Crop water relations, bioenergy options and ecosystem services in the La Plata Basin

Final report

"Landuse, biofuels and rural development in the La Plata Basin"

(IDRC 104783-001)

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Introduction

The Plata Basin hosts two contrasting types of situations that shape the interaction between hydrology and land use (Figure 1). The northeast of the basin has highly rolling landscapes with well defined watersheds developed on ancient rock materials. The rest of the basin is occupied by Quaternary sediments that in most of the area produced an extremely flat plain with very poor surface water networks. Our activities in the first situation included the exploration of land use and management impacts on stream flow and sediment transport. In the flat area, instead, we focused on the coupling of ecosystems and groundwater.

In addition to the hydrological activities, we developed a series of parallel initiatives associated with the overall goals of the IDRC-funded project which include the evaluation of bioenergy potential in dry forests and the adaptation of the "ecosystem service" concept as a usable tool to deal with land management conflicts in the region.

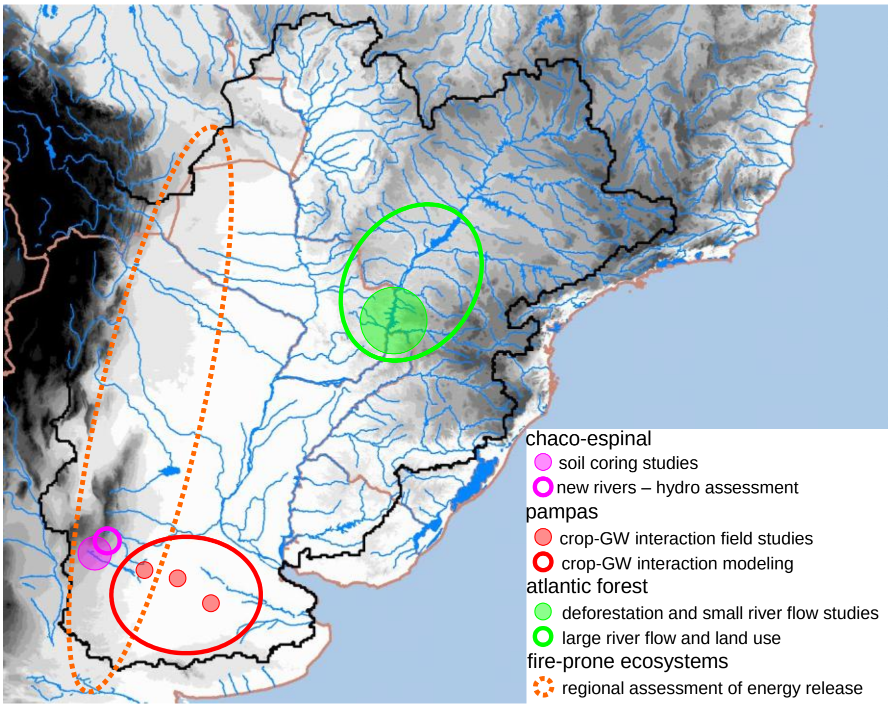


Figure 1. Plata Basin territory with its surface hydrologic network. Gray tones indicate elevation. Foci areas of the activities described below is shown. Some activities involve specific field studies in farm plots and small watersheds (filled circles) while others include modelling, remote sensing, and database synthesis approaches (empty circles).

Ecosystem-Groundwater interactions in the Chaco-Pampa plains

A vast fraction of the Plata Basin is occupied by aeolian sediments producing in most of the area an extremely flat plain with very poor surface water networks. In this context groundwater is the major hydrological component of the water cycle with an important role as a water resource for people and ecosystems and as factor of disturbance through flooding and salinization.

In the more humid part of these plains (Pampas), groundwater tends to be shallow and highly coupled with ecosystems and, for this reason, to human decisions on their management. We examined the reciprocal coupling between vegetation, climate, and groundwater depth in agricultural fields of the Pampa that had shallow water tables characteristic of the region (0–10 m depth). In such situations, ground water may help (water provision), harm (water logging), or have no influence on plant productivity. Understanding how climate and vegetation influence this relationship requires ecological data, such as leaf-area, rooting depth, and phenology, and hydrological data, such as rainfall variation across years and controls on lateral flow.

