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## 1. The IAI science programs - overview

This science report highlights achievements in four scientific programs, covering the period May 2010-April 2011: (1) Second Collaborative Research Network (CRNII), (2) Small Grants Program for the Human Dimensions (SGP-HD) (both funded by the NSF), (3) Land use change, biofuels and rural development in the La Plata Basin (funded by IDRC).

Project results described here were taken from project technical reports received in September 2010, update reports received for some projects in February 2011 and discussions with PIs during synthesis meetings held in 2010 and 2011. The section also includes an update on research-related communications and outreach outputs.

The projects in the **Second Collaborative Research Network (CRN II)** completed their fifth year in 2011. The CRNII Program received a no-cost extension from the National Science Foundation (NSF) until 2012. The CRN ‘network of networks’ has been further strengthened; in particular due to the enhanced facilitation by the Directorate in the cross-project synthesis process through meetings and the development of synthesis papers, particularly between CRNII and SGP-HD projects.

CRNII continues to play a substantial role in building scientific capacity. In total, 318 students have received scholarships (of between 1 month and 4 years duration) from projects. The total number of students who have participated in trainings and workshops promoted by CRNII projects is 1144.

Total funding leveraged in the program during the first 4 years was of approximately US\$22.5 million. The CRNII award will expire in August 2012.

The projects in the **Small Grants Program – Human Dimensions (SGP-HD)** continue to provide added value to the CRN projects, by linking economic and social science into the main programs and providing interactivity with the policy sector, thus effectively bridging the science-policy divide. Six SGP-HD projects started their work in September 2007 and five received a cost-extension from the NSF to complete their work in June 2011. Project SGP-HD009 did not receive an extension due to unsatisfactory reporting. SGP-HD014 was not extended since it was a 1-year project that started in April 2008 and closed in May 2009 (SGP-HD014). One project that was previously part of CRN2017 (2017-HD) received a 1-year grant under the SGP-HD extension, started in September 2010 and it will complete its work in June 2011 (SGP-HD013). The SGP-HD Award will expire in August 2011.

SGP-HD also plays a substantial role in building scientific capacity. In total, 25 students have received scholarships from projects and 437 students have participated in trainings and workshops promoted by SGP-HD projects. Total funding leveraged in the SGP-HD program for the 2 years was of approximately US\$4.5 million.

The research-development project “Landuse change, biofuels and rural development in the La Plata Basin”, funded by the Canadian IDRC since 2008, has received two extensions and concluded its activities in May 2011. As it was closely linked to CRN2031, its results are being reported here together with those of CRN2031.

## Program synthesis

Since 2009, the IAI has been organizing program synthesis meetings and developing cross-project summaries. The goal is to identify scientific insight emerging from an overarching synthesis that goes beyond the results of the individual projects. The goal of these meetings is to develop products through a process of presentations, discussions and interactive writing sessions. Synergies are identified and common lessons extracted to improve and solidify the knowledge derived from IAI research. Strategy papers or scientific review publications are in the final stages of editing for publication.

Cross-project meetings were held on climate modeling and hydrology; biodiversity and ecosystem services (both in August 2010, in Buenos Aires, Argentina); climate risk and water security (February 2011, Los Cabos, Mexico). An IDRC project meeting on land use, hydrology and climate in the La Plata basin was held in May 2010 (São José dos Campos, Brazil); a joint meeting of CRN, HD and IDRC projects followed in April 2011 in Asunción, Paraguay.

## Project results, outcome and impact

The CRNII and HD projects research between 2006 and early 2011 have provided a vast and varied amount of scientific knowledge, currently (April 2011) summarized in 343 joint scientific publications in refereed journals articles, books and book chapters. The IAI has two series of science briefs, “Science Snapshots”, that translate scientific findings into everyday language while conveying practical conclusions and policy messages, and the “IAI Communiqués”, in which the IAI reacts to current events. Policy briefs, project summary and synthesis reports are also made available periodically on

the IAI website. These publications are developed based on the scientific material available, in close collaboration with project scientists, to ensure the utmost accuracy of the information provided.

One of the mandates of IAI is to develop scientific knowledge as a basis for informed decision-making. Section 2 of this report on **Outcomes and Impact** specifically highlights those outcomes and impact beyond scientific results. Outcomes are project results that go beyond the direct scientific research findings and which have **impact** on the development of policies and scientific collaboration on the continent. We measure success of IAI research by looking at three aspects: how the Human Dimension (HD) Programs improved the Collaborative Research Networks (CRN) by adding specific social and economic research; how the CRN and HD programs improved the scientific networking of the scientists on the continent and with colleagues world-wide, and the specific policy impacts that were achieved in some of the CRN and HD projects. This chapter provides insight into how IAI is achieving its mandate to provide knowledge as a basis for informed decision-making.

In Section 3 of this report, **Progress Report**, we provide an overview on the scientific results produced over the past year in the projects. We have partly abandoned the project-by-project reporting in favor of short summaries across projects. The IAI Directorate makes original reports available upon request. All individual publications are listed under <http://www.citeulike.org/user/IAI>, the IAI's publications site.

The metrics of each project's progress in research and capacity building (number of publications, capacity building efforts) are provided in the **Annex**.

## 2. Outcomes & impact

Several projects had important outcomes beyond their scientific findings. The CRN network projects gained from stronger policy and social research components added through the Human Dimensions program and the IDRC-funded supportive project in the La Plata basin.

Many projects were also highlighted by PIs, students and partners for the cross-continent and global networking opportunities they provided, as a unique feature of the CRN program. Providing a greater international visibility and interactivity of Latin American scientists is one of the noteworthy contributions of the IAI.

