## Deuxième Workshop

# Global Change: Assessment and Adaptation to Mediterranean Region Water Scarcity

## Recueil des résumés

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# Présentation résumée du projet ERANET-MED

## « Global Change: Assessment and Adaptation to Mediterranean Region Water Scarcity »

Ces dernières années, plusieurs organisations internationales et une riche activité scientifique ont souligné l'enjeu stratégique que constituait l'eau pour le développement économique de la région méditerranéenne. Cette région se caractérise par un déclin sévère et continu des ressources, tant en termes de quantité que de qualité, associé à une augmentation de la demande, dont 70 à 80% concernent les activités agricoles. Cette situation est exacerbée sur la rive sud de la Méditerranée, où la spécificité du climat (sécheresses fréquentes) associée aux changements induits par les activités humaines augmente le risque de crises. Dans ce contexte hydrique difficile, l'équilibre séculaire fragile entre ressources et usages est donc aujourd'hui menacé par les bouleversements profonds et rapides de l'agriculture dans les régions semi-arides du côté sud. Les territoires agricoles, qui consomment et produisent de l'eau agricole et de l'eau potable pour satisfaire des besoins multiples, se caractérisent par une concurrence entre différents acteurs dont l'interdépendance résulte, entre autres, du cycle hydrologique. Ces problèmes sont communs à la plupart des pays méditerranéens, où les problèmes de durabilité, de concurrence et d'interdépendance se déclinent de différentes manières.

En réponse à ces questions sociétales, le projet vise à mettre en œuvre une approche systémique du fonctionnement éco-hydrologique des agro-systèmes en relation avec les réservoirs physiques (capacités de stockage et de renouvellement) et les acteurs (opérateurs et gestionnaires). Les échelles spatiales ciblées sont les échelles des processus de prise de décision allant de la parcelle pour la planification de l'eau d'irrigation, l'échelle intermédiaire du bassin versant pour la planification du bassin versant à l'ensemble de la région méditerranéenne. L'objectif de notre projet est double: (1) contribuer à une meilleure compréhension de l'évolution des ressources sous changement global et évaluer les trajectoires d'eau les plus probables et (2) proposer plusieurs solutions innovantes à moyen et long terme pour rationaliser utilisation de l'eau agricole dans la région sur la base des outils de décision existants développés par le consortium. La question de la gestion des ressources en eau et du cycle hydrologique associé est abordée selon la dualité de consommation (infiltration et stockage dans la zone racinaire) et de production (percolation des aquifères et des eaux de ruissellement vers des réservoirs artificiels), en tenant compte des interactions entre les zones en amont (enneigement, agriculture pluviale) et en aval (plaines irriguées).

Quatre bassins du sud de la Méditerranée sont considérés: les bassins du Tensift (Maroc), du Merguellil (Tunisie), du Lebna (Tunisie) et du Litani (Liban). Les quatre bassins se caractérisent par les interactions mentionnées ci-dessus entre les zones en amont et en aval et entre les cultures pluviales et irriguées. Le consortium est composé de 7 partenaires scientifiques avec le soutien de 7 parties prenantes. La mise en œuvre du projet sur les quatre agrosystèmes implique la mise en réseau de structures pérennes sur les rives nord et sud de la Méditerranée, à savoir deux laboratoires mixtes internationaux de l'Institut de Recherche pour le Développement avec ses partenaires (TREMA, NAÏLA), le laboratoire international associé du CNRS (O-LIFE) et quatre systèmes d'observation, dont trois sont impliqués dans des réseaux nationaux et / ou internationaux (Merguellil (réseau JECAM), Lebna (réseau national français OMERE), Tensift

(réseau national IRD, réseau JECAM) , Litani (O-LIFE). Cette mise en réseau induit une politique de mobilité forte entre les structures, pour échanger et partager des connaissances sur l'observation, la modélisation et l'analyse intégrée. Cette politique de mobilité sera principalement mise en œuvre pour les jeunes chercheurs afin de renforcer la dynamique méditerranéenne que ces jeunes chercheurs animeront dans les décennies à venir.

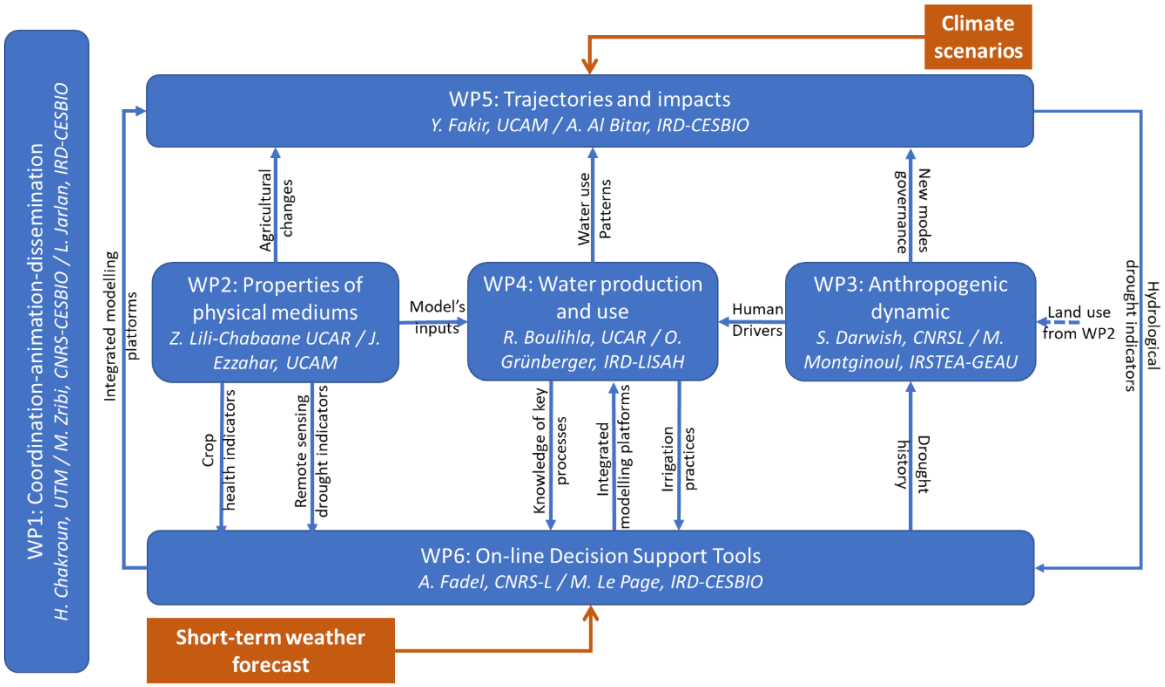


**Figure 1: Logique du projet CHAAMS**

## Mise en oeuvre

Afin de mettre en œuvre ce projet collectif et pluridisciplinaire, cinq actions clés qui constituent également les Work Package sont ciblées tandis que le WP1 est dédié à la gestion de projet et à la diffusion des résultats (Fig. 1). Le WP2 vise à caractériser les variabilités spatio-temporelles des propriétés biophysiques des agrosystèmes et le développement des indicateurs de stress hydrique et de sécheresse des cultures utilisés ultérieurement dans le WP6. Le WP3 est dédié à la compréhension des facteurs socio-économiques à la base de la prise de décision des agriculteurs et de la gouvernance des ressources en eau. Le WP4 vise à analyser les aspects de la qualité de l'eau et à identifier la production d'eau et à utiliser les modèles des principaux systèmes agricoles (modernes vs traditionnels, intensifs vs extensifs, plantes annuelles…) coexistant avec les changements observés au WP2 et WP3. Le WP5 vise à projeter les impacts de l'utilisation de l'eau agricole sur les réservoirs d'eau de surface et souterraine grâce à des outils de modélisation intégrés déjà mis en œuvre sur les sites d'étude ciblés et les scénarios climatiques et socio-économiques (WP3). Le WP6 vise à renforcer et à diffuser aux gestionnaires les solutions pré-opérationnelles existantes développées au sein du consortium pour rationaliser l'utilisation de l'eau agricole.

