COST Scientific Programme

Short Term Scientific Mission – COST Action ES9003

Final Scientific Report

A MULTI-SCALE APPROACH FOR ASSESSING WATER BALANCE AND BIOPHYSICAL PARAMETERS USING SATELLITE DATA AND GROUND MEASUREMENTS IN THE 'RIO COLORADO BASIN' (ARGENTINA)

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1. Introduction and purpose of the Short Term Scientific Mission

Irrigated agriculture in the Colorado River Basin of Argentina (Figure 1) is expected to be intensified strongly in the next decades. In the middle section of the basin, the irrigated area may increase up to 35 times compared to the current situation (around 2000 ha) (INTA, 2009). If Regional Development Plans are effectively implemented, the region will be converted in one of the largest irrigated oases in South America with a total irrigated area similar as the Diamante-Atuel oasis in the south of the Mendoza province (Argentina).

With a total length of 1114 km and a basin size of 48.500 km^2, the Colorado River in Argentina rises at the Andes Mountains and flows in the Atlantic Ocean crossing on its way 5 administrative provinces. The nivo-pluvial flow regime and its "interstate" nature makes this basin particularly vulnerable to the effects of climate change, and governance and management practices.

Figure 1. Location and hydrological boundary of the Colorado River Basin (Argentina) (COIRCO, 2011)

The Short Term Scientific Mission (STSM) developed under this grant aimed:

a) to carry out a preliminary assessment of the regional patterns of water use (evapotranspiration) in the basin using a satellite-based ecohydrological approach (Contreras et al., 2011)

b) to perform field and optical measurements of different biophysical variables in agriculture plots under irrigation in order to calibrate satellite-based crop models which will be finally used to validate regional estimates of evapotranspiration.The methodological framework and the spatially-distributed data provided by this project will be useful to farmers for optimizing their water use and productivity, and to water managers for quantifying how water is diverted among different uses (e.g., native vegetation, and dryland and irrigated agriculture) at the catchment scale.

2. Description of the work during the STSM

Activities during the STSM covered three main topics (Table 1), i.e.

1) technical-scientific work, including office work (preliminary satellite-based assessment of water use patterns) and field work (installation of sensors and first field-scale measurements). See below for more details regarding the conceptual methodology, and the experimental and optical sensors used during the field campaign,

2) preparation of a research proposal for the EU-Horizon2020,

3) networking activities, including the participation in a technical workshop, the giving of an academic seminar, and a meeting with personnel of the National Directorate of International Relations of the Argentinean Ministry of Science, Technology and Innovation (MINCYT).

4) others (e.g. guidance of PhD students and INTA technicians)

Table 1. Overview of activities and institutes visited during the grant period.

Institute	Staff contact/ num. days	Activity
Instituto Clima y Agua (INTA Castelar, BsAs, ARG)	Dr. Carlos di Bella 9 days	Assessment of vegetation-index spatial anomalies (preliminary results) Project proposal

		Academic seminar Networking with personnel of the MINCYT (nodes of COST & ENSOCIO-LA EU project)
Unid. Extensión y Desarrollo Territorial 25 de Mayo (INTA Anguil, La Pampa, ARG)	Ing. Agr. Dardo Roy Fontanella 4 days	Experimental design Installation of sensors and 1st field measurements Technical workshop with stakeholders PhDs Guidance

2.1. Regional assessment of interannual water use patterns – Conceptual approach

Preliminary estimates of the annual evapotranspiration in the region were retrieved for an area of ~100 km^2 approximately centered in the village of Colonia 25 de Mayo, just at the border between 'La Pampa' and 'Rio Negro' provinces. The conceptual approach is explained in detail by Contreras et al. (2008, 2011). This approach assumes that annual evapotranspiration in drylands can be linearly scaled according to the anomaly of a spectral vegetation index which is computed as the difference between the observed value reported by the satellite and an expected one if local rainfall would be the only water source for vegetation development (Figure 2). For retrieving the expected values, a regional relationship between mean annual precipitation (MAP) and the spectral vegetation index has to be firstly retrieved from a sample of reference non-degraded sites that besides rainfall do not receive any additional inputs of water. Because the contextual nature of the approach, the selection of reference sites by field inspection or by aerial or satellite image interpretation is critical for estimating the total water requirements of native vegetation and crops. The methodology uses the Enhanced Vegetation Index (EVI) to detect the anomalies in water available for vegetation growth and to establish a relationship with MAP.