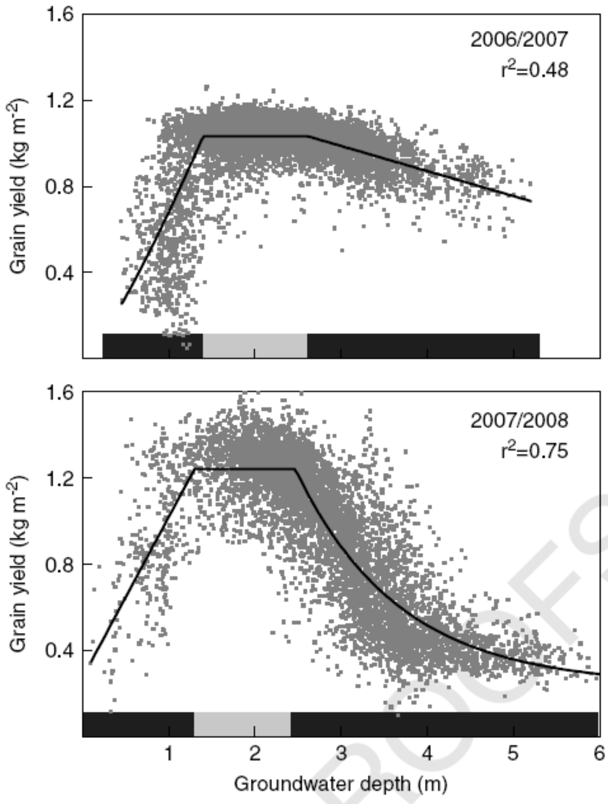
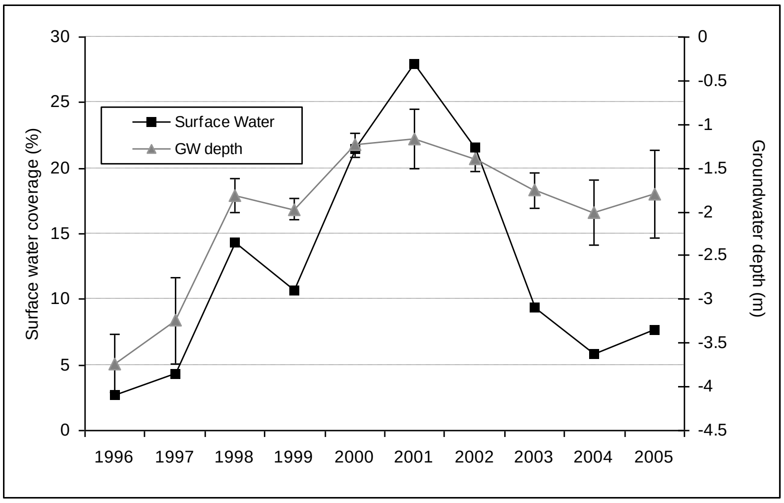


Figure 2. Relationships of corn yields and groundwater depth in the inland Pampas of Argentina for the relatively wet 2006–2007 (upper panel) and dry 2007–2008 (lower panel) growing seasons. Lower horizontal gray bars show the optimum yield zone.

Figure 2. Construction of a groundwater monitoring borehole in a wheat plot. A simple augering protocol has been developed and published in a farmers magazine (Jobbágy & Nosetto 2008 – **Revista CREA**) and is now applied consistently by farmers in different areas of the Pampas.

We combined high-resolution data on corn, soybean, and wheat yields with topographic maps and groundwater-depth sampling of 18 monitoring wells and nine boreholes to identify those groundwater depths which optimized crop yields across years. Through two growing seasons, the optimum groundwater depth ranges were 1.4–2.5 m for corn, 1.2–2.2 m for soybean and only 0.7–1.6 m for the shallower-rooted winter-season wheat plants (Nosetto et al. 2009 – **Field Crops Research**). Shallower water-table levels were associated with sharply dropping yields, most likely as a consequence of waterlogging and salinity. Deeper water table levels were accompanied by steady declines in yield until ground water was no longer accessible to plants. Direct groundwater use by crops also increased groundwater salinity up to levels that sometimes hindered further uptake and reduced growth.

Figure 3. Surface and ground water storage changes throughout the last flooding cycle of the Pampas. Surface water coverage obtained through remote sensing, groundwater level data obtained from a compilation of records by farmers and local agencies (Aragón & Jobbágy in preparation)



These relationships explain the stability of yields in some areas of the Pampas and are a valuable tool for crop and risk management in farm. An intense outreach and discussion activity of our team in forums like AACREA and AAPRESID meetings (major farmer associations), helps us to transform this information into useful tools. Results from this line have been presented in the most important farmers event of Argentina, (**Congreso AAPRESID**, November 2009, Rosario) by Jobbágy in a plenary session with more than 800 attendees and coverage in the media.

From a hydrological perspective, our work in agricultural systems highlighted not only their relevance in terms of groundwater dynamics regulation, but also their value as simplified system in which several challenging ecohydrological questions can be approached (Jackson et al. 2009, **Ecohydrology**).

We described regional flooding cycles associated to groundwater level raises based on remote sensing observations of surface water coverage and on an extensive compilation of water table level records for multiple points in the western Pampas. The last flooding cycle in the western Pampas increased water coverage from 3 to 27% (1997-2001) and water table elevation by 2.5 m, producing a net water storage gain of ~800 mm. Two important aspects of flooding are its high inertia regarding rainfall (cumulative response, which facilitates prediction) and a threshold dynamic involving high lateral water transport (once water coverage exceeds 20%, small bodies start coalescing into very extensive ones increasing hydraulic connectivity) (Aragon et al. 2010 – **Ecohydrology**).

