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Methodology for the Generation of Sustainability Indicators for Production Systems

Central-West Region of Argentina

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Responsible Editors

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Uni.
The first three letters of the word "University".
Popular, idiosyncratically used: "the Uni".
University, derived from the Latin word "*universitas*"
(people devoted to the leisure of wisdom), is contextualized, for us,
in our territorial anchorage and in the conception of knowledge
and wisdom socially built and shared.

The River (Río).
Light blue and orange. The water and sand of our Río Cuarto,
in constant confluence and evolution.

The Droplet. Accent and visual impact: water in a
free gliding movement from "us".
Knowledge that flows and quenches our thirst.

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Prologue

This Publication is the result of a joint initiative among researchers from seven National Universities geographically associated with the provinces of Córdoba, Mendoza, San Juan, San Luis and La Rioja, all of which make up the Central-West Region of Argentina. This initiative, in such a heterogeneous context in terms of geographies, interests, knowledge areas, and specific environmental problems, was motivated by a Targeted Scientific and Technological Research Project (Proyecto de Investigación Científica y Tecnológica Orientado, PICTO – National Inter-University Council [Consejo Interuniversitario Nacional, CIN] 2010 0050) managed by the Agencia Nacional de Promoción Científica y Tecnológica (National Agency for Scientific and Technological Promotion) on "Indicators for the Assessment of the Sustainability of Production Systems within the Central-West Region of Argentina." Its general objective was to "establish operational frameworks that allow a tangible assessment of the sustainability of different production systems within the Central-West Region, articulating ecological, social, and economic processes in an integrated and interdisciplinary way, with the purpose of generating specific recommendations for the management of public policies in the Region."

Sustainability is a concept widely used in the public sphere; it is almost overused and, in many cases, quite inaccurately. It is mostly associated with ecology or the environment, and, many times, under an extreme conservationist idea, without any regard for the different uses of the environment.

Considering this understanding, the originality of the proposed work lies in an attempt at an integrated analysis of sustainability, based on the simultaneous interaction of its four constituent dimensions —ecological, economic, social, and institutional— and with the human being as the holder of sustainable well-being. The analysis aims at the assessment of the sustainability of primary production systems; however, its conceptual flexibility allows for its application on any production system.

From this approach, the work tries to deliver a multidimensional methodology for the generation of sustainability indicators. Due to the inherent complexity of the subject matter, of its dimensions, and of its interactions, its treatment calls for interdisciplinary work that, at its genesis, was favored by the unique formation of the research team.

The proposed work is mainly oriented to the scientific community and to a wide spectrum of knowledge areas, by virtue of the multidimensionality of this approach to sustainability. It can also be of value to and usable by technicians related with the decision-making and policy-formulation spheres, while becoming a reference point in the development of discussion forums or other studies on the analysis of complex issues related to sustainability. Finally, the work can be a management and analysis tool for the creation of policies in line with the search of sustainability.

The work undertaken to achieve the Project's objective is worth considering at least two aspects, whose implications or outcomes go way beyond the written work being presented herein. One of them is the willingness, dedication, effort, open-mindedness, and respect of the participant individualities and of the group, which prevailed throughout the development of the work, towards addressing an issue of this nature and generating consensus proposals around it. The second significant aspect, to a large extent a consequence of the first one, is the building of a resulting "institutional capacity", represented by a scientific group with the ability to prospectively deal with other problems guided by this already built operational and working dynamics. This achieved capacity, which does not take place overnight, represents an investment in the widest sense of the word, and should be taken into account for tackling other issues involving scientific solutions to complex problems.

Last but not least, this scientific product was made possible thanks to both institutional and individual actors who deserve due acknowledgment and gratitude. To the Consejo Interuniversitario Nacional and the Universities, for choosing ours as one of the targeted topics and study subjects. To the Agencia Nacional de Promoción Científica y Tecnológica, for putting at our disposal the economic resources and the general management. To the Universidad Nacional de Río Cuarto, as Beneficiary Institution, for its work as Financing Management Unit. To all the Universities who participated in the Project, for their consent, willingness, inspiring welcome, and kind hospitality afforded by their

respective authorities during the various contacts and workshops held in most of their premises. To Adriana Abril, PhD, for her valuable inputs and analysis during the characterization of the vast region under study. To Claudia Rodriguez, PhD, and Miguel Ángel Besso, Esq., for the willingness and interest shown in the critical reading of the whole work, and who, by virtue of their scientific-professional expertise and background, provided their endorsement of the publication. Finally, as Head Researcher, I would like to express my great satisfaction for the efforts, in terms of both scientific work and human relations, made by each and every member of the Research Team. It has been a valuable experience in the widest sense of the word.