## Partenariat

Le consortium CHAAMS est composé de 7 partenaires de France (CESBIO, G-EAU et LISAH), du Liban (CNRSL), du Maroc (UCAM) et de Tunisie (UCAR et UTM). Ces partenaires ont été soigneusement

sélectionnés en fonction de l'expertise spécifique qu'ils apportent au projet. Dans la répartition des ressources, une tentative a été faite pour garantir un apport équilibré de chaque partenaire au projet. Seuls les partenaires qui dirigent le projet (CESBIO et UTM) ont reçu un peu plus de ressources en raison de la charge de travail supplémentaire liée à la coordination et à la gestion. Quatre grands domaines d'expertise sont nécessaires pour mener à bien le projet. Tous les champs sont bien couverts par au moins trois partenaires:

- Socio-économie (3 partenaires: G-EAU, UTM et CNRSL)
- Observation de la Terre et suivi agricole (4 partenaires: CESBIO, CNRSL, UCAR et UCAM)
- Modélisation hydrodynamique (4 partenaires: LISAH, UTM, UCAM et UCAR)
- Fonctionnement hydrologique des cultures (5 partenaires: CESBIO, LISAH, UCAR, UCAM

# Improving Evapotranspiration estimation by integrating surface soil moisture data in TSEB model

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A precise estimate of the evapotranspiration (ET) is fundamental for determining the crop water needs and subsequently for optimizing water management practices and irrigation regimes. Regarding data availability over large areas and at multiple scales, remote sensing observations provide very relevant information to feed ET models.. Surface soil moisture (SM) and land surface temperature (LST) are the essential components of the hydrological cycle, especially, for controlling soil evaporation and plant transpiration. The main goal of this work is to test a model of ET based on a combination of LST and SM data. For this purpose, SM data are integrated into an energy balance model (TSEB-SM) already constrained by LST and that explicitly represents the fluxes of soil and vegetation. TSEB-SM is derived from the TSEB formalism for the vegetation transpiration and represents the soil evaporation using empirical parameters ($a_{rss}$, $b_{rss}$) of the relationship between soil surface resistance ($r_{ss}$) and SM. For the vegetation cover fraction fc≤0.4, the model calibration consists of inverting $r_{ss}$ every 30-min. When fc>0.4, the calibration consists in estimating the Priestly Taylor coefficient ($\alpha_{PT}$) at the daily time scale. The procedure is applied over an irrigated wheat field in the Tensift basin, central Morocco. The mean retrieved values of soil resistance calculated for the entire study period are (6.06, 2). The calibrated daily $\alpha_{PT}$ ranges between 0 and 1.9. The high value of $\alpha_{PT}$ is mainly justified by the intense irrigation along the agricultural season. Moreover, the ET simulated by the model fits well with observations. The obtained correlation coefficient $R^2$, root mean square RMSE, and mean bias error MBE are 0.75, 92 and 59 W/m$^2$, respectively. Overall, the coupling of the soil resistance formulation with the TSEB formalism improves the estimation of soil evaporation, and consequently, improves the partitioning of ET. Analysis of the retrieved time series indicates that the daily $\alpha_{PT}$ mainly follows the phenology of winter wheat crop with a maximum value coincident with the full development of green biomass and a minimum value reached at harvest.

# Assessing soil moisture constraint on soil evaporation and plant transpiration fractioning

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Over semi-arid agricultural regions, detecting the crop water need at the onset of water stress is of paramount importance for optimizing the use of irrigation water. Evapotranspiration (ET) is a crucial component of the water cycle, it strongly impacts the water resource management, drought monitoring, and climate. Remote sensing observations provide very relevant information to feed ET models. In particular, the microwave-derived surface (0-5 cm) soil moisture (SM), which is the main controlling factor of soil evaporation, the visible/near-infratred-derived vegetation cover fraction (fc), which provides an essential structural constraint on the fractioning between vegetation transpiration and soil evaporation, and - thermal-derived land surface temperature (LST), which is a signature of both available energy and evapotranspiration (ET) rate. The aim of this work is to integrate those independent and complementary information on total ET within an energy balance model. As a state-of-the-art and commonly used model, we chose the TSEB modelling as a basis for developments. An innovative calibration procedure is proposed to retrieve the main parameters of soil evaporation (soil resistance, rss) and plant transpiration (Priestly Taylor coefficient, αPT) based on a threshold on fc. The procedure is applied over an irrigated wheat field in the Tensift basin, central Morocco. Overall, the coupling of the soil resistance formulation with the TSEB formalism improves the estimation of soil evaporation, and consequently, improves the partitioning of ET. Analysis of the retrieved time series indicates that the daily αPT mainly follows the phenology of winter wheat crop with a maximum value coincident with the full development of green biomass and a minimum value reached at harvest. The temporal variations of αPT before senescence are attributed to the dynamics of both the root zone soil moisture and the amount of green biomass.

# Evapotranspiration partition using the multiple energy balance version of the ISBA-A-gs land surface model over two irrigated crops in a semi-arid Mediterranean region (Marrakech, Morocco)

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The main objective of this work is to question the representation of the energy budget in surface–vegetation–atmosphere transfer (SVAT) models for the prediction of the convective fluxes in the case of irrigated crops with a complex structure (row) and under strong transient hydric regimes due to irrigation. To this objective, the Interaction Soil–Biosphere–Atmosphere (ISBA-A-gs) based on a composite energy budget (named hereafter ISBA-1P for 1 patch) is compared to the new multiple energy balance (MEB) version of ISBA using two representations of the canopy energy budget: a coupled approach (ISBA-MEB) where the vegetation layer is located above the soil and a patch representation corresponding to two-adjacent uncoupled source schemes (ISBA-2P for 2 patches). The evaluation is performed over a winter wheat field, taken as an example of homogeneous canopy and on a more complex open olive orchard. Continuous observations of evapotranspiration (ET) with Eddy covariance system, soil evaporation (E) and plant transpiration (Tr) with Sapflow and isotopic methods were used to evaluate the three representations. A preliminary sensitivity analyses showed a strong sensitivity to the parameters related to turbulence in the canopy introduced in the new ISBA-MEB version. The ability of the single and dual-source configuration to reproduce the composite soil-vegetation heat fluxes was very similar: the RMSE differences between ISBA-1P, -2P and -MEB did not exceed 10 W/m2 for the latent heat flux. These results showed that a composite energy balance on homogeneous covers is sufficient to reproduce the total convective fluxes. By contrast, differences were highlighted on the partition of ET. In particular, the ISBA-2P version showed an over-estimation of soil evaporation of about 20 % because of a direct exposition to incoming solar radiation and because there is no root extraction for the bare soil patch with regards to –MEB and -1P representations. By contrast, the dual source configurations including both the uncoupled (ISBA-2P) and the coupled (ISBA-MEB) representations outperformed the single source version (ISBA-1P) with slightly better results for ISBA-MEB in predicting both total heat fluxes and evapotranspiration partition over the moderately open canopy of the Olive orchard site. Concerning plant transpiration in particular, the coupled approach ISBA-MEB provides better results than ISBA-1P and, to a lesser extent ISBA-2P with RMSEs of 1.60, 0.90, 0.70 mm/day and R2 of 0.43, 0.69 and 0.70 for ISBA-1P, -2P and MEB respectively. In addition, it is shown that the acceptable predictions of composite convective fluxes by ISBA-2P for the Olive

orchard are obtained for the wrong reasons as neither of the two patches is in agreement with the observations because of a bad spatial distribution of the roots and of a lack of incoming radiation screening for the bare soil patch. This work shows that composite convection fluxes predicted by the SURFEX platform as well as partition of evapotranspiration in a highly transient regime due to irrigation is improved for moderately open tree canopies by the new coupled dual-source ISBA-MEB model. It also points out the need for further local scale evaluation on different crops of various geometry (more open rainfed or denser intensive olive orchard) to provide adequate parameterization to global data base such as ECOCLIMAP-II in the view of a global application of the ISBA-MEB model.