Some projects had direct impact on policies, provided information that supported national policy decision processes, or helped start discussions on adaptation strategies. This highlights how the CRN contributes to the mandate of the IAI to provide scientific knowledge input to support informed decision making.

### Value added by Human Dimensions projects

In 2007, the IAI developed the Small Grants Program for the Human Dimension (SGP-HD) Program to strengthen the socio-economic dimensions in projects of the Collaborative Research Network Program (CRN) that had started in 2006. As the SGP-HD projects are completing their work by the end of June 2011, the aggregated value that they have brought to CRN projects is becoming apparent. In the next paragraphs, those successful outcomes that promoted the interaction between natural and social sciences are being highlighted.

Due to its excellent interaction with the national Weather Services and Municipalities, the research network on urban pollution (CRN2017), together with its Human Dimensions project, ADAPTE, had many immediate outcomes. This network facilitates international collaboration on urban air pollutant emissions, their forecasting and climate modeling. A functional computer grid network was installed that links up institutions in Brazil and Chile as the basis for shared computing and climate modeling. Daily online forecasts of air pollutants are now available for Santiago, Medellín and Lima.

A specific dimension added by ADAPTE was the assessment and evaluation of the combined effects of pollution and extreme climate events on public health in large cities, the development of maps were developed of how risks to human health from these combined impacts vary in different parts of these cities. Project studies on urban traffic emission factors contributed to revisions of Santiago's attainment plan. In Bogotá, city authorities used detailed project emission data to update the city decontamination plan. In Medellín, SAEMC could provide crucial support to an urban decontamination now put in effect. In the greater Buenos Aires area, collaboration of scientists with municipal authorities was initiated by a recent seminar under IAI support. The city of Lima has gained a functional chemical-weather forecast thanks to the capacity building efforts of the project in collaboration with the Peruvian National Meteorology and Hydrology Service (SENAMHI). This project further gained from an added Human Dimensions project (see below).

The Tropi-Dry Network (CRN2021) project gained from analysis of the conservation effectiveness of parks and payments for ecosystem services provided by the associated Human Dimensions project HD008. Tropi-Dry has been seeking better protection of tropical dry forests, as currently only 4.5% of all such forests are legally protected in the American hemisphere. The additional insight from HD008 can now be used to develop better, more effective park allocation and design schemes and frameworks for their implementation. This scientific knowledge is also useful for the international REDD+ negotiations.

The project on land use in the La Plata basin (CRN2031) has greatly gained from several associated IDRC-funded projects as well as a Human Dimensions project (HD014). The economic analysis of agricultural production in the flood-prone parts of the western Pampas provided important insight on possible financial incentives for adaptive land use. Substituting soybean by pastures in the depressions and tree afforestation on the hilltops would not only reduce economic losses but also interact with the hydrological cycle to reduce the severity of future floods. IDRC-funding has also helped in the development of a pilot study on reforestation in sugarcane production areas under incentives given by the Green Counties program in São Paulo state, Brazil. While it is too early to assess the reforestation effects of the program that only started in 2007, it has become clear that those counties that adopted state policies to revert deforestation were also those with increased revenues from sugarcane production and enhanced social and economic indicators. Thus, important policy lessons emerge.

Further IDRC-funded studies looked into social dimensions such as the profound change in the structure of rural production systems since the advent, in the 1990ies, of so-called “pools de siembra” in Uruguay and Argentina. These network associations invest in the production of agricultural commodities. They plan production, procurement and commercialization, but outsource the production activities to field work sub-contracting companies, renting vast tracts of land for their activities, replacing the traditional family farm. However, the family farmers remain land owners, now making their living from the rent they receive. Incentives to steer sustainability and risk resilience in land use need to be completely revised to reflect this change in rural structure. The IDRC program also funded the development of agent-based models that integrate most of these findings. These models will be used to develop forecasts of agricultural risks and opportunities based on environmental constraints, taking farmer’s decisions into account.

Nevertheless, as farmers remain the agents of change in many parts of the Plata basin, farm cooperatives can be the vector of providing trustable scientific information that increases their resilience against climate change. This is successfully demonstrated by the Human Dimensions program (HD014) that develops and implements climate-based decision support systems for yield and climate risks in close cooperation with cooperatives of soybean producers in Eastern Paraguay and Rio Grande do Sul, Brazil. The web-based climate information systems, available for Paraguay (<http://py.agroclimate.org/>) and currently being developed for Brazil, help with adaptive planning. Several cooperatives were highly interested; some have purchased their own weather stations to support this system.

Supporting the project developing hydrological and glaciological research (CRN2047), two Human Dimensions projects (HD003, HD004) show the need for improved inter-agency coordination of adaptation measures, functional early warning systems and stronger institutional emergency plans for wa-

ter management. In the Chilean Maipo river basin, the 40-50% probability of water under-supply predicted under changed climate for 2080 largely exceeds the current 6-20% failure rate that farmers cope with in this irrigation system. In the Argentinean province of Mendoza with its billion-dollar wine industry depending on Andean water supplies, CRN2047 project investigators act as advisors to the Climate Change Agency (Agencia de Cambio Climático) on resource management policies. Such analyses improve planning and the adaptive capacity of agricultural producers and local administrations to climate change.

In the Human Dimensions project (HD005) associated to the project on hurricane forecasts in the Eastern Pacific (CRN2048), researchers identified deficiencies in how knowledge on climate and hydrology is communicated to rural and urban communities in the U.S.-Mexico Border region. Extension efforts by project associates are now improving knowledge support to rural and urban water planning.

