Chapter 11
Economics of Land Degradation in Argentina

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Abstract Argentina is one of the countries with a vibrant agricultural sector, which provides both economic development opportunities and environmental challenges. Argentina was selected as a case study due to its rich land degradation data, its diverse agroecological systems, and rapid poverty reduction. The country also represents high human development index countries. This study reports the cost of

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land degradation, the cost of inaction and cost and benefits of taking action against land degradation. The total loss of ecosystem services due to land-use/cover change (LUCC), wetlands degradation and use of land degrading management practices on grazing lands and selected croplands is about 2007 US$75 billion, which is about 16 % of the country's GDP. LUCC accounts for 94 % of the loss, underscoring the need for developing more effective land use planning and incentives land users to protect high value biomes. The returns to taking action against land degradation is about US$4 per US$ invested—justifying the need to take action to improve human welfare and environmental protection. The actions against land degradation include investment in restoration of degraded lands and prevention of land degradation through stricter regulation of agricultural expansion into forests and other higher value biomes. They also include reforestation and other restoration efforts; protection wetlands and restoration of degraded wetlands. The excessive use of agrochemicals also require action to regulate their potential off-site effects. Case studies also show that promotion of rotational grazing, extending conservation agriculture beyond soybean; tillage method and crop-livestock production systems offer promising strategies for addressing land degradation. The world has a lot to learn from Argentina—given its rapid poverty reduction and successful adoption rate of conservation agriculture using public-private partnership. If Argentina aims at maintaining its economic and social development, it will need to work harder to address its growth-related environmental challenges that affect the poor the most. Argentina is better prepared to face these challenges. This study will contribute to informing policy makers on the best strategies for taking action against land degradation and the returns to such actions.

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Introduction

With a GDP of US$ billion 475.502 in 2012, Argentina is the 26th largest economy in the world (World Bank 2014). Argentina has made significant economic progress in the past three decades. between 2000 and 2011, the country's middle income class increased from 34 to 53 % of the population of 41.8 million and people below the international poverty line (US$1.25 per capita per day) fell from 12.6 % in 2002 to only 0.92 % in 2010 (World Bank 2014). In three decades, the country's GDP per capita increased by about 40 % from 2005 US$4628 in 1981–90 to 2005 US$ 6388 in 2001–13 (World Bank 2014). What is even more interesting is that Argentina's "Doubly Green Revolution" (Conway 1997), seen from an on-farm-perspective, achieved higher agricultural productivity at lower energy and less pollution, compared to other countries using more intensive agricultural production technologies. A study by Viglizzo et al. (2011) of 1197 different farming systems ecological and environmental performance—which is quantified as the stocks and fluxes of soil carbon, nitrogen and phosphorous on water pollution, soil erosion, habitat intervention and greenhouse gas (GHG) emissions per hectare—showed significant increase in agricultural productivity but a negative impact on habitats and GHG emission. Due to widespread adoption of conservation agriculture (CA)—which in 2013 accounted for 64 % of cropland (AQUASTAT 2013)—and application of less aggressive pesticides, soil erosion, nutrient balance, and energy use per hectare were significantly less than other countries with intensive agricultural production, such as East Asia, West Europe, and the USA (Ibid). Another study showed that use of round-up ready herbicide—or glyphosate—which WHO puts in class IV of lowest toxicity level, led to a consumer surplus of US$ million 335.0 compared to a conventional tillage method and use of more aggressive pesticides (Qaim and Traxler 2005). However, recent experimental evidence show that glyphosate probably has carcinogenic characteristics—i.e. genotoxicity and pro-oxidant activities both in vitro and in vivo (IARC 2014). Consequently, the WHO has put glyphosate into a 2A class—i.e. "probably carcinogenic to humans" (IARC 2014).

As is the case with other middle income countries however, Argentinais experiencing environmental challenges as its economy grows. As the demand for soybean and livestock production increased, large-scale farmers have been acquiring more land—leading to migration of small farmers to urban areas (Paula and Oscar 2012). For example, Altieri and Pengue (2006) estimated that about a quarter of small farms in Argentina were acquired by large-scale farmers in 1998–2002 alone. The fast expansion of soybean, other crops, and pasture has led to deforestation and other land use/cover change (LUCC) that have led to a loss of ecosystem services.

Use of agrochemicals (measured in kg/ha) in Argentina has increased by 1000 % in the last 20 years, and glyphosate accounts for 75 % of the use in 2006 compared with only 50.1 % in 1991. Such large increase in herbicide use poses a concern for the ecosystems in the soybean farming area. It is for this and other reasons that Argentina is debating the overall social and environmental costsand benefits of GMO-based crop production.

While case-studies from the scientific sector are increasingly warning about harmful effects of glyphosate (Paganelli et al. 2010) on human health and the environment, other studies stress the benefits of conservation agriculture (CA) derived from the use of glyphosate and other herbicides, along with Argentina's comparative advantage of soybean production and its role in the modern global economy.

This study was conducted to analyze the economics of land degradation in Argentina as a case study. Argentina was selected as a case study to represent Latin American countries, specifically those that are middle income countries and those which experienced rapid economic growth. Argentina was also deemed an ideal case study since it is one of the Food and Agriculture Organization's (FAO) case study countries of the Global Land Degradation Assessment (GLADA). Argentina is also a good case study because it represents major agroecological zones in Latin America. The country spans from humid pampas and sub-tropical rainforest in the north to the Patagonia desert and additional arid areas in the north-west (Chap. 2).

The study was conducted in collaboration with the National University of Arturo Jauretche and a number of other national institutions such as the National Secretariat for Environment and Sustainable Development, the National Institute for Agricultural Technology, other National Universities, and local experts and technicians from the field. Four case studies in Argentina were conducted by the collaborating institutions to provide strong ground-validation and varying examples and land degradation.

The next section discusses the major natural resource management policies in Argentina. This is followed by discussion of the analytical approaches and data. The national level and four case study results are then discussed. The last section of the chapter discusses the major conclusions and their policy implications.

Natural Resource Management Policies in Argentina

The discussion below focuses on Argentina's policies on sustainable development and its implications on land management and decentralization of natural resource management. The discussion largely dwells on how such policies have been implemented.

Sustainable Land Management Enshrined in Argentina's Goal of Achieving Sustainable Development

Argentinasustainable development has achievement and challenges. The country's per capita CO_2 emission and withdrawal of water as percent of total renewable freshwater are both lower than the very high human development group to which Argentina belongs (Fig. 11.1). However, Argentina has higher depletion of natural resources as percent of gross national income (GNI) than countries with very high human development but lower than in LAC. Additionally, Argentina's deforestation rate is higher than the average in LAC. Forest cover in very high human development countries has actually increased—suggesting Argentina has a big challenge in matching such environmental achievement.

To address such challenges, Argentina has been increasingly formulating policies to address deforestation and other types of land degradation. As of 2009, the Minimum Standard Natural Forest Protection Law was setup to combat deforestation. It is the first federal compensation scheme in which provinces receive payment protecting forest through territorial planning and enforcement. About US$ 100 million have been paid out through the Minimum Standard Natural Forest Protection Law. About 19 % of the natural forest (916,255 ha) is under protection. The Minimum Standard Law requires provincial governments to implement comprehensive and participatory Land Use Planning Processes (LUPPs) to protect native forests (Seghezzo et al. 2011). The law established a moratorium on forest concessions, until each Province drafts a LUPP that comply with the Native Forests environmental criteria (Regúnaga and Rodriguez 2015). The forest law also requires provinces to perform environmental impact assessment and holding public hearing before any forest concessions are issued. Additionally, the forest law requires provinces to respect the rights of indigenous communities (Ibid). The Minimum Standard Law is under the mandate of the National Secretariat for

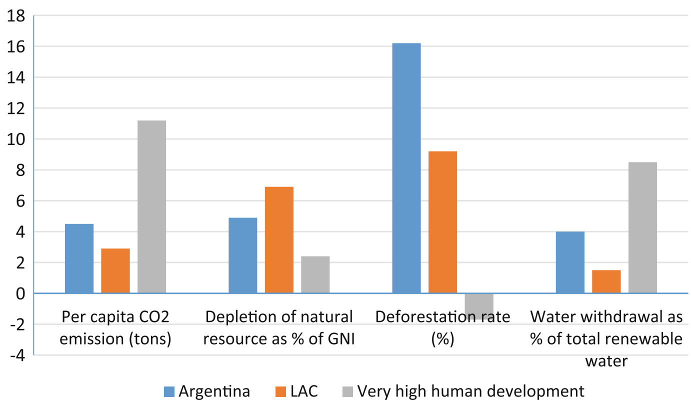


Fig. 11.1 Argentina's sustainable development achievement and challenges. *Source* Calculated from UNDP (2014)

Environment Sustainable Development, which coordinates a number of ministries and departments.

Likewise, the Environmental Report 2012 of the National Secretary of Environment and Sustainable Development of Argentina recognizes that land degradation is a major challenge in Argentina. Accordingly, Argentina ratified the United Nations Convention to combat Desertification (UNCCD) in 1996. In order to implement the UNCCD objectives, the Secretary for Environment and Sustainable Development prepared the National Action Plan (NAP) to coordinate all major sustainable land management (SLM) projects and programs. Argentina was one of FAO's six case study countries selected for studying Land Degradation Assessment in Drylands (LADA). As a follow-up to LADA, Argentina established the National land Degradation Observatory whose objectives are to monitor and assess land degradation and improvement in order to help formulate policies and strategies for controlling and mitigating land degradation and desertification. Seventeen representative land degradation and improvement observatory field sites have been identified for regular data collection. The National Land Degradation Observatory also facilitates exchange of information among ministries, departments, and other institutions that are directly and indirectly involved in land management.

The effect of foreign direct investment on the environment has also been a major concern since it increased significantly in the early 2000s. For example, in 2003 transnational corporations (TNC) accounted for more than 80 % of the value added generated by the 500 largest companies in Argentina (Chudnovsky and López 2008). About 5.9 % of the rural land area in Argentina is owned by foreigners. To address this problem, the Argentine Government passed a National Law on Land Grabbing in 2012 which limits foreign land acquisition to a maximum of 15 % per Federal State. It also creates a National Registry of Rural Land which monitors land acquisitions.

Argentina is also grappling with degradation of wetlands. Argentina ratified the RAMSAR Convention in 1991 and the country has 21 registered wetlands covering about 5 million ha.[1] Nonetheless, there is an increasing pressure on urban and peri-urban costal-wetlands, mainly as the result of urban and agriculture expansion and cattle ranching.

Given that agriculture contributes 56 % of Argentina's total value of exports (Regúnaga and Rodriguez 2015), the country has invested significantly to sustainably increase productivity in the sector. The Ministry of Agriculture promotes sustainable agricultural production through its Program of Agricultural Services in Provinces (PROSAP). The general objective of the PROSAP is to sustainably increase productivity and market participation at the provincial level. On average a total of 373.4 million is allocated to agriculture annually to support (with share of support in brackets) INTA (40 %), National Food Safety and Quality Service or SENASA[2] (39 %), PROSAP (10 %) and the remaining 11 % was allocated to family farming and regional development (Regúnaga and Rodriguez 2015).

[1]RAMSAR Argentina: http://www.ambiente.gov.ar/?idarticulo=1832.

[2]SENASA = Servicio Nacional de Sanidad y Calidad Agroalimentaria.