During the mission, a preliminary assessment of the MAP-EVI[1] functional relationship was retrieved for the study region. We use the long-term monthly average precipitation surfaces supplied by the "Climond" database (Kriticos et al. 2012), and the EVI fortnightly surfaces from the MOD13Q1 land product of MODIS (Solano et al. 2010). In a first step, pairs of values of MAP-EVI were extracted from

~25.000 pixels randomly selected, and a 75th-percentile regression was fitted over the resulting scatterplot.

In the following stages, the selection of reference sites should be improved in order to avoid the inclusion of sites which do not fully meet the requirements of non-degradation and purely rainfed. For this purpose, , a protocol was designed for identifying and characterizing reference sites in the field during our stay in Colonia 25 de Mayo. A field campaign will be organized by staff of INTA-Colonia 25 de Mayo for accounting the improvements for the MAP-EVI function retrieval.

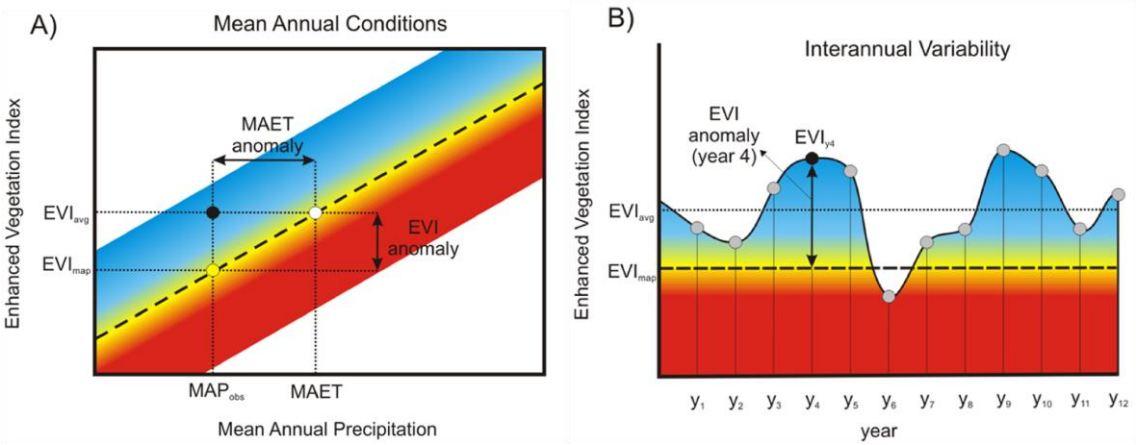

Figure 2. A) Conceptual scheme for estimating mean annual evapotranspiration figures at the regional scale. For a pixel with a given mean annual precipitation (MAP_{obs}) and an observed average mean annual EVI (EVI_{avg}) - black dot -, the EVI anomaly is defined as the difference against the rainfall-based expected value - yellow dot -. The mean annual water consumption of each pixel (MAET) is then computed projecting the observed EVI to the MAP-EVI regional function. The blue domain (positive EVI anomalies) represents the area in which vegetation consumption (~evapotranspiration) is met by local rainfall and other extraordinary water inputs (e.g. irrigation, groundwater). The red domain (negative EVI anomalies) integrates areas in which a fraction of the local rainfall is lost from the soil via deep percolation or surface runoff. B) Retrieval of interannual anomalies of EVI for a pixel located in the study area. These interannual EVI anomalies are finally used to estimate annual figures of water consumption by vegetation.

2.2. Biophysical measurements at the plot scale

2.2.1. Experimental design

The final aim of the STSM is to parameterize the relationships between a satellite-based vegetation index (e.g. EVI) and biophysical parameters (BPs) which are strongly related with the crop coefficient and the water effectively evapotranspired by the soil-vegetation domain. Calibrated EVI-BP- relationships will be integrated into an agronomic model to upscale the daily/fortnightly satellite-based observations of EVI into annual estimates of evapotranspiration. An additional objective of the field campaign, which will be extended during the 2013-2014 agronomic year, is to inter-calibrate two low-cost optical-radiometric

sensors, i.e. PARAMETER and PASTIS-57. PASTIS-57 is a system of low-cost sensors developed by personnel of INRA which measure instantaneous transmittance in the blue band (Lecerf et al., 2010). This spectral information has been demonstrated to be well correlated with greenness and the plant area index. Against the PASTIS-57, the PARAMETER system measures the Photosynthetically Active Radiation (PAR) reaching the surface, which has been also related with plant area index.

