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CONTRIBUTION OF REMOTE SENSING TIME SERIES ANALYSES FOR THE CHARACTERISATION OF FARMING SYSTEMS IN CAMARGUE, FRANCE

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1. Summary of the objective of the STM project

The objective of the project undertaken under the STM 2015 program was to develop a new application for remote sensing methods to characterize past land uses at the farm scales for rice production systems in Camargue, South of France. It targets to improve the accuracy of agronomic models for the assessment of future scenarios, by integrating land use change trajectories in the building of farm typologies.

2. General background

Modelling the evolution of farming systems under different scenarios of possible future target to inform both the final users (the farmers) and the policy makers about the possible consequences of future changes (Delmotte *et al.*, 2013). Modelling the evolution of the farming systems at the regional level requires the development of typologies of farming systems, in order to work on a selected number of farm types and to up-scale the results from the farm to the regional level (Landais, 1998; Blazy *et al.*, 2009; Righi *et al.*, 2011). Farming system typologies are usually static (based on a picture of the farming systems in a single year), what limit their operationally use for projections into the future, as the dynamic of changes are not considered (Andersen *et al.*, 2007). Taking into account the diversity of recent trajectories of changes of the farms in the typologies is a challenge for improving farming system models. However, analysing these trajectories require access to data about their evolution, that are almost never available in any database. If this type of information can be partially retrieved through farmers' interview, the cost of acquisition for a large sample of farms in a region is usually too high, and the reliability of the information obtained too low, as farmers most often don't keep track of their land use. The use of remote sensing analysis of satellite images to retrieve this information is therefore promising and should lead to improved farming system modelling and simulations.

3. Study area and data available

The Camargue is a deltaic and wet area in southern France with exceptional natural ecosystems, which led to the creation of a Natural Regional Park and of a National Reserve, as well as the labelling as a Biosphere Reserve (Man and Biosphere Program of UNESCO) since 1977. The region is a hot spot for green tourism due to the beauty of the landscapes and the high biodiversity, notably related to birds which attract more than a million of tourists every year. Agro-tourism is also an important activity, related to horse and bulls breeding used for traditional games.

Agriculture plays a crucial role in the economic, ecological and social equilibrium of the region. Most land is at sea level and salinization is a natural process due to the negative water balance between rain and evapo-transpiration. Irrigation of rice (the main crop grown in Camargue) plays then a role in desalinating the soils. Irrigation water that enters through pumping from the Rhone-River plays also a key function to maintain the level of water and salt concentration of the central natural lagoon of the Camargue, the Vaccarès (Figure 1) that is the temporary habitat of several migrating bird species.

Farming systems based on the production of cereals and on livestock breeding represent about 60 000 ha in Camargue, and more than 400 farms. The main crops of the region are rice, durum-wheat and in lower quantity sunflower, maize, oil seed rape, sorghum and alfalfa. Irrigated rice is the main important cropping activity with about 18,000 ha devoted in the recent years. Because of the high levels of investment required to grow crops in such an environment, cereal farms are big (from 150ha up to 1000 ha) and highly mechanized; most of them are family farms but some belong to companies and in that case the farm is run by a permanent manager. Despite side-activities like agro-tourism, bull rearing and hunting, main income stands on crops.

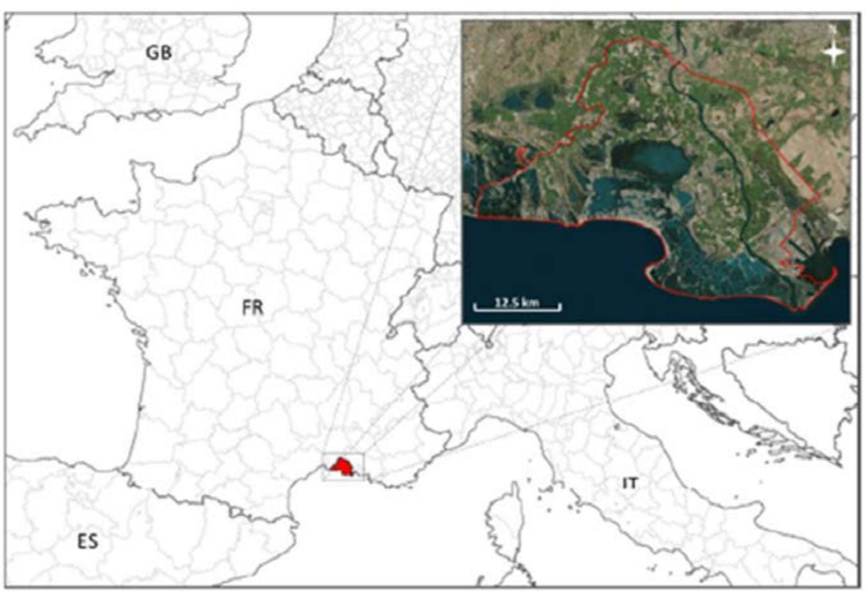

Figure 1: Map of the Camargue area, in the South of France.

