APPLICATION FORM
CALL FOR PROPOSALS 2015
ENVI-MED REGIONAL PROGRAMME

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A. General presentation

A1	Institution which is sponsoring and is responsible for the project
	Institut de Recherche pour le Développement (IRD)

NB: if the project sponsor (A1) is attached to an institution from one of the programme's partner countries, a co-sponsor attached to a French institution must be designated below (A1 Bis) .

A1 Bis	Institution co-sponsoring the project and co-responsible for the project in France (project's administrative management)

A2	Project title and acronym or abbreviation
	HighLandDEM: High-resolution Digital Elevation Models (**DEM**) in rainfed Mediterranean cultivated **Land**scapes for long-term monitoring of artificial features with hydrological impact.

A3	Research area
	Water resources : long term observation systems and modelisation – human impacts on ecosystems *Ressources en eau : systèmes d'observation long terme, modélisation intégrant les systèmes anthropiques et interface avec les acteurs socio-éconmiques - Impacts anthropiques sur les écosystèmes*

A4	Project aim
	The HighLandDEM project aims at linking Mediterranean education and research institutions having advanced experiences and activities in Mediterranean cultivated landscape geomorphometry in order to re-enforce the capacities of long-term observation systems on water and soil resources over Mediterranean areas, and further, help observation analyses, managers and land-use planners in water and soil resources management. For that purpose, the HighLandDEM project is focusing on robust methodologies for 1) high resolution DEM (Digital Elevation Models) generation and 2) the mapping of landscape objects that highly interacts on water and soil resources and fluxes (referred hereafter as SWCS) from ultra-fine DEMs. Another project aim is to disseminate the results through common pedagogic material for master students.

A5	Project summary
	Long-term observation systems which monitor Mediterranean cultivated rainfed areas often focus on physical processes and "areal" land use. However, full understanding of these processes - especially for long-term periods - also require the monitoring of artificial structures that can have high impacts on fluxes, and for which methods providing spatial data are lacking. Recent progresses in 3D mapping and geomorphometry give new insights into this monitoring issue. Teams joined in this project have each developed techniques for 3D mapping and/or artificial structures mapping from very-high resolution Digital Elevation Models (DEM) and the HighLandDEM project is an unique opportunity to share, disseminate, cross-validate these techniques and also to evaluate their performances for different cultivated rainfed areas throughout the Mediterranean. Project leaders will first set up a common numerical experimental framework based on existing data and algorithms. Meanwhile, DEM datasets will be completed through experimentations relocation. Then, sensitivity of different techniques to different datasets and resolution will be assessed. Finally, common practical exercises and courses will be built. Additionally to this new and shared pedagogical material, expected results of the HighLandDEM project are the development of robust methods of cost-efficient high resolution DEM generation and artificial linear structures mapping from ultra-fine DEMs. These will form new inputs for long-term monitoring systems and provide cutting-edge tools for water and soil resources management.

A5	Résumé du projet (in french)
	Les systèmes d'observation long-terme qui documentent les milieux cultivés pluviaux méditerranéens se focalisent le plus souvent sur les processus physiques et le suivi "surfacique" de l'occupation des sols. Cependant, pour une compréhension complète de ces processus, en particulier ceux dont les dynamiques sont lentes, il est nécessaire d'effectuer le suivi des évolutions des structures artificielles à impact hydrologique, suivi pour lequel des méthodes de cartographie efficaces manquent. Les récentes avancées en cartographie 3D et en géomorphométrie apportent un nouvel éclairage sur ce problème de mesure. Les équipes réunies au sein de ce projet ont chacune développé des techniques pour la cartographie 3D et/ou la cartographie des structures artificielles à partir de Modèles Numériques de Terrain (MNT) fins, et le projet HighLandDEM est une excellente opportunité de partager, diffuser, contre-valider ces techniques et même d'évaluer leur performances sur différents zones cultivées pluviales autour de la Méditerranée. Les participants au projet mettront d'abord en place un outil commun d'expérimentation numérique en s'appuyant sur les données et algorithmes existants. Dans le même temps la délocalisation des expériences déjà réalisées sur chaque site permettra de compléter la base de MNTs. Ensuite, la sensibilité des différentes techniques de cartographie des structures artificielles à la source du MNT et à sa résolution sera évaluée. Finalement, des travaux dirigés et des travaux pratiques seront élaborés en commun. Au delà de ce nouveau matériel pédagogique partagé, les résultats attendus du projet HighLandDEM sont le développement de méthodes robustes d'obtention de MNT fins à bas coût et de cartographie de structures artificielles à partir de MNT fins. De telles méthodes pourront venir compléter les dispositifs expérimentaux de systèmes d'observation long-terme et plus généralement fournir des outils performants pour la gestion de la ressource en eau et en sol.