Flooding in the region was mirrored by a decline of cultivation. Although cause-effect links are not fully resolved, data for the last 25 years (Viglizzo et al. 2009 – **HESS**) and modelling exercises based on a code developed by our team (VEGNAP, Contreras et al. in preparation) suggest that the replacement of pastures by annual crops could have favored flooding. This model has as a key rule, the functions shown in figure 3 dictating how transpiration responds to water table level. While deep groundwater levels favour a negative (stabilizing) feedback in which raising water facilitates evaporative evacuation, shallow groundwater favours a positive (destabilizing) feedback in which raising water tables cut evaporative evacuation facilitating a faster progress of flooding. The model captured this dynamic showing a bimodal behaviour under annual crops, in which lower water consumption, shallower rooting depths, and higher waterlogging sensitivity, created a more flooding prone situation. Parts of the VEGNAP routine have been included into standard crop models DSSAT and are now being used by agronomist in the region. A first paper on this improvement of DSSAT is in preparation..

Our estimates of water storage show a good correlation with those provided by the GRACE satellite system, suggesting that this could be a promising tool for groundwater monitoring in the region.

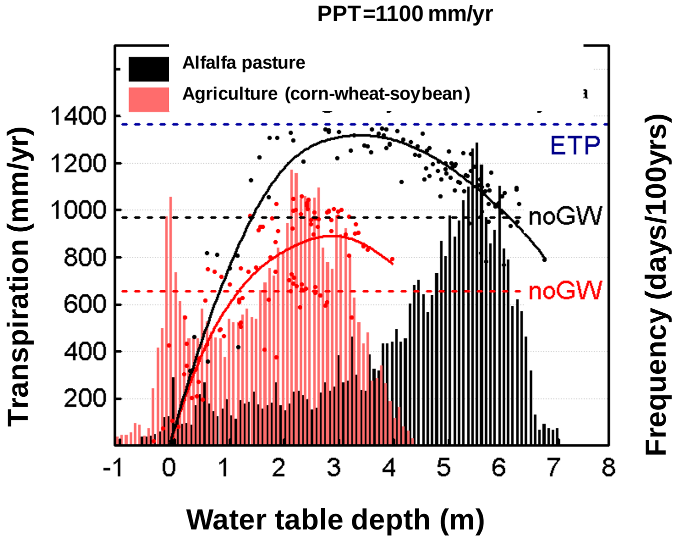


Figure 4. Modeling results showing how water table depth shifts with land use. Bars show the frequency distribution of water table depths measured as the number of days in 100 years in which the water table is located at a given depth. Agriculture (red bars), compared to Alfalfa pastures (black bars) created a shift towards shallower depths, favouring a bimodal distribution with a large frequency of floods (days with water table depth < 0.3 m). Horizontal dotted lines show Potential evapotranspiration and actual transpiration assuming no access to groundwater. Curve lines show the mean response of actual transpiration to groundwater depth.

In the drier section of the plains (Chaco-Espinal) groundwater is deeper and saltier and likely to be sensitive to agricultural expansion, as suggested by similar examples from the Sahel and Australia. There, we have explored the effect of dry forest replacement by annual croplands on water balance and groundwater recharge.

Deep soil sampling (> 7m deep), remote sensing data, and geoelectrical profiling showed that very subtle declines of annual evapotranspiration ET in cultivated areas have been sufficient to generate deep groundwater recharge and salt migration. At same sites salt accumulation under natural forests is >1kg/m2. Less than 3 decades of agriculture were enough to leach this salt load to groundwater (Jobbágy et al. 2008 – **Ecología Austral,** Santoni et al. 2010 – **WRR**, Jayawickreme et al. 2011, **Ecological Applications**). In the last decade several hydrological symptoms of increased recharge and salt mobilization showed up in the surface at several locations around the Chaco-Espinal including Eastern Paraguay, the Santa Fe- Santiago del Estero border, and San Luis. We are organizing this evidence and linking it with our plot stand studies.