Satellite images of MODIS with a spatial resolution of 250 m and 8-day composites were available covering a period of 13 consecutive years (2001 to 2013).

4. Method

The activities undertaken during the visit concerned 4 different steps of the research that are described below:

- Application of the remote sensing methods/rules developed at CNR-IREA to a set of satellite images (MODIS) to retrieve information about the evolution of the land use (characterized as winter or summer crops) at the farm level for 13 consecutive years (2001 to 2013).
- Validation of the accuracy of the crop detection, by comparing to external sources of data.
- Improvement of rules to determine the winter wheat establishment period from the signal dynamic obtained from remote sensing time series, check the accuracy of the prediction of crop establishment period by comparing to external sources of information (three farms interviewed).
- Analysis of results produced using statistical tools and expert knowledge
- Work on the drafts of the two papers to be submitted to peer reviewed journals.

5. Results achieved so far

a. Identification of winter and summer crops from remote sensing

Satellite images were acquired and processed to produce, for each pixel of 250m *250m, a vegetation index (VI) signal for a period of 13 years (2001-2013). From these signals, already existing algorithms were used to identify summer crops (and notably rice) (Boschetti *et al.*, 2009).

For winter crops, rules were defined on the basis of agronomical expert knowledge and on the observation of average VI- indices time signature derived from wheat cultivated areas, individuated using land cover data originating from a local partner in Camargue.

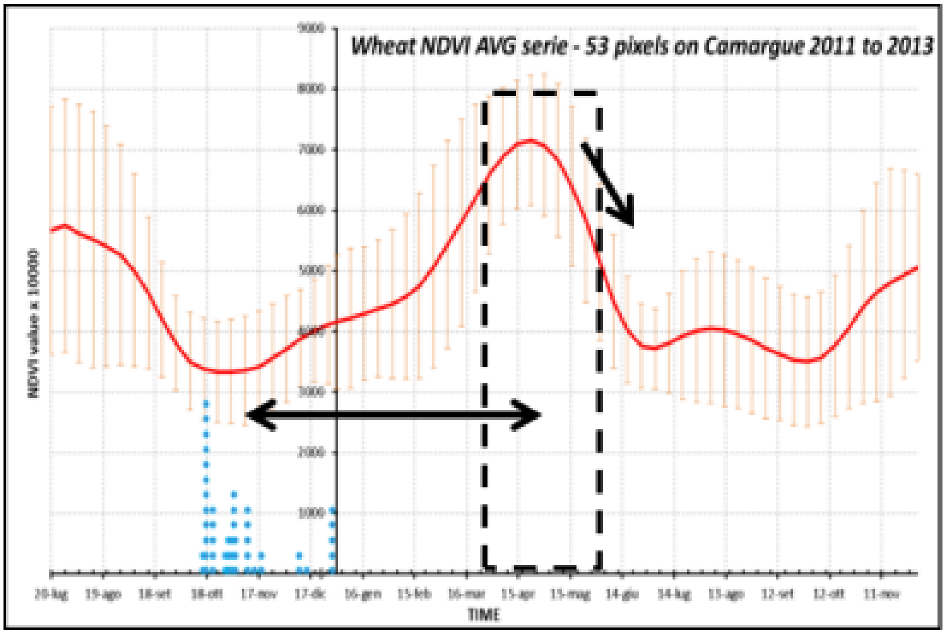

Figure 2 – Analysis of winter wheat time series signal for the identification of rules to retrieve winter wheat sowing dates.

These rules are based on the following concepts (Fig. 2): the identification of a maximum value of VI in the spring period (suggesting a crop leaf area maximum that is decreasing then due to the phenomenon of senescence), the identification of a local minimum around the sowing period (defined by a fixed window).

The details of the rules are the following:

Rules for the identification of points of local maximum within the time series:

- A local maximum point of EVI in the time series must be preceded by at least 3 positive derivatives in the window of the five previous composites (40 days) and must be followed by 3 negative derivatives in the window of the five successive composites;
- The maximum point must have an EVI value greater than 0.42 (4200);
- The EVI value must decrease of at least 33% with respect with value observed at maximum in the window of its 6 successive composites (48 days).

Rules for the identification of crop-related point of local minimum within the time series:

- A local minimum point of EVI in the time series must be followed by at least 3 positive derivatives in the window of the 5 successive composites (40 days);
- The minimum point must have an EVI value lower than 0.32 (3200).