Decentralized Natural Resource Management

Natural resource management in Argentina is highly decentralized. According to article 121 and Article 124 of the constitutional amendment, provinces "… have original ownership of natural resources existing in their territory." (República de Argentina 1994). The Federal Government holds mandate to influence the Natural Resource Management policies by setting guidelines and directives for provincial level environmental policy and institutional formulation. For example, the Federal government sets legal minimum environmental standards frameworks. National level economic policies and regulations also dictate the corresponding policies and regulations at provincial level that the provincial governments could formulate. For example, Argentina is a signatory of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This means provincial governments cannot be engaged in selling endangered species. The Federal government also has subsidy and tax regulations that apply to the entire country.

Research and extension services are also decentralized and operated by National Council of Scientific and Technical Research (CONICET), dedicated to the promotion of science and technology in Argentina, and the National Institute of Agricultural Technology (INTA). Nationwide, INTA has 15 regional centers, 5 research institutes, 50 experimental field-sites and more than 300 extension units. Since 1956 INTA has been conducting research activities and technological innovation that are specific to regions and agroecological zones. The research and extension services have focused on simultaneously increasing productivity and competitiveness and enhancing sustainable development. INTA also has public-private partnership that engages the private sector in provision of research and extension services as well as direct assistance to farmers. For example, PROHUERTA Program—a public policy implemented through the INTA—provides technical services and agricultural input support programs to family farms in peri-urban, urban, and rural areas. PROHUERTA also promotes marketing services to family-based agricultural production. More than three million people have participated in family farming through PROHUERTA.[3]

Analytical Approach

We briefly discuss the analytical approach used in this chapter.[4] As discussed in Chap. 6, we divide the causes of land degradation into two major groups and evaluate the cost for each:

[3]PROHUERTA: http://prohuerta.inta.gov.ar/.

[4]For details of the analytical approach, see Chap. 6.

(i) Loss of ecosystem services due to LUCC that replaces biomes that have higher ecosystem value with those that have lower value. For example, change from one hectare of forest to one hectare of cropland could lead to a loss of ecosystem services since the total economic value (TEV) of a forest is usually higher than the value of cropland. We focus on five major land use types: cropland, grassland, forest, woodland, shrublands and barren land. We do not include wetlands because of their small extent (5 %).

(ii) Using land degrading management practices on a static land use, i.e. land use did not change from the baseline to endline period. Due to lack of data and other constraints, we focus on cropland only.

The approach used for cost of land degradation due to LUCC and use of land degrading management practices on static cropland is discussed in detail in Chap. 6. The approach for determining the cost of action for degradation due to LUCC is also discussed in Chap. 6. Analytical methods for cost of land degradation on static grazing are discussed in Chap. 8.

For analysis of cost of land degradation due to use of land degrading management practices on static cropland, we focus on four major crops: maize, rice, soybean and wheat, which in total cover about 67 % of cropland Argentina (Table 11.1).

Maize, wheat and rice yields have been increasing in most countries despite land degradation. As Fig. 11.2 shows, this is the case for all four crops considered. Use of improved seeds and higher fertilizer application rates account for the yield increase. Nitrogen fertilizer rate increased significantly over the past two decades from 12 to 21 kg/ha (FAOSTAT).

We also use some case studies to illustrate the cost of land degradation for crops and livestock for selected sites. The analytical methods used for each case study are discussed briefly in the case study section.

Table 11.1 Cultivated area of the three most important crops in Argentina

Crop	Area (million ha)	% of total
Soybeans	15.44	44.1
Wheat	4.93	14.1
Maize	3.00	8.6
Rice	0.18	0.5
Total	23.55	67.3

Source FAOSTAT (2015)

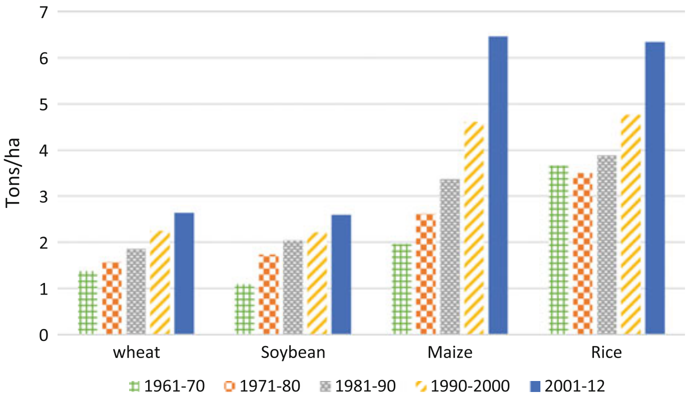


Fig. 11.2 Crop yield trend of wheat, soybean, maize and rice in Argentina, 1961–2012

Data

LUCC

We use the Moderate Resolution Imaging Spectroradiometer (MODIS) landcover data to analyze land-use and land-cover change (LUCC). MODIS data are collected by NASA's two satellites (Terra (EOS AM) and Aqua (EOS PM)) and have three levels of resolutions (250, 500, and 1000 m) (NASA 2014) and were launched in December 1999. For our study we use the 500 m spatial resolution land cover data that matches the International Geosphere-Biosphere Program (IGBP) land cover classification scheme. The MODIS land cover data are quality controlled and ground-truthed (Friedl et al. 2010). The overall accuracy of land use classification is about 75 % (Friedl et al. 2010).

Total Economic Value Data

We derive the TEV from the economics of ecosystems and biodiversity (TEEB) database, which is based on a number of case studies in Latin America and Caribbean (LAC) countries shown in Fig. 11.3. Unlike the approach used in Chap. 6, we include inland wetlands. It is clear that the studies are well-distributed in LAC.

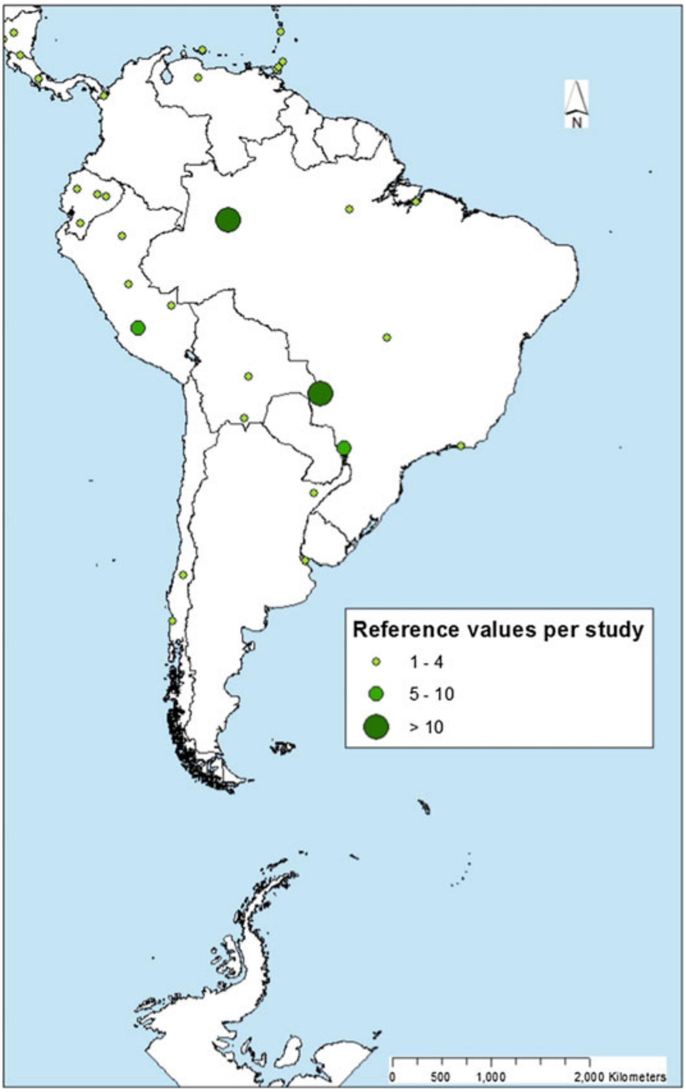


Fig. 11.3 Location of TEEB database of terrestrial ecosystem service valuation studies in LAC. *Source* Derived from TEEB database, the TEV of the five major biomes is shown below

Land Degradation on Static Cropland

DSSAT Crop Simulation

The DSSAT crop simulation baseline land management practices were based on a compilation of global dataset and literature reviews. Given that there is a large difference between irrigated and rainfed land management practices, both the baseline and ISFM scenarios for irrigated and rainfed systems are simulated separately. In the irrigated simulation, a water management scenario is only applied to areas where water management is practiced.

We face a challenge to determine the adoption rate of ISFM in Argentina, a country that has not done an agricultural survey. We use adoption of CA as an indicator of ISFM and assume the 64 % adoption rate for maize, wheat and rice and 100 % for soybean.

Land Degradation on Static Grasslands

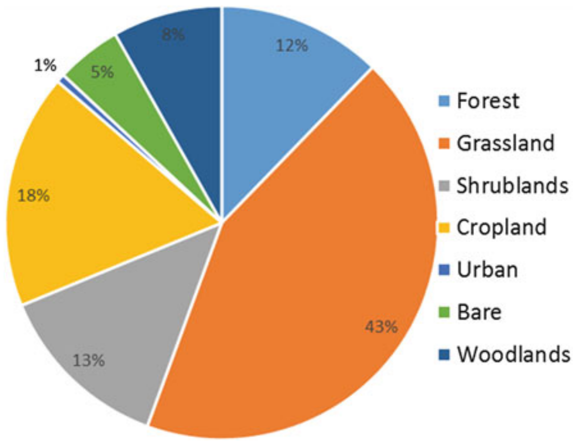
Details of data used for calculation of cost of land degradation on static grasslands are given in Chap. 8.

Land-Use/Cover Change in Argentina

About 43 % of Argentina's land was covered with grasslands (pampas) in 2001 (Fig. 11.4). Pampas covers most of the Buenos Aires, La Pampa, Santa Fe, Entre Ríos and Córdoba provinces. Croplands is the second largest biome accounting for about 18 % of the land area (Fig. 11.4). As Fig. 11.5 shows however, significant land-use/cover change (LUCC) has occurred.

About 10 % of forested area in 2001 was cleared and the clearance was most significant in the humid area in northwestern Argentina (Table 11.2). This is also consistent with Volante et al. (2012) who used MODIS data to calculate changes. Land clearing was done mainly for crop production and ranching (Ibid).