# Simple and spatialize approach to optimize irrigation water and wheat yield in the semi-arid areas

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The Merguellil catchment, located in central Tunisia, is characterized by a semi-arid climate. The catchment extends on an area of about 1200 km² upstream El Houareb dam. Streamflow and erosion modelling were carried by the Soil and Water Assessment Tool model.

This model requires a number of spatial and temporal inputs including the digital elevation model, the soil map as well as the physical-chemical characteristics of each soil layer, the land use map, and climatic data. The catchment witnessed many soil and water conservation works changing its hillslopes.

A sensitivity analysis of the hydrological model to input data was carried to identify the needed rainfall stations for modelling. The calibration of the model was made for theupper part of the basin delimited by the hydrometric station of Haffouz over the 1992-2005 period using SWATCUP based on the algorithm SUFI-II. The calibration allowed identifying the most sensitive parameters. The model was then validated at the El Houareb dam based on the water level of the dam converted into flows. The performance of the model is satisfactory and the Nash-Sutcliffe Efficiency coefficient is 0.52. It was shown that the soil and water conservation Works (Counter ridge) contributed to the retention of a large amount of sediment and reduced runoff within the Merguellil basin.

***Keywords:*** Modeling, Merguellil, SWAT, Calibration, Soil and Water Conservation Works.

# Impact des changements climatiques sur l'arboriculture fruitière dans la région de Kairouan

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Actuellement, la Tunisie est parmi les pays les plus vulnérables aux changements climatiques. La région de Kairouan sera parmi les régions les plus touchées par le changement du climat dans le futur et aura une baisse de pluviométrie de 2 à 4% et augmentation des températures entre 1.7 et 1.8 °C en 2050. Cette région aura une baisse accrue de pluviométrie de 15 à 20% en 2100 et une augmentation considérable de températures entre 2.3 et 2.4 °C pour la même période. Les hausses de températures entrainent un manque de froid et une consommation plus importante en eau ce qui exerce une pression conséquente sur les ressources naturelles. Dans ce sens, il est nécessaire d'évaluer l'impact des changements climatiques futurs ainsi que l'adaptation des espèces fruitières dans la région de Kairouan. En effet, au cours de notre étude, nous avons réalisé des projections des quantités de froid historiques et futures en utilisant 78 scénarios climatiques pour le RCP4.5 et RCP8.5 et pour deux périodes 2041-2070 et 2071-2100 pour évaluer l'évolution de la disponibilité du froid hivernal dans la région de Kairouan. L'évolution de l'accumulation du froid au cours du temps et au passé entre 1980 et 2019 a été aussi suivie. Nos résultats ont montré que durant les 40 dernières années, la région de Kairouan a subi des diminutions des quantités de froid hivernales accumulées et devra encore perdre des quantités de froid dans le futur qui seront plus sévères vers la fin du siècle. Ceci pourra avoir des conséquences graves sur le secteur agricole en Kairouan et très peu d'espèces fruitières seront adaptées. Il limitera ainsi le choix des espèces et variétés à planter et changera le patrimoine génétique, car certaines espèces seront abandonnées et d'autres seront introduites. Des mesures d'adaptation et de mitigation aux changements climatiques devront être alors adoptées. Une reconsidération des besoins en eau devra être établi surtout pour des nouvelles espèces adaptées selon les changements futurs et une prédiction de la disponibilité des quantités d'eau devra être réalisée.

***Mots clés :*** Changements climatiques ; Kairouan ; Espèces fruitières ; Besoins en eau

# Assessing the linkages between agricultural drought index derived from remote sensing data and a Land Data Assimilation system and cereal production in Morocco

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In Morocco, cereal production shows a high interannual variability due to uncertain rainfall and recurrent drought periods that may occur at key phenological stages. In view of the importance of this resource to the country's economy, it is important to better characterize the impact of drought strength and duration on yields in order to better anticipate production at the seasonal scale. While meteorological drought is usually derived from precipitation anomalies, the monitoring of agronomical drought may be more complex because of data availability issues. In this study, drought is assessed through, on one hand, classical indices derived from remote sensing data (Vegetation Condition Index -VCI-, Temperature Condition Index -TCI-, Vegetation Health Index -VHI- and Soil water index SWI ) and on the other hand, the outputs of a land data assimilation system (LDAS). The LDAS has been developed by the CNRM/Meteo-France and is composed of the ISBA-A-gs land surface model forced by ERA-5 re-analysis constrained by LAI product and a surface soil moisture derived from scatterometer data. LAI, Transpiration and soil moisture at different depth are used. Correlation analysis was conducted to examine the relationships between drought indices during the growing season and final yield, according to data collection from 2000 to 2017. The results show that the correlation between drought indices computed using remote sensing data are depend on phenological stage of development. A strong correlation was found between VCI and cereal yield during heading stage for all provinces (R= 0.6 to 0.93). For TCI the relationship with cereal yield was found to be higher during development stage (R= 0.61 to 0.82). Finally, for SWI the correlation was strong during sowing to emergence stage for all province (R= 0.57 to 0.95) except Kenitra province which dominated by irrigated cereal. On the other hand, the result of this study confirmed that drought influences on crop production differently, depending on the development stage at the time of its occurrence. Comparing the correlation between this indices and yield at monthly and phenological stage show that the correlation at phenological stage was improved. In addition, the contribution of VCI and TCI in to VHI was optimized. This optimization was established at phenological stage scale, with using yield anomaly as independent drought index reference. The results show that during growing season of cereal, at development stage the contribution of TCI in vegetation health was found to be higher. By contrast, during heating stage the contribution of VCI was found to be higher. Finally, outputs from the LDAS appeared very promising as strong correlation were obtained with LAI assimilated in March (R=0.92), with transpiration from February until March (R=0.85-0.9) and for soil moisture at the beginning of crop season (December R=0.86) during emergence. Our current work is focused on the development of empirical models for early forecasting cereal production at the provincial and national scales based on machine learning approach.

# Climate change and Mediterranean agriculture: Impacts on irrigated wheat grain yield and irrigation requirements

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The southern Mediterranean regions are likely to face drastic climate changes (CC). Agricultural yields, particularly of cereals, could be severely affected, especially if significant changes occur at the key phenological stages. In addition, while agriculture is expected to meet around 83% of North African food demand by 2050, the increase in agricultural water requirements due to the intensification of practices, the extension of arable land and the expected warming could jeopardize the water supply of other key economic sectors. In this context, the present work aims to quantify the impact of CC on the grain yields of irrigated cereals and their water requirements in the Tensift-Haouz region of Morocco. The Med-CORDEX ensemble runs under scenarios RCP4.5 and RCP8.5 are first evaluated and disaggregated using the quantile-quantile approach. The impact of CC on the duration of the main wheat phenological stages based on the degree-day approach is then analysed by considering three typical sowing dates (early, around November 15th; intermediate, around December 15th; and late, around January, 15th). The results show that the rise in air temperature causes a shortening of the development cycle of up to 50 days (around 30%). The impacts of rising temperature, increasing atmospheric CO2 concentration and changes in precipitation on wheat yields are next evaluated, based on the AquaCrop model (previously calibrated on several plots of winter wheat in the region of study), both with and without taking into account the fertilizing effect of CO2. As expected, optimal wheat yields for all climate scenarios and time horizons will decrease on the order of 7 to 30% depending on the sowing date, if CO2 concentration rise is not considered. The results also show that the fertilizing effect of CO2 can counterbalance yield losses, since optimal yields could increase by 7% and 13% respectively at mid-century for the RCP4.5 and RCP8.5 scenarios. Finally, water requirements are expected to decrease by 13 to 42% depending on sowing date, scenario and horizon, mainly in response to the shortening of the cycle. This decrease is associated with a change in temporal patterns, with the requirement peak coming two months earlier than under current conditions. This study provides some quantitative elements for agricultural practices adaptation, in particular concerning the sowing date and also for water management in the south mediterranean region related to the temporal patterns of the crop water needs.