A6	**Information on the project sponsors ***			
	Mediterranean partner A: Italy		**Mediterranean partner B: Tunisia**	
	Organization	**University of Padova (UNIPD) – TESAF department**	Organization	**University of Tunis El Manar – École nationale d'ingénieurs de Tunis – Laboratoire de Télédétection et SIRS**
	Name of project leader	Dr. Paolo Tarolli	Name of project leader	Dr. Rached Boussema
	Address	Department of Land, Environment, Agriculture and Forestry - University of Padova viale dell'Universita' 16, 35020 - Legnaro (PD), Italy	Address	ENIT - BP 37, 1002 Tunis Le Belvédère, Tunisia
	Tel/Fax	+39(049)8272677	Tel/Fax	+216 71 874 700 (Poste 563) / +216 71 872 729
	E-mail	paolo.tarolli@unipd.it	E-mail	rached.boussema@enit.rnu.tn
	French partner A:		**French partner B:**	
	Organization	**IRD – UMR LISAH**	Organization	**AgroParisTech -UMR LISAH**
	Name of project leader	Dr. Denis Feurer	Name of project leader	Dr. Jean-Stéphane Bailly
	Address	IRD - Tunisie 2 Rue des Sports BP 434 - El Menzah 1 - 1004 Tunis, Tunisie	Address	UMR LISAH, 2 place Viala, Bâtiment 24 34060 Montpellier Cedex 1, France
	Tel/Fax	+216 71 286 833 / +216 71 750 254	Tel/Fax	+33-499 61 28 09 / +33 467 63 26 14
	E-mail	denis.feurer@ird.fr	E-mail	bailly@agroparistech.fr

* Each project must link at least one French research team, including teams attached to French research units based abroad, with at least two teams from two different Mediterranean countries, at least one of which must be a non-EU state.

A7	Other associated organizations	
	Mediterranean partners - INAT and INRGREF (OMERE observatory)	**France** - Mic-Mac Developers community who provides support for stereo-photogrammetry DEM generation - CNES (French Space Agency) who provided Pleiades satellite data for DEM generation and comparison. - INRA and Montpellier SupAgro (OMERE Observatory) - Theia-Land Languedoc Roussillon , for further satellite data acquisition - IGN (French Mapping Agency) who provided support for stereo-photogrammetry DEM generation from Pleiades images

B. Project details

B1. Main focus of the project (basic research – targeted research with or without company involvement) – *200 words max.*

Mediterranean cultivated rainfed areas are hotspots of global change that are highly susceptible to water scarcity and land degradation. On such areas, long-term observation systems provide continuous monitoring of hydrological, soil erosion responses and "areal" land use. However, Mediterranean cultivated rainfed areas are often located on hilly landscapes and are also historical areas of many water and soil conservation structures, such as terraces, bench terraces, hill reservoirs, etc (Tarolli et al., 2014). Hence, interpretation of long term hydrological or erosion response also require the monitoring (mapping) of artificial out-plot linear structures within landscape that can highly impact hydrological and erosion fluxes (Gallart et al., 2008, Dages et al., 2009, Moussa et al., 2004).

Due to recent progress in geomorphometry (Tarolli et al., 2015, Boussema et al., 2015, Bailly et al., 2014) and high spatial resolution DEM generation from remote sensing (Tarolli et al., 2013, Feurer et al., 2015), monitoring of such features by remote sensing appears as mature and cost-efficient. Linking institutions and advanced experiences in the Mediterranean, the HighLandDEM project aims at developing robust methods of 1) cost-effective high-resolution DEM generation and 2) artificial linear structures mapping from ultra-fine DEMs to re-enforce long-term observation systems capacities and further, help managers and land-use planners in water and soil resources management.

B2. Project description - *2 pages max.*

Due to intense and hazardous rain events, poorly cohesive soils, high slopes, and high water deficits, Mediterranean cultivated rainfed areas have always been intensively arranged by farmers or land planners in order to stock water, or favor water infiltration and prevent soil erosion.

Such landscape arrangement techniques include a variety of soil and water conservation structures, or more generally landscape objects that highly interact with water and soil resources and fluxes (objects referred hereafter as SWCS). These objects can be found all over Mediterranean countries: terraces (France, Italy, Tunisia), bench terraces, hedgerows (Tunisia, France), ditches (France, Italy), roads, tracks and paths (France, Italy, Tunisia), convex field borders and numerous hill reservoirs (Tunisia).

All these structures are linear or punctual elements within landscapes and highly impact the integrated hydrological or erosional response of a catchment. Consequently, long-term observation systems in Mediterranean cultivated rainfed areas and catchments should also include the systematic monitoring of changes in SWCS in order to properly interpret changes in hydrological responses and provide correct previsions of water resource evolution. This is particularly true in a global change context where land degradation and abandonment arises (France, Italy) or when important land planning operations may occur (Tunisia).

However, if long-term observatories often include the integrated abiotic (water, soils, solutes) fluxes observation as well as the land-use monitoring (areal land use maps), it very rarely includes changes in SWCS, wrongfully considered as fixed. Cost-efficient SWCS monitoring and mapping techniques are thus required, even to better diagnose a non-observed given catchment.

Recently, Tarolli et al. (2014, 2015), Sofia et al. (2014a, 2014b), Prosdocimi et al. (2015), Bailly et al. (2008, 2012) and Feurer et al. (2015) proposed geomorphometric or remote sensing methods to map some of these SWCS structures from high spatial resolution DEM: terraces, ditches, hill reservoirs, hedgerows.