Two experimental plots with a mixed of lucerne-triticale (*Medicago sativa* - x *Triticosecale*) and maize (*Zea mays*) were selected as pilot sites for monitoring the seasonal dynamics of crop height (H), vegetation coverage, Fraction of Photosynthetically Active Radiation (FPAR, i.e the ratio between the total incoming radiation reaching a bare surface and that measured below the canopy), Plant Area Index (PAI) and Leaf Area Index (LAI). 12 and 6 Elemental Sample Units covering 6 and 3 pixels of MODIS (2 ESUs per pixel) were identified in the lucerne and maize experimental plot, respectively (Figure 3). In each ESU, a coupled system of 7 PARAMETER-PASTIS was installed (Figure 4, Figure 5), and 10 measurements of PAR-FAPAR with a ceptometer, and cenital, oblique at 57.5° and hemispherical pictures were additionally taken (Figure 6).

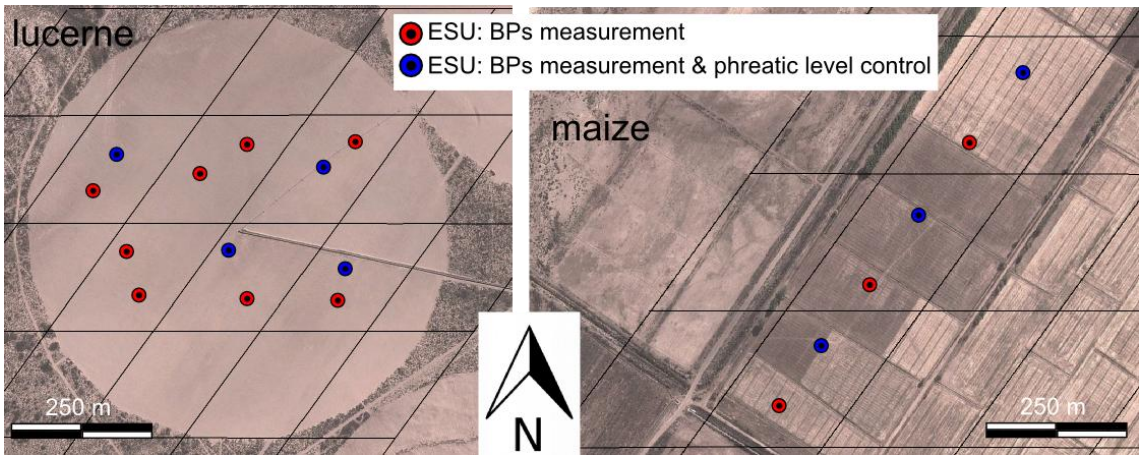

Figure 3. Distribution of Elementary Sample Units in the two experimental crop systems. The grid mesh shows the original boundaries of the MODIS pixels (spatial resolution: 233 m, sinosouidal projection). Measurements of biophysical parameters will be collected in all ESUs (red and blue points), and the phreatic level will be additionally monitored in the blue ESUs.

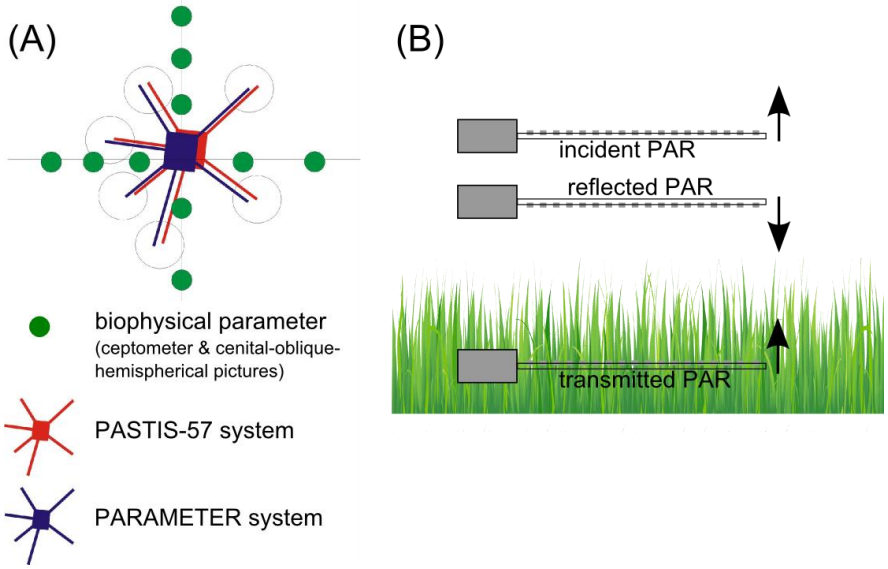

Figure 4. (A) Coupled PASTIS-PASTURE system configuration and biophysical measurements installed and taken in each Elementary Sample Unit. (B) Measurement scheme for retrieving FPAR with a ceptometer.