# Evaluation of the potential of Sentinel-1 and Sentinel-1 data for clay content mapping

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Soil texture is a key parameter in agricultural processes and an important measure for agricultural prediction, water cycle, filtering of pollutants and carbon storage. Besides, its estimation is essential for agronomists, hydrologists, geologists and environmentalists and for modeling in these application areas. Several studies have been based on understanding and modeling the biological, physical and chemical processes in the soil. Regarding the texture of the soil, few researches propose soil texture spatialization, and are generally based on ground measurements. Among other things, field observations or laboratory analyzes are very expensive and are not very representative. Indeed, the soil texture presents a strong heterogeneity even at the scale of a field. It is then necessary to use precise and spatialized information on soils.

These methods are generally based on remote sensing data and particularly optical data to restore soil component. However, these techniques are strongly affected by atmospheric conditions. This constraint is not valid for Radar sensors (Radio Detection And Ranging). Radar data are mainly sensitive to soil moisture and soil roughness, and has also been evaluated for its ability to perform texture measurements.

The aim of this study is evaluate the potential of these techniques based on optical and radar data for soil texture estimation. By its composition, its structure, its texture and its porosity, soil moisture is strongly influenced by the soil nature. With the arrival of Sentinel-1 (S-1) and Sentinel-2 (S-2) ESA spatial missions, data are acquired with high spatial and temporal resolution between July and early December 2017, on a semi-arid area in central Tunisia. This study is therefore conducted using S-2 SWIR (Short-Wave Infrared) bands (B11 and B12, most sensitive to clay) and soil moisture products derived from radar data. And algorithms based on the support vector machine (SVM) and random forest (RF) methods are proposed for the classification and mapping of clay content.

In order to evaluate the approach and determine the adequate data (between optical and radar data) allowing to precisely characterize the clay content, a cross-validation was used. The SWIR bands lead to less satisfactory outcomes compared to soil moisture. With an overall accuracy of approximately 65%, soil moisture achieved the best performance for estimating soil texture. The results also showed that RF and SVM are robust classifiers for texture estimation despite the small number of training data. However, RF displays greater accuracy and speed of simulation compared to SVM.

# Water productivity of cereals by SENTINEL-2 and LANDSAT-8 in Lebna watershed (Cap Bon)

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A good assessment and monitoring of water productivity (WP) is a crucial step to properly manage agricultural water resources and ensure food security. This requires knowledge on the water consumption of crops and on the crop production. The present study explores the contribution of remote sensing in the estimation of cereals water productivity in the Lebna watershed (Cap-Bon). The adopted methodology was based on the WATPRO model combining the Monteiths theoretical framework for biomass evaluation and the energy balance for water consumption. A simplified version of the model allows the assessment of WP from albedo and NDVI spatial variables in combination with the extraterrestrial radiation and the air temperature. This version of the WATPRO model was tested using time series images LANDSAT-8 and SENTINEL-2 images between 2015 and 2018.

At the plot level, results show close WP values derived from LANDSAT-8 ($WP_{wheat}$ = 0.364 Kg/$m^3$ $WP_{barley}$ = 0.408 Kg/$m^3$) and from SENTINEL-2 ($WP_{wheat}$ = 0.372 Kg/$m^3$ , $WP_{barley}$ = 0.408 Kg/$m^3$ ). However, the various NDVI formulas combining SENTINEL-2 red edge bands result in more important WP variations with $WP_{wheat}$ varies between 0.199 and 0.372 Kg/$m^3$ and $WP_{barley}$ varies between 0.242 and 0.431 Kg/$m^3$. For spatial variability evaluation of cereals WP at the Lebna watershed level, a maximum likelihood classification of SENTINEL-2 image was carried to extract the cereals class. During the 2015-2016 season, the highest WP areas (> 0.5 kg/ $m^3$) represent 31% of cereal cultivated areas based on SENTINEL-2 compared to 23% when the model is based on LANDSAT-8. The time-series exploration based on SENTINEL-2 images acquired between 2015 and 2018 allow the fellow up of cereals WP showing a correlation between annual precipitation and the WP of cereals. The WATPRO model simplicity allows its use with the available SENTINEL-2 data to assess the main driving factors of the cereal water productivity regarding the various climatic and edaphic conditions in the Lebna watershed for a more efficient water management.

**Key words**: Lebna, Water Productivity, Cereals, SENTINEL-2, LANDSAT-8, WATPRO

# First diagnosis of pesticides fate in runoff water inside grain farming cultivation system in Cap Bon (Tunisia).

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The degradation of surface and/or groundwater quality is one of the major consequences of current intensive agriculture, which is mainly marked by the presence of considerable levels of organic pollutants, particularly pesticides. In the Tunisian context, this aspect remains very little studied and research around the behavior of the pollutants in use under these environmental conditions. This study aims to carry out an initial diagnosis of the quality of surface water in small grain farming in the Kamech watershed located in the Cap Bon region, Northern Tunisia, in order to assess the effects of a change in phytosanitary practices on the quality of surface water. The experimental site chosen on the Kamech catchment site, belongs to an Environmental Research Observatory (ORE-OMERE) https://www.obs-omere.org/ which provides runoff measurements, including phytosanitary products concentrations at nested scales from the plot to the outlet of the catchment area. In addition First analysis of 9 surface water samples revealed the detection of pesticide active ingredients in 9 hillside lakes adjacent to the Kamech watershed. The molecules detected are: 2,4-D, dinoterbe and glyphosate as herbicides; carbendazim and boscalid as fungicides and imidacloprid as insecticide. Their concentrations vary according to the lake. However, glyphosate marks a remarkable highest concentration with a value of 0.92 µg $L^{-1}$ exceeding the European potability limit of 0.1 µg $L^{-1}$.

In addition, according to our recent survey and discussion with farmers, we noted a recent introduction of glyphosate into their agricultural practices, which prompted us to consider it as a candidate to understand and quantify the mechanism of pesticide transfer during rainy events. Indeed, the evolution of glyphosate concentrations and its metabolite Amino Methyl Phosphonic Acid (AMPA) at the plot scale are significant after the first rainfall episodes following application (118.4 µg $L^{-1}$ for glyphosate and 18.4 µg $L^{-1}$ for AMPA). These concentrations tend to decrease as they move away from the date of treatment. The total exported flow from the plot is low and estimated at 0.7% of the initial quantity of glyphosate applied.

The adsorption analysis of this molecule on the studied soil resulted in an adsorption coefficient $K_d$ equal to 81.50 L $Kg^{-1}$. This value shows a moderate affinity of glyphosate with soil component. However, it is strongly necessary to complete the results study of this process and the degradation of glyphosate in the study soil to explain the quantities of glyphosate exported during floods.
**Key words**: Intensification, cereals, surface water, pesticides, watershed, glyphosate.