The oceanography project (CRN2076) that studies the Patagonian shelf is complemented by the Human Dimension project HD76 investigating artisanal fisheries in a large Southern Brazilian lagoon. The Patos Lagoon is linked to the shelf by ocean currents and river outflows that vary under El Niño. The project found that shrimp productivity in the basin, and with it, the fisher's income, depends on the balance of nutrients and water temperatures provided by ocean currents and river flow. The effects of environmental processes are exacerbated by policies widely regarded as inadequate, such as the inflexibly set shrimp fishing season, or easy credit facilitating the unsustainable expansion of the fishing fleet. Unsustainable shrimp fishing is the consequence but could be minimized by more flexible regulations.

## Networking

**Scientists in many IAI networks have highlighted the unique opportunities those networks create for them to interact with fellow scientists and other organizations across national borders.** Here we summarize specific aspects where CRN's fostered or developed activities in international and global networks..

CRN2047 work linked with an international initiative (Long-term multi-proxy climate reconstructions and dynamics in South America; IGBP-PAGES LOTRED-SA) developing a detailed paleo-environmental database for the last 2000 years for southern South America has led to the first reconstructions of annual austral surface air temperature, pressure and precipitation fields for South America (20-55°S) for the last 700-900 years using a variety of proxy data. Mean summer temperatures between 900 and 1350 mostly exceeded those in 1901-1995. Between 1350 and 1700, the climate got colder and subsequently warmed. These long records are necessary to determine multi-decadal natural climate variability; 500-1000 year-long drought and streamflow reconstructions have been developed for Mexico, Chile, Argentina and the Altiplano.

The exceptional role of the CRN2017 program in connecting South American scientists and students across national borders is often mentioned by project PIs and former trainees. It has allowed developing a functional network that remains active even after the project concluded its activities in December 2010. The project is now recognized within the International Global Atmospheric Chemistry (IGAC) framework as an outstanding South American project on megacities.



Partnerships developed in CRN2031 have improved research capacities in Uruguay and Paraguay through joint research with investigators and by integrating graduate students into CRN research. Particularly the associated Human Dimensions programs 003, 004 and 014, as well as the supportive IDRC-funded project already mentioned above, were instrumental in this. One result has been a strong presence of Paraguay in the IAI synthesis, training and outreach activities, lately in a Policy Forum in April 2011 at the National University of Asunción. Paraguay also is hosting the 2011 Executive Council meeting and Conference of the Parties of the IAI.

### **Policy impact of the projects**

**Several projects could provide state-of-the-art scientific knowledge to directly inform political decision makers.** This demonstrates that, by making available scientific information, IAI-fostered research has a potential for policy impact.

The Tropi-Dry (CRN2021) project team provided scientific expertise towards a decision on protecting the dry forests in Minas Gerais, and a 2010 State law that had lifted the protection status from large important forest areas was revoked by legal action of the Brazilian State and Federal Environmental Attorney Offices. The project's remote-sensing products now form the basis of the official land cover maps for Costa Rica. Project scientists also contributed to continental policy initiatives developed for arid and semi-arid regions by the Inter-American Development Bank.

In Chile, the project on Andean hydrology (CRN2047) contributed to the Native Forest chapter for the National Commission for the Environment's (CONAMA) report on the state of the environment. One project scientist is on the Native Forest Advisory Council which coordinates water, soil and wetlands protection and subsidies to land owners for forest preservation. In Mexico, project scientists are involved in several conservation policy initiatives. Project investigators also have led the initiative to develop a new national inventory of glaciers in Argentina, recently awarded to the Instituto de Nivología, Glaciología y Ciencias Ambientales (IANIGLA), and have made significant inputs to the development of the national Glacier Protection Law, using IAI-funded research to document the case at National Senate hearings.

Members of the projects investigating biodiversity and forest margin dynamics (CRN2005, CRN2015) were requested in 2010 to provide expert opinion during parliamentary discussions of a new forest protection law in the Córdoba Province Parliament, Argentina. They could provide evidence in favor of secondary forests and mixed species-rich shrublands, ecosystems considered of inferior importance but which provide multiple services such as carbon storage and forest products important for resource-poor rural families. The parliament ended up approving an alternative law proposal facilitating forest transformation into cropland, but this does not reduce the role the project played in making scientific knowledge available to the parliamentary decision process. This emphasizes that IAI research has started to play a role in fostering informed decision-making stipulated by the IAI mandate.

[The IAI has continued to participate in the Research dialogue at meetings of United Nations Framework Convention on Climate Change (UNFCCC) Subsidiary Body for Scientific and Technological Advice (SBSTA). In 2011, the contribution will focus on improving adaptive resilience of the land use, hydrology and biofuel crop development options in the La Plata basin (the CRN2031, 2047 and 2094

projects). Last not least, several IAI researchers take part in the work groups developing the IPCC's Fifth Assessment Report].

### 3. Progress report

#### **CRN2005 - From landscape to ecosystem: across-scales functioning in changing environments**

*Argentina, Brazil, Canada, Germany, USA, and Venezuela (lead)*

The scientists in this project examined how ecosystem boundaries are displaced by climate change. This is important to understand whether and how far ecosystems may be displaced, reduced in size or totally extinguished under climate change. First, they determined what establishes these boundaries; e.g. a mix of temperature extremes, humidity and radiation defines the transition between Andean páramo and cloud forest. Human disturbance removes forest and favors recolonization by páramo vegetation. Thus, while climate warming may shift the tree lines upward, human interference moves it downward. Particularly vulnerable are Andean cloud forests, which are losing area from being “squeezed” in between temperature rise and development pressures from below and grazing impacts from above.

