlin, O., Coudert, B., Er-Raki, S., and Lagouarde, J. P., 2015. The SPARSE model for the prediction of water stress and evapotranspiration components from thermal infra-red data and its evaluation over irrigated and rainfed wheat, Hydrology and Earth System Sciences, 19, 4653-4672.
- Duchemin, B., P. Maisongrande, G. Boulet, and I. Benhadj, 2008. A simple algorithm for yield estimates : Evaluation for semi-arid irrigated winter wheat monitored with green leaf area index, Environmental Modelling & Software, 23, 876–892.
- Merlin, O., Olivera-Guerra, L., Hssaine, B. A., Amazirh, A., Rafi, Z., Ezzahar, J., Gentine, P., Khabba, S., Gascoin, S., and Er-Raki, S., 2018 A phenomenological model of soil evaporative efficiency using surface soil moisture and temperature data, Agricultural and Forest Meteorology, 256, 501-515.


**Relevant projects:**

- FP6 INCO IRRIMED (2003-2007). Improved management tools for water-limited irrigation: combining ground and satellite information through models
- ANR TRANSMED AMETHYST (2014-2018). Assessment of changes in MEdiTerranean HYdro-resources in the South: river basin Trajectories.
- H2020 RISE REC (2015-2018). Root zone soil moisture Estimates at the daily and agricultural parcel scales for Crop irrigation management and water use impact – a multi-sensor remote sensing approach.
- ERA-NET MED CHAAMS (2018-2021). Global Change: Assessment and Adaptation to Mediterranean Region Water Scarcity.
- H2020 RISE ACCWA (2019-2021). Accounting for Climate Change in Water and Agriculture management.

**Description of significant infrastructure and technical equipment:**

- CESBIO co-manages with UCAM (Morocco) observatory in Tensift study site.
- CESBIO co-manages with INAT (Tunisia) observatory in Merguellil study site.
- CESBIO is co-leading with UCAM the TREMA ("Remote Sensing and Water Resources in semi-arid Mediterranean") Joint International Laboratory with UCAM,
- CESBIO is part of NAILA and O-LIFE Joint International Laboratories.

## #3 INSTITUTE OF AGRIFOOD RESEARCH AND TECHNOLOGY (IRTA)

**Description:**

IRTA is a research institute owned by the Government of Catalonia (Spain) whose mission is to contribute to modernizing, improving, boosting competitiveness and fostering sustainable development in the sectors of agriculture, food, agro-forestry, aquaculture and fishing. The Efficient Use of Water in Agriculture program at IRTA has the mission of bringing to the agricultural sector

updated knowledge and experience on managing irrigation. The team has a deep scientific background on plant physiology, resource management in orchards, vineyards and field crops, and usually addresses the development of optimized irrigation and fertigation strategies. In the most recent years, new R&D lines in the group have focused on the development of precision irrigation technologies aiming to integrate soil/crop sensor networks, remote sensing and simulation on decision support systems for irrigation and fertigation.

**Members**

- Héctor Nieto (PI-IRTA) (M) obtained his PhD degree on ¨Remote Sensing, GIS and Cartography¨ at the University of Alcala in 2010. After completion of his PhD, he joined the Hydrological Observatory of Denmark for 5 years, where he worked on the use of satellite remote sensing at different scales for evapotranspiration modelling. Later, he was awarded in 2014 with an FP7-MCA-COFUND action on the use of very high resolution imagery for estimating evapotranspiration over heterogeneous vegetated areas, where he worked at the USDA-Hydrology and Remote Sensing Laboratory (Maryland, USA) and the Institute for Sustainable Agriculture (Spain). Dr. Nieto is currently the responsible at IRTA of two international projects (MOIST and SENET). According to Scopus he has 25 peer-reviewed scientific publications, with 539 citations and h-index=12.
- Joaquim Bellvert is a research scientist (PhD) specialized on the use of remote sensing technologies for precision irrigation to improve irrigation efficiency and water productivity. His main line of research consists in using high-resolution thermal and multispectral imagery to estimate within-field spatial variability of water status and crop evapotranspiration.

**Relevant publications:**


- García-Tejera, O., López-Bernal, A., Testi, L., and Villalobos, F. J. (2017). A soil-plant-atmosphere continuum (SPAC) model for simulating tree transpiration with a soil multi-compartment solution. Plant and soil, 412(1-2), 215-233.
- Kustas, W.P., Nieto, H., Morillas, L., Anderson, M.C., Alfieri, J. Hips, L., Villagarcia, L., Domingo, F., and Garcia, M. (2016) Revisiting the paper "Using radiometric surface temperature for surface energy flux estimation in Mediterranean drylands from a two-source perspective". Remote Sensing of Environment. 184, 645-653.
- Bellvert, J., Zarco-Tejada, P.J., Marsal J., Girona, J., Gonzalez-Dugo E., and Fereres, E. (2016) Vineyard irrigation scheduling based on airborne thermal imagery and water potential thresholds. Australian Journal of Grape and Wine Research, 22, 307-315.
- Guzinski, R., Nieto, H., Stisen, S., and Fensholt, R. (2015) Inter-comparison of energy balance and hydrological models for land surface energy fluxes estimation over a whole river catchment, Hydrology and Earth System Sciences, 19 (4), 2017-2036
- Villalobos, F.J., Testi, L., Orgaz, F., García-Tejera, O., Lopez-Bernal, A., González-Dugo, M.V., Ballester-Lurbe, C., Castel, J.R., Alarcón-Cabañero, J.J., Nicolás-Nicolás, E. and Girona, J. (2013) Modelling canopy conductance and transpiration of fruit trees in Mediterranean areas: a simplified approach. Agricultural and forest meteorology, 171, 93-103.