# Evaluation of TSEB model over a complex agricultural landscape using eddy covariance and scintillometry measurements

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An accurate assessment of evapotranspiration (ET) is crucially needed at the basin scale for studying the hydrological processes and water balance especially from upstream to downstream. In the mountains, this term is poorly known because of various challenges, including the vegetation complexity, plant diversity, lack of available data and because the in-situ direct measurement of ET is difficult in complex terrain. The main objective of this work was to investigate the potential of a Two-Source-Energy-balance model (TSEB) driven by the LANDSAT and MODIS data for estimating ET over a complex mountain region. The complexity is associated with the type of the vegetation canopy as well as the changes in topography. For validating purpose, a large aperture scintillometer (LAS) was set up over a heterogeneous transect of about 1.4 km to measure sensible (H) and latent heat (LE) fluxes. Additionally, two towers of eddy covariance (EC) systems were installed along the LAS transect. In the vicinity of these towers, measurements of soil and vegetation as well as the meteorological parameters were continuously collected.

First, the model was tested at the local scale against the EC measurements using multi-scale remote sensing inputs at the satellite overpasses. While the input variables (surface temperature, albedo and emissivity) derived from LANDSAT-7/8, were aggregated based on the EC footprint, TSEB was run with the same variables at 1 km derived from MODIS. In overall, the use of the LANDSAT data showed better agreement between estimated and measured LE than with MODIS data. The obtained averaged values of the root mean square (RMSE) and correlation coefficient (R) were about 62.6$Wm^{-2}$ and 0.71 and 72.4 $Wm^{-2}$ and 0.42 for LANDSAT and MODIS data, respectively. Secondly, the potential of the TSEB model for evaluating LE at large scale was investigated by aggregating the derived parameters from both satellites based on the LAS footprint. As for the local scale, the comparison of LE simulated by TSEB driven by LANDSAT data performed well against those measured by the LAS (R = 0.79, RMSE = 72.4 $Wm^{-2}$) while slightly more scattering was observed when MODIS products were used (R = 0.52, RMSE = 82.0 $Wm^{-2}$). Based on the obtained results, it can be concluded (1) that the TSEB model can be fairly used to estimate ET over the mountain regions; (2) medium to high resolution inputs are a better option than coarse resolution products for describing this kind of complex terrain.

***Keywords:*** Latent heat flux; sensible heat flux; Two-source energy balance; Eddy-covariance system; scintillometer.

# Mapping evapotranspiration over complex surface using modified Shuttleworth-Wallace model

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The main goal of this work was to evaluate the potential of the Shuttleworth-Wallace (SW) model for mapping actual crop evapotranspiration (ET) over complex terrain located within the foothill of the Atlas Mountain (Morocco). This model needs many input variables to compute soil ($r_s^s$) and vegetation ($r_s^v$) resistances, which are often difficult to estimate at large scale particularly soil moisture. In this study, a new approach to spatialize $r_s^s$ and $r_s^v$ based on two thermal-based proxy variables is proposed. Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) derived from LANDSAT data were combined with the endmember temperatures for soil ($Ts_{min}$ and $Ts_{max}$) and vegetation ($Tv_{min}$ and $Tv_{max}$), which are simulated by a surface energy balance model, to compute the temperature of the two components, namely the soil ($Ts$) and the vegetation ($Tv$). Based on these temperatures, two thermal proxies ($SI_{ss}$ for soil and $SI_{sv}$ for vegetation) were calculated and related to $r_s^s$ and $r_s^v$, with an empirical exponential relationship (with a correlation coefficient (R) of about 0,6 and 0,5 for soil and vegetation, respectively). The proposed approach was firstly evaluated at a local scale, by comparing the results to observations by an eddy covariance system installed over an area planted with olive trees intercropped with wheat. In a second step, the new approach was applied over a large area which contains a mixed vegetation (tall and short vegetation) crossed by a river to derive $r_s^s$ and $r_s^v$, and thereafter to estimate ET. A Large aperture scintillometer (LAS) installed over a transect of 1.4 km and spanning the total area is used to validate the obtained ET. Such comparison confirms the ability of the proposed approach to provide satisfactory ET maps with an RMSE and R2 equal to 52.51 W/m2 and 0.80, respectively.

***Keywords:*** Evapotranspiration; Shuttleworth-Wallace model; thermal stress index; soil resistance; vegetation resistance.

# Impacts de l'irrigation sur la disponibilité en eau dans le bassin du Haouz (Tensift)

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Dans les bassins (semi) arides, la disponibilité de l'eau souterraine joue un rôle primordial pour la durabilité de l'approvisionnement en eau. L'évaluation de cette disponibilité devient complexe dans les zones où les interactions eau de surface-eau souterraine existent et interfèrent avec les activités anthropiques.

Dans la plaine du Haouz, les études réalisées montrent que la ressource en eau subit globalement un épuisement sous l'effet de la surexploitation principalement destinée à l'irrigation. En effet, des indicateurs de disponibilité de l'eau (calculés à partir du système de modélisation SAMIR-WEAP-MODFLOW) attestent de baisses importantes et chroniques de la ressource en eau en générale et de l'eau souterraine en particulier.

En amont de la plaine du Haouz, les zones de piémont sont irriguées de manière prioritaire par l'eau des oueds générée dans le Haut-Atlas. Cette irrigation crée des zones où un équilibre est encore possible entre la ressource en eau et les usages. Cet équilibre est néanmoins très précaire et menacé par différents facteurs : changement climatique, baisse des débits dans les oueds, migration des exploitations agricoles et pollution.

# Evaluation of a distributed snow model to estimate the snow water equivalent in a Mediterranean mountain region (Mount Lebanon)

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**Abstract.** In many Mediterranean mountain regions, the seasonal snowpack is an essential yet poorly known water resource. Here, we examine, for the first time, the spatial distribution and evolution of the snow water equivalent (SWE) during three snow seasons (2013-2016) in warm Mediterranean mountain regions in the coastal mountains of Lebanon. We run SnowModel (Liston and Elder, 2006a), a spatially-distributed, process-based snow model, at 100 m resolution forced by new automatic weather station (AWS) data in three snow-dominated basins of Mount Lebanon. The model is evaluated against continuous snow depth and snow albedo observations at the AWS, manual SWE measurements, and MODIS snow cover area between 1200 m and 3000 m a.s.l.. We evaluate a recent upgrade of the liquid water percolation scheme in SnowModel, which was introduced to improve the simulation of SWE and runoff in warm maritime regions. The results show that the new percolation scheme yields better performance especially in terms of SWE but also in snow depth and snow cover area. Over the simulation period between 2013 and 2016, the maximum snow mass was reached between December and March. Peak mean SWE (above 1200 m a.s.l.) changed significantly from year to year in the three study catchments with values ranging between 73 mm and 286 mm we (RMSE between 160 and 260 mm w.e.). We suggest that the major sources of uncertainty in simulating the SWE, in this warm Mediterranean climate, can be attributed to forcing error but also to our limited understanding of the separation between rain and snow at lower-elevations, the transient snow melt events during the accumulation season, and the high-variability of snow depth patterns at the sub-pixel scale due to the wind-driven blown-snow redistribution into karstic features and sinkholes. Yet, the use of a process-based snow model with minimal requirements for parameters estimation provides a basis to simulate snow mass SWE in non-monitored catchments, characterize the contribution of snowmelt to the karstic groundwater recharge in Lebanon, and assess the vulnerability of snowpack to climate change in this typical warm Mediterranean Mountainous region.

Keywords: Snow water equivalent; Snowmelt; Snow hydrology; Lebanon; Mediterranean climate

# Gestion pluriannuelle des épisodes de crue et de sécheresse dans le nord de la Tunisie par référence aux années sèches (2016-17-18)

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L'art de la gestion de l'eau dans le contexte tunisien consiste ainsi à savoir stocker la manne des années fastes pour la reporter sur les années sèches et savoir transférer le surplus des régions bien arrosées aux régions desséchées.