Elevated atmospheric carbon dioxide levels from fossil fuel emissions ‘fertilize’ vegetation. In both Canada and Brazil, an increase in tree productivity was observed but in Canada, it is counterbalanced by reduced water availability under warmer temperatures. Understanding how climate change affects complex system interactions in not always linear ways helps to predict how these ecosystems will transform.

#### **CRN2014 - Functional links between aboveground changes and belowground activity with land use in the Americas: Soil biodiversity and food security**

*Brazil (lead), Canada, Ecuador, Mexico, USA*

Symbiotic soil fungi (so-called mycorrhiza) are associated with many plants’, a symbiosis important for plant nutrient acquisition in dry environments. Research indicates that they may be vulnerable to climate change, particularly if rainfall regimes change. This knowledge allows selecting more resilient plant assemblages used to restore prairie grasslands, as well as wheat genotypes with improved symbiotic relationships for these environments. This helps to improve nutrient use efficiency by the crops. In addition, the research team developed practical applications such as so-called *inocula*, the application of fungal ‘fertilizers’ that improve potato growth. These results provide knowledge on how to restore these drylands while contributing to food security and improving soil water holding capacity and carbon storage, important ecosystem services.

#### **CRN2015 – Functional biodiversity effects on changing ecosystem processes and services and sustainability: interdisciplinary approach**

*Argentina (lead), Brazil, Costa Rica, the Netherlands, USA*

'Functional diversity' describes the role and ecological function that organisms play in their environment. For example, grasses grow quickly and cover the soil surface, hindering trees from getting established. In contrast, the more slowly growing trees, once established, store higher biomass, evaporate more water and change microclimate more drastically. If more different life-forms are found in an ecosystem, it is said to have higher functional diversity. Investigations of how these traits determine ecosystem functioning and ecosystem service provision, for example in Mexican lowland tropical forests, show that functional diversity recovers quickly after shifting cultivation and increases linearly with species richness. This indicates that each species fulfills a different role in the ecosystem; removing one species leaves a functional gap that cannot be filled by others. This is important for conservation policies; only if full species assemblages are preserved, full ecosystem services can be provided.

Nutrient cycling is one important ecosystem service. A long-term field experiment on plant diversity and nutrient cycling in the Chaco demonstrates that symbiotic soil fungi (mycorrhiza) and soil chemistry hardly react to land use changes. This suggests that nutrient cycling may be more resilient to aboveground system changes than previously thought. Undisturbed dry Chaco forest in central Argentina stocks a total of 187 tons of carbon per hectare. Two thirds of this biomass (71%) are belowground. Careful selective extraction of timber and firewood and moderate grazing — traditional forms of land use practiced by poor Chaco communities — would allow using the land while sequestering carbon in soils. In contrast, if converted to shrubland or intensive agriculture, soils significantly lose carbon. This is important for the development of carbon policies.

### **CRN 2017- South America Emissions, Megacities and Climate (SAEMC)**

#### ***SGP-HD013 – Adaptation to the health impacts of air pollution and climate extremes in Latin American cities (ADAPTE)***

*Partners from Argentina, Brazil, Chile (lead), Colombia, Germany, Peru, USA*

About four fifths of the total South American population lives in cities. Vehicles are a major pollution source, and due to fleet modernization they have now much reduced individual emissions. Nevertheless, the vehicle fleet is growing and industrial point sources are also increasing in numbers. In consequence today, in major urban agglomerations (e.g. Bogotá, Lima, Mexico City, Santiago de Chile, São Paulo, Rio de Janeiro) pollution levels above the WHO standards indicating chronic health effects for the populations of these cities. Advanced climate modeling developed at the Brazilian National Institute for Space Research (INPE) was used to implement urban pollution forecasts with greater precisions, and these models now form the basis for daily pollution (chemical weather) forecasts available for Lima, Medellín, and Santiago. In Bogotá, monitoring by project scientists of the emissions by each vehicular group and estimates of their share in overall traffic volume together with cost-benefit considerations were used to implement the new decontamination plan for the city that should more than halve current emission levels until 2020. The city of Medellín followed suit with their own decontamination plan, also put in practice with input from project scientists.

Project findings also helped to rectify erroneous past assessments. For example, pollution with nitrous compounds (NO<sub>x</sub>) in Santiago was overestimated two to three times in the past, leading researchers to propose the use of mathematic optimization algorithms to develop an effective distri-

bution plan for the costly measurement stations across cities. This approach has raised interest in other cities such as La Plata and Buenos Aires, Argentina.

Under global warming, urban areas in Latin America are likely to be strongly affected by heat waves, and it is not known how vulnerable urban populations are to these waves and their interaction with air pollution. The associated Human Dimensions program HD017 (also called ADAPTE) explores the independent and combined effects of exposure to weather and air pollution and assesses how human risk varies under those combined stressors. The inhabitants of Mexico City, Santiago, Buenos Aires and Bogotá are exposed to high levels of pollution. World Health Organization (WHO) standards are exceeded for dust particles by about 90%, and for nitrogen oxide by up to 73%. However, the risk varies across cities according to localized sources of emissions (exposure) but also in response to demographic factors such as income or age. For example, during the warm season, inhabitants of Buenos Aires and Mexico City have the highest risk of respiratory mortality. Periods of warmer winter temperatures, in contrast, protect citizens against mortality, for example in Buenos Aires. Often, children or the elderly are over-proportionately affected by extreme weather if this comes in combination with pollution from dust particles or ozone: in Bogotá, children are most affected during the cold season, and here elderly people most succumb to cardiovascular mortality during the warm season. Citizens living in wealthy districts of Bogota and Santiago are less exposed to airborne dust particles. Thus, while overall pollution levels must be reduced, knowledge of how risks differ between districts and population strata allows for more targeted urban prevention planning. Results from CRN2017 were presented to representatives from the provincial and municipal governments of La Plata during a one-day meeting in March 2011.