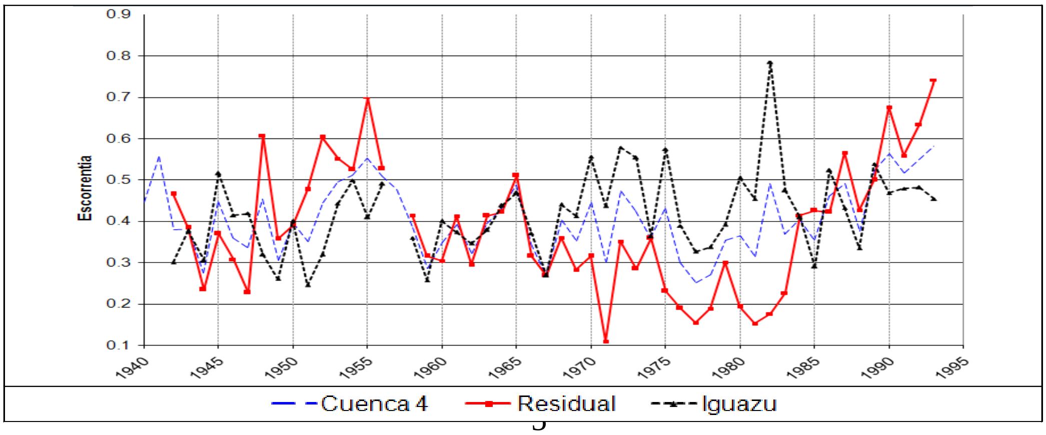
With the aid of geoelectrical tools, stream monitoring equipment such as continuous level and salinity meters, and satellite information for the last two decades, we characterized the development of new streams in a region that lacked any surface water manifestation since sediments were deposited 9000 years ago but was one of the first areas to be cleared for agriculture about a century ago. First streams developed in the late seventies and are now causing severe land degradation problems. This region can be seen as the “canary in the mine” of an incipient dryland salinity syndrome developing in the dry forests of the Plata Basin and since it already attracted a strong attention from farmers and the general public, it helped us illustrate the connection between land use and hydrological regulation (Santoni et al. 2009, presentation in **AGU meeting**, also local media reports and paper in preparation).

Figure 5. “New river” in San Luis. These type of streams are formed by the sudden liquefaction of sediments in the sloped plains close to the foothills of San Luis. As opposed to gullies created by surface erosion, these streams are generated by raising groundwater flowing at increasingly faster rates. Salty waters and highly dynamic and unpredictable transport of sediments, make this processes very damaging for agriculture and infrastructure. Our team is linking it to land use and climate changes in the area. In the picture, student Celina Santoni is standing on the edge of a stream (red arrow) that emerged in 2007 and deepened by 3 m (white line) in 2010.

Water yield and agriculture expansion in the Atlantic Forest of Paraguay

We explored the impact of the transformation of humid forests to annual croplands in the rolling landscape of Paraguay through the analysis of long-term river flow datasets. This line of the project, led by Andres Wehrle from Universidad Nacional de Asunción, has multiple scales of analysis. At the end of the project we have finished results on the broadest scale which involves portions of the Parana river basin. The isolation of the contributions from the segment of the river between Guaira and Posadas (discounting the Iguazu river), which drains the most deforested area of Paraguay (130.000 km2 that, as we estimated, went from 95% forest cover in 1970 to 5% in 2000), reveals a steady jump in the contribution of this zone to the total water flow of the river (Figure 6). Based on precipitation records for the whole basin we have found that 40% of rainfall inputs reached the river in the period of high forest coverage (1940-1980), whereas a steady rise on this value has accompanied the deforestation process (1980-1996) reaching levels close to 70% at the end of the period.

Figure 6. Water yield (river flow / precipitation) for the segment of the Paraguay river fed by the most deforested area of that country (red line). This value is calculated based on (a) the difference of flow at two points in the river that encompass the section of interest (i.e. residual) and (b) the precipitation within that region. The overall water yield for the Paraguay river and for one of its tributaries, the Iguazu are also presented (blue and black lines). Note the steady raise of the red line in a period in which the other lines are not showing strong trends.



Evaluation of the bioenergy potential of fire-prone ecosystems

We identified a unique opportunity to progress on the issue of energy production in (agro)ecosystems, often conflictive due to the possible trade-offs between energy generation, food production, and ecosystem service provision (e.g. hydrological regulation as shown in the previous section). We explored whether fire-prone dry forests can become a sustained energy source capable of replacing fossil fuels for electricity generation with little competition over food production and synergies with forest preservation. This possibility has several justifications including (a) the extent of fire-prone ecosystems is expanding due to climate change (ecosystems that never burned before are starting to burn frequently) (b) the fraction of ecosystem NPP that is proposed to be used to generate energy would otherwise be dissipated by fire, (c) the reduction of this fires through fuel removal and processing in nearby bioenergy plants will eliminate a negative threat to ecosystems and societies, (d) a win-win radiative forcing solution may be achieved by simultaneously replacing fossil fuels, eliminating the emission of gases with high greenhouse power which are generated in the field fire but not in the plants and by skipping the low albedo situations generated after fires leave a charred surface.

Based on our new global analysis of the energy generation and spatial distribution of fires, we estimate that biomass energy could be harvested economically in specific emerging economies, such as Argentina and Brazil, while preserving native habitats. Between 2003 and 2006, global fires consumed ~8500 ± 460 PJ y-1 of energy, equivalent to ~39% of global electricity consumption and exceeding consumption in 55 countries. In Argentina, where forest fires release more energy than the 360 PJ of national electricity consumption, Chaco forests alone could provide a sustained output of 9 GJ ha-1 yr-1, reducing habitat loss to soybean agriculture and maintaining ecosystem services. Bioenergy can help preserve native ecosystems while reconciling their use for energy supply.