D'où les deux piliers de la stratégie de mobilisation des eaux de surface en Tunisie :

- l'implantation de grands barrages réservoirs et leur interconnexion pour stocker les apports des années pluvieuses et assurer, en cas de besoin, leur approvisionnement les uns des autres.

- l'implantation des canaux de transfert pour véhiculer l'eau des régions d'abondance vers les régions en déficit.

Si cette stratégie, couplée à celle de la mobilisation souterraine, a permis de répondre à la demande en eau du pays durant les 30 dernières décennies, elle est néanmoins confrontée à l'orée de ce XXIème siècles à trois défis majeurs : 1/ l'envasement des retenues des barrages, 2/ l'augmentation de la demande en eau, 3/ le réchauffement climatique.

La nouvelle stratégie à mettre en place doit être en mesure de répondre simultanément à ces trois défis.

D'ailleurs, l'épisode de sécheresse de ces trois dernières années 2015-2018 a bien mis en évidence la précarité de nos ressources en eau. Les pénuries qui peuvent en résulter pour certains utilisateurs, vient de nous alerter sur l'urgence de la mise en place de cette stratégie afin de prévenir les conflits qui ne manqueront pas de surgir entre les différentes régions du pays d'une part, et entre les différents opérateurs économiques et sociaux dans chacune de ces régions, d'autre part.

L'action du Ministère de l'Agriculture, des Ressources hydrauliques et de la Pêche (MARHP) a permis de circonscrire les problèmes urgents qui s'étaient posés au cours de ce dernier cycle de sécheresse.

À cet effet, nous exposerons, dans la première partie, la gestion de crise au cours de la sécheresse que nous venons de vivre durant les années 2015-2018.

Mettant à profit cette expérience, et tenant compte des contraintes environnementales, économiques et sociales qui s'annoncent, nous exposerons en seconde partie de ce rapport la stratégie à mettre en place à l'orée de ce XXIème siècle pour une GESTION DYNAMIQUE DE NOS RESSOURCES EN EAU À MOYEN ET LONG TERMES.

# Adapting landscape mosaics of Mediterranean rainfed agrosystems for a sustainable management of crop production, water and soil resources: outcomes from the ALMIRA Project.

Frédéric Jacob, Insaf Mekki, Mohamed Chikhaoui, and the ALMIRA Team project.

Mediterranean rainfed agrosystems provide multiple agri-environmental and economic services. These services have significant potential for improvement, but their provision is threatened by the combined pressures of climate change, demographics and markets. ALMIRA aims to explore the modulation of landscape mosaics, given significant progresses are expected by reasoning spatial organizations. For this, ALMIRA proposes to design, implement and test an integrated modelling approach that explicitly accounts for landscape evolutions and associated processes.

ALMIRA focuses on (1) land use as a landscape mosaic and (2) agricultural production, water production in dams and minimization of erosion as ecosystem services. It overcomes methodological challenges related to (1) digital mapping of landscape properties, (2) the design of evolution scenarios, (3) the coupling of biophysical processes, and (4) the economic evaluation of landscape functioning. The first challenge is addressed by developing methods combining different sources of information and different approaches. The second challenge is addressed by spatializing regional trends through biophysical and socio-economic stress fields. The third challenge is addressed by proposing a calibration method involving several landscape functions. The fourth challenge is addressed by considering different points of view and combining different landscape features.

Innovative approaches have made it possible to (1) characterize landscape features such as agricultural parcels or soil depth, (2) deepen stakeholders' analysis of land use change based on spatialized trends, (3) simulate landscape functionalities by modulating land use and climate forcing, and (4) exploit the landscape dimension to quantify the impact of erosion on agricultural incomes. The results obtained at the landscape level permit to enrich the elements of rationalisation available to the bodies in charge of agricultural land development.

# Simple and spatialize approach to optimize irrigation water and wheat yield in the semi-arid areas

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In this study, we developed a simple and spatialized wheat yield method based on the Monteith's three efficiency model. The originality of the method consists in: (1) the expression of the conversion coefficient ($\varepsilon_{conv}$) by considering an appropriate stress threshold ($k_{sconv}$) for triggering irrigation, (2) the substitution of the product of the two maximum coefficients of interception ($\varepsilon_{imax}$) and conversion ($\varepsilon_{conv\_max}$) by a single parameter $\varepsilon_{max}$, (3) the modeling of $\varepsilon_{max}$ as a function of the Cumulative Growing Degree Days (CGDD) since sowing date, and (4) the dynamic expression of the harvest index HI as a function of the CGDD and the final harvest index $HI_0$ depending of the maximum values of the Normalized Difference Vegetation Index (NDVI).

The calibration and validation of the proposed model were performed by using observed dry matter (DM) and grain yield (GY) on wheat conducted on the irrigated zone R3 of the Haouz plain (center of Morocco), during three agricultural seasons 2002/2003, 2008/2009 and 2012/2013. The model calibration allowed the parameterization of $\varepsilon_{max}$ in four periods according to the wheat phenological stages. By contrast, a linear evolution was sufficient to represent the relationship between HI and CGDD. The model validation was performed at the field and regional scales. For the field scale, the obtained results showed a good agreement between the estimated and observed values of DM and GY with Root Mean Square Error (RMSE) of about 1.07 t/ha and 0.57 t/ha for DM and GY, respectively. Likewise, at the regional scale, the proposed approach was tested over the irrigated district (R3) by using Landsat/spot images for mapping GY and DM. The RMSE values were 1.21 t/ha and 0.34 t/ha between measured and simulated DM and GY, respectively.

***Keywords:*** wheat, dry matter, grain yield, semi-arid, Monteith model, remote sensing.

# Detection of irrigation events on maize plots using sentinel-1 soil moisture products

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An accurate knowledge of irrigation timing and rate is essential to compute the water balance of irrigated plots. However, at the plot scale irrigation is a data essentially known by the irrigator. These data do not go up to higher management scales, thus limiting both the management of water resources on a regional scale and the development of irrigation decision support tools at the farm scale. The study focuses on 6 experimental plots in the south-west of France. The new method consists in assessing surface soil moisture (SSM) change between observations and a water balance model. The approach was tested using both in situ measurements and surface soil moisture (SSM) maps derived from Sentinel-1 radar data. The score is obtained by assessing if the irrigation event is detected within +/- three days. The use of in situ SSM showed that: (1) the best revisit time between two SSM observations is 3 days; short gaps is subject to uncertainties while longer gap miss possible SSM variations; (2) in general, higher rates (>20mm) of irrigation are well identified while it is very difficult to identify irrigation event when it is raining or when irrigation rates are small (<10mm). When using the SSM microwave product, the performances are degraded but are still acceptable given the discontinuity of irrigation events: 34% of absolute error and a bias of 5% for the whole season. Although high vegetation cover degrades the SSM absolute estimates, the dynamic appeared to be in accordance with in-situ measurements.

# Modernisation des périmètres irrigués : une solution aux effets contrastés pour les agriculteurs et la ressource en eau. Le cas d'un périmètre du N'Fis (Maroc)

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**Mots clés** : modernisation des périmètres irrigués, Maroc, enquête, gestion des eaux souterraines

Le goutte-à-goutte est une technique d'irrigation qui permet d'apporter de l'eau au plus près des besoins de la plante, évitant ainsi des pertes inutiles d'eau. C'est pourquoi, dans les périmètres irrigués traditionnellement en gravitaire et lorsque la ressource est limitée, les autorités publiques demandent aux agriculteurs de passer à une irrigation localisée, solution supposée permettre une meilleure valorisation économique de l'eau. Le Maroc s'est fixé des objectifs ambitieux de 'modernisation', c'est-à-dire de passage au goutte-à-goutte, à la fois pour les usagers individuels et certains périmètres publics.