### **CRN2021– Understanding the human, biophysical and political dimensions of tropical primary and secondary dry forests in the Americas**

#### ***SGP-HD008 - Conservation policy impacts in tropical dry forest: regional & spatially focused analyses given other social and natural drivers of land use***

*Brazil, Canada (lead), Costa Rica, Cuba, Mexico, Venezuela*

Tropical dry forest areas are much less-recognized than rainforests, yet also highly threatened. Their biodiversity is similar to that of rainforests, and they provide important hydrological and climate regulation and carbon storage. Their open, park-like character invites colonization and conversion to cropland. Only 40% is left of the original tropical dry forest area in the hemisphere. Only 4.5 % of them are currently protected in parks and reserves, many too small for successful protection. Tropical dry forest dynamics are subject to climate change in opposing ways. They found that changes in rainy season length increase their productivity in some regions, while decreasing it in others. While declining productivity reduces biomass, carbon storage and water retention, increasing productivity may intensify their conversion to cropland. As these forests yield important ecosystem services, the benefits of protecting them go far beyond carbon sequestration. In addition to protection in parks, other protection schemes such as payments to land owners for avoided deforestation are needed, and land management outside of reserves and parks needs to become more effective through economic and fiscal incentives.

The associated Human Dimensions project (HD008) showed that the conservation effectiveness of parks and payments for ecosystem services can be much improved by judicious placement of parks: Parks in remote, inaccessible or steeply sloped areas were shown to have little effect as there was little threat to these areas. More effective park allocation and design schemes as well as implementation frameworks can now be designed. This is also useful scientific input to the international REDD+ negotiations.

**CRN2031 – Land use change in the Rio de la Plata Basin: linking biophysical and human factors to understand trends, assess impacts, and support viable strategies for the future**

**CRN2094– The impact of land cover and land use changes (LCLUC) on the hydroclimate of the La Plata Basin**

*With*

*SGP-HD003 - Climate change and irrigated agriculture towards a better understanding of driving forces and feedbacks between decision makers and biophysical environment and their impacts on hydrological cycle and land use*

*SGP-HD004 - Coming down the mountain: understanding the vulnerability of Andean communities to hydroclimatologic variability and global environmental change*

*SGP-HD009 - Designing a methodology to evaluate local knowledge on global change and its role in the construction of future land use scenarios by local actors (SCENARIOS)*

*SGP-HD014 - Decision support system (DSS) for risk reduction in agriculture phase II: soybean DSS for eastern Paraguay and Rio Grande do Sul*

*Argentina (leads 2031), Brazil, Paraguay, Uruguay, USA (leads 2094)*

Replacing permanent pastures with arable agriculture has significantly altered the regional hydrology of the La Plata basin by about one third. Recurrent floods, affecting 16 million hectares in the western Pampas, reduce agricultural output by, on average, 21%. This project showed the strong coupling between (agro) ecosystems and groundwater - and not increased rainfall - to be an underlying cause. The grain crops that are now grown everywhere let rainfall surpluses accumulate in the soil, which raises the groundwater table, stresses the crop plants, salinizes soils and reduces yields and income. Land use alternatives have been developed in close interaction with farmers. An associated economic analysis financed by IDRC revealed that those changes involve reforesting the 16% of the land that is on hilltops while establishing pastures in the 33% of the land that is in lowlands, instead of planting soybean everywhere. This would reduce economic losses, feed back into the hydrological cycles, and could strongly reduce the severity of future floods.

In the eastern humid Pampas, reduced water availability was documented by CRN2094 (Argentina (lead), Brazil, US) under afforestation with Eucalypt and Pine for pulp production of natural grassland. These plantations, with their greater transpiration of water to the atmosphere, halved the river base flow in the watershed. Since base flow is seen as the minimum water supply on which people

and ecosystems can rely, this greatly increases vulnerabilities in small river basins. The management of human interactions with the ecohydrology of floods and with “ecosystem services” in the Pampas has been exposed in two books on land use planning for the professional public.

In the Pampas, cropland expansion over previous permanent pastureland has reduced soil carbon (C) by about 30% over the past 25 years and biofuels have become a major crop. Calculations in CRN2031 of the carbon-neutrality of these biofuels need to consider this additional carbon emission from the land conversion. Soil carbon gains when natural vegetation recovers on degraded agricultural land would counterbalance those from corn alcohol for a 40-year period. Other ecosystem services such as hydrological regulation are also provided by the protected land and need to be weighed against the benefits from remote C offsets by crop-derived biofuels. Producing cellulosic ethanol from biomass harvests in set-aside grassland would provide for the highest C sequestration and the highest net present values. Project researchers already quantified opportunities from harvesting fuel normally consumed by wildfires in the Chaco and developed possible operative schemes.

Better natural system management could also help to balance interactions between the greenhouse effects from released carbon and the direct surface heating of afforested former grasslands and cultivated former dry woodlands. Land use change in the La Plata basin is significantly affecting the albedo (surface reflectance) of large areas. Regional climate models developed in CRN2094 (Argentina (lead), Brazil, U.S.) indicate reduced reflectance after land use change, e.g. tree plantations having 30% lower albedo than natural grasslands. The land warms up, which could reduce the benefits of carbon sequestration in these afforestations. In contrast, the enhanced albedo after deforestation of the semiarid Chaco - which reduces warming - could counterbalance the greenhouse effects of the released carbon. Estimating net effects of these processes would go a long way towards better, more intelligent climate mitigation.