**Relevant projects:**

- TELERIEG, use of remote sensing technologies for irrigation recommendation and management in the SUDOE space. EU / Programme Interreg IVB-Sudoe (2009 – 2011)

- Sentinels for Evapotranspiration, SEN-ET will develop an open source implementation of evapotranspiration estimation software, based on data from Sentinel 2 and Sentinel 3. European Space Agency (2017-2019)
- Vineyard Integrated Smart Climate Application, VISCA will provide a Climate Service (CS) and Decision Support System (DSS) that integrate climate, agricultural and end-user specifications to design adaptation strategies to climate changes. H2020 project (2017-2020).
- Managing and Optimizing Irrigation by Satellite Tools, MOIST provides new, scientifically based satellite products to farmers in Denmark and abroad for intelligent irrigation management. Innovation Fund Denmark (2017-2020)
- Low Input Sustainable Agriculture, LISA aims to advance in the application of precision agriculture for more efficient practices at both farm and irrigation district level (2018 – 2020)

**Description of significant infrastructure and technical equipment:**
Platform for code sharing.

**#4 UNIVERSITY OF CAGLIARI (UNICA)**

**Description:**
The Department of Civil and Environmental Engineering and Architecture is the polytechnic expression of the University of Cagliari. It is the place of training for architects, civil and environmental engineers, with important projections to applied geosciences, professionals and researchers in planning and land management. Expertise inside the Department, such as environmental protection, sustainability, energy efficiency, Cultural Heritage, ICT, are key themes for the third millennium model of development in advanced societies. The hydraulic and hydrology group aims to promote projects and studies mainly related with the hydraulic risk evaluation, protection of the environment, protection of the marine environment, environmental hydraulic and soil–atmosphere interactions. Design of civil structure/infrastructures, hydrological networks, design of maritime structures and Hydraulic System Design are also the main themes promoted. The expertise in the fields of water resources planning and management, ecohydrology, micrometeorology, geophysics, and design of hydraulic infrastructures allows to address the activities and the objectives of the proposal and match the tasks.

**Members:**
- Nicola Montaldo (PI-UNICA) (M) is associate professor of Hydrology and water resources at the University of Cagliari (Italy) in the Department of civil and environmental engineering and architecture. He graduated in Civil Engineering at the University of Cagliari in 1995 and obtained a Ph.D. in Hydrology at the Polytechnic of Milan in 2000. He was assistant professor at Polytechnic of Milan from 2003 to June 2006 and visiting professor at University of Virginia (USA) in 2001, at Duke University (USA) in 2002, 2004, 2005, 2013 and 2017, at the Swedish University of Agricultural Sciences (Umeå, Sweden) in 2014, and Cornell University (USA) in 2015. Research interests: distributed hydrological modelling, unsaturated zone hydrology, land-atmosphere exchange, eco-hydrology, remote sensing and data assimilation in hydrological modelling. On these topics he was funded for research support as PI by many Italian and European institutions, as Italian Spatial Agency, National Institute for Scientific and Technological Research on Mountains, Italian Ministry of University, European Community “Programme Italy/France

'Maritime' 2007-2013", Sardinia Research, Regional Sardinian authority. He is author of more 100 publications.

- Giulio Vignoli (M) graduated in Physics at the University of Ferrara and received a PhD in Applied Geophysics from the same institution with a thesis focusing on inversion strategies. He is currently Associate Professor at the University of Cagliari and Adjunct Senior Researcher at the Geological Survey of Denmark and Greenland (GEUS). His research interests include near-surface characterization especially with airborne electromagnetic and seismic surface wave methods
- Andrea Saba (M) is Assistant Professor in water resources at University of Cagliari. His research activity is mainly related to design and optimisation of hydraulic infrastructures.
- Francesco Viola (M) is assistant professor at University in Cagliari in hydrology. His research activity is mainly related to surface hydrology.
- Alessandro Seoni (M) is a civil engineer, technical staff at University of Cagliari.
- Antonio Mascia (M) is technical staff at the Hydraulic Laboratory of University of Cagliari.

**Relevant publications:**

- Montaldo N., J. D. Albertson and M. Mancini, Vegetation dynamics and soil water balance in a water-limited Mediterranean ecosystem on Sardinia, Italy. Hydrology and Earth System Science Discussion, 5, 219–255, 2008.
- Montaldo N, Corona R, J D Albertson. On the Separate Effects of Soil and Land Cover on Mediterranean Ecohydrology: Two Contrasting Case Studies in Sardinia, Italy. Water Resources Research, 0043-1397, 2013.
- Montaldo N and Oren R. The way the wind blows matters to ecosystem water use efficiency. Agricultural and forest meteorology, 217, 1-9, 2016.
- Montaldo, Nicola, Sarigu, Alessio. Potential links between the North Atlantic Oscillation and decreasing precipitation and runoff on a Mediterranean area. Journal of Hydrology, 553, 419-437, 2017.
- Montaldo, N., Oren, R. Changing seasonal rainfall distribution with climate directs contrasting impacts at evapotranspiration and water yield in the western Mediterranean region. Earth's Future, 6, 841–856.

**Relevant projects:**

- IDROSAR: remote sensing soil moisture estimation and data assimilation system (CRP2_708, LR 7/2007) (C)
- CLIMB: Climate Induced Changes on the Hydrology of Mediterranean Basins: Reducing Uncertainty and Quantifying Risk through an Integrated Monitoring and Modeling System, "7th Framework Programme", call FP7-ENV-2009-1, topic ENV.2009.1.1.5.2 (P).
- Monitoring and modelling for water resources estimate in the Flumendosa basin under climate and land use change scenarios (CRP2_708, LR 7/2007) (P);
- Micrometeorological and remote sensing measurements integration within distributed hydrological modelling for the evapotranspiration assessment (FIRB, LR7/2007) (P);
- SEDEMED II: Dryness and Turning into a desert in the Mediterranean basin, Interreg IIIB MEDOCC (P).