Yet, these methods were often applied on a single area and their robustness were not assessed by testing them on a collection of diverse areas and structures. Moreover, these techniques often use metric DEM coming from airborne laser scanner data set, although metric DEM for structures than can have widths as little as half a meter may be a limit (Bailly et al., 2008). Cost efficient DEM generation with sub-metric resolution being now available from bi or tri-stereo satellite image (Bailly et al. 2014) or from structure from motion using kite or UAV vectors even for large domains (Feurer et al. 2015), this issue can potentially be overcomed.

Location of the HighLandDEM test sites

In the HighLandDEM project, we technically aim to:
- Cross-validate methods for SWCS mapping from high-resolution DEMs from Italy, France and Tunisia by applying it systematically on French (Roujan), Italian (Cinque Terre) & Tunisian (Lebna : Kamech & Fortuna) sites among same DEM data characteristics (source, resolution).
- Infer the sensitivity of mapping performances regarding the DEM spatial resolution (1 m, 50 cm, 20 cm DEMs) by acquiring ultra-fine DEM with UAV/Kite multi-images technique over the three sites in Tunisia, Italia and France.
  In particular, this task will enable the assessment of the use of old aerial photographs and hence potentially provide the means for retrospective long-term observations.
- Infer the sensitivity of mapping performances regarding the DEM source (UAV/Kite multi-images, available laser scanner data and Pleiades tri-stereo images).
- Evaluate the benefits of produced SWCS maps using the integrated assessment tool by Boussema (1996) to help water/land managers.
- Share experiences, lectures and produce common pedagogic material at master level between Mediterranean institutions acting in education and learning and impulse a unique Mediterranean consortium for future land-surface geomorphometry research and education.

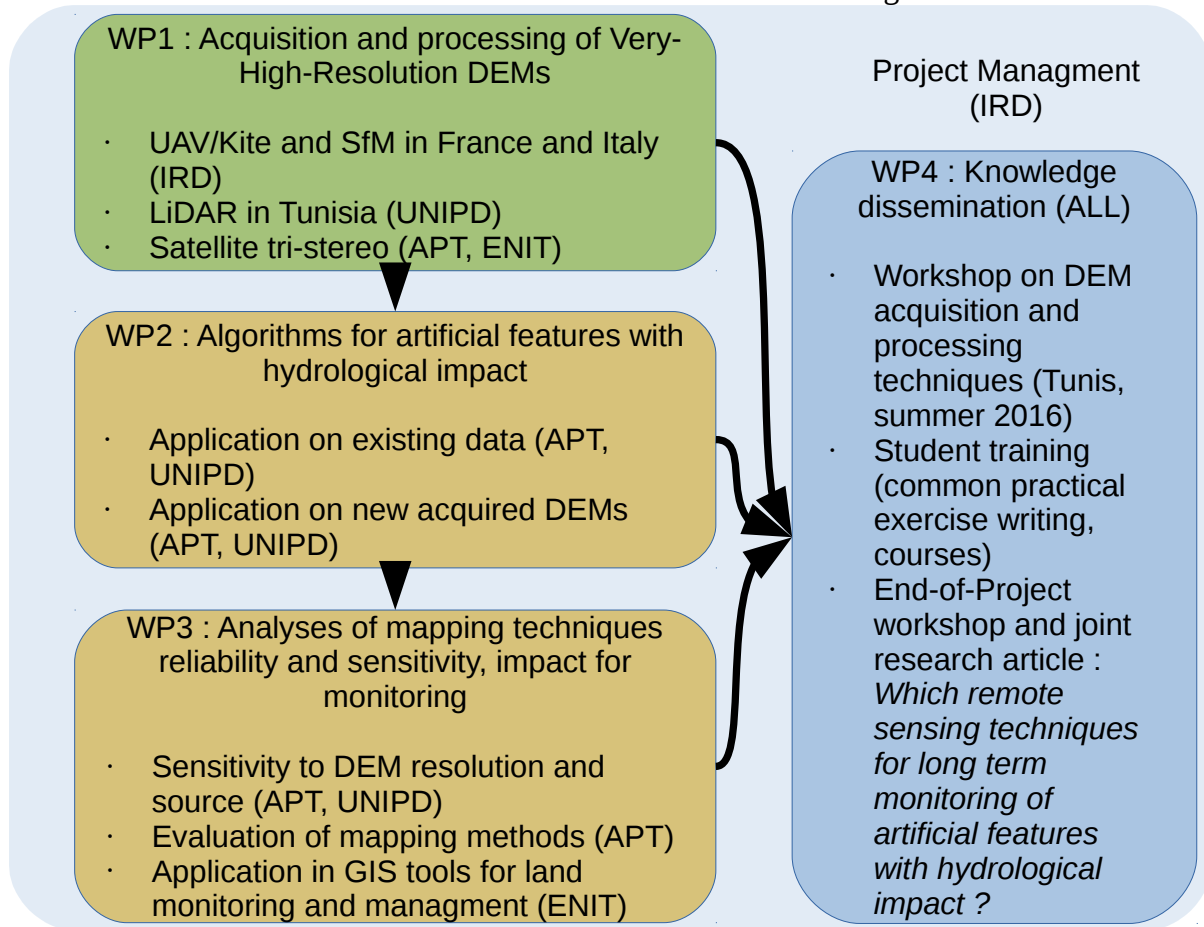The expected HighLandDEM results are:
- To share and re-enforce capacities, methods, algorithms, lectures, between Meditteranean researchers/lecturers on both DEM acquisition/generation and DEM processing for SWCS mapping.
- To proof the performance of SWCS long-term monitoring from regular and high-resolution DEM generation.
- To estimate the benefits/disadvantages from frugal approaches for DEM generation (Kite/UAV multi-images) as alternative to less frugal ones (airborne laser scanner, Pleiades tri-stereo) and in an operational deployment perspective.
- To produce pedagogic material (a gradual series of lectures and practical exercises) as a basis for a future MOOC on the use oh high resolution DEM for anthropogenic land surface characterization.