Fig. 11.4 Argentina land use type, 2001



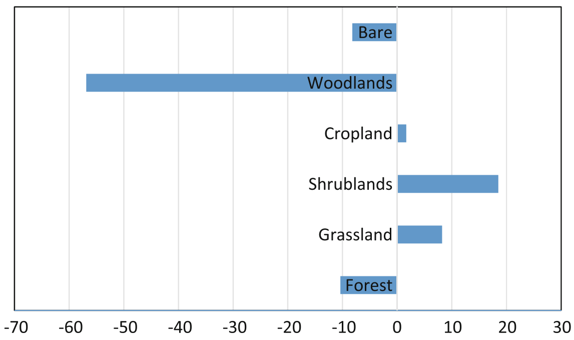


Fig. 11.5 LUCC in Argentina, 2001–09

Table 11.2 Landuse/cover change (LUCC) in Argentina, 2001–09

Agroclimatic zone	Area (million ha), 2001	Loss	Gain	Change (%)
	Forests			
ASAL	10.73	1.3	3.1	17
Sub-humid	17.74	7.4	4.1	−19
Humid	5.25	2.5	0.6	−36
Total	33.71	11.2	7.7	−10
	Grasslands			
ASAL	114.51	10.3	6.3	−3
Sub-humid	4.35	7.5	16.6	209
Humid	0.23	0.9	5.6	2043
Total	119.09	18.7	28.5	8
	Shrublands			
ASAL	14.83	8.1	13.5	36
Sub-humid	14.8	1.9	3.1	8
Humid	6.6	0.2	0.3	2
Total	36.23	10.1	16.8	18
	Woodlands			
ASAL	4.16	3.7	1.4	−55
Sub-humid	15.03	12.5	3.7	−59
Humid	3.31	2.8	1.1	−51
Total	22.5	19	6.2	−57
	Croplands			
ASAL	5.09	1.9	1.9	0
Sub-humid	39.48	7	8.9	5
Humid	3.61	2	0.9	−30
Total	48.17	10.9	11.7	2
	Bare			
ASAL	13.13	3	2.1	−7
Sub-humid	0.2	0.1	0	−50
Humid	0.07	0	0	0
Total	13.4	3.2	2.1	−8

Notes ASAL (<700 mm/year); Sub-humid (700–1200 mm/year); Humid (>1200 mm/year)

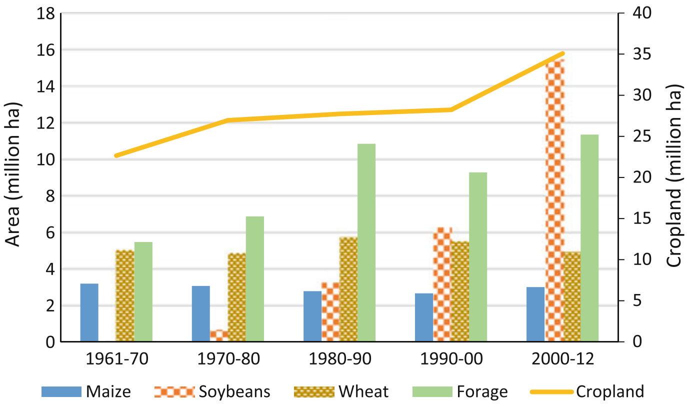


Fig. 11.6 Decadal trend of harvested area of major crops and forage, Argentina

Producing about 49.3 million tons of soybean in 2013, Argentina is the third largest soybean producer in the world—after USA and Brazil (FAOSTAT 2015). Argentina's soybean processing industry in Rosario region is the largest in the world (Altieri and Pengue 2006). The increasing demand for soybean is driven by the increasing demand for animal feeds and biodiesel (Tomei and Upham 2011). Currently, soybean accounts for about 44 % of cropland in Argentina (Fig. 11.6). On the positive note however, use of CA has increased Argentina's agricultural energy use efficiency (Friedrich et al. 2009; Viglizzo et al. 2011). The rapid adoption of CA in Argentina was a result of close collaboration of private companies selling agrochemicals,—particularly herbicides and GM seeds—agricultural extension service providers, and agricultural ministries and department. Such public-private partnership underscores the importance of collaborative efforts for promoting new technologies..

Results

Land Degradation Due to LUCC

Argentina loses about US$70 billion ecosystem services due to LUCC-related land degradation (Table 11.3), an amount which is equivalent to 27 % of its GDP or 12 % of the total value of its ecosystem services (Fig. 11.7). Considering only provisioning services that are locally tangible, cost of land degradation as share of GDP is 12 %. This underscores the high cost of land degradation and the need for the government to take action. The losses were highest in the subhumid zone, which accounted for 82 % of cropland area in 2001 (Fig. 11.6). Grassland area in the subhumid zone more

Table 11.3 Cost of land degradation due to LUCC

	ASAL	Sub-humid	Humid	Argentina
TEV 2001	418.9	180.4	46.5	645.8
Annual cost of land degradation	2007 US$ billion			
– All ecosystem services (ES)	22.0	38.6	9.0	69.7
– Provisioning services only	12.9	15.7	3.3	31.9
Cost action 30 years	36.6	67.7	19.1	123.4
Opportunity cost of taking action	35.7	66.5	18.9	121.1
Cost of inaction, 30 years	163.6	259.5	63.8	486.9
MRR of taking action	4.5	3.8	3.3	3.9

Note: *ASAL* Arid and semi-arid lands

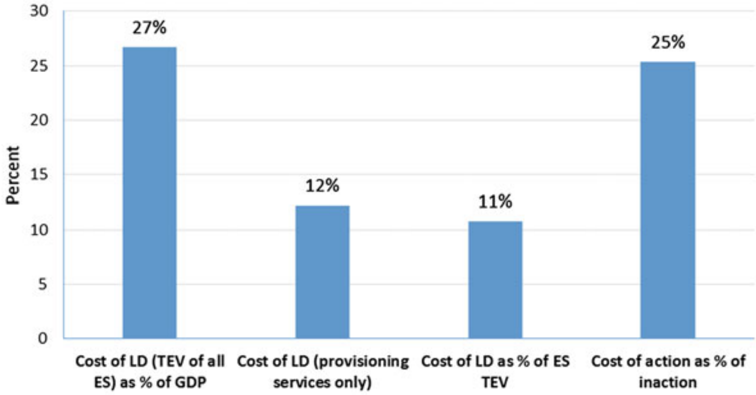
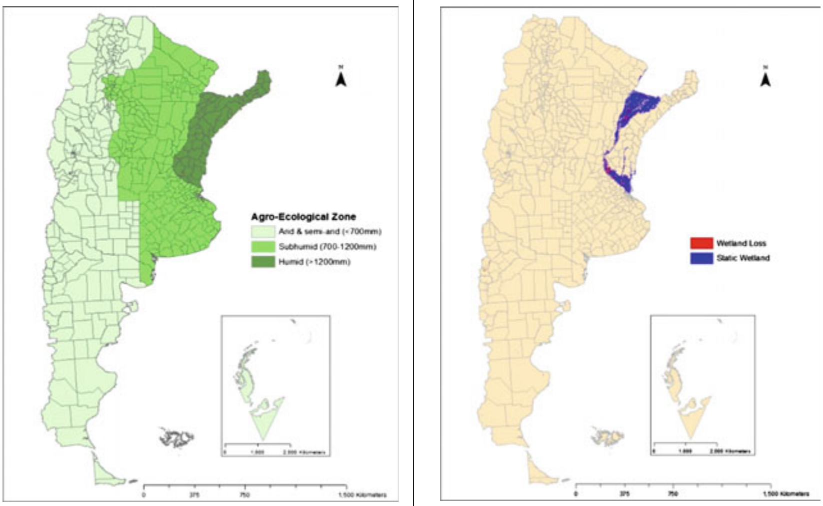


Fig. 11.7 Cost of land degradation as percent of GDP and ecosystem service TEV

than doubled while cropland area increased by about 3 million ha between 2001 and 2009 (Table 11.2). The ecosystem losses in the subhumid area accounted for about 55 % of the total value of land degradation (Table 11.3). Similarly there was a net loss of about 2 million ha of forest area in the humid zone. This is consistent with Altieri and Pengue (2006) and confirms the loss of biodiversity and ecosystem services in pristine forests due to expansion of crop and livestock production.

Using a 30 year planning horizon, the cost of inaction against land degradationis about half a billion 2007 US dollars. Taking action against land degradation over the same period 30 years will cost only 2007 US$123.4 Billion or 25 % of the cost of inaction. The marginal rate of returns (MRR) for taking action against land degradation is about 4, which indicates high pay-off for taking action to prevent LUCC-related land degradation or restore higher value biomes. This further provides empirical evidence for taking action to prevent land degradation or rehabilitate degraded lands in Argentina. Action would include strict protection of forest area and prevention of LUCC that replaces high value biomes with low value biomes. Regulating crop-landexpansion is also required to ensure the country keeps its rich biomes.



Agroclimatic zones	Wetland losses, 2005-09

	Area (million km)	Land area	Forest	Grass-lands	Shrub-lands	Crop-lands	Urban	Bare	Wood-lands
	Percent of national total								
Arid & semi-arid (<700 mm)	1.64	59	32	96	41	11	38	98	18
Subhumid (700-1200 mm)	0.95	34	53	4	41	82	55	1	67
Humid (>1200 mm)	0.20	7	16	0	18	7	7	1	15

Fig. 11.8 Agroclimatic zones and extent of wetlands loss

Land Degradation Due to Loss of Wetlands

Wetlands covered about 6.4 million ha in 2005 or 2.3 % of the land (Table 11.5). Even though Argentina is a signatory of the RAMSAR convention—whose mission is “conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world”—the country lost about 750,000 ha of wetlands in only five years (Table 11.5). In an attempt to understand the nature of loss and their relationship to MODIS land use types used in the cost of land degradation discussed above, we overlaid the GlobCover, which defines wetlands in more detail in Argentina than MODIS. Results show that about a third of the wetlands lost were located in the grasslands and 29 % were located in areas which MODIS classifies as permanent wetlands (Table 11.4 and Fig. 11.7). During field visits of the ELD team in Patagonia, ranchers and INTA scientists explained that the loss of wetlands in grasslands was mainly due to overgrazing—which forms gullies that lead to

Table 11.4 Loss of wetlands and their relationship with MODIS land use types

MODIS land use type	GlobCover wetland area (000 ha)				% of total loss
	2005	2009	Loss	% loss	
Forest	467.5	384.9	82.7	17.7	11.0
Shrublands	976.1	854.8	121.3	12.3	16.2
Grasslands	2952.3	2703.7	248.7	8.4	33.2
Wetlands/natural vegetation	1632.5	1412.6	219.9	13.5	29.3
Cropland	326.9	253.6	73.3	22.4	9.8
Urban	15.3	12.2	3.1	20.4	0.4
Barren	2.3	1.5	0.8	35.87	0.1
Total	6373.0	5623.2	749.7	11.8	

drainage of the wetlands. For example, Molihue wetlands has drained because overgrazing occurred upstream and soil erosion occurred forming gullies that drained the wetlands in the grasslands. Loss of wetlands leads to lower livestock productivity since they serve as grazing areas during the dry season (Fig. 11.8).

In highly populated rural areas, wetlands have been drained by construction of canals connecting inland wetlandswith rivers, valleys and other natural drainage systems (de Prada et al. 2014). This was done in response to sporadic flooding, which prompted farmers and rural communities to ask local and federal governments to construct canals. The wetland draining canals—or locally known as canalization—increased from 97 km in 1975 to 504 km in 2001. The canalization changed hydrologic systems and led to stronger runoff (Ibid). The rural canalization and poor construction of drainage systems in urban areas has resulted in even more flooding and sedimentation (de Prada et al. 2014; Tucci 2007). For example, Buenos Aires has suffered frequent flooding due to its location along the River Plata, unplanned settlement in wetlands, and other low-lying areas and poor drainage systems (Tucci 2007).