Farmers are often the agents of change in the Plata. They can be provided with trustable scientific information to make more informed decisions. A Human Dimensions program (HD014) developed and implemented a climate-based decision support systems for yield and climate risks in close cooperation with cooperatives of soybean producers in Eastern Paraguay and Rio Grande do Sul (Brazil). A web-based climate information system that is already available for Paraguay (<http://py.agroclimate.org/>) helps them evaluate adaptive management options (soybean varieties, planting dates). Several cooperatives were highly interested; some have even purchased weather stations to support this system.

### **CRN2047 - Documenting, understanding and projecting changes in the hydrological cycle in the American Cordillera**

*Argentina, Bolivia, Brazil, Canada (lead), Chile, Mexico*

This team examined past and current hydroclimate conditions, snow pack and glacier dynamics in the American cordillera with a wide variety of proxy data to model future changes and develop strategies to reduce vulnerabilities from limited water availability under climate change.

While land-use changes, deforestation, and overgrazing have increased runoff and changed flow patterns of important streams that supply water for industrial, agricultural and urban uses. The replacement of native forest by commercial plantations in small stream basins of the coastal range in Chile shows a 14% decrease in summer discharge for each 10% increase in plantation coverage in areas of former native forests. Runoff in 30% of thirty-seven Andean rivers in Central Chile is now peaking significantly earlier in the year.

But streamflow from Andean rivers in Chile and Argentina between 30-37°S, dominated by runoff from winter snowpack, shows a weak negative trend in discharge over the last 100 years. Modeling of future streamflows in the river catchments in Chile indicates reductions of 20-30% over the next century (based on the IPCC's A2 scenario), which will also reduce hydroelectric generation capacity by up to 20%. In the 1967-68 drought in the Mendoza basin of Argentina, the reduction of generating capacity had equal or greater economic impacts as the direct effects on agriculture. Current and historic data demonstrate the significant economic and social effects of local and regional droughts in both recent and pre-Hispanic times.

Streamflow changes by climate change are often hidden under more dramatic multi-decadal shifts in mean values, for example, a 31% decrease in mean streamflow of the studied rivers in 1945 and a 28% increase in 1977 coincide with shifts in the Pacific Decadal Oscillation (PDO). Contemporary studies and reconstructions of the last 500-1000 years in Mexico indicate the spatial and temporal variability in the influence of long term oscillations (PDO, but also El Niño - ENSO, and the Atlantic Multidecadal Oscillation - AMO) on precipitation and streamflow patterns. This and reconstruction of snowpack changes over the last 900 years show the difficulty of interpolating future trends from relatively short (<50 years) instrumental records.

CRN2047 work linked with an international initiative developing a detailed paleo-environmental database for the last 2000 years for southern South America has led to the first reconstructions of annual austral surface air temperature, pressure and precipitation fields for South America (20-55°S) for the last 700-900 years using a variety of proxy data. Mean summer temperatures between 900 and 1350 mostly exceeded those in 1901-1995. Between 1350 and 1700, the climate got colder and subsequently warmed. These long records are necessary to determine multi-decadal natural climate variability; 500-1000 year-long drought and streamflow reconstructions have been developed for Mexico, Chile, Argentina and the Altiplano.

Most Andean glaciers between 17-55°S have receded significantly during the last hundred years. The Southern Patagonian Icefield has lost approx. 1,000 km<sup>2</sup> (ca. 7%) of its ice cover between 1944 and 2009 and the annual loss rate has doubled in the last 25 years. Glacier Upsala has lost more than 45 km<sup>2</sup> since 1986. However, individual glacier behavior is complex (a few continue to advance) and there is need for more detailed studies. Project members have led the initiative to develop a new national inventory of glaciers in Argentina, a task recently awarded to IANIGLA, and made significant inputs to the development of the national Glacier Protection Law, using IAI-funded research to document the case at National Senate hearings.

Two related Human Dimensions projects (HD 003, 004) show that better inter-agency coordination of adaptation measures is needed, as well as better early warning systems and institutional emergency plans. In the Chilean Maipo river basin, a 40-50% probability of water under-supply predicted



under changed climate for 2080 largely exceeds the current 6-20% failure. Such analyses are needed to improve planning and the adaptive capacity of agricultural producers and local administrations to climate change. In the Argentinean province of Mendoza with its billion-dollar wine industry depending on Andean water supplies, project investigators act as advisors to the Climate Change Agency (Agencia de Cambio Climático) on resource management policies. In Chile, the project contributed to the Native Forest chapter for the National Commission for the Environment's (CONAMA) report on the state of the environment. One project scientist is on the Native Forest Advisory Council which coordinates water, soil and wetlands protection and subsidies to land owners for forest preservation. In Mexico, project scientists are involved in several conservation policy initiatives.

A continent-wide network of scientists is now beginning to synthesize knowledge on water security. Coordinated by the IAI Directorate, these initiatives provide important international synergies and new insights into one of the most important and least predictable components of global change on the continent.