B3. Timetable and main implementation stages

WP	Tasks	T1Y1	T2Y1	T3Y1	T4Y1	T1Y2	T2Y2	T3Y2	T4Y2
	Processing / Field Work / Dissemination	2016				2017			
WP2	Numerical framework setup : applying ones's mapping algorithms on others's existing data	ALL	ALL						
WP4	Project leaders first meeting – Tunisia	ALL							
WP1	High-resolution DEM from satellite data (Tunisia and Italy)	ENIT, APT	ENIT, APT						
WP2	Mapping algorithms applied on various resolution DEMs		UNIPD, APT			UNIPD, APT			
WP1-2-4	Workshop on DEM and SWCS mapping methods – Tunisia		ALL						
WP1	New high-resolution-DEM acquisition – LiDAR at Kamech/Fortuna		UNIPD	UNIPD					
WP1	Ground Truth on Tunisian sites		ENIT						
WP1	New high-resolution-DEM acquisition – SfM Roujan			IRD	IRD				
WP1	New high-resolution-DEM acquisition – SfM Cinque Terre				IRD	IRD			
WP4	Reporting				IRD, ALL				
WP2	Mapping algorithms applied on DEMs with various provenance					UNIPD, APT	UNIPD, APT		
WP3	Systematic evaluation of mapping performances						APT		
WP3	Evaluating impact of mapped features for water and land managment							ENIT	
WP4	End-of-project Workshop – France							ALL	
WP4	Common practical exercise writing and course for mater students							APT, ALL	
WP4	Joint research article – Reporting								IRD, ALL

B4. Contributions - *1 page max.*

Presentation of the links between the various contributions and each organization's share

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┌─────────────────────────────────────────────────────────────────────────────┐
│  ┌──────────────────────────────────┐                                        │
│  │ WP1 : Acquisition and processing │      Project Managment                 │
│  │     of Very-High-Resolution DEMs │            (IRD)                        │
│  │                                  │                                        │
│  │  · UAV/Kite and SfM in France    │   ┌──────────────────────────────┐     │
│  │    and Italy (IRD)               │   │ WP4 : Knowledge               │     │
│  │  · LiDAR in Tunisia (UNIPD)      │   │    dissemination (ALL)        │     │
│  │  · Satellite tri-stereo          │   │                              │     │
│  │    (APT, ENIT)                   │   │  · Workshop on DEM           │     │
│  └──────────────────────────────────┘   │    acquisition and           │     │
│  ┌──────────────────────────────────┐   │    processing                │     │
│  │ WP2 : Algorithms for artificial  │   │    techniques (Tunis,        │     │
│  │   features with hydrological     │   │    summer 2016)              │     │
│  │           impact                 │   │  · Student training          │     │
│  │                                  │   │    (common practical         │     │
│  │  · Application on existing data  │   │    exercise writing,         │     │
│  │    (APT, UNIPD)                  │   │    courses)                  │     │
│  │  · Application on new acquired   │   │  · End-of-Project            │     │
│  │    DEMs (APT, UNIPD)             │   │    workshop and joint        │     │
│  └──────────────────────────────────┘   │    research article :        │     │
│  ┌──────────────────────────────────┐   │    *Which remote             │     │
│  │ WP3 : Analyses of mapping        │   │    sensing techniques        │     │
│  │   techniques reliability and     │   │    for long term             │     │
│  │   sensitivity, impact for        │   │    monitoring of             │     │
│  │         monitoring               │   │    artificial features       │     │
│  │                                  │   │    with hydrological         │     │
│  │  · Sensitivity to DEM resolution │   │    impact ?*                 │     │
│  │    and source (APT, UNIPD)       │   └──────────────────────────────┘     │
│  │  · Evaluation of mapping         │                                        │
│  │    methods (APT)                 │                                        │
│  │  · Application in GIS tools for  │                                        │
│  │    land monitoring and           │                                        │
│  │    managment (ENIT)              │                                        │
│  └──────────────────────────────────┘                                        │
└─────────────────────────────────────────────────────────────────────────────┘
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IRD:
- DEM generation at 1, 0.5, 0.2 m on Roujan, Lebna (Kamech & Fortuna) and Cinque-Terre sites
- Expertise of long-term observation systems, project management