Roberto Ángel Seiler

Introduction

Framework and General Objectives of the Work

The Central-West Region of Argentina includes the provinces of Córdoba, La Rioja, Mendoza, San Juan, and San Luis (Figure 1). It represents a geographic area amounting to 15.2% of the country's territory and holds 16.2% of Argentina's population.

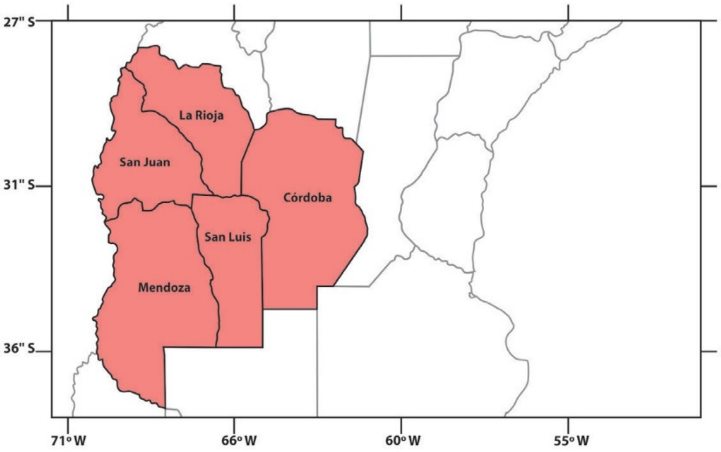

Figure 1. Central-West Region of Argentina.

The region features plains and mountains; dry, semidesert, wet, and flood-prone areas; fresh water stillwaters, both natural and man-made; rivers with endorheic basins and rivers which form the Plata basin and the Colorado basin; it has a natural vegetation gradation that ranges from humid/subhumid on the east to xerophytic in the arid areas of the west; fauna made up of native breeds from the northern and southern areas of the continent, and a variety of soils consistent with a subhumid climate, characterized by mild and dry winters on the east, which harshen westwards amidst semiarid, arid, and, eventually, high-altitude climates while approaching the Andes.

Vast areas of the Central-West Region have been significantly transformed by anthropogenic forcing which, throughout time, has caused changes on the ecological, social, and economic systems, thus modifying –either directly or indirectly– the environment and its functioning. Economic growth, based on different production systems, and population density and growth rate fully influence the ecosystem services demand. Impoverished environments affect the communities' development and quality of life, thus conditioning access to employment and education opportunities, which, in turn, deepens marginalization, social disintegration, and human migration, among others.

With the purpose of providing studies that contribute to the sustainable development of the region, there arises the need to systematically assess its distinctive features, potentialities, and ecological, economic, social, and institutional conditioning factors. The availability of indicators which allow the assessment of the current status and future changes of the different dimensions (ecological, economic, social, and institutional) and their respective interactions –in each geographic area– stands as a promising prospect for this analysis. In the country, there are indicators for each of these dimensions that may be applied to the Central-West Region; however, what is missing is an interrelated set of the mentioned indicators which allows to assess the sustainability of the region in an integrated way and to guide the decision-making process and the actions taken by both the public and the private sectors.

In response to such an absence, this project intends to establish a methodological and operational framework which can contribute to the assessment of the sustainability of the Central-West Region using the production systems that exist therein as a departing point. In this sense, the work intends to articulate the ecological, economic, social, and institutional dimensions in an integrated and interdisciplinary manner with the purpose of generating an information system that can contribute to the management of the Region's sustainability, from the realm of public policy and from private actions as well.