Discussion with scientists during a field trip of the authors also revealed that about 20 % of Buenos Aires wetlands have been lost due to mining soils for making bricks and building houses on wetlands. Drainage of wetlands for brick making has also occurred in other countries. For example, the extent of Uganda's wetlands decreased from 32,000 km^2 in 1964 to 26,308 km^2 in 2005, or about a 20 % loss, where brick making was one of the leading drivers of such loss (Aryamanya-Mugisha 2011). Brick making is a lucrative business in urban areas since natural gas and oil used is subsidized at a rate of about 65 %. This leads to overuse of oil and gas for brick making.

Loss of wetlands leads to high costs since they provide a number of ecosystem services and their total economic value (TEV) is second only to coral reefs. The TEV of wetlands is about 2007 US$25,682/ha (De Groot et al. 2010). Table 11.5 shows that in 2005–09, about 12 % of wetlands in Argentina was lost. The TEV of the lost wetlands is about 2007 US$3.85 billion or 1.5 % of the 2007 GDP. The losses of provisioning services of other biomes is high. For example,

Table 11.5 Wetland loss in Argentina

Class	2005	2009	% loss
	000 ha		
Closed to open (>15 %) broadleaved forest regularly flooded (semi-permanently or temporarily)—fresh or brackish water	11.2	11.2	0 %
Closed (>40 %) broadleaved forest or shrubland permanently flooded—saline or brackish water	0.2	0.2	0 %
Closed to open (>15 %) grassland or woody vegetation on regularly flooded or waterlogged soil—fresh, brackish or saline water	6366.3	5615.9	11.8 %
Cost of loss (US$ million)			19,271.78
Cost of loss per year (US$ million)			3854.36
Loss as % of GDP (2007 US$260.769)			1.5 %

Notes One hectare of inland wetlands is worth about US$25,682/ha (de Groot et al. 2010)
Other types of wetlands identified by the GLC2000 are closed to open (>15 %) broadleaved forest regularly flooded (semi-permanently or temporarily)—fresh or brackish water, which covers 11,150 ha. The second category is Closed (>40 %) broadleaved forest or shrubland permanently flooded—saline or brackish water, which covers only 175 ha
Sources GlobCover (2005, 2009)

de Prada et al. (2014) estimated that the annual cost on cropland due to wetland degradation is about $128/ha.

Weak enforcement of environmental laws is the major reason behind wetland degradation, soil mining for brick making, and poor zoning of house construction (de Prada et al. 2014). In general, it seems that proper land-use-planning is the solution to this problem. In order to protect the country's most important and most affected wetland areas, coordinating between different stakeholders and federal jurisdiction, the national Government created the Plan for Integral Strategic Planning for Conservation and Sustainable Development of the Paraná Delta Region (PIECAS—DP). Its main objective is to set up a territorial land-use which enables the maintenance of the ecosystem services provided by the Paraná wetlands to more than 15 million people.[5]

Land Degradation Due to Use of Land Degrading Practices on Soybean Maize, Rice and Wheat

Land degradation due to using land degrading management practices in Argentina is about US$81 million, which is largely due to use of inorganic fertilizer only on the three crops.

[5]See this program: http://obio.ambiente.gob.ar/plan-integral-estrategico-para-la-conservacion-y-el-desarrollo-sustentable-en-la-region-delta-del-parana—piecas-dp_p339.

The loss is not including the environmental degradation due to overuse of agrochemicals (Jergentz et al. 2005). As discussed, agrochemical use increased tenfold in the last 20 years. This leads to air pollution that in turn causes loss of pollinators and other fauna and contamination of water resources. Both types of externalities affect people's health (Tomei and Upham 2009).

A study conducted by the National Institute for Agricultural Technology (Cruzate and Casas 2009)[6] on soil depletion due to excessive nutrient extraction on the main mono-cultivars (wheat, maize and sunflower), had alarming results, showing that nutrient balance is −60 %. The study also ranked the crops by soil nutrient mined per unit quantity harvested and found that soybean is a leading nutrient mining crop followed by sunflower and maize. In 2006/07 alone, about 2.3 million tons of soil nutrients were mined without replenishment.

Land Degradation on Static Grasslands

Argentina loses about 2007 US$0.6 billion per year due to degradation of grazing lands. This is equivalent to about 11 % of livestock GDP of US$5490 in 2005 (FAO 2005). The loss is largest in the subtropic-warm/semi-arid, arid, and humid areas (Table 11.6). This is not surprising given that the subtropic humid areas have

Table 11.6 Cost of grazing land degradation in Argentina

AEZ	Milk	Meat	Total
	Cost of land degradation (2007 US$ million)		
Boreal	0.973	1.006	1.979
Subtropic-cool/semi-arid	8.215	0.797	9.012
Subtropic-cool/arid	20.67	1.501	22.172
Subtropic-cool/sub-humid	0.152	0.035	0.187
Subtropic-warm/semi-arid	141.17	6.413	147.583
Subtropic-warm/arid	154.892	8.852	163.744
Subtropic-warm/humid	167.65	10.386	178.036
Subtropic-warm/sub-humid	28.976	1.205	30.181
Temperate/semi-arid	0.393	0.02	0.413
Temperate/arid	19.101	12.049	31.151
Temperate/sub-humid	0.137	0.012	0.149
Tropic-cool/semi-arid	0.708	0.054	0.762
Tropic-cool/arid	0.35	0.022	0.372
Tropic-warm/semi-arid	0.028	0.001	0.029
Total	543.415	42.354	585.769

[6]See report: http://inta.gob.ar/documentos/extraccion-de-nutrientes-en-la-agricultura-argentina/at_multi_download/file/Extraccion_de_nutrientes.pdf.

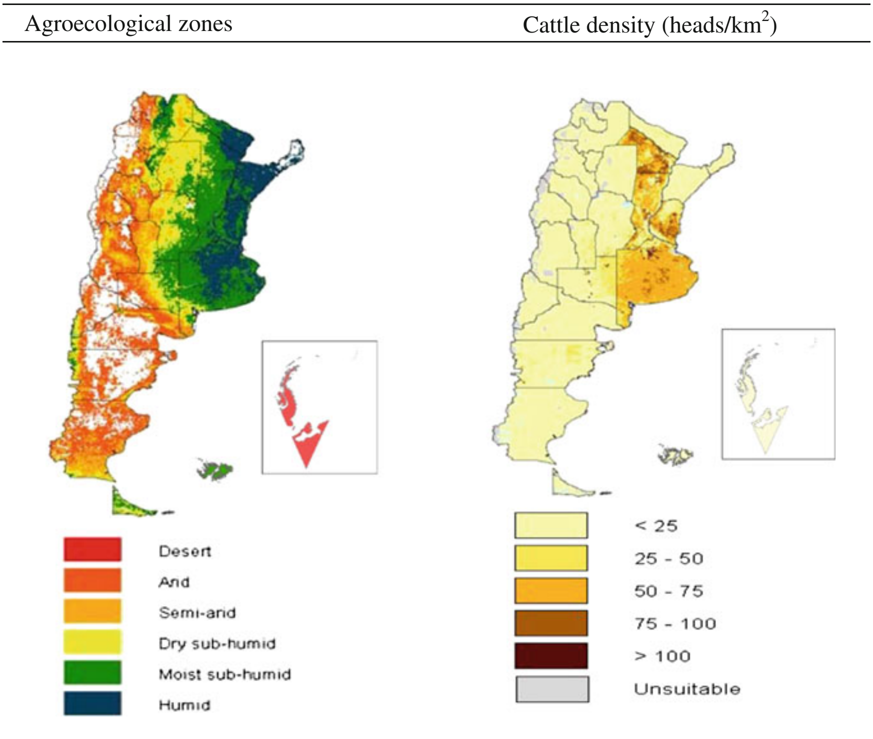


Fig. 11.9 Agroecological zones and corresponding cattle density, 2000. *Source* Extracted from FAO (2005)

the highest concentration of livestock(Fig. 11.9). The losses arising from reduced milk production account for over 90 % of loss. This shows the milk production sensitivity to biomass production.

Case Studies

Patagonia Rangelands and Merino Wool Production

The wool production in Argentina is predominant in the Patagonia steppe, an area which covers about 800,000 km^2 (Ares 2007). The pastoral communities in Patagonia have raised their sheep using a traditional extensive and continuous grazing practice in which grazing is done with minimal human control of livestock movement (Ares 2007; Oliva 2012). Because sheep are highly selective grazing herbivores (Cibils et al. 2001), continuous grazing has led to depletion of preferred forage, such that even after fallowing, palatable forage does not fully recover

(Ares 2007). For example, long-term studies have shown that full recovery of preferred forage required two to three decades of resting in eastern Patagonia (Bertiller et al. 2002).

Rotational grazing has been shown to sustainably keep the preferred forage productivity. The recommended rotational grazing requires putting sheep in the wetlands (malines) during the dry season and in the highlands during the spring season (Golluscio et al. 1998). A special type of rotational grazing has been developed by the Rangeland Research Program at the national research institute—INTA. The recommendation is called a low input management technology (Tecnología de Manejo Extensivo—TME)—appropriately nicknamed "take half leave half". TME is a grazing plan developed after remote sensing assessment is done to determine the carrying capacity. The farmer is advised to manage grazing such that half of aboveground biomass preferred forage is left before animals are moved to another paddock (Anderson et al. 2011).

As discussed above, there has been degradation of wetlands in Patagonia, which has also affected grassland productivity. Additionally, climate change has further reduced the carrying capacity of pasture in Patagonia. The recent volcanic eruption in Chile also deposited ash on pasture, causing significant loss of merino wool production (Easdale et al. 2014). Worse still, wool prices have been falling since World War II largely due to increased used of synthetic fiber (Jones 2004). As a result, sheep population in Argentina fell from about 50 million in 1961 to 15 million heads in 2013 (FAOSTAT 2015).

Despite the decrease in sheep population however, rangeland degradation has continued to occur due to continuous grazing. According to Golluscio et al. (1998) widespread adoption of rotational grazing is constrained by three major challenges: (i) slower recovery of preferred forage due to the fact that fallowing should occur during pasture growth, which is in the spring and early summer period when there is ideal precipitation and temperature. In drier areas, livestock movement during this time is harder (ii) animal movement increases mortality of lambs and therefore is not preferable to farmers (iii) a cultural system of uncontrolled grazing is the major constraint to adoption of rotational grazing. For example, due to the strongly held traditional continuous grazing systems, only 6 % of sheep farmers in southern Patagonia have adopted TME (Anderson et al. 2011). Below, we discuss a case study in Jacobacci to better understand the impact of land degradationand climate change. This study illustrate the steps that the federal and provincial government have done to help farmers cope with land degradation, climate change, and volcanic ash deposition.

Starting with the case study in Jacobacci, following are four case studies highlighting different issues of land degradation in Argentina. Figure 11.10 highlights these areas which are discussed below.