University of Padova (UNIPD):
- Extract terraces according to Tarolli et al. (2014) method, using high-resolution DEM on the 3 selected sites
- Provide exhaustive ground truth data on terraces, hedgerows on Cinque Terre site (available lidar data will be compared with new kite multi images)
- Provide TLS (Laser scanner) and perform complementary TLS acquisition on Tunisia site

AgroParisTech (APT):
- Help providing bi or Tri-stereo Pleiades data on 3 sites (CNES, Geosud)
- Provide exhaustive ground truth data on terraces, hedgerows, ditches, roads, etc... on French site (Roujan) as well as comparative LiDAR data
- Extract Terraces with method from Bailly and Levavasseur (2012) on 3 sites
- Perform a systematic evaluation of SWCS mapping algorithms using specific metrics previously developed to linear landscape features (Thommeret et al. 2011, Heipcke et al., 2007)
- Lead Master level practical exercises and courses writing at the end of the project

ENIT:
- DEM generation based on satellite very-high resolution Pleiades data and kite photographs
- Provide ground truth in Tunisian sites
- Expertise on Soil and water conservation practices in Tunisia
- Perform catchment diagnostic using the produced SWCS maps in using the SAGATELE tool.

B5. Organization and Qualifications - *1 page max.*

AgroParisTech (APT)-UMR LISAH:
AgroParisTech is the French leading institute for education and research in life sciences, agronomy, food technology and environment. AgroParisTech trains Masters of Engineering, Masters of Science and Doctoral students, and develops research with public and private centers.
Leader: J.S. Bailly, Ph.D., UMR LISAH
Jean Stéphane Bailly received the Ph.D. degree in hydrology from the University of Montpellier, France. He is a member of the French Civil Corps of Water and Forestry Engineers (IPEF) since 1991. He is senior lecturer and scientist in physical geography at AgroParisTech, Montpellier, France. His research is devoted to spatial observations and parameterizations for hydrological modeling (http://www.researcherid.com/rid/C-2391-2011).

University of Padova (UNIPD): Founded in 1222, the University of Padua is among the earliest universities of the world and the second oldest in Italy. In 2010 the university had approximately 65,000 students and in 2013 was ranked "best university" among Italian institutions of higher education with more than 40,000 students.
Leader: P. Tarolli, Ph.D
Paolo Tarolli is Associate Professor of Soil and Water Resources Management at the University of Padova (Italy). He has held Visiting Professor positions at several universities (e.g. China University of Geosciences in Beijing, National Cheng Kung University, EPFL). He is expert in geomorphic signatures of Earth surface processes and their interaction with humans, anthropogenic landscape analysis, natural hazards, hydrogeomorphology, digital terrain analysis, lidar, and structure-from-motion photogrammetry. He is Editor of the journal Natural Hazards and Earth System Sciences (NHESS), and member of the editorial board of five journals. He is Science Officer of the EGU for the Natural Hazard Division (NH6: Remote Sensing & Hazards).

IRD-UMR LISAH:
IRD is an original and unique research organization on the European development scene. Emphasizing interdisciplinarity, the IRD has focused its research activities for over 65 years on the man/environment relationship, aiming at contributing to the southern countries development.
Leader: D. Feurer, Ph.D, UMR LISAH
Born in 1980, Denis Feurer received an engineering degree from ISAE/SUPAERO in 2002 and a Ph.D degree in Geomatics in 2008 from Laval University and AgroParisTech. He is research associate at IRD since 2010 and works now in Tunisia as an expatriate. He develops methods for temporal and spatial very-high-resolution mapping by remote sensing, especially low aerial photography and 3D mapping and is co-manager of the Kamech site of the OMERE observatory.

ENIT (National Faculty of Engineers of Tunis, University Tunis El Manar)-LTSIRS:
Founded in the late sixties, ENIT is the oldest engineering schools in Tunisia. It welcomes over 400 students each year for a 3-year program in one of six disciplines. The Laboratoire de Télédétection et Systèmes d'Information à Référence Spatiale (LTSIRS), founded in 1990, is an interdisciplinary laboratory federated by imaging and spatial data. With 3 research teams (Remote sensing, Geo-informatics, Applications) and 15 researchers including 4 professors, it is also a basement for Master, PhD and postdoc education in remote sensing and geoinformatics.
Leader: R. Boussema, Ph.D, LTSIRS
Born in 1953, Mohamed Rached Boussema is Professor at ENIT since 1999. After obtaining the Bachelor degree in Mathematics in 1978, he received an engineering degree in 1979 and doctor engineer degree in 1981, both in Geodetic Sciences at ENSG (France). He obtained a Master degree in Mathematical Statistics from the Pierre and Marie Curie University in 1980, and a Ph.D. at the Faculty of Sciences of Tunis in 1994. Research professor at ENIT since 1981, he created the Laboratory for Remote Sensing and GIS in 1990. His main research activities are in the field of geomatics. Specialized in remote sensing and GIS, he has supervised more than thirty PhD and master dissertations and has published over 160 publications.