Energy yields from biomass harvesting in the Chaco and other dry forests compare favorably with biodiesel production from soybeans in the region. Based on our analysis, for the first 30 years after deforestation soybean biodiesel would result in a net emission of ~580 g CO2e MJ-1 in excess of the petroleum diesel produced (91 kg CO2e GJ-1), with 614 kg CO2e GJ-1 coming from land use change (a loss of ~230 Mg CO2 ha-1). This strong effect of deforestation would take ~550 years to repay (12, Table S2). In contrast, bioelectricity would offset GHG emissions from electricity generated from fossil fuels by 170 to 345 kg CO2e GJ-1. Energy yield per hectare is higher for soybean biodiesel than for bioelectricity,12.5 vs. 9 GJ ha-1 y-1, respectively, but it involves a much higher appropriation of NPP as a result of a higher harvesting intensity (36 vs 11%) and, indirectly, through the decreased NPP of crops vs. forests (5.6 vs. 13.5 Mg. ha-1 y-1). These results are being evaluated for their publication in **Journal of Geophysical Research** (Verón et al. 2010)

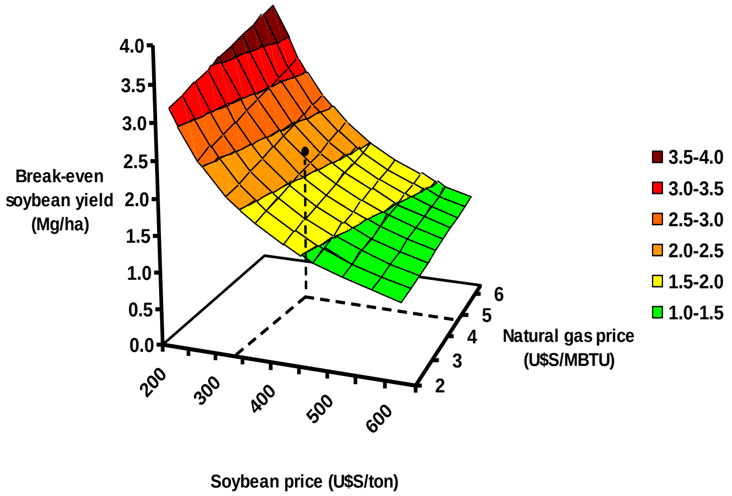


Figure 7. Break-even soybean yield (i.e. the minimum yield required to match the gross margin of wood production) as a function of soybean and natural gas international prices. Wood prices were allowed to vary according to the price of natural gas (the energy source potentially replaced by wood at thermo-electrical plants). Broken lines indicate actual soybean (U$S 330) and natural gas (U$S 4.65/MBTU) prices and the break even soybean yield (2.2 Mg/ha). Average 2003-2008 soybean yield was 1.9 Mg/ha. Local taxes (35%) were discounted to international soybeans prices.

Making a zoom in the driest portion of the Chaco region, we explored how the primary productivity of native ecosystems is being funnelled to forest and animal products (charcoal, firewood, meat, milk) and dissipated energy (livestock respiration and fires) under contrasting types of land users, such as small goat herders, large extensive calving units, and newer intensified cattle ranches that include C4 pastures. At the end of this project only the results from the regional level are available. The unit of analysis at this level was the county (1000 to 8000 km2), for which production outputs are regularly survey/reported. We found that less than 8% of the primary productivity of these forests is currently captured by human through grazing and forestry. Ratios of biomass consumption are 6:1:1 for grazing, forestry and wildfires. Charcoal is the dominant forest product. Extensive livestock systems have a very high respiratory energy dissipation (80%) and that could be reduced through improved management. Animal productivity is strongly related to the area under pastures, being 20X in pastures than in native forests. This line has been part of the dissertation work of Carla Rueda, a PhD student from Santiago del Estero that will reinsert in her home institution within the dry Chaco after finishing her graduate studies. A first publication for **Ecología Austral** (argentine journal) is under preparation.

Figure 8. Charcoal ovens in the dry Chaco of Argentina. Poorly quantified and studied, these facilities and the whole charcoal production chain, represent an important output of the region, suggesting that these dry forest are already focused on "bioenergy" production. Our team developed tools to quantify energy and charcoal outputs with the aid of remote sensors. We explored the diversity of actors and contexts in which charcoal production takes place, including multifamily systems associated with forest clearance operations and small traditional single-oven systems run by one family, usually in association with livestock production.