Nous présentons ici les principaux enseignements issus d'une enquête réalisée en 2019 sur un secteur du Nfis (1-2, plaine du Haouz) au Maroc : un des secteurs pilotes au niveau national pour la modernisation des périmètres publics desservant à partir de la captation d'eau de surface certains territoires. Cette enquête cherchait à décrire et analyser la mise en œuvre de la phase II du projet de reconversion (aménagements internes) et d'évaluer l'impact de cet investissement au regard des objectifs qu'il poursuivait.

Elle a comporté trois étapes : des entretiens semi-directifs exploratoires auprès d'acteurs institutionnels (ORMVAH, CMV), des enquêtes auprès des 28 agriculteurs et des mesures sur les parcelles irriguées.

Elle confirme l'impact contrasté de la modernisation sur l'eau et les agriculteurs et les multiples difficultés rencontrées dans le déploiement du goutte-à-goutte ; des adaptations locales ont été observées permettant au système de fonctionner mais pouvant, à l'échelle collective, avoir des effets pervers. Cette modernisation a conduit à un changement d'assolement, à une intensification et même parfois à une extensification des surfaces irriguées. Toutefois cette transformation est étroitement dépendante d'un accès aux eaux souterraines qui restent très sollicitées. Enfin certains gaspillages de ressource ont pu ou risquent d'être constatés : les infrastructures mises en place sont parfois inutilisées et certains matériaux sont ou risquent d'être délaissés, constituant autant de sources de pollution.

Ainsi cette étude met en lumière la difficulté de procéder à un changement, dès lors qu'une organisation ayant atteint un certain équilibre préexiste, du fait notamment des statuts fonciers et de l'assolement initial. Toutes les parties prenantes sont concernées, à plus ou moins long terme, et en particulier les agriculteurs qui cultivent les parcelles, les gestionnaires des réseaux collectifs, les filières notamment en aval de l'agriculture, mais aussi la ressource en eau en particulier d'origine souterraine et plus généralement l'environnement.

# Spatialization of meteorological variables over south mediterranean catchments. Case of the Tensift (Morocco).

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The spatialization of meteorological variables when the ground network is scattered and the relief is disturbed is a major issue for watershed hydrology or for the characterization of agricultural water consumption. The aim of this study is to set up the SAFRAN re-analysis system on the Tensift catchment area in Morocco. To this end, all the meteorological measurements acquired on the site between 2004 and 2014 by several organisations were gathered in a single database and quality control was carried out. SAFRAN was then assessed according to a leave-one-out approach, which consists of removing a station from the database and comparing the re-analysis with the data from this station. It was also compared to another technic for meteorological variables spatialization named MICROMET (Liston et al., 2006). Particular attention was paid on the mountainous areas. In order to reproduce the high climate variability in this area, SAFRAN is also set up with an irregular grid up to 1 km resolution and compared to the regular version (8 km grid point). The results show that the re-analysis on the irregular grid is much better than on the regular grid, especially in the mountains. For example, the validation at the Aremd mountain station (2058 m) shows that the bias and RMSE on the surface temperature decreased from -4.8°C and 6.2°C for the regular grid to 0.6°C and 3.6°C for the irregular grid. Likewise, for precipitation, the correlation coefficient is improved by more than 23% for the regular grid. Concerning the visible radiation, MICROMET is strongly biased compared to the measurements carried out at the Aremd station (86 W/m²) whereas for SAFRAN, the bias is only 48W/m². Our current work concerns the mapping of vertical soil-vegetation-atmosphere exchanges over the catchment area using SAFRAN forcing on the irregular grid. The challenge is notably to represent irrigation, which strongly modifies the surface water states.

# DROUGHT ASSESSMENT USING MICRO-WAVE TIME SERIES OF PRECIPITATION AND SOIL MOISTURE OVER THE MENA REGION

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The Middle East-North Africa (MENA) region has a prevailing hot and dry climate. The increasing demographic pressure brings an increased demand on water resources. In this study, we analyzed the drought dynamics using precipitation and soil moisture remote sensing over the MENA region in the last two decades. Two types of remotely sensed micro-wave datasets (i.e. TRMM 3B43 and ESA-CCI) were used, to depict meteorological and agricultural droughts. Our results showed that Standardized Precipitation Index (SPI) [1] from TRMM showed a good correlation with SPI from in-situ rainfall data and predicted successfully historical droughts. The standardized index shows lesser extreme agricultural droughts than meteorological drought in that same periods. The region faced the biggest number of extreme meteorological droughts in 2015 and the biggest number of extreme agricultural droughts in 2013. These outputs help local and regional water management authorities as well as policy makers in combating water scarcity in the region. Further studies will look into optical remote sensing.

# Surface soil moisture mapping over wheat crops using the backscattering coefficient and the interferometric coherence derived from Sentinel-1

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The main objective of this work is estimate surface soil moisture over wheat fields using an approach based on the use of C-band Sentinel-1 radar data only. Over the study site, field measurement are collected during 2016-2017 and 2017-2018 growing seasons over two fields of winter wheat with drip irrigation located in the Haouz plain in the center of Morocco. Two polarizations (VV and VH) and two angles of incidence (35.2° and 45.6°) are investigated for both fields. In addition, data of other sites in Morocco and Tunisia are taken for validation purposes. The validation database contains a total number of 20 plots divided between irrigated and rainfed wheat plots. Two different information extracted from Sentinel-1 products are used: the backscattering coefficient and the interferometric coherence. A total number of 408 GRD and 419 SLC images were processed for computing the backscattering coefficient and the interferometric coherence, respectively. The analysis of Sentinel-1 time series over the study site show that coherence is sensitive to the development of wheat, while the backscatter coefficient is widely linked to changes in surface soil moisture. Later on, the Water Cloud Model coupled with the Oh et al, 1992 model were used for better understand the backscattering mechanism of wheat canopies. The coupled model is calibrated and validated over the study site and it proved to goodly enough reproduce the Sentinel-1 backscatter with RMSE ranging from 1.5 to 2.52 dB for VV and VH using biomass as a descriptor of wheat. On the other side, the analysis show that coherence is well correlated to biomass. Thus, the calibrated model is used in an inversion algorithm to retrieve soil moisture using the Sentinel-1 backscatter and coherence as inputs. The results of inversion show that the proposed new approach is able to retrieve the surface soil moisture at 35.2° for VV, with a correlation coefficient R, RMSE and bias of 0.82, 0.0 5m3/m3 and 0.0m3/m3,respectively. For the VH polarization, the obtained R, RMSE and bias are about 0.73, 0.06 m3/m3 and -0.03 m3/m3. Using the validation database of Morocco and Tunisia, R is always greater than 0.7 and RMSE and bias are less than 0.008 m3/m3 and 0.03 m3/m3, respectively even that the incidence angle is higher (40°). In order to assess its quality, the approach is compared to four SSM retrieval methods that use radar and optical data in empirical and semi-empirical approaches. Results indicate that the proposed approach shows an improvement of SSM retrieval between 17% and 42% compared to other methods. Furthermore, the degradation of performance with regard to vegetation development is limited to 2.5% while it reaches 13% to 40% for the other methods. Finally, the validated new approach is used for SSM mapping, with a spatial resolution of 10*10 m, over irrigated perimeters of wheat in Morocco.

***Keywords:*** Surface soil moisture, Sentinel-1, Modeling, Mapping, Backscattering coefficient, Interferometric coherence, Winter wheat, Semi-arid region.