B6. Further relevant information - *1 page max.*

- Project leaders' experiences in implementing similar projects

Rached Boussema had experiences in similar projects in the area of water and soil conservation involving remote sensing data: FLAUBERT (1997-2001) and LANDWATERMED (2001-2003) EU projects: the Canadien (IDRC) funded project SAGATELE (1994-1998).

Jean-Stéphane Bailly already leaded international research projects on remote sensing applied to Hydrology: FLASH 2012-2014 with Canada; HYDRODIN 2008-2010 with Mali. He also leaded research projects aiming at developing remote sensing for cultivated landscape object mapping (PNTS 2001-2003, PNTS 2008-2010, PNTS 2012-2014). He was animating the CNES-ORFEO program for Hydrology from 2010 to 2014.

Denis Feurer contributed to the "Lebna" (2011-2013) project (MISTRALS/SICMED) involving very-high-resolution topography mapping by photogrammetry, to the ALMIRA (2014-2016) project (ANR TRANSMED) and is co-manager of Kamech site of the OMERE long-term observation system.

Paolo Tarolli leaded two research projects funded by University of Padova on the use of high-resolution topography (derived by lidar) for understanding Earth surface signatures and related processes in mountain and urbanized floodplains, with the specific purpose to analyze humans-Earth interactions as a support to landscape planning. He was also involved as co-PI of a research project in Taiwan, where purpose was to process lidar data for the detection of deep-seated landslides under forest. He worked also at a project in China at China University of Geosciences in Beijing, on the use of UAV and structure from motion for mapping open-pit mining areas.

- Presentation of existing activities related to the project's main aim

Partners have been sharing previous activities related to the HighLandDEM project and they are planning some bi-lateral activities for the next two years especially, thanks to other projects:

- Regular Erasmus Mundus and Erasmus+ teacher and Master student exchanges and co-supervision (started 4 years ago) between University of Padova and AgroParisTech on geomorphometry/hydrology topics, including student seminars. They also jointly organised a EGU summer school on high resolution DTM to better understand processes in alpine environments (http://intra.tesaf.unipd.it/cms/summeregu2013/).
- Research activities related to the HighLandDEM project is underway between IRD and ENIT within the Mistrals Sicmed program on Lebna catchment (El Maaoui et al., 2012, Feurer et al., 2014, Mosbahi et al., 2014). These activities are dealing with the contribution of imagery to soil/water conservation.
- The organisation between partners in Tunisia of an international seminar on UAV imagery for research and observatories (Nov 2015, http://www.enit.rnu.tn/pdf/IRD_ENIT.pdf)
- IRD and AgroParisTech staffs are joined within a unique research unit "UMR LISAH" with a specific unit support. UMR LISAH is working on both sides of the Mediterranean sea (France, Tunisia, etc.) on anthropogenic landscape spatial dynamics impacting water and soil resources and managing (with INAT, INGREF and HSM) the ORE OMERE Observatory (www.obs-omere.org/). IRD, ENIT, AgroParisTech and University of Padova also got instruments (TLS, Kites/UAV, Topometry, etc.), data, processing power and regular activities for DEM generation.

Activities and data shared between partners are currently mostly bi-lateral and are or have already been supported (MISTRALS/SICMED 2011-2013, PNTS 2001-2002 , PNTS 2008-2010, PNTS 2013-2014, ORFEO Program and RCT Pleiades 2010-2014 (CNES), ALMIRA 2014-2016, ORE OMERE, and LTSIRS, LISAH and UNIPD/TESAF own budgets). Among these, the HighLandDEM project is a unique opportunity to extend and link these activities between project partners in order to reach and test an integrated DEM use for better water and soil processes observation and understanding in Mediterranean rainfed eco-agrosystems with the aim to implement these techniques for water resources and land surface long-term monitoring.

- Prospects of maintaining collaboration beyond this programme's financing period

Collaboration after the HighLandDEM project will be secured especially thanks to:

- The construction to an Erasmus+ call for strategic partnership (ex intensive programs) to share courses and seminars on geomorphometry using DEMs for water/soil resources management in an unique location for master students between University of Padova and AgroParisTech, with collaboration with IRD and ENIT.
- The next submission of partners to the call CNES-TOSCA and Theia program on a research program focusing on the mapping of linear elements in cultivated landscapes (pre-proposal already submitted in 2014 called 'TRIPL' - 'Télédétection hautement Résolue d'Infrastructures Paysagères Linéaires').
- The insertion of the consortium into the KaliDEOS MedUSE and Theia-Land expertise centers (Spot Heritage, etc.) to help alternative satellite images acquisition on partners's sites.
- The ongoing Naïla LMI/IJL (International Joint Laboratory) construction (IRD-INRGREF-INAT-ENIT-INRAT-CERTE). Naïla stands for "maNAging water resources in tunIsian ruraL Areas", which fully falls within the scope of the HighLandDEM project.