Ecosystem Services: Shaping a common vision

As we progressed on the previous lines our team realized that the notion of ecosystem services was a very valuable tool to discuss our results in particular and the broader issue of agricultural expansion, both in the scientific and the public arenas. However, different visions and definitions of ecosystem services made the debate difficult. Motivated by this challenge/opportunity we jointly organized a workshop on Ecosystem Services with INTA that took place in November of 2009. The workshop had as its main goal the production of a book on Ecosystem Services & Agricultural

Expansion/Intensification that will bridge science and decision making in the context of increasing conflicts and trade-offs associated with land use. Inspired on the Dahlem Conferences, we commissioned several participants with the task of writing book chapters before the meeting. The first full drafts of these chapters served as the background for the 3 days discussion that took place later. Four task groups focused on (1) Justification, (2) Dimensions, (3) Methodologies, (4) Action regarding Ecosystem Services generated a synthetic chapter for the book, whose first drafts are now under review. Participants included social and natural scientists (Ecologists, Agronomist, Economists, Lawyers, Sociologists) as well as representatives from the Academic, Governmental, Productive and NGO "Spheres". Although focused on the Argentinean case, the workshop included participants from Uruguay (Altesor, Piñeiro), Mexico (Balvanera), and Chile (Lara, Urrutia) and the material, written in Spanish, will be of value for the broad Latinamerican public. IDRC funds were used to cover one third of the workshop costs with the rest being covered by INTA. The book **"Valoración de Servicios Ecosistémicos: Conceptos, Herramientas y Estudio de Casos"** (744 pages, 32 chapters) edited by Laterra, Jobbagy & Paruelo is currently in the press with its printing being sponsored by INTA and IAI through CRN 2031.

Outputs

Scientific publications

SUBMITTED

Baldi G, Jobbágy EG, Alcaraz D. The role of biophysical and human contexts shaping productivity in the dry subtropics. SUBMITTED to **Global Ecology and Biogeography**

Veron SR, Jobbágy EG, Di Bella CM, Paruelo JM, Jackson RB. Diverting biomass from widlfires to bioenergy: A developing-world opportunity. SUBMITTED to **Geophysical Research Letters**

Baldi G, Jobbágy EG. Land use in the dry subtropics: Vegetation composition and production across contrasting human contexts. ACCEPTED WITH REVISION in **Journal of Arid Environments**

IN PRESS & PUBLISHED

Jayawickreme DH, Santoni CS, Kim JH, Jobbágy EG, Jackson RB. Changes in hydrology and salinity accompanying a century of agricultural conversion in Argentina. **Ecological Applications**, in press

Nosetto MD, Jobbágy EG, Brizuela AB, Jackson RB. The hydrological consequences of land cover change in central Argentina. **Agriculture, Ecosystems and Environment**, in press

Jobbágy EG, MD Nosetto, PE Villagra, RB Jackson. Water subsidies from mountains to deserts: Their role sustaining groundwater-fed oases in a sandy landscape. **Ecological Applications**, in press

Aragón R, Jobbágy EG, Viglizzo E. Surface and groundwater dynamics in the sedimentary plains of the Western Pampas (Argentina). **Ecohydrology,** in press

Contreras S, Jobbágy EG, Nosetto MD, Villagra PE, Puigdefábregas J. 2011. Satellite-based estimate of evapotranspiration in arid regions: An ecohydrological approach for central Argentina. **Journal of Hydrology**, 397:10-22

Viglizzo E, Frank F, Carreño L, Jobbágy EG, Pereyra H, Clatt J, Pincén D, Ricard F. 2011. Ecological and environmental footprint of 50 years of agricultural expansion in Argentina. **Global Change Biology**, 17:959-973

Santoni CS, Jobbágy EG, Contreras S. 2010. Vadose transport of water and chloride in dry forests of central Argentina: the role of land use and soil texture. **Water Resources Research**, 46: art. no. W10541

Portela SI, AE Andriulo, EG Jobbágy, MC Sasal. 2009. Water and nitrate exchange between cultivated ecosystems and groundwater in the Rolling Pampas. **Agriculture, Ecosystems & Environment**, 134:277-286.

Jackson RB, EG Jobbágy, MD Nosetto MD. 2009. Ecohydrology in a Human-Dominated Landscape. **Ecohydrology**, 2:383-389

Nosetto MD, EG Jobbágy, GA Sznaider, RB Jackson. 2009. Reciprocal influence between crops and shallow ground water in sandy landscapes of the Inland Pampas. **Field Crops Research**, 113: 138-148

Viglizzo EF, EG Jobbágy, LV Carreño, FC Frank, R Aragón, L de Oro, VS Salvador. 2009. The dynamics of cultivation and floods in arable lands of central Argentina. **Hydrology & Earth System Science** 13, 491-502

Jackson RB, JT Randerson, JG Canadell, RG Anderson, R Avissar, DD Baldocchi, GB Bonan, K Caldeira, NS Diffenbaugh, CB Field, BA Hungate, EG. Jobbágy, LM