**Description of significant infrastructure and technical equipment:**

Three eddy covariance – based towers with 3D sonic anemometers, gas analysers, net radiometers, rain gauges, meteorological sensors, data loggers. Sap flow sensors, soil moisture sensors, soil water potential sensors, data server, flow meters, leaf water potential meter, Accupar ceptometer for leaf area index measurements, soil physics laboratory, facility for chemical analysis, hydraulic laboratory. Several ground penetrating radar antennas allowing surveys at different resolutions and depth of investigation, frequency and time – domain electromagnetic devices, equipment for 2D and 3D electrical resistivity tomography.

**#5 NATIONAL COUNCIL FOR SCIENTIFIC RESEARCH OF LEBANON (CNRS-L)**

**Description:**
Established in 1995, the CNRS-L / Remote Sensing Centre (RSC) is a leading agency on most recent insights in remote Sensing and GIS technology. Conceived as support for decision making, the RSC is a revolving platform among various ministries. The centre address environmental monitoring and data acquisition, as well as staff training on remote sensing and GIS, for a large panel of thematic, including watershed management, forestry, urban settlements, archaeology, integrated coastal zone management, public participation, natural hazards, natural resources (water, soil, biodiversity). Over the past years, the Remote Sensing Centre has successfully implemented more than 40 projects either through bilateral programs with France, Italy and Syria; or International programs (NOSTRUM, TERCOM, INCAM) and projects funded by international agencies such as IDRC, FAO, EU, WB/GEF. Members involved in ALTOS provide skills on water resources, climate change, forests, land cover and agriculture.

**Members:**

- Dr. Ali Fadel (PI-CNRS-L) (M) PhD in Environmental Engineering (2014), ENPC. Has worked on the development and implementation of monitoring programs and alerting systems to improve and manage freshwater bodies quality. Actually, conducting research on multidisciplinary topics related crop productivity, remote sensing techniques, and hydrodynamic modelling. Served as expert consultant on projects funded by international agencies. Author of several refereed publications.
- Amin Shaban (M) is a senior scientist CNRS-L. He holds a PhD from Bordeaux University and he has achieved a Fulbright program in the United States (Boston University). He is specialized in the use of satellite images to study water resources, including monitoring water resources, watershed management, and climate change impact on water. He has more than 50 Publications in International Journals, as well as participated in more than 75 seminars worldwide.
- Talal Darwish (M) is a senior scientist at CNRS-L. He has served since 1980 as principal investigator in research projects on soil mapping and soil-water-plant interaction, sustainable soil and water management in view of desertification and land degradation. Author of 1:50.000 soil map of Lebanon. Former Member of the IWG on land degradation and current member of the ITPS of the FAO GSP. Has 140 papers in refereed journals and proceedings.

**Relevant publications:**

- Fadel, A., & Slim, K. (2018). Evaluation of the Physicochemical and Environmental Status of Qaraaoun Reservoir. In the Litani River, Lebanon: An Assessment and Current Challenges (pp. 71-86). Springer, Cham.

- Darwish, T., & Fadel, A. (2017). Mapping of soil organic carbon stock in the Arab countries to mitigate land degradation. Arabian Journal of Geosciences, 10(21), 474.
- Fayad, S. Gascoin, G. Faour, P. Fanise, L. Drapeau, J. Somma, A. Fadel, A. Al Bitar, R. Escadafal (2017). Snow observations in Mount-Lebanon (2011–2016), Earth System Science Data, 9(2), 573.
- Shaban, A., Khawlie, M., & Abdallah, C. (2006). Use of remote sensing and GIS to determine recharge potential zones: the case of Occidental Lebanon. *Hydrogeology Journal*, *14*(4), 433-443.
- Shaban, A., Faour, G., Khawlie, M., & Abdallah, C. (2004). Remote sensing application to estimate the volume of water in the form of snow on Mount Lebanon. *Hydrological sciences journal*, *49*(4).


**Relevant projects:**

- Enhancing the Use of Salt Affected Soils and Saline Water for Crop and Biomass Production and Reducing Land and Water Quality Degradation in ARABIA States Parties (IAEA).
- Potassium level and water use efficiency in fertigated potato under deficit irrigation (GRP).
- ERANET-MED CHAAMS Global Change: Assessment and Adaptation to Mediterranean Region Water Scarcity (2018-2021).
- Using remote sensing and 3D modelling to monitor, understand and manage harmful algal blooms in Qaraaoun reservoir (Lebanon). (GRP).
- Snow hydrology of the Lebanese Mountain Chains (GRP).

**#6 LEBANESE AGRICULTURAL RESEARCH INSTITUTE (LARI)**

**Description:**

The Lebanese Agricultural Research Institute (LARI) is a governmental organization under Minister of Agriculture Supervision. The institute conducts applied and basic scientific research for the development and advancement of the agricultural sector in Lebanon. In addition, the Institute keeps close ties to the farmers and tries to develop research activities aiming at solving their problems. LARI has at its disposal twelve experimental stations (Tal Amara, Terbol, Kferdan, Kfarchakhna, Abdeh, Sour, Fanar, Lebaa, Klaiat, Hermel and Hasbaya) in an area of more than 300 hectares of agricultural lands. The stations are located in agricultural areas where rainfed, irrigated crops and fruit trees are researched and produced. LARI is involved in many research and applied projects on several disciplines that are financed by the national and international funding agencies and commissions such as CNRS-Lb, FAO, UNDP, ICARDA, EU, USAID, Swiss Cooperation, and others.