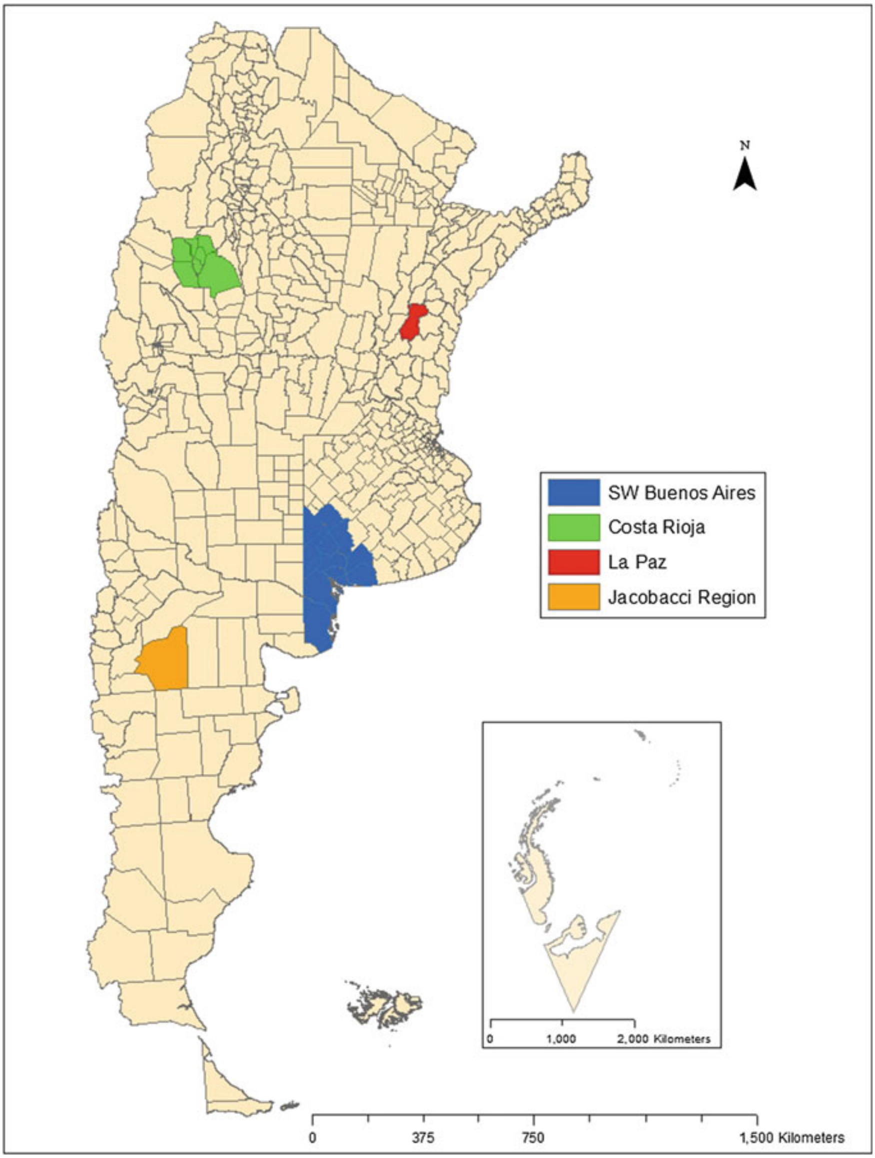


Fig. 11.10 Case study locations of land degradation

Jacobacci Patagonia Case Study

Jacobacci is located in the southwest of the Rio Negro province (Fig. 11.10) and has predominantly semi-shrubby-grass steppe vegetation and Aridisoles and Entisoles soils. There are about 900 farms practicing extensive sheep and goat rearing for wool. About 54 % of farms have fewer than 2500 ha and the remaining share of farmers have larger farms.

As is the case for other areas in Patagonia, overgrazing is a common problem in Jacobacci (Ares 1990). This has resulted in a loss of vegetation and consequently accelerated water and wind erosion (Rostagno and Degorgue 2011). However, the sheep population has declined from more than 750,000 heads in 1930 to the current population of fewer than 350,000 heads. The falling wool price has been the major driver of the declining sheep population. Climate change, which has led to a longer dry season and deposition of volcanic ash from the eruption of mount Puyehue volcano-Caulle in 2011 have also contributed to falling sheep population. This has led to migration of some sheep farmers to urban areas and job losses of farm workers. To address land degradation, the TME recommendation has been given but its adoption rate remains low (Anderson et al. 2011). Diversification to wool and mutton (meat sheep) has also been one of the strategies to address the falling wool price. The sheep farmers also have received from federal and provincial programs compensation for the losses caused by volcanic ash deposition. Other programs include subsidies and low or zero interest loans. Some investments have also been made to improve sheep production. They include construction of shearing and calving sheds, paddock construction with electric fencing to help adoption of rotational grazing and TME, and improving access to drinking water, etc. Strengthening of local institutions have also been promoted through sheep producer organizations and cooperatives. In the past 5 years a range of grants from the National Institute of Indigenous Affairs was also established. The farmer groups and cooperatives have received a variety of assistance in the form of subsidies and zero or low interest rates, etc.

Crop and Livestock Production in La Paz

The La Paz case study lies in the humid agroecological zone with an annual precipitation of 1100 mm and temperatures below 20 °C, it covers an area of 74,691.30 ha (Fig. 11.10). The major economic activity in La Paz is crop and livestock production, but cattle production accounts for the largest land area. Compared to Patagonia however, farmers in La Paz have smaller farms as 72 % of the area is occupied by farmers with smaller than 100 ha lot sizes. The type of land tenure is leasehold, sharecropping and renting.

Land degradation processes. Social and Economic Impacts: Anthropogenic activities in La Paz have resulted in reduced vegetation cover but with increasing heterogeneity (Secretaría de Ambiente y Desarrollo Sustentable de la Nación 2007). The extent of native forests is 42,726.91 ha, of which 59.1 % has not experienced LUCC. The disturbed forest are replaced by succession forests—trees and shrubs that grow on a recently disturbed area—whose dominant trees are exotic species such as Gleditsia triacanthos, Melia azedarach, Morus alba and Ligustrum lucidum (Sabattini et al., In review).

Agricultural expansion is the main driver of LUCC in La Paz (Wilson 2007). The extent of native forest decreased by 19.3 % in 2011 compared to 1991. This suggests an annual deforestation rate of 1.12 % (Sabattini et al. in press). Given that forests provide a variety of ecosystem services, deforestation is causing significant losses that affect both local people and the rest of the world (Zaccagnini et al. 2014). The soybean monoculture has increased the risk of soil erosion and water contamination due to use of herbicides (Wilson 2007).

Efforts to prevent and reverse land degradation processes are being made. They include land use planning to develop more diversified and integrated land use/cover. A watershed approach is promoted to ensure that the planned land use/cover is supported by the natural capacity of the watershed and is consistent with the socio-cultural characteristics of the resident communities (Wilson and Sabattini 2001). In this regard, a number of institutions are conducting evaluation of LUCC, habitat fragmentation, soil and water quality, soil erosion, and other ecosystem indicators in the basin of Arroyo. The institutions include INTA EEA Paraná and FCA UNER with CONICET and SAyDS[7] of Argentina. Furthermore, indicators are seeking to determine the impact of the changes on social issues related to education, health, state assistance, housing quality, land tenure, profitability of agricultural enterprises, and household income.

Thus, it is possible to have scientific technical elements useful in assessing and monitoring, to generate early warnings of degradation processes of natural resources, and from this information, implement appropriate planning of land use policies. This initiative is important in demonstrating Argentina's resolve to develop a monitoring and evaluation of land degradation and improvement as well as developing land use planning based on an ecosystem approach. This is consistent with the country's M&E of land degradation at a country level that follows the LADA case study.

Land Degradation in Southwest of Buenos Aires Province

The case study is located in the Southwest, covering 25 % of the Province of Buenos Aires, is an area with three major agroecological zones (sub-humid, semiarid and arid) and with average rainfall ranging from 300 to 700 mm (Fig. 11.11). The major farming system is rainfed wheat and extensive cattle ranching.

About 30 % of the case study area suffers some form of land degradation. Degradation is especially severe due to the El Nino Southern Oscillation phenomenon which comes up with long cycles of droughts and floods. The Mollisols soil types—which cover 74 % of the land area of southwest Buenos Aires province—are highly susceptible to water, wind erosion, and compaction (Silenzi et al. 2010).

[7]At the National level, SayDS—the Secretariat of Environment and Sustainable Development (SayDS)—is mandated to make environmental policy.

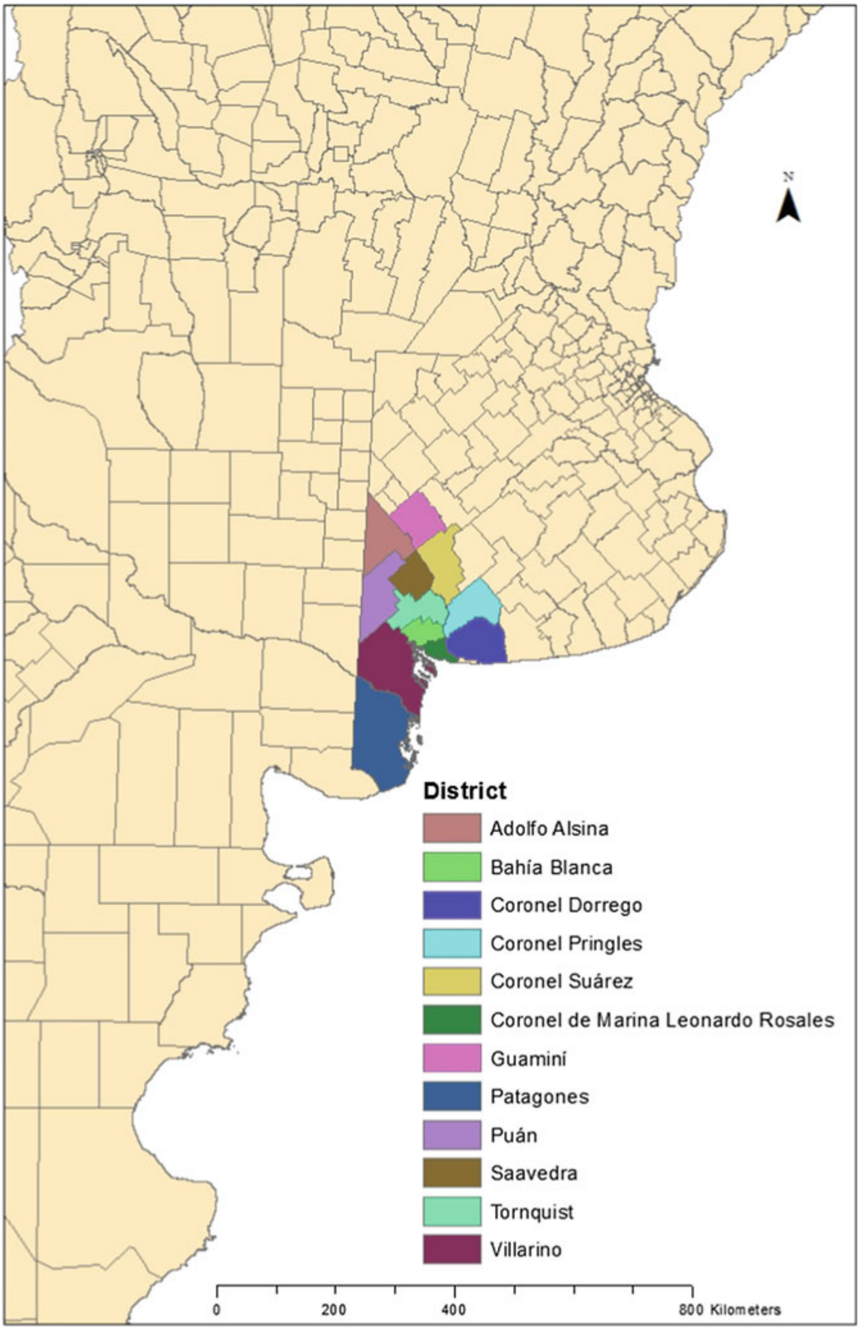


Fig. 11.11 Districts of Southwestern Buenos Aires

Climate change—which has prolonged the dry period—has worsened susceptibility to soil erosion and other forms of land degradation (Silenzi 2011). Given that severe droughts follow the El Niño Southern Oscillation (ENSO) (Glave 2006), its occurrence to some degree is predictable.