Kueppers, MD Nosetto, DE Pataki. 2008. Protecting climate with forests. **Environmental Research Letters**, 3:044006

Piñeiro G, EG Jobbágy, J Baker, B Murray, RB Jackson. 2008. Set-Asides Can Be Better Climate Investment than Corn-Ethanol. **Ecological Applications**, 19:277-282

Jobbágy EG, MD Nosetto, CS Santoni, G Baldi. 2008. El desafío ecohidrológico de las transiciones entre sistemas leñosos y herbáceos en la llanura Chaco-Pampeana. **Ecología Austral**, 18:305-322

Baldi G, MD Nosetto, R Aragón, F Aversa, JM Paruelo, EG Jobbágy. 2008. Long-term satellite ndvi data sets: Evaluating their ability to detect ecosystem functional changes in South America. **Sensors**, 8:5397-5425

Farley KA, G Piñeiro, SM Palmer, EG Jobbágy, RB Jackson. 2008. Stream acidification and base cation losses with grassland afforestation. **Water Resources Research**, 44, W00A03, doi:10.1029/2007WR006659

Nosetto MD, EG Jobbágy, T Toth, RB Jackson. 2008. Regional patterns and controls of ecosystem salinization with grassland afforestation across a rainfall gradient. **Global Biogeochemical Cycles,** 22-10.1029/2007GB003000

BOOKS

Laterra PE, Jobbágy EG, Paruelo JM. 2011. Valoración de Servicios Ecosistémicos: Conceptos, Herramientas y Estudio de Casos. Ediciones INTA. Buenos Aires, Argentina. 744 pp

Viglizzo EF, Jobbágy. 2010. Expansion de la Frontera Agropecuaria en Argentina y su Impacto Ecologico-Ambiental. Ediciones INTA. Buenos Aires, Argentina. ISBN 978-987-1623-83-9. 102 pp.

DIVULGATION

Nosetto MD, Jobbágy EG, Mercau JL. 2011. Ambientacion y aplicacion variable de insumos en areas con influencia freatica. Agricultura de Precision y Manejo por Ambientes - **AAPRESID**, Revista Especial. 15-20.

Jobbágy EG & MD Nosetto. 2009. Napas freáticas: pautas para comprender y manejar su impacto en la producción. Actas XVII **Congreso AAPRESID**. 151-155.

Jobbágy EG. 2009. Regímenes hidrológicos según usos de la tierra: Efectos de la actividad forestal en sistemas semiáridos y húmedos. Pp: 7-16 en: PJ Donoso (editor) **Tala Rasa: Implicancias y desafíos**. Universidad Austral de Chile, Valdivia.

Jobbágy EG y MD Nosetto. 2008. Pautas y criterios para el monitoreo de niveles freáticos en sistemas de producción agrícola pampeanos. **Revista CREA**

Web sites & databases

Collaborative site: http://lechusa.unsl.edu.ar
Collaborative site: http://napas.iyda.net

Databases and data sharing
Our team has developed a web site in which all users can download long-term satellite NDVI series (lechuSA, see above). We developed a similar initiative for data access on phreatic groundwater levels in the Pampas in collaboration the company IyDA.

Network development

Our team includes the following participants

Initial research team
Jose Paruelo, Facultad de Agronomía – Universidad de Buenos Aires
    In charge of remote sensing research. Involved in fire activity
Hugo Velasco, IMASL – CONICET & Universidad Nacional de San Luis
    Support on modeling actitivies – Ecohydrological research in the Pampas and Chaco- Espinal
Marcelo Nosetto, IMASL – CONICET
    In charge of field exploration of crop-groundwater interactions
Ernesto Viglizzo – INTA La Pampa
    In charge of regional exploration of groundwater/flooding – land use interactions
Carlos Di Bella – INTA, Instituto de Clima y Agua
    In charge of remote sensing of fires.
Pedro Laterra – INTA Balcarce
    Development of links with farming stakeholders and policy makers

Additions to the research team
Santiago Verón – INTA, Instituto de Clima y Agua
    Leading fires and bionenergy acitivity
Andres Wehrle – Universidad Nacional de Asunción
    Leading land use – river hydrology interactions activity
Robert Jackson – Duke University
    Bioenergy issues – Geophysical techniques for ecohydrology
Tamara Von Bernard – CREA
    Rural Economy

Stakeholders with active participation in the research process
Jorge Mercau – Farming consultant / Universidad de Buenos Aires
    Crop modelling, development of decision support rules based on groundwater information
Gustavo Sznaider – Precision agriculture consultant / Universidad de Buenos Aires
    Development of groundwater depth and crop yield mapping methods for massive application in farms.
Gustavo Duarte – Farming consultant & Farmer
    Conduction of field measurements in América location
Guillermo Mangas – Agronomist & Farmer
    Conduction of field measurements in Vicuña Mackenna location