Figure 5. Elementary Sample Unit with dataloggers (left) connected to PARAMETER-PASTIS coupled system (right).

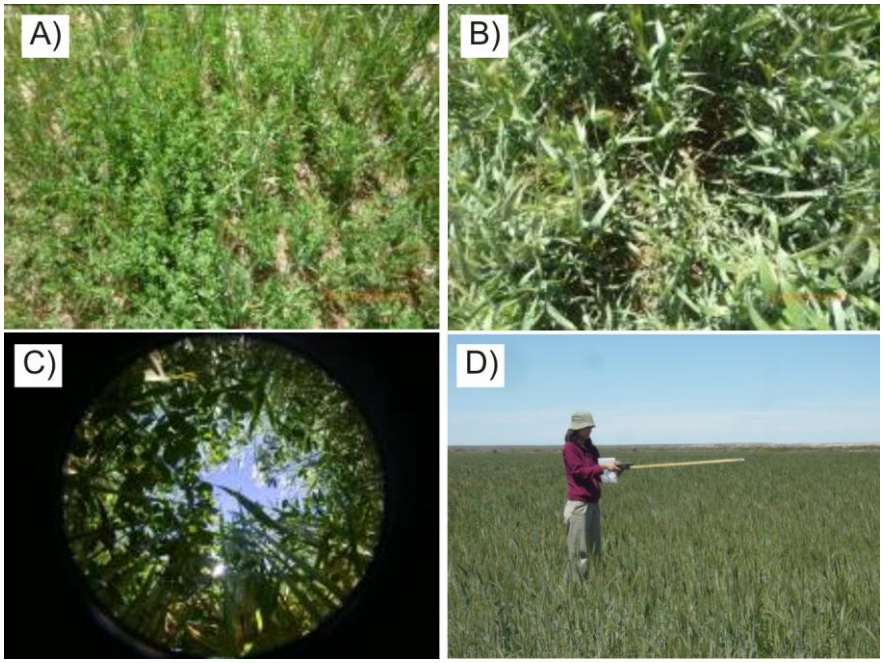

Figure 6. Cenital (A), oblique at 57.5^0 (B), and hemispherical (C) pictures, and PAR measurements (ceptometer) taken at one Elementary Sample Unit.

2.3 Main results

3.1. Regional assessment of interannual water use patterns

The regional MAP-EVI function for the study area and the resulting map of EVI anomalies are shown in Figure 7.

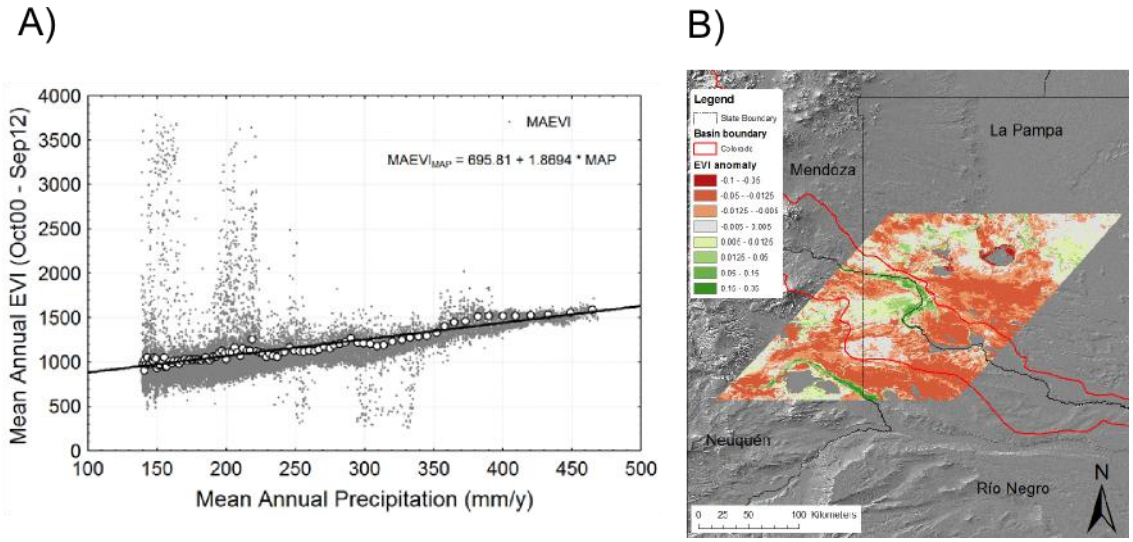

Figure 7. A) Regional MAP-EVI function for the study region, and B) Map with the mean annual EVI anomalies.