Rules to associate a crop-related minimum point to its crop-related maximum point in order to identify a general crop cycle in the analysed year:

- The minimum point must be followed by a crop-related maximum point in a pre-defined time window of [min+16 composites to min+28 composites] values. It means that at least a period of 128 days occurs between crop establishment and crop heading.

Rule to select a winter crop among the identified crops:

- Only the identified crops with maximum (heading) point occurring between the end of March and the beginning of June (from DOY 89 to DOY 153) will be considered as winter crop.

b. Validation of winter wheat detections

To validate the crop detection procedure, we first compared the land use map produced from MODIS analysis to land use maps LC-2006 provided by a local partner of INRA in Camargue on the basis of aerial photography. However, discrepancies obtained from this comparisons, led us to conduct a further analysis by superimposing the land use data and a high resolution (30 m) Landsat Thematic Mapper images (Figure 3).

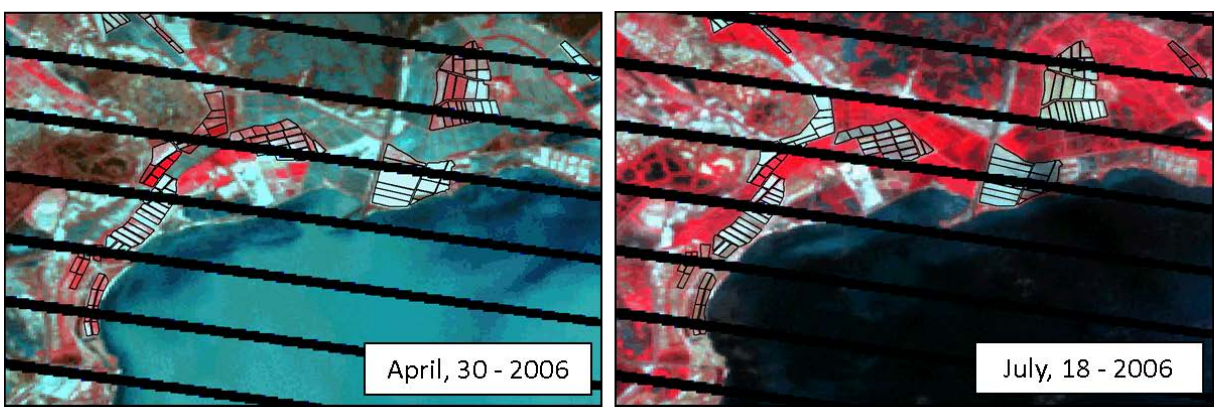

Figure 3 – Incongruences between land cover data LC-2006 and Landsat Thematic Mapper images of April and July 2006.

False colour composites of Landsat Thematic Mapper images enhance in red colour the presence of vegetation, in white colour a bare soil condition and in cyan colour agricultural flooding. Winter wheat polygon fields according to the LC-2006 dataset are overlapped in black colour. It is expected that winter wheat cultures has a red colour in late April (heading) and a white colour in late July (after harvest soil).

We therefore adopted a new strategy to validate the detection of winter crop from remote sensing using Landsat Thematic Mapper images corresponding to the heading points of winter crops and summer crops (late April and late July). We randomly selected a set of MODIS pixel within the study area and we labelled each pixel as “winter crop” or “other crop” on the base of expert-based interpretation of Landsat images data. This approach to the validation will be done for the year 2003-2006-2009-2012. For each year we collect at least 50 truth points labelled as winter wheat.

An example of results of this test of the remote sensing procedure is presented in table 1 below for the year 2006.

Table 1 - Error matrix representing the validation of winter crop presence detections for the year 2006. MODIS based estimations were compared with Landsat (expert visual interpretation) used as reference ground truth data. UA: User Accuracy, PA: Producer Accuracy, CE: Commission Error, OE: Omission Error. OA: Overall Accuracy

		Landsat_ground_truth		
		wheat	Other	tot.
MODIS SRNP1 EST	Wheat	38	2	40
	No Wheat	44	210	254
	tot.	82	212	294

UA	PA	CE	OE
0.95	0.46	0.05	0.54
0.83	0.99	0.17	0.01
		OA:	0.84

As our aim is not to produce a thematic map of winter wheat but instead to identify a sample of pixels for which we can be highly confident in the detection, the rules that we defined (and that are presented earlier in this document) are conservatives, i.e. they tend to create a lot of omissions in the classification (pixels that are not classified as winter crops (wheat in table 1), but very limited commissions (pixels that are not correctly classified). We therefore consider that the above presented results for 2006 as satisfying for the purpose of this study.

c. Tests of the method for analysing farm scale land use trajectories

Different tests of the method have been done to format the output of the detection procedure. Figure 4 is an example of results for a selected farm, to illustrate the type of output. Discussions were held to think about the way to analyse the data produced, and different clustering approaches are being studied.