# Exploitation of backscatter diurnal differences for water stress detection over irrigated wheat crops in semi-arid areas

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Global warming, climate change and increasing water shortages are a worldwide challenge that particularly threatens the Mediterranean regions. Within these regions, the irrigation mobilizes more than 80% of the available water. The increasing of the global food demand for a continuously increasing population makes critical the relation between food security and optimizing the water-use. This requires the implementation of methods for monitoring the crop water status through the early water stress detection. Volume water content (VWC) is sensitive to the water status of the plants and thus to water stress. Changes in VWC cause change in vegetation dielectric properties and therefore backscattering coefficient. As a conclusion, water stress causes diurnal differences in radar backscatter through diurnal changes of VWC. Nevertheless, most of the studies that have investigated the diurnal cycle of the backscattering coefficient are on forest canopies while the behavior of this cycle over agricultural crops remains poorly documented. Within this context, this study aims to improve the potential use of C-band radar for early water stress detection in agricultural canopies. For this purpose, the diurnal differences of Sentinel-1 backscatter between two orbits (morning and evening) over an irrigated and voluntarily stressed wheat field on Morocco is analyzed. Results show encouraging future of radar for monitoring water stress. In order to further our understanding of the impact of VWC diurnal variation on the radar backscatter for different values of SSM and DBM, a backscatter model is used. The model is a physical backscattering model, based on the resolution of the radiative transfer equation. A new configuration for wheat is proposed in this work. Wheat canopy is considered as the integration of two layers: heads and leaves. Within each layer, scatterers are modeled as randomly oriented ellipsoids with an erectophile distribution. Statistical metrics show that the model reproduces the Sentinel-1 signal with good accuracy. For instance, R=0.80, RMSE=1.08 dB and bias=-0.04 dB at VH and 45.6° of incidence angle. Hereafter, the model is implemented for a sensitivity test of the backscattering coefficient differences ($\Delta\sigma^0$) to the VWC changes for different conditions of soil moisture and biomass. Results show that for 10% differences in VWC, the maximum value of $\Delta\sigma^0$ is less than 1dB whatever the SSM and biomass values are. By contrast, when the differences of VWC reaches 40%, $\Delta\sigma^0$ at 45.6° reaches up to 3 dB at VV and 5 dB at VH for dry soil with maximum biomass. These results indicate that during periods of stress, differences in backscatter are preferentially attributed to vegetation than changes in SSM. Obviously, $\Delta\sigma^0$ is more important at VH and higher incidence angles because of the volume scattering dominance

***Keywords:*** Water stress, Backscattering coefficient, Modeling, Winter wheat, Semi-arid region.

# Use of different approaches based on the photochemical reflectance index (PRI) to monitor the water status of winter wheat in semi-arid regions

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Agriculture is considered to be the human activity that consumes the most water mobilized on a global scale. However, this activity alone accounts for significant water losses to groundwater and the atmosphere. In order to reduce these losses, rational management of irrigation water by monitoring rapid changes in plant physiology is necessary. The remotely sensed photochemical reflectance index (PRI) represents a promising information medium for monitoring the dynamics of xanthophyll pigments. An experiment on winter wheat was carried out over two agricultural seasons (2016 to 2018) in the Haouz basin which is located in the Marrakech region to better assimilate the temporal dynamics of PRI. In this study, three different approaches are proposed to investigate the functioning of wheat: 1- an approach based on the solar inclination to separate the structure effect (PRI0) from the PRI signal and deduce a water stress index PRIj, 2- an approach based on the global radiation (Rg) to extrapolate a theorical PRI (PRIth) when the Rg is null and calculate a water stress index PRIlin, 3- an approach that determines an optimal PRI (PRIpot) on the criterion of available water content (AWC) in order to derive a stress index I-PRI. The results of this work show a strong correlation between the PRI0 and the leaf area index (LAI) with a determination coefficient equal to 0.92, indicating that it is possible to isolate the structural effects of wheat. Also, throughout the period of the experiment a significant correlation between PRIj and the AWC was observed with a coefficient of determination reach to 0.7. Finally, the PRI reveals its potential to monitor the water status of plants and their responses to changes in environmental conditions.

# Salinization processes and drought indices assessment in the Cape Bon peninsula and Kairouan (Tunisia)

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Irrigated agriculture is often accompanied by groundwater degradation processes. The overexploitation of the aquifers has caused a continuous lowering of the piezometric level and an increase in the concentration of salts. Climate change inducing temperature rise and rainfall depletion is expected to enhance these processes. The presentation will focus on four case studies undertaken in the Cape Bon peninsula and Kairouan in Tunisia. The first one presents groundwater investigations carried out along two transects (S1 and S2) perpendicular to the shoreline in Korba coastal aquifer in northern Tunisia from 2006 to 2013. It aimed to identify the potential origin of groundwater salinization and to study associated processes using geochemical modelling, multivariate statistics and geophysical techniques. The second work studied the impact of rainfall structure and climate change on soil and groundwater salinization using field observations in Korba irrigated soils and numerical modelling. Daily rainfall structure and annual rainfall transition under both MarKov Chain and climate change (RCP4.5 and RCP8.5) were assessed. Different climatic scenarios were then introduced as boundary conditions in HYDRUS-1D, to test the influence of rainfall on solute fate. The third study is not a part of CHAAMS project but was carried out in the same study area (Cape Bon) and will be presented to assess the opportunities to integrate same aspects in future actions. It dealt with modelling the impact on root water uptake and solute return flow of different drip irrigation regimes with brackish water. Soil water content and salinity were monitored in a fully drip irrigated potato plot with brackish water (4.45 dSm−1) Oued Souhil (Nabeul). The HYDRUS-1D model was used to investigate the effects of different irrigation regimes (deficit irrigation (T1R, 70% ETc), full irrigation (T2R, 100% ETc), and farmer's schedule (T3R, 237% ETc) on root water uptake, root zone salinity, and solute return flows to groundwater. The last study presents an assessment of aquifer response to precipitation variability based on correlations between the Standardized Precipitation Index (SPI) and the Standardized Groundwater Index (SGI) at different time scales in the Kairouan region.

**Keywords**: Salinization, HYDRUS-1D, SPI, SGI, Deficit Irrigation, Climate Change

# Land cover mapping with Sentinel2 time series using robust decision trees approaches. Case of the Haouz plain (Marrakech, Morocco).

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Land Cover is a major variable required for agricultural management and biophysical modelling. Remote sensing is the best way to map this information although robust method are still hardly available especially in semi-arid areas were the development of crops is very heterogeous, crops often have low vegetation densities (tree plantations) are crops are often associated. Besides, the major problem of classical land cover classification approaches, including the recent Sentinel2 Agri system recently developed based on random forest , is that they require ground data for calibration every year.

To solve both land cover complexity and ground data availability problems, we propose decision tree approaches based on phenological criteria assumed to remain true for any year. The first application is done in the Haouz plain (Marrakech, Morocco) where land cover is classified in 6 main classes, namely: bare soil, evergreen trees (Olive and citrus), deciduous trees (apricot, apple, pomegranate…), winter crops (wheat), summer crops (melon and watermelons), fall crops (peas and broadbean). The decision tree is build on criteria supposed to be independent of the year, linked either to the dynamic of NDVI (min, max and range of NDVI are compared to thresholds) and the period in which the peak or the minimum of NDVI happen (linked respectively to the max of vegetation of annual crops and to the leave fall for trees). This preliminary work has to be followed up in order to check if correct results can be achieved for several years using a single parameterization of the decision tree. The second application was to develop a simplified version of the previous decision tree to build a time series of irrigated areas in the Haouz plain between 1984 and 2018 at yearly time scale using the whole Landsat archive on the area. The advantage of processing each year instead of only some dates, as frequently encountered in the literature, is that it gives a better idea of uncertainties and provides a more robust trend.

**Key words :** Remote sensing, land cover, Sentinel, decision trees