C. Budget proposals

C.1 Total budget

	Income	Expenditure (detail for ENVIMED support requested in C.2)
Year 1	Mediterranean partners: 4 300 € (mobility, field work, grants) *Erasmus, UNIPD/TESAF and ENIT/LTSIRS own budgets*	**Total of eligible expenditures for ENVIMED support including other funds if any** Mobility[1] - Researchers: 3 500 € (1 100 € already funded) - Doctoral students: 2 400 € (Tunisia) - Post-doctoral students: 2 200 € (Italy) International seminars - Logistics: 1 900 € - Mobility[1]: 2 100 €
	French partners: 10 800 € (mobility, field works, data, equipment, grants) *PNTS, OMERE, MISTRALS/SICMED Lebna, Erasmus and IRD/LISAH own budget*	**Other expenditures (please specify):** Equipment and data: 4 300 € (cameras, UAV/kite, computing power, Pleiades-like stereo images) Operations: 4 100 € (field work) Grants: 5 600 €
Year 2	Mediterranean partners: 2 000 € (mobility) *ALMIRA, Erasmus and ENIT/LTSIRS own budget*	**Total of eligible expenditures for ENVIMED support including other funds if any** Mobility[1] - Researchers: 2 000 € (already funded) - Doctoral students: 1 400 € (Tunisia) - Post-doctoral students: 1 400 € (France) International seminars - Logistics: 3 800 € - Mobility[1]: 2 500 €
	French partners: 5 600 € (grants) *ALMIRA*	**Other expenditures (please specify):** Equipment: Operations: Grants: 5 600 €
Total	22 700 €	42 800 €

ENVI-MED regional programme, can only provide a financial contribution for the additional costs relating to the international nature of the projects, i.e. the mobility of researchers, doctoral students or post-doctoral students (travel and accommodation expenses), or the organization of international workshops and seminars (mobility and logistics).

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1 Mobilities have been evaluated with a perdiem basis of 125€ for mobilities in Tunisia and 115,50€ for mobilities in France and Italy. Mean travel expenses for round trips between France, Tunisia and Italy are between 500 and 600€. Travel expenses for grouped field trips have also been taken into account.

C.2 Support requested from the ENVI-MED programme:

Year 1	Mobility[2] - Researchers: 2 400 € - Doctoral students: 2 400 € - Post-doctoral students: 2 200 € International seminars - Logistics: 1 900 € - Mobility[2]: 2 100 €
Year 2	Mobility[2] - Researchers: 0 € - Doctoral students: 1 400 € - Post-doctoral students: 1 400 € International seminars - Logistics: 3 800 € - Mobility[2]: 2 500 €
Total*	20 100 €

* The total amount allocated by ENVIMED may not exceed a total of €20,000 for the two years of the project.

References

- Baccari, N., Nasri, S., Boussema, M. R. & Lamachère, J. M. (2007). Contour ridge efficiency on land erosion, water filling and silting up of a hill reservoir in a semi-arid region in Tunisia. Proceedings of the international Conference " Water Saving in Mediterranean Agriculture & Future Research Needs" (WASAMED Project) 14-17 February 2007-Valenzano, (Italy). Edited by CIHEAM- Bari. Vol. III, p.351. Session N° 5 pp 141-149
- Baccari, N., Boussema, M.R. & Snane, M.H. (2005). Nécessité de développement d'une méthodologie d'inventaire basée sur les photographies aériennes numérisées, la réalité du terrain et SIG ; cas des aménagements de conservation des eaux et du sol en Tunisie. Télédétection, vol. 5, n° 1-3, p 3-18.
- Bailly, J.-S. & Levavasseur, F. (2012), Potential of linear features detection in a Mediterranean landscape from 3D VHR optical data: Application to terrace walls, in 'Geoscience and Remote Sensing Symposium (IGARSS), 2012 IEEE International', IEEE, 345 E 47TH ST, NEW YORK, NY 10017 USA, Munich, Germany, pp. 7110-7113.
- Bailly, J.; Lagacherie, P.; Millier, C.; Puech, C. & Kosuth, P. (2008), 'Agrarian landscapes linear features detection from LiDAR: application to artificial drainage networks', International Journal of Remote Sensing 29(12), 3489-3508.
- Bouchnak, H., Sfar Felfoul, M., Boussema, M. R. & Snane, M. H. (2009). Slope and rainfall effects on the volume of sediment yield by gully erosion in the Souar lithologic formation (Tunisia). CATENA, Volume 78 Issue 2, 15 August 2009 p 170-177
- Boughattas, N. H., Snane, M. H., Sfar Felfoul, M. & Boussema, M.R. (2010). The Impact of exceptional rain events on the development of gullies in geological formation in Dhkekira watershed. International Workshop Advances in statistical hydrology. Taormina, Italy, 23 – 25 May 2010.
- Boussema, MR. (2013) "Three-dimensional reconstruction of soil surfaces and study of their roughness and moisture by satellite imaging radar". 35th International Symposium on Remote Sensing of Environment (ISRSE35) /GlobeSar 20, Beijing 2013, 22 - 26 April 2013, 6p .
- Boussema, M. R., Chevallier, J. J. & J. Pouliot, J. (1996). SAGATELE : Système d'aide à la gestion et à l'aménagement du territoire pour la lutte contre l'érosion. ORSTOM Editions, collection Colloques et Séminaires, Paris, pp. 219-229.
- Boussema, M. R. & Snane, M. H. (2013). Contribution of airborne photography to erosion gully study in semi-arid area. 35th International Symposium on Remote Sensing of Environment (ISRSE35), Beijing 2013, 22 - 26 April 2013, 6p.