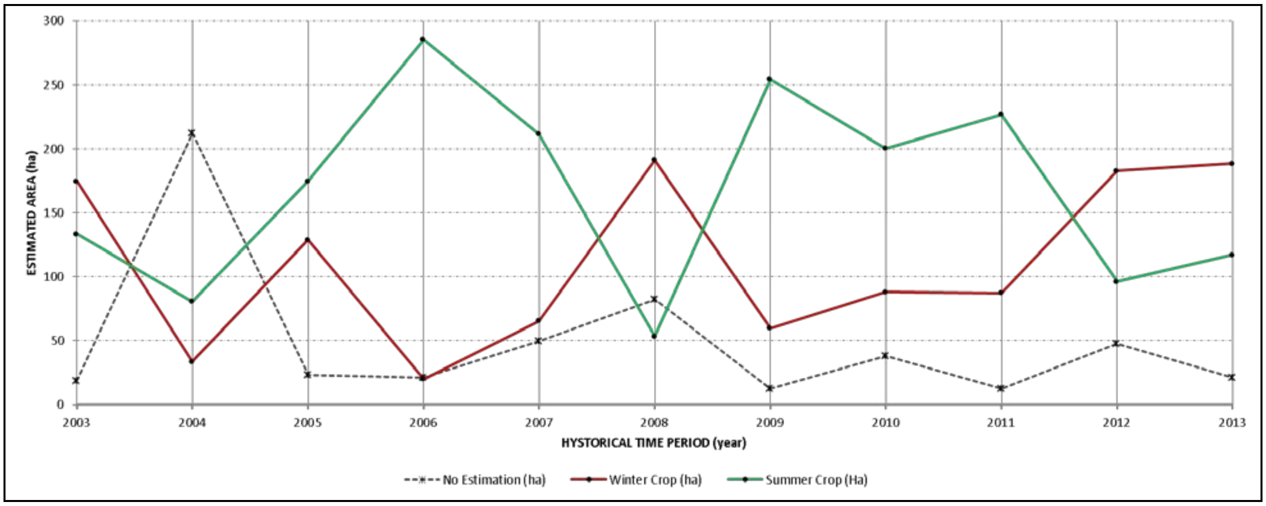

Figure 4: Example of results obtained from the analysis of MODIS data time series for a selected farm.

6. Next steps

Even if the results obtained after this stay are already considerable, the activities related to this study need to be continued in the coming months.

First of all, the validation of the detection procedure has to be performed for a greater sample of years, to avoid effects of single year and inter-annual variation of winter and summer crop area. The validation will therefore be produced also for the year 2003, 2009 and 2012. In order to reach a representative amount of at least 200 winter crop pixels over 4 years.

Secondly, once the procedure will be validated, the data at farm level will be produced and the farms on which conducting the land use change trajectories analysis will be selected. Different clustering approaches will be tested, possibly including fuzzy clustering technics. Finally, the first draft of the papers developed during this STM visit will be updated accordingly to be latter submitted to a peer-reviewed international journal.

References

Andersen, E., Elbersen, B., Godeschalk, F., Verhoog, D., 2007. Farm management indicators and farm typologies as a basis for assessments in a changing policy environment. Journal of Environmental Management 82, 353-362.

Blazy, J.-M., Dorel, M., Salmon, F., Ozier-Lafontaine, H., Wery, J., Tixier, P., 2009. Model-based assessment of technological innovation in banana cropping systems contextualized by farm types in Guadeloupe. European Journal of Agronomy 31, 10-19.

Boschetti, M., Stroppiana, D., Brivio, P.A., Bocchi, S., 2009. Multi-year monitoring of rice crop phenology through time series analysis of MODIS images. Int. J. Remote Sens. 30, 4643-4662.

Delmotte, S., Lopez-Ridaura, S., Barbier, J.-M., Wery, J., 2013. Prospective and participatory integrated assessment of agricultural systems from farm to regional scales: Comparison of three modeling approaches. Journal of Environmental Management 129, 493-502.

Landais, E., 1998. Modelling farm diversity: new approaches to typology building in France. Agricultural Systems 58, 505-527.

Righi, E., Dogliotti, S., Stefanini, F.M., Pacini, G.C., 2011. Capturing farm diversity at regional level to up-scale farm level impact assessment of sustainable development options. Agriculture, Ecosystems & Environment In Press, Corrected Proof.