**Members:**

- Ihab JOMAA (PI-LARI) (M) is the head (2011 – current) of the Department of Irrigation and Agrometeorology at LARI. He is the coordinator of several applied research projects in the field of irrigation in different regions of Lebanon. He is also involved in hydrology models for the sake of measuring sediment flows in mountainous areas. He runs several field research trials on different cropping systems, irrigation managements, new irrigation techniques and

agrometeorological models for plant water requirements. He is responsible on managing an agrometeorological network of more than 50 weather stations distributed over the Lebanese territory.

- Dr. Marie Therese Abi Saab (F) head of the Climate and Water Unit at LARI-Fanar station, has been working in the fields of crop growth and water productivity modelling, irrigation management and climate change impacts on agriculture and water resources. She also worked on EU-funded project, ACLIMAS and leaded the activities in Lebanon. She contributed to the FAO Irrigation and Drainage Technical Paper 66 on "Crop response to water" and development of the FAO AquaCrop crop growth model. She also conducted several experimental trials on the wastewater reuse in irrigation with FAO.

**Relevant publications:**

- Darwish T., Atallah T., Jomaa I., Baydoun S. 2018. Lebanon. Chapter 6. In CHALLENGES AND OPPORTUNITIES FOR CROP PRODUCTION IN DRY AND SALINE ENVIRONMENTS IN ARASIA MEMBER STATES. Joint FAO/IAEA program. IAEA-TECDOC-1841.
- Jomaa I., Shabaan A. 2018. Improving Water-Use Efficiency and Productivity in the Litani River Basin. In: The Litani River, Lebanon: An Assessment and Current Challenges. Springer International Publishing.
- T. Atallah, I. Jomaa, Ali F., H. Khatoun, H. Youssef, T. Darwish 2017. Performance of two genotypes of millet [Pennisetumglaucum [L] R.Br] in saline conditions, coastal Lebanon. LAAS, The 23rd International Science Conference, 6-7 April, 2017, Fanar Lebanese University.
- Jomaa I, Jaubert R. 2017. Improving the irrigation efficiency in the Bekaa Valley. CIHEAM, Watch Letter, no 38.
- Jomaa I., Saade Sbeih M., Jaubert R. 2015. Sharp expansion of extensive groundwater irrigation, semi-arid environment at the northern Bekaa Valley, Lebanon. Natural Resources, 6: 381-390.

**Relevant projects:**

- Improving Water Management for Sustainable Mountain Agriculture: Jordan, Lebanon, Morocco (IFAD)
- Middle East Water and Livelihoods Initiatives (WLI) (ICARDA-USAID)
- Irrigation Water Management in Central and Northern Bekaa, Lebanon SDC-Swiss Fund
- Mapping agricultural communities vulnerable to the impact of climate change and enhancing their livelihood in selected countries of MENA and SSA Regions (CODRA) (ICBA-IFAD)
- Adaptation to Climate Change of the Mediterranean Agricultural Systems (ACLIMAS), EU funded within the WIM programme of the EC

### #7 CADI AYYAD UNIVERSITY OF MARRAKECH (UCAM)

**Description:**

The Cadi Ayyad University of Marrakech was created in 1978. UCAM has more than 250 conventions of collaborations with Mediterranean, European and North-American social and economic institutions and Universities in different research areas. It is considered as a leader in the water study topics. UCAM hosts the National Centre of Studies and Research on Water and Energy (CNEREE) and shelters the focal point of the national pole of competences on water and

environment. The team involved in this project is focusing on water management and bio-environmental systems of arid areas, and the use of new technologies in this field (micro-meteorology, remote sensing, geographic information system and models). 20 researchers of UCAM are involved together with the National Weather Service (DMN, Casablanca) and the Centre for Energy, Space Science and Technology (CNESTEN, Rabat) in the Joint International Laboratory TREMA (Remote Sensing and Water Resources within semi-arid Mediterranean) co-lead by Pr. Salah Er-Raki (UCAM) and Vincent Simonneaux (CESBIO/IRD).

**Members:**

- Said Khabba (PI-UCAM) (M) is a physician and has a background in agro-climatology and modelling. PhD in Thermal transfer from UCAM. Senior Lecturer at UCAM since 1996, his research is focused on modelling the water crop requirement, growth, development and yield of cultivated plants in semi-arid areas. With his expertise in the areas of process modelling, field observation and satellite imagery, he has supervised a dozen PhDs. He published more than 65 peer-reviewed papers. His h-index is 13.
- Salah Er-Raki (M) is a researcher (PhD) on micrometeorology, remote sensing and modelling. He published more than 56 peer-reviewed papers. His Scopus h-index is 16.
- Jamal Ezzahar (M) is a researcher (PhD) on micrometeorology, remote sensing and modelling. He published more than 37 peer-reviewed papers. His Scopus h-index is 15
- Lahoucine Hanich (M) is a hydrogeologist (PhD) and has a background in snow hydrology, hydrology modelling and climate change. His Scopus h-index is 11.
- Younes Fakir (M) is a hydrogeologist (PhD) and works in integrated water modelling and on aquifer recharge. He published more than 15 peer-reviewed papers. His Scopus h-index is 8
- Mounia Benghanem (F) Engineer at the Tensift Hydraulic Basin Agency (ABHT). She is responsible of the ABHT data service.
- Said Rachidi (M) Engineer at the ABHT and member of the national program “Integrated Management of Water Resources (AGIRE)”.
- Fathallh Sghir (M) Engineer at the Agricultural Office of the Haouz plain. He is responsible for the irrigation department.