As part of efforts to understand the most effective methods of controlling soil erosion, studies have been done to determine the impact of land cover and soil productivity on wind erosion. An inverse linear relationship between wind Erosion Risk (WER) and soil productivity index (PI) was established:

$$\mathrm{WER} = 95.23 - 2.09 * \mathrm{PI}$$
$$R^2 = 66\ \%.$$

The equation suggests that WER increases as PI declines. A large proportion of wheat is planted on land affected by moderate wind erosion (Silenzi et al. 2010). Table 11.7 reports results used in the equation to determine the cost of land degradation due to wind erosion. Similarly on grazing lands in the arid zone of Caldenal, vegetation cover was less than 50 % and soil compaction was high on areas with high livestock density (Echeverría 2014).

Research by Bouza (2014) and Bouza et al. (2009, 2012), observed that soil loss for each wind storm reached up to 22 t/ha on bare soils. They also found an inverse relationship between vegetation cover and soil erosion. For example Bouza (2012) showed that 30 % of vegetation cover reduces wind erosion by 80 %—underlying the importance of promoting conservation agriculture and other practices that enhance vegetation cover.

An evaluation of the impact of soil erosion on wheat production showed that the loss of wheat production due to soil erosion was 319,859 million tons per year (Silenzi et al. 2009), which is worth 2007 US$ 86 million (Table 11.7 and Fig. 11.11).

In the last 50–75 years, wind erosion in some arid or semiarid areas has exceeded the regenerative capacity of land, i.e., the tolerance level (T) according to the criteria established by the American Society of Agronomy and Soil Science Society.

As for livestock production, loss of vegetation cover has exposed land to serious soil erosion and compaction and consequently loss of livestock productivity. In 34 years (1975–2009) native forest cover decreased by 32 or 9.5 % per year due to agricultural land expansion in the Southwest of the Provinces of Buenos Aires and Northeast Rio Negro. A study was done to evaluate the grassland productivity with and without land degradation arising from soil compaction due to excessive trampling and overgrazing (Silenzi et al. 2014). The results show that rangeland productivity fell by 40–51 % during spring, summer and autumn but surprisingly increased by 84 % during winter season (Table 11.8). The increase in winter could be due to increased unpalatable species that are better adapted to cold seasons.

Table 11.7 Economic cost of soil erosion on wheat production, Southwestern Buenos Aires Province

District	Area					Loss of production due to soil erosion (1000 t/year)	Cost of land degradation (Million US$)	I (t/ha/year)	C (%)	WER (t/ha/year)	PI (%)
	Total (1000 ha)	Harvested area (1000 ha)	% of total area	Wheat area eroded (1000 ha)	(%)						
Adolfo Alsina	587.5	92.4	15.7	58.2	63	29.1	7.86	64.2	42	27	31
Bahía Blanca	230	46	20	37.7	82	18.9	5.10	39.3	57	22.4	34
Cnel Dorrego	586.5	234.1	39.9	65.6	28	32.8	8.86	53.1	35	18.6	46
Cnel Pringles	524.5	115.7	22.1	24.3	21	12.2	3.30	32.2	14	4.5	43
Cnel Rosales	129.5	41.5	32	27.8	67	13.9	3.75	87.6	55	48.2	32
Cnel Suárez	598.5	128.1	21.4	5.1	4	2.6	0.70	30.2	7	2.1	48
Guaminí	484	39.5	8.2	33.6	85	16.8	4.54	59.6	5	3	10
Patagones	1360	222.6	16.4	153.6	69	76.8	20.74	87.2	120	104.6	10
Puan	638.5	120.3	18.8	69.8	58	34.9	9.42	67.9	18	12.2	32
Saavedra	350	92.6	26.4	56.5	61	28.2	7.61	34.9	7	2.4	42
Tornquist	418.3	90.2	21.6	32.5	36	16.2	4.37	32.2	21	6.8	39
Villarino	1140	110.5	9.7	75.1	68	37.6	10.15	85.7	37	31.7	16
Total	7047.3	1 333.5	19	639.8	48	319.9	86.4	56.2	34.8	23.6	31.92

Key Area: total harvested wheat area eroded by wind per year; annual decrease in production wheat due to wind erosion. Wind erodibility of soils (“I”), aggressiveness climate (“C”), risk of wind erosion (WER) and Productivity Index (PI)

Table 11.8 Impact of land degradation on grazing biomass productivity

	Coppice (Caldenal) species	Degraded forests (scrub)—Fachinal	% loss of productivity
	Dry matter productivity (tons/ha/year)		
Spring	1.5	0.86	42.7
Summer	1.0	0.33	67.0
Autumn	1.3	0.64	50.8
Winter	0.5	0.92	−84.0

Source Silenzi et al. (2012)

Table 11.9 Impact of tillage methods on soil fertility, Southeast Bonaerense

Tillage method	Soil cover (%)	Water content in 0–60 cm layer (mm)	Soil bulk density (15 cm depth, tons/m^3)	Root density (m/m^3)	Wheat yield (tons/ha)
Vertical plowing (vertical chisel) VP	19	72		7000	2.5
Conventional tillage (CT)	16	72	1.29	6500	2.15
No Tillage (NT)	96	75	1.22	6000	2.5

NB Bonaerense; *SO* Sud Oeste—or southeast. *Source* Silenzi et al. (2011)

The same study showed disappearance of palatable forage species. Consequently, beef production has fallen by 35 % between 2002 and 2009. As is the case for Patagonia, livestock population and number of farmers have also been falling. The number of farmers decreased by 19 % in 2002 compared to 1988 but the grazing area increased by 22 % during the same period. This is a reflection of land degradation which leads to expansion of grazing lands.

Land management practice for addressing land degradation

Tillage methods: A tillage experiment conducted in the SW of Buenos Aires province have shown that No tillage (NT) is more sustainable than the Conventional tillage (CT). NT used less energy, N and P to achieve the zero net balance of both nutrients. Conventional tillage (CT) also showed to have greater erosion risk than NT. However, CT showed lower risk of pesticide contamination than NT (Silenzi et al. 2004). Soil water content was comparable across all tillage method (Table 11.9). Wheat yield was slightly higher for the VT and NT than the conventional method.

Adoption of NT is higher in the subhumid region than in arid and semiarid areas. One of the challenges of widespread adoption of NT is its difficulty to integrate into a mixed system agricultural livestock. The crop-livestock systems have been shown to be suited to climatic and market risks as they provide greater flexibility and stability to the local system than specialized crop or livestock production systems. Additionally, livestock-crop production systems increase demand for labor, and enable more efficient land use, thus contributing to economic and social development

(Iurman 2010). However, in the southern region, an area of adverse and changing conditions, a pure livestock system is recommended due to the predominantly permanent pasture and low rainfall that is unfit for rainfed crop production (Iurman et al. 2012).

Conventional crop-livestock production versus sustainable livestock production systems: This cost-benefit analysis was done to compare the traditional wheat dominated crop-livestock production systems—business as usual (BAU) and sustainable systems of intensive cattle-ranching. The BAU scenario consists of mixed crop and livestock production while the intensive cattle-ranching scenario involved planted gramine (PG) and natural regeneration rangelands (NR) and reduced crop production. Using a 500 ha farm as a case study, the BAU and the alternative production systems (PG and NR) were compared in terms of productivity, gross-benefits and sustainable stocking rates (Fig. 11.13). As reported in Fig. 11.12, wheat is a dominant crop and pasture management is not practiced in the BAU, while pasture management dominates in the alternative scenario. The results show that the alternative pasture management increased the sustainable stocking rate by 54 % and livestock productivity by 64 % (Fig. 11.13).

The cost of production is lower for the BAU but both the profit and marginal rate of return (MRR) for the alternative production system (PN and PG) is more than five times higher (Fig. 11.14 and Table 11.10).

The results suggest that livestock production using PN and NR is much more profitable and sustainable than the BAU.

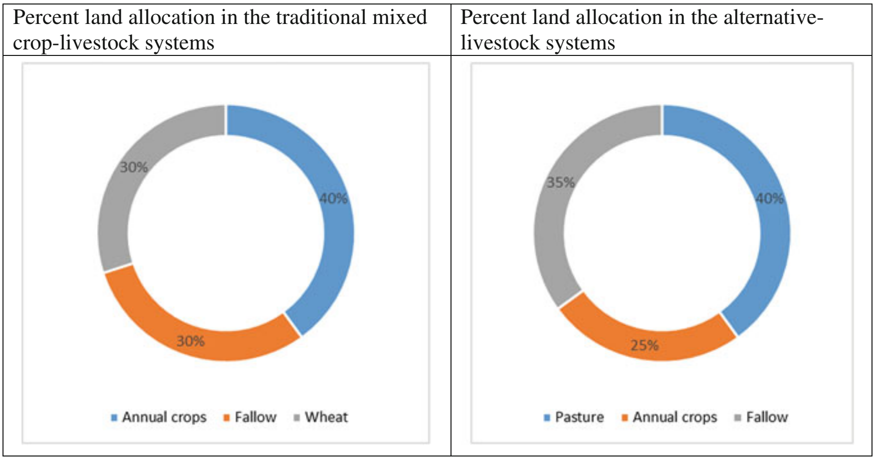


Fig. 11.12 Land allocation to crops and pasture in the traditional and alternative management practices

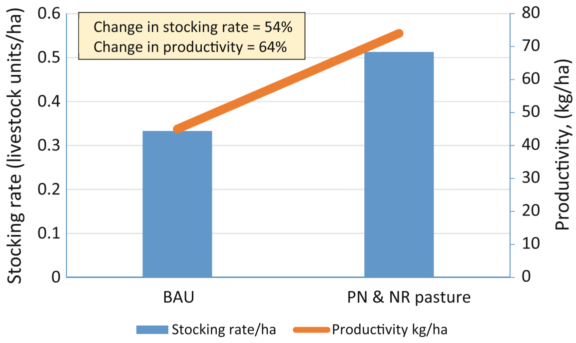


Fig. 11.13 Sustainable stocking rate and beef productivity in the BAU and alternative systems

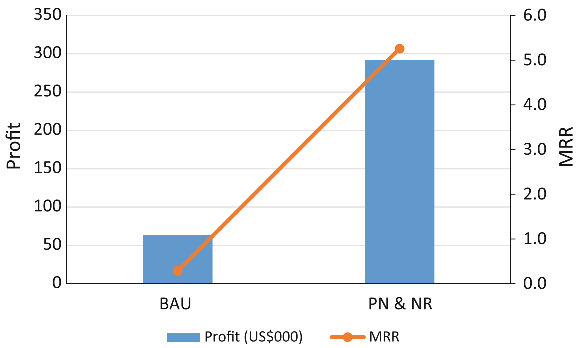


Fig. 11.14 Returns to investments, BAU and PN and NR

Table 11.10 Production and revenue of BAU and PN and NR

	Enterprise	BAU	PN & NR
		US$ (thousands)	
Production cost	Crops	128.16	0.00
	Livestock	92.46	55.51
Revenue	Crops	132.77	0.00
	Livestock	151.19	347.33

La Rioja Case Study

The arid valleys of La Rioja province occupy the northern portion of the Monte Desert biome in northwest Argentina—regarded as the driest region in Argentina (Abraham et al. 2009). Climate is arid with an average annual rainfall of 270 mm and an average annual temperature of 16 °C. The vegetation is an open shrubland dominated by "jarilla" (Larrea cuneifolia), Bulnesia broom, Fabaceae shrubs and cacti. Woodlands are open and marginal with azonal vegetation, i.e., with plant communities that are influenced more by edaphic factors than climatic factors. The case study has seven villages with population that range from 180 to 1300 inhabitants, located on the eastern slopes of the Sierra de Velasco mountain range.