The Significance of the Problem

The assessment of the sustainability of production systems through the use of indicators referring to theoretical concepts is an increasingly used practice. This enables to get a general diagnosis of the system by means of the measurement or observation of a reduced number of parameters. Indicators must reflect the global operation of the system and estimate future scenarios to lead to its sustainable management, on a temporal and spatial scale.

In Argentina, in the Central-West Region, there are recognizable areas with strong anthropogenic intervention dedicated to either intensive or extensive production (agriculture and livestock, oasis-irrigated agriculture, mining, among others) There are also other areas with a lesser degree of intervention, mostly devoted to agriculture and livestock, which are considered marginal for these activities (stockbreeding; tree and bush felling to obtain wood, firewood, or charcoal; and plant collecting for aromatic and medicinal purposes, among others). This anthropogenic intervention has increased substantially as a result of the slipping of the agricultural and livestock border —due to a rise in precipitation— and of the increase in the surface area devoted to agricultural activities —owing to the application of modern management techniques—, which have brought about changes in the structure and functioning of natural environments. Woodlands and scrublands used for grazing have been transformed into large cattle raising platforms after the clearance of vegetation and the introduction of grazing lands; the use of irrigation systems for agriculture has caused, in many cases, the salinization of the soils in the region; the introduction of large-scale mining activities —at the sources of rivers giving rise to production oases— and of oil-drilling activities —at areas defined as natural reservations— have also brought about equally significant transformations along with other economic activities, such as industry and service provision. The lack of a development in harmony with the environment and the use of natural resources has caused, for different reasons, negative impacts on ecological and socioeconomic systems at both local and regional level.

Nowadays, there is information available on different sustainability indicators and on their respective selection criteria, which are used throughout the world. These entail the acknowledgment that sustainable development needs to be approached by integrating all dimensions: ecological, economic, social, and institutional. From this perspective, the purpose is not only to obtain information about the four converging dimensions of sustainability, but also to analyze the interrelations among them, in an attempt to enhance human well-being.

In Argentina, most proposed sustainability indicators have been developed and validated in reference to the national context and scale in an aggregated way, or in reference to distinctive features of the different production systems, which has led to a reduced availability of information on works with aggregated indicators at the level of the Central-West

Region. The analysis of sustainability in this Region deserves a special effort due to the existence of different conditioning factors. These include arid and semiarid environments prone to short-term degradation or deterioration; a long-standing history of intervention on the ecosystems within the areas closest to the Humid Pampa; lack of systematization of the results of research performed on the main changes occurred; poor tradition of alternative forms of citizen involvement in the decision-making and public policy-formulation processes; an increasing socioeconomic interdependence between rural and urban populations, and increasingly-higher social and environmental costs, deriving from production systems and their changes.

Global Framework of Sustainable Development

Sustainable Development has become an essential goal when it comes to making political action-related decisions in the socioeconomic field, which has direct implication on the environment and the services provided by ecosystems through natural resources. However, the concept of development per se is subject to ambiguities and diverse interpretations, as well as criticism, from both the academic point of view and everyday practice. In this light, the formulation of an organizing conceptual framework becomes a must for its own assessment and implementation for the benefit of consensual progress in pursuit of sustainability.

Towards the 1960s, awareness around nature destruction begins to express itself associated with the concept of economic progress, along with an understanding of the restraints on economic growth (Leff, 2008). These effects gave rise to a world-scale debate by sectors alarmed with the environmental situation and sectors worried about the condition of markets and the increase of productivity within production conglomerates during the second half of last century. Table 1 offers a review on international actions taken and publications made in connection with this topic.

In this context, the United Nations Conference on the Human Environment (Stockholm, Sweden, 1972) and the United Nations Conference on Human Settlements (Vancouver, Canada, 1976) laid the foundations that later on, in 1987, would be reflected in the United Nations World Commission on Environment and Development’s document entitled *Our Common Future,* also known as the *Brundtland Report*. This report summarizes the global challenges as regards the environment and defines the concept of sustainable development as one that *meets the needs of the present without compromising the ability of future generations to meet their own needs*. This concept incorporates the notions of human well-being, ecological well-being, and their interactions (Brundtland, 1987).