**Relevant publications:**

- Amazirh A., Merlin O., Er-Raki S., Gao Q., Rivalland V., Malbeteau Y., Khabba S., Escorihuela M.J., 2018. Retrieving surface soil moisture at high spatiotemporal resolution from a synergy between Sentinel-1 radar and Landsat thermal data: a study case over bare soil. Remote Sensing of Environment, 211, 321–337.
- Ait Hssaine B., Merlin O., Rafi Z., Ezzahar J., Jarlan L., Khabba S., Er-Raki S. 2018. Calibrating an evapotranspiration model using radiometric surface temperature, vegetation cover fraction and near-surface soil moisture data. Agricultural and Forest Meteorology, 256–257, 104–115.
- Nassah H., Er-Raki S., Khabba S., Fakir Y., Raibi F., Merlin M., Mougenot B. 2018. Evaluation and analysis of deep percolation losses of drip irrigated citrus crops under non-saline and saline conditions in a semi-arid area. Biosystems Engineering, 165, 10-24.
- Diarra A., Jarlan L., Er-Raki S., Le Page M., Aouade G., Tavernier A., Boulet G., Ezzahar J., Merlin O., Khabba S. 2017. Performance of the two source energy budget (TSEB) model for the monitoring of evapotranspiration over irrigated annual crops in North Africa. Agricultural Water Management, 193: 71–88.

- Zkhiri W., Tramblay Y., Hanich L., Jarlan L., Ruelland D., 2018. Spatiotemporal characterization of current and future droughts in the High Atlas basins (Morocco), Theoretical and Applied Climatology.

**Relevant projects:**

- ANR-TRANSMED AMETHYST—ANR-12-TMED-0006-01: "Assessment of changes in MEdiTerranean HYdro-resources in the South: river basin Trajectories (AMETHYST) 2013-2018
- H2020 REC/645642: "Root zone soil moisture Estimates at the daily and agricultural parcel scales for Crop irrigation management and water use impact – a multi-sensor remote sensing approach, 2015-2019
- PHC-Maghreb 14 MAG 22/32592VE: " Spatialized estimation of water use by rainfed and irrigated agriculture in the Maghreb " 2013-2016.
- Project PPR/ 2015/45. SAGESSE (Decision Support System for Water Resources Management). 2015-2018.
- Project RS/2011/09, National Sectoral Research Development Programme (dev-RS): " Resource and eco-hydrological functioning of the Tensift watershed, Marrakech ". 2011-2014

**Description of significant infrastructure and technical equipment:**

- UCAM co-manages with CESBIO (France) observatory in Tensift study site.
- UCAM is co-leading with CESBIO (France) the TREMA ("Remote Sensing and Water Resources in semi-arid Mediterranean") Joint International Laboratory.

**#8 NATIONAL AGRICULTURAL INSTITUTE OF TUNISIA (INAT)**

**Description**:
National Agricultural Institute of Tunisia is the main national agronomic institute of Tunisia. The mission of INAT is to provide agronomical engineering diploma, master and PhD degrees and Research in several fields, mainly water resources management, agronomy and plant biotechnology, animal production, fishery, food processing industry, plant diseases and rural economy and management. INAT have a national cooperation with different institutions and international cooperation with over than 50 foreign universities in the 5 continents. Within INAT, LR-GREEN-TEAM is a multidisciplinary research laboratory created in 2017 and under the double supervision of the National Agronomic Institute of Tunisia and Carthage University. GREEN-TEAM brings together researchers from INAT, INRGREF and INSAT with various disciplines (Remote sensing, Hydrologists, soil scientists, hydrogeologists, agronomists, eco-physiologist, environmental scientists).

**Members:**

- Aouissi Jalel (PI-INAT) (M) is an assistant Professor (PhD) in hydrology and Water Soil conservation at INAT. He graduated from the National Agronomic Institute of Tunisia. His research is focused on water resources management using ecohydrological modelling using SWAT model.
- Sihem Benabdallah (F) is a researcher who graduated (PhD) from Purdue University. Her research is focused on integrated water management, land use changes and environmental impact assessment in semi-arid areas.

- Adel Zghibi (M) is an assistant-Professor (PhD) of Hydrogeology and water engineering at the Faculty of Sciences of Tunisia. He graduated from the INAT. His research is mainly focused on modelling flow and mass transport processes in heterogeneous porous and fractured media.
- Zohra Lili Chabaane (F) is a Professor in Rural engineering Water and Forest in the University of Carthage / National Institute of Agronomy of Tunisia (INAT). She received the Double Master and Engineering degree from INAT and ENSA-Rennes in 1989 in rural engineering / Hydraulic and Agricultural Climatology, and the PhD degree from ENSA-Rennes (AGROCAMPUS OUEST), Rennes, France on 1993 in "Physics - Remote sensing, Rural and Process Engineering". She is expert and specialized in remote sensing, GIS and spatial analysis for water resources management.
- Hanène Chaabane- Boujnah (F) is an Associate-Professor in Pesticide Sciences (phyto-pharmacy) at the National Institute of Agronomy of Tunisia. She graduated from Faculty of Exact and Experimental Sciences, University of Perpignan, France (agro-chemistry). Her research is focused on pesticide sciences especially: Pesticide residues in fruits and vegetables.
- Ines Oueslati (F) is an assistant professor and researcher in INAT. She has a PhD (2010) in Water and Land Management Engineering (Department of Environment, Territory and Infrastructures; Polytechnic University of Turin) concerning the development of Methodologies for the determination of the spatial distribution of soil hydraulic properties. She has worked on the evaluation of the current and future water balance using the WEAP model.
- Zeineb Kassouk (F) is an assistant professor at INAT and a researcher at GREEN TEAM lab. She has eleven year experience in geo-informatics, water resource management and land use survey and is skilled in the use of remote sensing and spatial analysis. She holds a PhD degree in remote sensing at Paris Est University.