About 77 % of the 556 farms included in the case study are smallholder farmers with an average farm size of 2.4 ha (Lossino et al. 2002). There is considerable flood irrigation which draws water from the permanent rivers that are recharged on the high elevations of the mountains. Only large holdings of vineyards have sufficient irrigation investment and use drip irrigation. Some large holdings also use groundwater, pumped from up to 300 m deep. Of a total of 867 ha, 255 ha use drip irrigation, and only 7 of the 429 smallholder farmers use groundwater for irrigation (Lossino et al. 2002). Rainfed farming use summer rainfall and grow corn, squash and forage—an ancient practice started by pre-Hispanic inhabitants. Other land uses are extensive grazing of goats and cattle. Hunting is also a traditional livelihood but is prohibited by provincial law.

Land Degradation Processes and Impacts on Ecosystem Services

Deforestation and continuous grazing are among the major land degradation types in the case study area. Since 1988, approximately 5000 ha of forests have been converted to agriculture, while additional 19,000 ha have been acquired by the government. In many cases, due to inadequate planning, degraded lands are abandoned.

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Pachauri et al. 2014) estimates that by 2020/2029, precipitation in northwest Argentina will decrease by 2–12 % and temperature will increase by 1–1.4 °C. Given that deserts are fragile ecosystems that are not easily restored once altered (Yanelli et al. 2014), the consequences of climate change, coupled with land degradation by anthropogenic causes, could have irreversible effects on population who heavily depend on natural resources. This could lead to much more severe shortages and consequent conflicts among land users.

Strategies for Addressing Land Degradation

The provincial and Federal governments are implementing a number of strategies to address land degradation in the arid valleys of La Rioja. The Regional Center for Scientific and Technological Research of La Rioja (CRILAR)—which belongs to the CONICET—is monitoring land degradation and improvement. This will help to design appropriate interventions and policies of land use that could lead to socially and environmentally sustainable management practices.

An environmental education to primary school children through CONICET Programs such as "Scientists go to schools" is promoting conservation of biodiversity. The Pro-Huerta Program of INTA and the Ministry of Social Development also promote organic agricultural practices to local farmers. Additionally, the CRILAR participates in the provincial technical board which was created for land use planning, protection and enforcement of compliance with Minimum Standards for environmental Protection Act of the Native Forests of the Province of La Rioja.

Fuel-efficient cook stoves, heating systems and alternative energy are also being promoted to reduce native forest harvesting for fuelwood. A project implemented by INTA is also promoting conservation of agricultural water resources in the Catamarca-La Rioja region. The project aims to improve the use of surface and groundwater resources for irrigation through the provision of appropriate technologies.

Conclusions and Policy Implications

Argentina's economy has grown significantly in the past decade and this has significantly reduced the number of people below the international poverty line (US $1.25/day/capita) from 12.6 % in 2002 to only 0.92 % in 2010 (World Bank 2014). Argentina's adoption of conservation agriculture (CA) is also the highest in the world. Such high CA rate of adoption and other environmental achievements have improved the country's ecological and environmental performance to a higher level than most other countries using intensive agricultural production technologies (Viglizzo et al. 2011). The high adoption of CA in Argentina has demonstrated the effectiveness of public-private partnership in agricultural development but has also highlighted the potential environmental impacts of such partnership. The seemingly "doubly green revolution" has come at an ecological cost due to the rapid expansion of croplandand pasture production into forest and other higher value biomes. Our study shows that the loss of ecosystem services due to land-use/cover change (LUCC) is 2007 US$70 billion or 26 % of the country's 2007 GDP. Considering only provisioning services with tangible local benefits, land degradation due to LUCC is about 12 % of the GDP. Wetland degradation also coststhe country 2007 US$3.8 billion or 1.5 % of the 2007 GDP. The major drivers of wetland degradation are human settlement and mining soil for brick making. Gully formation due to soil erosion in the grasslands in Patagonia and other areas has also drained water from wetlands. A crop simulation model that only considers soil fertility mining shows that land degradation in wheat, maize and rice farms costs about US$81 million per year.

Cost of land degradation on grazing land on milk and meat production is about 2007 US$586 million or 11 % of the livestock GDP. Such high losses require immediate action given the increasing demand for livestock products and its potential to simultaneously increase farmer income, sequester carbon, reduce soil erosion, and other ecosystem service benefits.

The high cost of land degradation calls for action to address it. Our study shows that the returns to taking action against land degradation is about US$4 per US$ invested. The high returns to taking action against land degradation strongly justify investment in restoration of degraded lands and prevention of land degradation. Action against land degradation will require stricter regulation of agricultural expansion into forests and other higher value biomes. This also requires reforestation and other restoration efforts. Argentina faces great challenges ahead regarding the protection of wetlands, addressing the ecological imbalance caused by wetland degradation through LUCC, especially urbanization and waste-disposal of coastal cities.

The case studies also revealed the potential of promising strategies that could achieve sustainable land management. Sheep production in Patagonia is experiencing land degradation but the rotational grazing system designed by INTA (TME) has been shown to be sustainable but its adoption rate is low. Increasing its adoption would require concerted efforts to provide extension services, incentives, and support that could help ranchers to overcome the high upfront costs. The incentives and material support could be justified by the ecosystem benefits that result from rangeland management.

The case studies in La Paz, and La Rioja also reveal that diversified crop-livestock systems are more sustainable and profitable and reduce production risks than specialized production systems. In the case of the SW Buenos Aires Province however, specialized pasture management does offer more sustainable and profitable production systems crop production. But farmers practice mixed systems as a strategy to contend with production and market risks.

Conservation agriculture also need to extend beyond the soybean production. This is especially important in dry areas affected by wind erosion. For example the study in Buenos Aires showed that 30 % of vegetation cover reduces wind erosion by 80 %. This will simultaneously increase agricultural productivity and reduce dust storms in cities and other heavily populated areas.

Argentina has laid out elaborate land use planning strategies, land degradation and improvement monitoring that informs policy formulation. This was a result of political efforts which were strongly backed by FAO's land degradation assessment (LADA) that was completed in 6 different countries. The countries could learn from Argentina's groundbreaking initiative of establishing an elaborate monitoring and evaluation of land degradation and improvement. It is therefore that Argentina started to share its knowledge in this field through its Technical Cooperation Facility of the Ministry of Foreign Affairs ((FOAR), through which LADA experts of the Secretary of Environment and Sustainable Development gave training to institutions and farmers in other Latin-American countries.

The world has a lot to learn from Argentina given its rapid poverty reduction and successful adoption rate of CA using public-private partnership. For Argentina to maintain its economic and social development, it will need to work harder to address its growth-related environmental challenges that affect the poor the most. Argentina of today is much better prepared to face these challenges and take advantage of the emerging opportunities. This study will provide policy makers with empirical evidence to take action against land degradation.

References

Abraham, E., del Valle, H. F., Roig, F., Torres, L., Ares, J. O., Coronato, F., & Godagnone, R. (2009). Overview of the geography of the Monte Desert biome (Argentina). *Journal of Arid Environments, 73*, 144–153.

Altieri, M., & Pengue, W. (2006). GM soybean: Latin America's new colonizer. Seedling January 2006. Online at http://www.grain.org/es/article/entries/588-gm-soybean-latin-america-s-new-colonizer. Accessed 25 Sept 2014.

Anderson, D. L., Bonvissuto, G. L., Brizuela, M. A., Chiossone, G., Cibils, A. F., Cid, M. S., et al. (2011). Perspectives on rangeland management education and research in Argentina. *Rangelands, 33*(1), 2–12.

Aquastat. (2013). Aquastat database. Online at http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en. Accessed 14 April 2015.

Ares, J. O. (2007). Systems valuing of natural capital and investment in extensive pastoral systems: Lessons from the Patagonian case. *Ecological Economics, 62*(1), 162–173.

Ares, J., Beeskow, A. M., Bertiller, M., Rostagno, M., Irisarri, M., Anchorena, J., et al. (1990). Structural and dynamic characteristics of overgrazed lands of northern Patagonia, Argentina. *Ecosystems of the World, 17*, 149–175.

Aryamanya-Mugisha, H. (2011). *20 years of wetlands conservation in Uganda—have Uganda's wetlands become wastelands again?* Paper presented at the WORLD WETLANDS DAY, February 2, 2011, Kamapal Uganda. Online at http://www.natureuganda.org/downloads/presentations/WETLANDS%20STATUS.pdf. Accessed 25 Sept 2014.

Bertiller, M. B., Ares, J. O., & Bisigato, A. J. (2002). Multiscale indicators of land degradation in the Patagonian Monte, Argentina. *Environmental Management, 30*(5), 0704–0715.

Bouza, M. E. (2014). Estudio del proceso de erosión eólica en el Sudoeste Bonaerense. Validación de un modelo predictivo. Tesis Magister en Ciencias Agrarias de la UNS, 156 pp. Bratislava, EAAP.

Bouza, M. E., Silenzi, J. C., Echeverría, N. E., & De Lucia, M. P. (2012). Analysis of erosive events for a soil in the southwest of Buenos Aires Province, Argentina. *Aeolian Research, 3*, 427–435.

Bouza, M. E., Silenzi, J. C., Echeverría, N. E., & De Lucía, M. P. (2009). Monitor station of wind erosion in south west of Buenos Aires province. Drylands Science for Development (DSD). United Nations Convention to Combat Desertification (UNCCD). First Scientific Conference: Understanding Desertification and Land Degradation Trends. Poster Session at the UNCCD COP-9. Buenos Aires. http://dsd-consortium.jrc.ec.europa.eu/documents/Poster_Session_Abstract_Book.pdf

Chudnovsky, D., & López, A. (2008). *Foreign investment and sustainable development in Argentina*. Working Group on Development and Environment in the Americas. Discussion Paper Number 12.

Cibils, A. F., Coughenour, M. B., & Gallegos, S. C. (2001). Impact of grazing management on the productivity of cold temperate grasslands of Southern Patagonia-a critical assessment. In *Proceedings of the XIX International Grassland Congress* (pp. 807–811). Sao Pablo, Brazil.

Conway, G. (1997). *The doubly green revolution: Food for all in the twenty-first century* (335 pp). New York (USA): Penguin Books.