Interannual EVI anomalies reported in the region were used to estimate annual evapotranspiration figures according (Contreras et al., 2011). A preliminary intercomparison between these estimates and those retrieved from a VI-k_c FAO-based approach (Contreras et al., 2013) are shown in Figure 8. This alternative approach estimates actual evapotranspiration every 16 days as the product of the reference evapotranspiration and an effective crop coefficient. This crop coefficient is computed by scaling the EVI observations between two EVI-k_c thresholds which represent the opposite conditions of a bare soil and maximum vegetation or crop coverage. The parameterization adopted for these two conditions are shown in Table 2.

Table 2. Values adopted for the parameters in the EVI-k_c FAO-based approach.

Crop	Bare Soil Condition (FVC = 0)		Maximum Vegetation Coverage (FVC = 1)	
	EVI_{min}[1]	$k_{c,min}$	EVI_{max}[1]	$k_{c,max}$[1]
Lucerne	0.16	0.10	0.82	1.20
Maize	0.15	0.10	0.61	1.15
Vineyard	0.10	0.10	0.41	0.70
Forestry	0.14	0.10	0.57	1.20
Reference evapotranspiration (mm/day)				4.0

[1] Min/Max value = 5th/95th percentile of the EVI timeserie observed in the Oct2000-Sep2012 period.

[2] Values extracted from Allen et al. (1998)

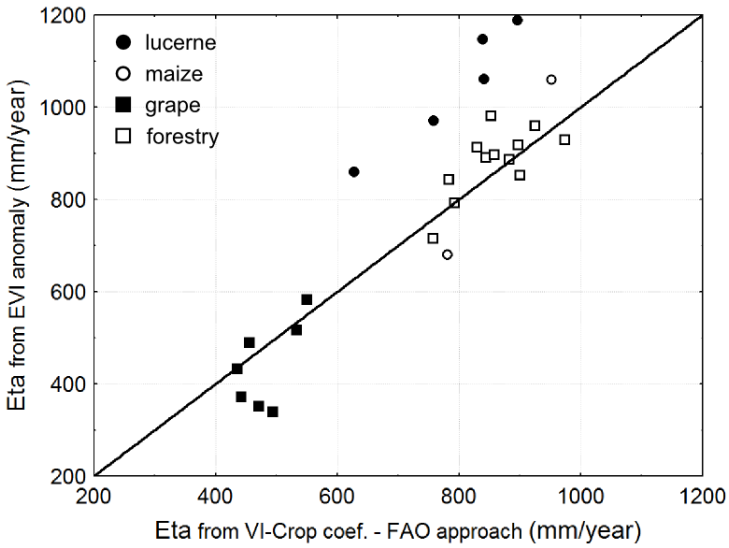

Figure 8. Intercomparison of annual evapotranspiration figures estimated from the EVI anomaly based-approach (Contreras et al., 2011) and a VI-Kc FAO-based approach which uses fortnight EVI figures as direct surrogates of the effective crop coefficient.

3. Future collaborations with the host institution

Biophysical parameters and radiation measurements at both lucerne and maize experimental plots will be collected fortnightly during one agronomic year. This will be done by INTA personnel in the framework of several Argentinean national projects. Improvements concerning the calibration and validation of the regional satellite-based approach will be achieved in the framework of a PhD thesis carried out at INTA. During the STSM, a roadmap of activities in the short term was identified, and a concept project proposal for the next EU-Horizon2020 call was also described. Other international partners from EU and South America are being contacted at present. A strong collaboration between both nodes, FutureWater and INTA, will be maintained in the next months in order to seek financial support, at the local, national and international levels.

It is expected that Dr. Carlos di Bella will visit FutureWater at Spain next April 2014 for continuing with the main activities started in Argentina.

4. Other comments

During the STSM, one technical workshop and an academic seminar were realized. The workshop was organized by the Unidad de Extension Agraria de 25 de Mayo and celebrated at 22nd Oct in the Local Irrigation Agency. During this workshop

activities done by the di Bella's research group and by FutureWater were presented. The launched scientific project was explained to local stakeholders, including farmers and water managers. The academic seminar was realized at 29th Oct at Instituto Clima y Agua (INTA-Castelar) and preliminary results from the STSM were also shown. Two press notes were published on the INTA webpage.

http://inta.gob.ar/noticias/una-fructifera-experiencia-junto-a-futurewater/

http://inta.gob.ar/documentos/una-aproximacion-multi-escala-para-la-evaluacion-del-balance-de-agua-en-la-cuenca-del-rio-colorado

6. References

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[1] EVI = Enhanced Vegetation Index