**Relevant publications :**


- Aouissi J., Ben Abdallah S, Lili Chabaane Z, Cudennec C. (2018). Valuing scarce observation of rainfall variability with flexible semi-distributed hydrological modelling - Mountainous Mediterranean context. Sci Total Environ. 2018 Jun 22;643:346-356.
- Launeau P., Kassouk Z., Debaine F., Roy R., Mestayer P., Boulet C., Rouaud J.-M., Giraud M., 2017. Airborne hyperspectral mapping of trees in an urban area. International Journal of Remote Sensing. 38. 1277-1311.
- Oueslati I., Lili Chabaane, Z, Shabou M, Zribi M, Glafassi D, Rathwell K, Hoff H., Pizzigalli C., 2014. WEAP model as a tool for Integrated Water Resources Management in Merguellil watershed (central Tunisia). Sustainable Watershed Management 2014, ISBN: 9781138000186, 230 pages.
- Bird D N, Benabdallah S , Gouda N, Hummel F, Koeberl J, La Jeunesse I, Meyer S, Prettenthaler F, Soddu A, Woess- Gallasch S, 2016. Modelling climate change impacts on and adaptation strategies for agriculture in Sardinia and Tunisia using AquaCrop and value-at-risk, Science of The Total Environment, vol. 543, 1019–1027.
- Ala Bouagga, Hanène Chaabane, Wiém Chtioui, Amira Mougou Hamdane, Bouzid Nasraoui. (2018). Pesticides Used in Tunisian Vineyards: What is the Risk for the Environment and the Human Health? In A. Kallel et al. (eds.), Recent Advances in Environmental Science from the Euro-Mediterranean and Surrounding Regions, Advances in Science, Technology & Innovation, Springer International Publishing AG 2018.

**Relevant projects:**

- ANR AMETHYST (Assessment of changes in MEdiTerranean HYdro-resources in the South: river basin Trajectories)
- FP7 CLIMB (Climate induced changes on the hydrology of Mediterranean basins)
- 2018-2021: ERANET-MED CHAAMS, Global Change: Assessment and Adaptation to Mediterranean Region Water Scarcity.
- FP7 WASSERMed, Water Availability and Security in Southern Europe and the Mediterranean, Grant agreement no.: 244255.

**Description of significant infrastructure and technical equipment:**

- INAT co-manages with LISAH (France) and INRGREF (Tunisia) the OMERE observatory in the Cap Bon study site.
- INAT is part of the NAILA ("Managing water resources in Tunisian rural areas") Joint International Laboratory.
- Equipment for the extraction phase of pesticide residue from many matrices like water, soil or fruits and vegetables: shaker, Solid Phase Extraction, Spectrophotometer UV-visible, Spectro-radiometer (visible near infrared), Five GPS.

## #9 NATIONAL RESEARCH INSTITUTE FOR RURAL ENGINEERING (INRGREF)

**Description**:

The National Research Institute for Rural Engineering, Water and Forestry (INRGREF) is a legal entity, under the legal restraint of the Ministry of Agriculture and Water Resources and belongs to the Carthage University - Tunisia. INRGREF mission is to contribute to the aforementioned fields, to participate in the protection, conservation and rationalization of the exploitation of natural resources, to value the results of its research and its scientific know-how and its insertion in the economic and social field. Improving water management models for rainfed and irrigated agriculture, aim of ALTOS, is consistent with the scientific priorities of INRGREF. The team involved in the project consists of three researchers; this group is part of the Joint International Laboratory (LMI) NAILA.

**Members:**

- Rim Zitouna-Chebbi (PI-INRGREF) (F) Associate professor (PhD) in water and soil sciences. Her research focuses on soil-water-atmosphere continuum, deficit irrigation and impact of climatic change on agricultural productions in semi-arid regions. She has experiences in the fields of rain-fed and irrigated agriculture of orchards and on annual crops. She is the co-manager of Mediterranean observatory of the rural environment and water OMERE.
- Insaf Mekki (F) Associate professor (PhD) in water and soil sciences. She studies water and land management on irrigated perimeters and rainfed agrosystems. She has worked in many projects on the assessment of spatiotemporal variability of water flows due to natural variability and human activities. She is involved in the analysis of societal and biophysical aspects within irrigated and rainfed agrosystems dynamics. She is the co-director of the NAILA International Joint Laboratory.
- Abdelaziz Zairi (M) Professor (PhD) on water resources management. He has been involved in several research fields oriented to modernize irrigation systems at farm and irrigated scheme

levels under an environmental and economic perspective to induce a more efficient use of irrigation water. He has a long experience in capacity building and knowledge dissemination. He chairs the user committee of the NAILA international joint laboratory.

**Relevant Publication**:

- Mekki, I. Bailly, J.S., Jacob F., Chebbi H., Ajmi T., Blanca Y., Zairi, A., Biarnès A. 2018. Impact of farmland fragmentation on rainfed crop allocation in Mediterranean landscapes: A case study of the Lebna watershed in Cap Bon, Tunisia. Land use policy, 75, 772-783.
- Ferchichi, I. Marlet, S. Zairi A. 2017, How farmers deal with water scarcity in community–Managed irrigation systems: A case study in northern Tunisia. Irrigation and Drainage.
- Mekki I., Zitouna-Chebbi R., Jacob F, Ben Mechlia N., Masmoudi M., Prévot L., Albergel J., Voltz M. (2018). Impact of land use on soil water content in a hilly rainfed agrosystem: a case study in the cap bon peninsula in Tunisia. AGROFOR International Journal, Vol. 3, Issue 1, pp 64-75.
- Voltz M., Mekki I., Molénat J., Prévot L., Raclot D., Zitouna-Chebbi R. 2016. Long term agro-ecosystem observatories in the Mediterranean. Sub-chapter in The Mediterranean region under Climate change. A scientific update. IRD editions, Marseille. p 467-474.
- Zitouna-Chebbi R., Prévot L., Chakhar A., Marniche-Ben Abdallah M., Jacob F. (2018). Observing actual evapotranspiration flux tower Eddy covariance measurements within a hilly watershed: case study of the Kamech site, Cap Bon peninsula, Tunisia. Atmosphere 2018, 9(2), 68.