### **CRN2048 – Tropical cyclones: current characteristics and potential changes under a warmer climate**

#### ***SGP-HD005 - Information flows and policy: use of climate diagnostics and cyclone prediction for adaptive water-resources management under climatic uncertainty in western North America***

*Costa Rica, Cuba, Mexico (lead), USA*

The Eastern Pacific basin is the most active hurricane region on earth, yet remains one of the least studied ones. Tropical cyclones often produce heavy rains, causing landslides, flooding, property damage and taking human tolls upon landfall. Scientists from the project followed and modeled hurricane tracks and showed that weaknesses in both models and atmospheric data collection caused erroneous and late hurricane track predictions. In response, the Mexican Meteorological Service is now taking more upper atmosphere soundings needed for the models. Furthermore, the Service and the US National Hurricane Center (NHC) now collaborate towards improving their track and intensity forecasts for tropical cyclones. Reliable advance warning of tracks will help save lives and property while possibly also reducing unnecessary evacuations (<http://bit.ly/d6pUfV>). The erratic rainfall brought from hurricanes also contributes to filling the aquifers in this dry region. With projected temperature increases up to 4°C by 2100 and precipitation decreases of 10-15% by 2100, human water security in the region will greatly depend on improved understanding of hurricanes, their rainfall interactions and groundwater.

In an associated Human Dimensions project researchers identified deficiencies in how knowledge of climate and hydrology is communicated to rural and urban communities in the U.S.-Mexico Border region. Extension efforts by project associates are now improving knowledge support to rural and urban water planning.

## **CRN2050 - Paleotempestology of the Caribbean region: a multi-proxy, multi-site-study of the spatial and temporal variability of Caribbean hurricane activity**

*Canada, Costa Rica, Mexico, USA (lead)*

More hurricanes are to be expected in the Caribbean. This is the result of CRN2050 researchers studying the variability of past hurricane landfalls along American coastlines and in the Caribbean region. Statistical climate models combined with long-time series of proxy data for sediment records and climate variables such as air or ocean temperature allow now to document Atlantic hurricane activity over the past 1500 years. This unique data set covers the Western Atlantic from New England to Puerto Rico. Atlantic hurricane activity peaked during medieval times (ca. AD 900-1100), but calmed down afterwards, notably after AD 1500, to pick up again after 1850, and especially after 1980. The medieval peak, as high as recent levels of hurricane activity, is associated with a period of warm Atlantic sea surface temperatures (SSTs), while the low hurricane period partially coincides with the Little Ice Age. Warm Atlantic surface temperatures are associated with more hurricanes, and current global warming is also warming the oceans. These records therefore point at future higher hurricane frequency to be expected in the Caribbean (Snapshot: <http://bit.ly/d4Hsl7>).

A numerical analysis of El Niño Southern Oscillation (ENSO) shows that the number of El Niño events has increased, and that of La Niña events has decreased in last decades. Mathematical tools revealed significant underlying oscillations around 1,000, 180 and 4.5 years and minor oscillations around 360 and 83 years. This shows that not all multi-decadal ENSO trend changes can be attributed to global warming. The nonlinear nature of the oscillations suggests a role of solar and volcanic forcing. Stronger La-Niña-like conditions are predicted for the next decades, which would affect climate, hydrology, agriculture and land use over the continent. Already today, for example, lower rainfall in La Niña years in irrigated areas in Argentina negatively affects summer crop yields (see above, HD003).

Besides hurricanes, another important risk factor for people living in coastal areas is ocean level rise in consequence of global warming. A rise of 18-59 cm until 2100 is predicted. Project scientists are mapping vulnerable coastal areas. They combined highly accurate satellite-derived elevation measurements and freely available public data sets on population and shore geography in a geographic information system (GIS) to develop the first reliable coastal elevation maps. These now reveal that 19 million people reside within one kilometer distance from the shoreline in the conterminous U.S.. This corresponds to 10.0 % of the combined population of the 23 U.S. coastal states and 6.4% of the whole U.S. population (Snapshot: <http://bit.ly/c9OIM5>). This information can now help to develop better impact mitigation and prevention strategies in coastal zone planning and disaster management. Similar maps are currently being developed for the Caribbean region flood-prone inland areas in the La Plata basin. First results for the Caribbean show that the Bahamas, Belize, and Guadeloupe will have at least 20% of their populations impacted if sea level rises by 6 meters.

## **CRN2060 - Effective adaptation strategies and risk reduction towards economic and climatic shocks: lessons from the coffee crisis in Mesoamerica**

*Costa Rica, Guatemala (lead), Mexico, USA*

Although already minor climate changes can reduce the production of high quality coffee crops, Central American farmers perceive market fluctuations as the bigger threat to their livelihoods (CRN 2060). Since pest and disease control is routine in coffee production, producers also do not perceive the link between climate change, disease incidence, and crop production as a particular threat, even though temperature changes have been documented for the study region and all farmers report warmer nights and higher maximum temperatures than in the past. Adaptation to climate change is left to the farmers themselves, and their strategies depend on their risk perceptions. Their current adaptation strategies include growing alternative crops, diversifying income sources, and migration. In Honduras, 25% of coffee farmers have migrated, often the rural youth, which disrupts the social fabric of communities and ages the rural workforce. To help the coffee farmers to adapt to global change locally, supportive government strategies would be to improve access to information about markets and climate and to insurance and credit, and to step up support to local cooperatives that supply government input and peer support to the farmers. Policy briefs and extension products have been developed in this project to disseminate this information to decision makers in policy and farmers. As an outcome of the project, the principal investigators were called upon to advise the Guatemalan government on strategies under the UNFCCC.