Federico Albina - Agronomist & Farmer

Conduction of field measurements in Pehuajo location

Santiago Gonzalez Venzano – Consultant

Development of a web-based system for groundwater depth data integration and application in agricultural decision making (http://napas.iyda.net/)

NOTE: all these participants had been involved directly on the information generation process after the participation of the research team in workshops and other events with farmers/stakeholders

Students directly involved in the project

Posdoctoral:
Dushmantha Jayawickreme – Dept. Biology, DUKE University
Sergio Contreras – GEA, Universidad de San Luis
Roxana Aragón – GEA, Universidad de San Luis
Santiago Verón – INTA Clima y Agua
Domingo Alcaraz – Universidad de Buenos Aires & University of Maryland

Graduate:
Carla Rueda– GEA, Universidad de San Luis
Silvina Ballesteros– GEA, Universidad de San Luis
Celina Santoni– GEA, Universidad de San Luis
Germán Baldi– GEA, Universidad de San Luis
Andres Wehrle– Universidad de Asuncion (Paraguay) & GEA, Universidad de San Luis
Silvina Portela– GEA, Universidad de San Luis
Ivan Perino– GEA, Universidad de San Luis

Policy relevance & public outreach, involvement of policy/decision makers, users, policy implications

Policy relevance: some of our results fit directly into the process of land use regulation. So far we have been actively involved in the discussion of two issues: a) dry forest replacement by agriculture and its influence on hydrology/salinity in the context of the San Luis province government, and b) afforestation of grasslands and its impacts on soil and water quality in the context of the national government of Argentina. Our team participated in workshops with policy makers in both cases and some of our proposals are being considered in the development of new regulations.

Public outreach: We implemented several outreach avenues including divulgation (Jobbagy & Nosetto 2008) and teaching publication (Jobbágy et al. 2008) as well as open web sites for land use observation and understanding (http://lechusa.unsl.edu.ar) and for groundwater/flooding understanding and monitoring (http://napas.iyda.net). In addition we contributed to the media (local TV, newspapers, radio) on land use – hydrology issues (http://gea.unsl.edu.ar/eventos.php).

Interaction with stakeholders involved not only outreach activities but the knowledge generation process. As it has been pointed out in the previous sections we are collaborating with farmers, agronomist, and consultants in data gathering, analysis, synthesis and application along the line of groundwater-crop interactions. Our team has participated in 29 workshops and training events with farmers and policy makers focused on groundwater-crop interactions:

Event	Type of event	Location	Date
Congreso de Asoc Arg Cs del Suelo	Conferencia	San Luis	may-08
Empresa El Ganado	Taller	25 de Mayo	ago-08
Grupo CREA Henderson-Daireaux	Taller	Daireaux	ago-08
Congreso Asoc Arg Produccion Animal	Conferencia	San Luis	oct-08
Asoc Arg Cs del Suelo	Mini curso	Lincoln	nov-08
Región Crea Oeste-JAT	Conferencia	Daireaux	nov-08
Jornada Don Mario- DZD	Presentacion a campo	America	feb-09
INTA La Carlota	Mini curso	La Carlota	may-09
UNESCO-Programa Hidrologico Internacional	Conferencia	Montevideo	jun-09
AACREA	Curso	Buenos Aires	jul-09
Congreso AAPRESID	Conferencia	Rosario	ago-09
Jornada Napas - Agrotecnica Bell Ville	Mini curso	Bell Ville	ago-09
Empresa La Biznaga	Taller	Buenos Aires	sep-09
Regional AAPRESID Mackenna	Taller	V Mackenna	sep-09
Congreso Meteorologico Latinoamericano	Conferencia	Buenos Aires	oct-09
Grupo CREA Tandil	Taller	Tandil	dic-09
Regional AAPRESID Rio IV	Mini curso	Rio Cuarto	abr-10
Grupo CREA Washington-Mackenna	Taller	V Mackenna	may-10
INTA - Seminario del Agua	Conferencia	Santa Rosa	may-10
Univ. Católica de Cba-Seminario salinizacion	Conferencia	Corodoba	may-10
Mesa Intercambio Agrícola - CREA centro	Taller	Rio Cuarto	jun-10
Congreso de Asoc Arg Cs del Suelo	Conferencia	Rosario	jun-10
Empresa el Tejar	Taller	Venado Tuerto	jun-10
Curso de Ag Precision	Mini curso	Manfredi	jul-10
Grupo CREA Roque Perez-Saladillo	Taller	Saladillo	ago-10
INTA Mercedes SL	Conferencia	Mercedes	ago-10
Grupo CREA Cañada Seca	Taller	Cañada Seca	oct-10
Empresa Santa Felicitas-MD Consultores	Taller	Larraoude	oct-10
CREA Soven	Taller	Batavia	nov-10