**Relevant Projects**:

- 2003-2007: IRRIMED / A Euro-Mediterranean Research Project on Improved Management Tools for Water-Limited Irrigation: Combining Ground and Satellite Information Through Models.
- 2010-2015 : SICMED/Mistrals (Mediterranean Integrated studies at regional and local scales (France): Biophysical and socio-economic approach to water management in the Cape Bon region.
- 2013-2017: ANR TRANSMED: ALMIRA – “Adapting Landscape Mosaics of Mediterranean Rainfed Agrosystems for a sustainable management of crop production, water and soil resources”.
- 2011-2015: European Union and African Union cooperative research to increase Food production in irrigated farming systems in Africa/ EAU4Food. FP7-AFRICA-2010, Project Number 265471.
- 2018-2021: ERA-NET MED CHAAMS: Global Change: Assessment and Adaptation to Mediterranean Region Water Scarcity.

**Description of significant infrastructure and technical equipment:**

- INRGREF co-manages with LISAH (France) and INAT (Tunisia) the OMERE observatory in the Cap Bon study site.
- INRGREF is co-leading the NAILA ("Managing water resources in Tunisian rural areas”) Joint International Laboratory with LISAH (France).

**#10 HIGHER SCHOOL OF COMMUNICATIONS OF TUNIS (SUPCOM)**

**Description:**

The Higher School of Communications of Tunis (SUPCOM) is the leading school of engineering in telecommunications in Tunisia at the university of Carthage. SUPCOM also has a dual supervision of the Ministry of Higher Education and Scientific Research and the Ministry of Information Technologies and Communication. Sup'Com main vocations are (i) the training of high level scientific and technical engineers, able to design, implement and manage telecommunications services, systems and networks, (ii) contribution to the national effort for scientific and technological research in the field of information technology and communication (ICT), (iii) qualifying training of senior executives in the ICT field. The research carried out by SUPCOM research laboratories and in particular COSIM, a member of the ALTOS project, focuses on innovation and the application of scientific results for the development of adapted and lower-cost solutions to the country's priority problems, in particular the management of water resources and soil resources. This is fully in line with the objectives of the ALTOS project.

**Members:**

- Riadh Abdelfattah (PI-SUPCOM) (M) is Professor at the Higher School of Communications for engineers (SUPCOM) at the University of Carthage in Tunisia. He also is an Associate Researcher at the Department ITI at IMT-Atlantique, Brest, France. Between 2000 and 2002 he was a postdoctoral researcher at the ”Telecom National School”, Paris. He is a founding member of the Research Unit in Satellite Imagery and its Applications (URISA) in January 2004 (2004-2011), and a founding member of the Communication, Signal and Image Laboratory (COSIM-Lab) in November 2011 at SUPCOM. He is an elected member at the scientific council of the University Agency of French-speaking countries (AUF, 2016-2018). He is a senior member of the IEEE and he served as a member of the Executive Committee of the IEEE Tunisia Section (2013-2015). He has authored and co-authored more than 70 journal papers, conference papers and book chapters. His main research interests include interferometric radar imagining, multitemporal and multiscale image analysis, flooding mapping from remote sensed data, and SAR-nanosatellite development.
- Sadok El Asmi (M) received a Ph.D. degree in mathematics and control theory from Paris XI, Orsay University. He is Professor of applied mathematics, Tunis Engineer School in communications, Carthage university, and a member of COSIM Laboratory. His research interests include algebraic and statistical signal processing, identification, estimation and equalization of nonlinear channel. The recent research activity is related to water science, using extreme value theory.
- Sofiane Cherif (M) received a PhD degree in electrical engineering from the National Engineering School of Tunis (ENIT), University of Tunis-El Manar, in 1998. He is a professor of telecommunication engineering at SUP'COM. From 2011 to 2014, he led the communication technology doctoral school. Since 2014, he leads the COSIM Research Lab at SUP'COM. His current research interests are signal processing for communications, resource allocation, and interference mitigation in wireless networks, wireless sensor networks, and cognitive radio.

**Relevant publications:**

- W. Ben Abdallah and **R. Abdelfattah**, " Two-dimensional wavelet algorithm for interferometric synthetic aperture radar phase filtering enhancement", Journal of Applied Remote Sensing, Vol. 9, No. 1, pp. 096061, 2015.
- M. Barbouchi, **R. Abdelfattah**, K. Chokmani, N. Ben Aissa, R. Lhissou, A. El Harti. Soil Salinity Characterization Using Polarimetric InSAR Coherence: Case Studies in Tunisia and Morocco. IEEE

Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 8(8), pp. 3823–3832, 2015.

- A. Elmzoughi, **R. Abdelfattah**, V. Santalla Del Rio and Z. Belhadj**,** Optimal Rain Rate Estimation Algorithm for Light and Heavy Rain Using Polarimetric Measurements, *Natural Hazards and Earth System Sciences*, Vol. 11, pp. 3067–3079, November 2011.
- Nehla Debbabi M., Kratz Mamadou M., El Asmi S.: Combining algebraic approach with extreme value theory for spike detection. EUSIPCO 2012, pp. : 1836-1840
- Z. Jellali, L. Najjar-Atallah, **S. Cherif**. Improving Rare Events Detection in WSN through Cluster-Based Power Control Mechanism. International Journal of Distributed Sensor Networks, 2016.

**Relevant projects:**

- FIRESENS Project ID. 244088, funded under FP7-ENVIRONMENT
- SECREDAS, H2020 project ECSEL JU (Call Research and Innovation Actions 2017).