Cruzate, G. A., & Casas, R. (2009). Extraccion de nutrients en la agricultura Argentina. Mimeo Inta. Online at http://inta.gob.ar/documentos/extraccion-de-nutrientes-en-la-agricultura-argentina/at_multi_download/file/Extraccion_de_nutrientes.pdf. Accessed 13 Jan 2015.

de Groot, R., Brander, L., van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., et al. (2010). Benefits of investing in ecosystem restoration. *Conservation Biology, 27*(6), 1286–1293.

De Prada, J. D., Shah, F., Degioanni, A. J., Cisneros, J. M., & Cantero, A. (2014). The external impact of agriculture on inland wetlands: A case study from Argentina. *European Scientific Journal, 10*(17), 1857–7881.

Easdale, M. H., Sacchero, D., Vigna, M., & Willems, P. (2014). Assessing the magnitude of impact of volcanic ash deposits on Merino wool production and fibre traits in the context of a drought in North-west Patagonia, Argentina. *The Rangeland Journal, 36*(2), 143–149.

Echeverría, N. E. (2014). Incidencia de disturbios antropogénicos sobre el escurrimiento y erosión hídrica en el sur de la Región Semiárida Pampeana. Tesis Magister en Ciencias Agrarias de la UNS, 166 pp.

FAO. (2005). Livestock sector brief. Argentina.

FAO. (2006). Fertilizer use by crop. FAO Fertilizer and Plant Nutrition Bulletin No. 17. Online at ftp://ftp.fao.org/agl/agll/docs/fpnb17.pdf. Accessed February 2, 2015.

FAOSTAT. (2015). Online agricultural database. http://faostat3.fao.org/faostat-gateway/go/to/home/E. Accessed 23 Jan 2015.

Friedl, M., Sulla-Menashe, D., Tan, B., Schneider, A., Ramankutty, N., Sibley, A., & Huang, X. (2010). MODIS global land cover: Algorithm refinements and characterization of new datasets. *Remote Sensing of Environment, 114*(1), 168–182.

Friedrich, T., Kassam, A., & Taher, F. (2009). Adoption of conservation agriculture and the role of policy and institutional support. Invited paper for the International Consultation on "No-Till with Soil Cover and Crop Rotation: A Basis for Policy Support to Conservation Agriculture for Sustainable Production Intensification", Astana & Shortandy, Kazakhstan, 8–10 July 2009.

Glave, A. (2006). La Influencia climática en el Sudoeste Bonaerense y el Sudeste Pampeano en: Revista Producción. *Animal, 31*, 18–23.

Globcover. (2005). Global land cover 2005. http://due.esrin.esa.int/page_globcover.php. Accessed 13 Jan 2015.

Globcover. (2009). Global land cover 2009. Online at http://www.gelib.com/globcover-2009.htm. Accessed 13 Jan 2015.

Golluscio, R. A., Deregibus, V. A., & Paruelo, J. M. (1998). Sustainability and range management in the Patagonian steppes. *Ecología Austral, 8*(2), 265–284.

IARC (International Agency for Research on Cancer). (2014). Monographs on the Evaluation of Carcinogenic Risks to Humans. World Health Organization (WHO), Internal Report 14/002.

Lossino, B. N., Heredia, O. S., Sainato, C. M., Giuffré, L., & Galindo, G. (2002). Potential impact of irrigation with groundwater on soils of Pergamino stream basin, Buenos Aires Province, Argentina. Impacto potencial del riego con agua subterránea sobre los suelos en la cuenca del arroyo Pergamino, Provincia de Buenos Aires, Argentina. *Ecología Austral*, *12*, 55-63

Iurman, D. (2010). Sistemas agropecuarios de Villarino y Patagones. Análisis y propuestas. Boletín técnico INTA Ascasubi. http://inta.gob.ar/documentos/sistemas-agropecuarios-de-villarino-y-patagones.-analisis-y-propuestas/

Iurman, D., Larreguy, V., Demarchi, R. (2012). Evaluación económica de un sistema ganadero en Levalle, partido de Villarino. No publicado.

Jergentz, S., Mugni, H., Bonetto, C., & Schulz, R. (2005). Assessment of insecticide contamination in runoff and stream water of small agricultural streams in the main soybean area of Argentina. *Chemosphere, 61*(6), 817–826.

Jones, K. G. (2004). *Trends in the US sheep industry*. Washington, DC: USDA Economic Research Service.

NASA (National Aerospace Authority). (2014). Moderate-resolution imaging spectroradiometer (MODIS). Online at http://modis.gsfc.nasa.gov/about/media/modis_brochure.pdf. Accessed 27 May 2014.

Oliva, G., Ferrante, D., Puig, S., & Williams, M. (2012). Sustainable sheep management using continuous grazing and variable stocking rates in Patagonia: A case study. *The Rangeland Journal, 34*(3), 285–295.

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., et al. (2014). Climate change 2014: Synthesis report. In R. Pachauri, & L. Meyer (Eds.), Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, Switzerland, IPCC, 151 pp. ISBN: 978-92-9169-143-2.

Paganelli, A., Gnazzo, V., Acosta, H., López, S. L., & Carrasco, A. E. (2010). Glyphosate-based herbicides produce teratogenic effects on vertebrates by impairing retinoic acid signaling. *Chemical Research in Toxicology, 23*(10), 1586–1595.

Paula, B. M., & Oscar, M. N. (2012). Land-use planning based on ecosystem service assessment: A case study in the Southeast Pampas of Argentina. *Agriculture, Ecosystems & Environment, 154*, 34–43.

Qaim, M., & Traxler, G. (2005). Roundup ready soybeans in Argentina: Farm level and aggregate welfare effects. *Agricultural Economics, 32*, 73–86.

Regúnaga, M., & Rodriguez, A. T. (2015). Argentina's agricultural policies, trade, and sustainable development objectives. Online at http://www.ictsd.org/sites/default/files/research/Argentina%20Agricultural%20Trade%20Policy%20and%20Sustainable%20Development.pdf. Accessed 23 Jan 2015.

República de Argentina. (1994). Constitución de 1994. Online at http://pdba.georgetown.edu/Constitutions/Argentina/argen94_e.html. Accessed 23 Jan 2015.

Rostagno, C. M., & Degorgue, G. (2011). Desert pavements as indicators of soil erosion on aridic soils in north-east Patagonia (Argentina). *Geomorphology, 134*(3), 224–231.

Secretaría de Ambiente y Desarrollo Sustentable de la Nación. (2007). Primer Inventario Nacional de Bosques Nativos. 2da. Etapa: Inventario de campo de la Región del Espinal (Distritos del Caldén y del Ñandubay). BIRF 4085 AR. 236 p y un Anexo.

Seghezzo, L., Volante, J. N., Paruelo, J. M., Somma, D. J., Buliubasich, E. C., Rodríguez, H. E., et al. (2011). Native forests and agriculture in Salta (Argentina): Conflicting visions of development. The Journal of Environment & Development, 1070496511416915.

Silenzi, J. C., Echeverría, N. E., Bouza, M. E., & De Lucia, M. P. (2011). Degradación de suelos del SO Bonaerense y su recuperación. Academia Nacional de Agronomía y Veterinaria. Jornada sobre: "Evolución y Futuro del Desarrollo de Producciones Agrícolas y Ganaderas en el SO Bonaerense". Tomo LXV, pp. 382–404. ISSN: 0327-8093.

Silenzi, J. C., Echeverría, N. E., Bouza, M. E., & DeLucía, M. P. (2009). The wind erosion cost in the south west of Buenos Aires province. Drylands Science for Development (DSD). United Nations Convention to Combat Desertification (UNCCD). First Scientific Conference: Understanding Desertification and Land Degradation Trends. Poster Session at the UNCCD COP-9. Buenos Aires.

Silenzi, J. C., Echeverría, N. E., Bouza, M. E., & De Lucía, M. P. (2014). Incidencia del manejo sobre el ambiente de montes del Caldenal semiárido y árido. Inédito.

Silenzi, J. C., Echeverría, N. E., Vallejos, A. G., Bouza, M. E., & De Lucía, M. P. (2010). Wind erosion risk for soils of Buenos Aires southwest province and its relationship to the productivity index. In International Conference on Aeolian Research (ICAR VII) Santa Rosa, Julio de 2010. Trabajo en Actas: Technical session 6, p. 130.

Silenzi, J. C., Echeverría, N. E., Vallejos, A. G., Bouza, M.E., & De Lucia, M. P. (2012). Wind erosion risk in the southwest of Buenos Aires Province, Argentina and its relationship to the productivity index. *Aeolian Research, 3*, 419–425.

Silenzi, J. C, Vallejos, A. G., Echeverría, N. E., De Lucía, M. P. (2004). Análisis de la gestión ambiental en la producción de trigo mediante labranza convencional y siembra directa. Indicadores de sustentabilidad 8 a 12. VI Congreso Nacional de Trigo y IV Simposio Nacional de Siembra Otoño Invernal. 20 al 22 de Octubre de 2004. Universidad Nacional del Sur.

Tomei, J., & Upham, P. (2009). Argentinean soy-based biodiesel: An introduction to production and impacts. *Energy Policy, 37*(10), 3890–3898.

Tomei, J., & Upham, P. (2011). Argentine clustering of soy biodiesel production: The role of international networks and the global soy oil and meal markets. *The Open Geography Journal, 4*, 45–54.

Tucci, C. (2007). Urban flood management. Online at http://www.gwp.org/Global/GWP-SAm_Files/Publicaciones/Gesti%C3%B3n%20de%20Inundaciones/Gestion-de-inundaciones-urbanas-ing.pdf. Accessed 25 Sept 2014.

UNDP (United Nations Development Program). Human Development Report. (2014). *Sustaining human progress: Reducing vulnerabilities and building resilience* (p. 212).

Viglizzo, E. F., Frank, F. C., Carreno, L. V., Jobbagy, E. G., Pereyra, H., Clatt, J., et al. (2011). Ecological and environmental footprint of 50 years of agricultural expansion in Argentina. *Global Change Biology, 17*(2), 959–973.

Volante, J. N., Alcaraz-Segura, D., Mosciaro, M. J., Viglizzo, E. F., & Paruelo, J. M. (2012). Ecosystem functional changes associated with land clearing in NW Argentina. *Agriculture, Ecosystems & Environment, 154*, 12–22.

Wilson, M. G. (2007). Uso de la Tierra en el área de bosques nativos de Entre Ríos, Argentina. Tesis Doctoral. Universidad de la Coruña, España. 277 pp.

Wilson, M., & Sabattini, R. (2001). Sustentabilidad de los agroecosistemas de bosques de Entre Ríos: Revisión crítica y modelo conceptual. *Revista Facultad de Agronomía, 21*(2), 117–128.

World Bank. (2014). Country database. Online at http://www.worldbank.org/en/country/argentina

Yanelli, F. A., Tabeni, S., Mastrantonio, L. E., & Vezzani, N. (2014). Assessing degradation of abandoned farmlands for conservation of the Monte Desert biome in Argentina. *Environmental Management, 53*, 231–239.

Zaccagnini, M. E., Wilson, M. G., & Oszust, J. D. (2014). Manual de buenas prácticas para la conservación del suelo, la biodiversidad y sus servicios ecosistémicos. Área piloto Aldea Santa María. 1ª. Edición. Buenos Aires. ISBN 978-987-1560-55-4. Programa Naciones Unidas para el Desarrollo—PNUD. Secretaría de Ambiente y Desarrollo Sustentable de la Nación; INTA. Bs. As. 95 pp.