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2 Same as note 1 on the preceding page

- El Maaoui, M. A., Sfar Felfoul, M., Boussema, M. R. & Snane, M. H. (2012). Sediment yield from irregularly shaped gullies located on the Fortuna lithologic formation in semi-arid area of Tunisia. CATENA, vol 93 June, p 97-104 DOI: 10.1016/j.catena.2012.02.004 ISSN: 0341-8162
- Feurer, D., El Maaoui, M. A., Boussema, M.R. & Planchon, O. (2014). Méthode opérationnelle de production d'orthophotos et de MNT décimétriques à l'échelle du kilomètre carré par cerf-volant. Colloque scientifique francophone Drones et moyens légers aéroportés d'observation, Montpellier, 24-26 Juin
- C. Heipke, H. Mayer, C. Wiedemann, and O. Jamet, "Evaluation of automatic road extraction," International Archives of Photogrammetry and Remote Sensing, vol. 32, no. 3 SECT 4W2, pp. 151–160, 1997.
- Mosbahi, M., Benabdallah, S. & Boussema, M. R. (2014). Impact of SWAT input data on soil erosion in a semi-arid catchment. LJEE, N° 13 & 14, 8 pages
- Mosbahi, M., Benabdallah, S. & Boussema, M. R. (2011). Determination of Critical Source Areas for Sediment Loss: Sarrath River Basin, Tunisia. International Journal of Civil and Environmental Engineering 3, 206
- Pouliot, J., Thomson, K. P. B., Chevallier, J.J. & Boussema, M. R. (1994). Integrated Application of Geomatic Techniques in the Context of Agricultural Anti-Erosion Management. Canadian Journal of Remote Sensing. Volume 20, Issue 4, 1994. Special Issue on Integrated Analysis of Spatial Data from Multiple Sources. DOI: 10.1080/07038992.10874584, pages 419-425
- Prosdocimi, M., Sofia, G., Dalla Fontana, G., Tarolli, P. (2015). Bank erosion in agricultural drainage networks: effectiveness of Structure-from-Motion for post-event analysis, *Earth Surface Processes and Landforms*, ISSN: 1096-9837, doi:10.1002/esp.3767.
- Sofia, G., Prosdocimi, M., Dalla Fontana, G., Tarolli, P. (2014a). Evidences and effects of changes in the artificial drainage network during the past half-century: a case study in the Veneto floodplain (Italy), *Anthropocene*, 6, 48-62, ISSN: 2213-3054, doi:10.1016/j.ancene.2014.06.005.
- Sofia, G., Mariniello, F., Tarolli, P. (2015, in press). Geomorphologic portrait of anthropogenic landscapes, *Earth Surface Processes and Landforms*, ISSN: 1096-9837.
- Sofia, G., Mariniello, F., Tarolli, P. (2014b). A new landscape metric for the identification of terraced sites: the Slope Local Length of Auto-Correlation (SLLAC), *ISPRS Journal of Photogrammetry and Remote Sensing*, 96, 123-133, ISSN: 0924-2716, doi:10.1016/j.isprsjprs.2014.06.018.
- Sofia, G.; Bailly, J.-S.; Chehata, N.; Tarolli, P. & Levavasseur, F. (Submitted), 'Terrace walls detection from a Pleiades Digital Elevation Model', *IEEE JSTARS*.
- Tarolli, P., Sofia, G., Calligaro, S., Prosdocimi, M., Preti, F., Dalla Fontana, G. (2015). Vineyards in terraced landscapes: new opportunities from lidar data, *Land Degradation & Development*, 26, 92-102, ISSN: 1099-145X, doi:10.1002/ldr.2311.
- Tarolli, P., Preti, F., Romano, N. (2014). Terraced landscapes: from an old best practice to a potential hazard for soil degradation due to land abandonment, *Anthropocene*, 6, 10-25, ISSN: 2213-3054, doi:10.1016/j.ancene.2014.03.002. (Review Article)
- Tarolli, P., Calligaro, S., Cazorzi, F., Dalla Fontana, G. (2013). Recognition of surface flow processes influeced by roads and trails in mountain areas using high-resolution topography, *European Journal of Remote Sensing*, 46, 176-197, ISSN: 2279-7254, doi:10.5721/EuJRS20134610.
- Thommeret, N.; Bailly, J. & Puech, C. (2011), A hierarchical graph matching method to assess accuracy of network extraction from DTM, *in* T. Hengl; I. S. Evans; J. P. Wilson & M. Gould, ed., 'Geomorphometry 2011', pp. 49-52.