## #11 WATER RESEARCHES AND TECHNOLOGIES CENTRE OF BORJ CEDRIA (CERTE)

**Description:**

CERTE was established on February the 16th, 2005. It is a public establishment with, administrative nature, a legal personality and a financial autonomy. It is the research component of the water Technopole Borj-Cedria. The CERTE is specialized in water research and contributes to the development and dissemination of science and water-related technologies. The main research themes connected to ALTOS are: characterization and mapping of deep reservoir aquifers; hydrogeology, hydrology, geochemistry and modelling of surface and subsurface waters; artificial refilling of water tables; follow - up and assessment of dams and great hydraulic shells; geographic information systems and decision making tools; interactions between waters, soil and water tables.

**Members:**

- Fethi Lachaal (PI-CERTE) (M) is a CERTE researcher-assistant professor. He holds a PhD in Hydrogeology and Geophysics, from Carthage University in the framework of cooperation between INAT, CERTE, and IRD. He is a permanent member in the Geo-resources Laboratory (CERTE) form 2002. He has led several projects sponsored by the Minister of Agriculture of Tunisia. He interests lie in aquifer investigation, hydro-geophysics, hydrodynamic, groundwater modelling, and aquifer refilling. He has more than 17 years of experience in field experiments and research developments designed for arid and semi-arid groundwater characterization and sustainable management. He has published more than 18 papers in peer referred journals and his h-index is 6.
- Anis Chekirbane (M) graduated from the University of Tsukuba in Japan and obtained a PhD in Sustainable Environmental Studies in 2013. His research focuses on the interaction between groundwater and surface water in arid and semi-arid environments. He is a CERTE assistant-professor. He is involved and leads research projects addressing groundwater resources.
- Sameh Chargui (F), is a CERTE assistant-professor. She holds a PhD in Hydrology, from Carthage University in the framework of cooperation between INAT and IRD. She has led several projects. He interests lie in rainfall-runoff variability modelling in semi-arid and arid regions, statistical distribution of rainy events characteristics.

- Hajer Azaiez (F), PhD in Geology/Geophysics, is a CERTE assistant-professor since 2008. She works on geophysical method applications for groundwater resource exploration, pollution, and soil characterization. She participated in many research programs and published several journal papers.
- Ammar Mlayah (F), PhD in Geology/Geochemical, is a CERTE Professor, His research focuses on groundwater quality, mining activity, and environmental science. He has published more than 22 papers in peer referred journals and his h-index is 8.
- Mohamed Dhaoui (M), PhD in geophysics. He is a CERTE assistant-professor since 2015, He interests in application of potential geophysical methods (gravity, magnetic, and electrical methods) and inverse modelling techniques. His h-index is 4.

**Relevant publications:**


- Lachaal, F., Mlayah, M., Bédir, B., Tarhouni, J and Leduc, C., 2012. Development and application of three–dimensional groundwater flow numerical model to complex aquifer system in arid and semi-arid regions using MODFLOW and GIS tools: Zéramdine–Béni Hassen Miocene aquifer system (east–central Tunisia). Computers & Geosciences, 48, 187–198.
- Chekirbane A., Tsujimura M., Kawachi A., Lachaal F., Isoda H and Tarhouni J., 2014. Use of Time Domain Electromagnetic Method (TDEM) with geochemical tracers to explore the salinity anomalies in a small coastal aquifer in north-east of Tunisia. Hydrogeology Journal, 22, 8, 1777-1794.
- Jellalia, D., Lachaal, F., Andoulsi, M., Zouaghi, T., Hamdi, M., Bedir, M., 2015. Hydro-geophysical and geochemical investigation of shallow and deep Neogene aquifer systems in Hajeb Layoun-Jilma-Ouled Asker area, Central Tunisia. Journal of African Earth Sciences 110, 227–244.
- Lachaal, F., Chekirbane, A., Chargui, S., Sellami, H., Tsujimura, M., Hezzi, H., Faycel, J., Mlayah, A., 2016. Water resources management strategies and its implications on hydrodynamic and hydrochemical changes of costal groundwater: case of Grombalia shallow aquifer, NE Tunisia. Journal of African Earth Sciences. 124, 171-188.
- Lachaal, F., Chargui, S., Messaoud, R.B., Chekirbane, A., Tsujimura, M., Mlayah, A., Massuel, S., Leduc, C., 2017. Impacts of Global Changes on Groundwater Resources in North-East Tunisia: The Case of the Grombalia Phreatic Aquifer. Environmental Earth Sciences.


**Relevant projects:**

- The Tunisian "dorsal" and its confines: water potential, reservoirs and quality for integrated water resources management, CERTE/ MHSER, 2015-2018.
- CHAAMS: Global Change: Assessment and Adaptation for Mediterranean Region Water Scarcity, ERANET-MED program, 2018-2021.
- Water Availability and Security in Southern Europe and Mediterranean, WASSERmed, 2010-2013.

**Description of significant infrastructure and technical equipment:**
**Geophysical equipments: ABEM Terrameter SAS 4000, Syscal R2, and Transient Electromagnetic-ABEM WAlkTEM.**

**4.2. Third parties involved in the project (including use of third party resources)**

No third party involved.

## Section 5: Ethics and Security

### 5.1 Ethics

The ALTOS project involves human participants who are volunteers for social or human sciences research. In particular, the co-construction of management modes for water resources implies participative seminars for (1) designing scenarios of structure modulations (i.e., land use, reservoir and bench densities, irrigation conversion) and (2) assessing the impact of these structure modulations (i.e., water fluxes through cultivated landscapes and storages within landscape compartments). These seminars involve several stakeholders (farmer associations, resources managers). The seminar minutes are confidential and the resulting reports do not mention any identity. This modus operandi has been used the last years with the end user committees of the NAILA, TREMA and O-LIFE international laboratories.

### 5.2 Security[24]

☐ Activities or results raising security issues: **NO**.
☐ 'EU-classified information' as background or results: **NO**.

[24] See article 37 of the PRIMA Model Grant Agreement