## **CRN2061 - Caribbean coastal scenarios (CCs): an integrated analysis of Inland-Coastal linkages to guide sustainable use and protection of coastal ecosystems**

*Cuba, Dominican Republic, Haiti, Jamaica, U.S. (lead)*

Increasing populations, agricultural and industrial water use and pollution coupled with a drier future climate raise the pressure on water resources in Caribbean islands. This, in turn, affects economic development and livelihoods. CRN2061 researchers work to understand the relationships between development and water resources in Jamaica, the Dominican Republic and Puerto Rico by monitoring and modeling the effects of land use and climate trends on water quality and variability in so far two watersheds, the Great River and Rio Cobre, Jamaica. Streamflow until 2065 is forecasted to increase by up to 40% in some models, but decreases in others. The forecasted potential evapotranspiration (which indicates higher water losses by plants to the atmosphere) consistently is up by 1-8% until 2065. These balances are regionally disaggregated and coupled with dominant land use in sub-watersheds, which allows identifying more sustainable land uses to reduce evapotranspiration and preserve streamflow, e.g. forest cover. These findings are used in stakeholder workshops in those islands to discuss mitigation and adaptation policies to climate change.

## **CRN2076 - SACC: An international consortium for the study of oceanic related global and climate changes in South America**

### ***SGP-HD076 - Climate change, oceanographic variability and the artisanal fisheries in the South West Atlantic***

*Argentina (lead), Brazil, Chile, U.S.*

Climate variation affects also the productivity and fisheries in the South Atlantic. River outflows concentrate continental constituents in the coastal ocean, and the Rio de la Plata exerts a remarkable influence on the biological, geological and physical characteristics of the continental shelf off eastern South America. The distribution of Plata waters fluctuates seasonally, marking the pace of fisheries along the coasts of southern Brazil, Uruguay and northern Argentina. Inter-annually, the Plata discharge is modulated by the El Niño/Southern Oscillation (ENSO), but its distribution critically depends on the along-shore winds which counteract the ocean currents.

CRN2076 surveys over the shelf and adjacent western boundary currents have revealed important links to global and climate change: the region is a strong sink of atmospheric CO<sub>2</sub>, at rates comparable to the northern North Atlantic. This is due to photosynthesis of phytoplankton around ocean fronts, where vertical circulations bring nutrients to upper layers. Exchange processes between the deep ocean and the Patagonian Shelf determine the primary biological activity here. This is why the Patagonian shelf hosts one of the most productive marine ecosystems on earth. The interaction of the nutrient-rich Malvinas Current with the bottom slope induces permanent upwelling along the shelf break.

Satellite data suggest that step-like structures in the sea floor and barotropic pressure gradients created by the Brazil and Malvinas Currents strongly influence continental shelf circulation, causing a northward spreading of mid-shelf waters from Patagonia up to southern Brazil, creating the strong Subtropical Shelf Front. Similar frontal characteristics have since been identified between the South and Mid Atlantic Bights on the US east coast.

A warmer climate is expected to enhance the vertical stratification in the upper ocean due to warming of the surface ocean. This might trigger a chain of events: It will decrease the flux of nutrients to the upper ocean, which may limit the growth of some phytoplankton groups, reduce the biological carbon uptake, the so-called “biological pump”, and concentrate more CO<sub>2</sub> in the upper layer, thereby further limiting the capacity of the ocean to absorb CO<sub>2</sub> from the atmosphere. The Patagonian continental shelf absorbs large amounts of CO<sub>2</sub> from the atmosphere. In southern Patagonian waters during spring and winter, both the biomass of certain flagellated algal groups and their contribution to autotrophic biomass increased directly with seawater temperature and the level of stratification. This supports the recent idea that increases in sea surface temperature due to global warming could alter the “biological pump” in favor of groups such as dinoflagellates that are less efficient in sequestering carbon.

Despite the high productivity of the region, there are signs of overfishing which together with global change are affecting marine food webs. One prediction yet to be fully documented is the increase of jelly fish population as a consequence and therefore an indicator of the disruption of food webs. The project has tested novel acoustic techniques for the detection and quantitative estimates of jellyfish

abundance which can re-examine past echo records to permit long-term analysis. This provides a unique practical application of the teams' research.

An associated human dimensions project found that shrimp productivity in a large Southern Brazilian lagoon also depends on the balance between ocean currents and river flow. For the regional economy these environmental effects are compounded by policy constraints. Inflexibly set fishing seasons would need to be changed to account for the ecological drivers of productivity shown by this project.

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## 4. Annex: Project statistics

### **Second round of Collaborative Research Network Program (CRNII)**

*2006-2011*

- Total additional funding leveraged: US\$22 472,729 million
- Investigators & co-investigators: 180 (13 PIs, 167 co-PIs)
- Institutions: 97
- Countries: 18
- 318 students have received IAI scholarships
- 560 students involved in projects
- 1144 students participated in project training courses and workshops

### **Small Grants for the Human Dimensions Program (SGP-HD)**

*2007-2009*

- Total additional funding leveraged: US\$4.5 million
- Investigators & co-investigators: 49 (7 PIs, 42 co-PIs)
- Institutions: 33
- Countries: 12
- 24 students have received scholarships
- 43 students involved in projects
- 437 students participated in project training courses and workshops

### **Landuse change, biofuels, and rural development in the La Plata Basin (IDRC)**

*2008-2011*

- Investigators & co-investigators: 29 (1 PIs, 28 co-PIs)
- Institutions: 13
- Countries: 3
- 40 students have received scholarships
- 69 students participated in project training courses and workshops

### **Assessment of research and institutional needs to cope with the effects of climate change on Andean biodiversity (John D. and Catherine T. MacArthur Foundation)**

*2008-2011*

- Investigators & co-investigators: over 400 professionals participated in the consultation process
- Institutions: 183
- Countries: 12
- 7 national meetings held in Bolivia, Colombia, Ecuador, and Peru; 4 regional workshops; 1 science-policy forum

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