Chart 1. International actions and publications in relation to the environmental debate during the 20th century

1948. Creation of the International Union for the Conservation of Nature (IUCN).
1955. Symposium on Man's Role in Changing the Face of the Earth, Princeton (USA).
Conference of Non-Aligned Nations, Bandung.
1960-70. Publishing of highly influential books: R. Carson's *Silent Spring* (1963); K. Boulding's *The Economics of the Coming Spaceship Earth* (1966), and P. Ehrlich's *The Population Bomb* (1968).
1971. Publishing of the Meadows Report, *The Limits to Growth*, Club of Rome.
Creation of UNESCO's Man and Biosphere Programme.
1972. United Nations Conference on the Human Environment, Stockholm (Sweden). Creation of the United Nations Environment Programme (UNEP).
1976. United Nations Conference on Human Settlements (HABITAT-I), Vancouver
1980. Creation of the *Ecoville* Programme of the International Federation of Institutes for Advanced Study (IFIAS)
1970-1980. Publishing of numerous highly influential books, including: H. T Odum's *Environment, Power, and Society* (1971); B. Commoner's *The Closing Circle* (1972); E. F.Schumacher's *Small is Beautiful* (1973); H. T. Odum's *Energy Basis for Man and Nature* (1976); A. Lovins's *Soft Energy Paths* (1977); B. Commoner's *The Poverty of Power* (1979), and G. O. Barney's *The Global 2000 Report to the President (1981).*
1980-1999. Following the drop in the price of oil and raw material in general, there is a decrease in the number of publications on energy and material management in the industrial civilization, and an increase in the amount of literature on economic instruments for waste management and appraisal of externalities aimed at incorporating environmentally related topics into standard economic reasoning.
1987. Publishing of the World Commission on Environment and Development's Brundtland Report: *Our Common Future.*
1991. Publishing of the European Commission's Green Paper on the Urban Environment.
1992. Publishing of the second Meadows Report, *Beyond The Limits*, Club of Rome. United Nations Conference on Environment and Development (UNCED), Rio de Janeiro (Brazil). Maastricht Treaty.
European Union's Fifth Environmental Action Programme.
1993. Publishing of the European Union's White Paper on *Growth, Competitiveness, and Employment*.
Creation of the Sustainable Cities Programme.
1994. The idea of sustainability appears in Local Development Agendas.
1996. Second United Nations Conference on Human Settlements (HABITAT-II), Istambul.
1998. United Nations Climate Change Convention, Kyoto (Japan).

Source: Adapted from Naredo (2001)

In the Earth Summit (Rio de Janeiro, Brazil, 1992), it is acknowledged that production and consumption patterns, especially in developed countries, had reached unsustainable levels, thus posing a threat to the stability of the natural environment, provider of various goods and services ensuring both the continuity of production activities and quality of life. The purpose of the Rio Conference was to pave the way for the reversal of such a situation for the benefit of humanity as a whole, which results in the creation of the *Programme of Action for Sustainable Development*, also known as *Agenda 21*, aiming at standardizing the development process around the principles of sustainability (Leff, 2008). The document states that *indicators of sustainable development need to be developed to provide solid bases for decision-making at all levels and to contribute to a self-regulating sustainability of integrated environment and development systems*.

From this perspective, the concept of sustainable development considers the human being as the center or core of every strategy, in which the improvement of the quality of life is the result of productive efficiency, but in harmony with the preservation of natural resources. The purpose of structuring the analysis of sustainability around the social, economic, environmental, and institutional categories or subsystems is to identify not only likely cause-effect scenarios for a given socioenvironmental phenomenon, but also the essential factors or aspects that may guide the lines of action to be followed around such phenomena.

Reasserting these principles and the implementation of Agenda 21, the representatives of the countries attending the World Summit on Sustainable Development (Johannesburg, 2002) committed themselves to reaching the internationally agreed goals in relation to sustainable development, understood as *the development model which aims at increasing the amount of goods and services available in a society on the condition that they be allocated with increasing equity in order to put behind social inequality and eliminate poverty by including the environment* (quoted from Secretaría de Ambiente y Desarrollo Sustentable [Department of Environment and Sustainable Development], 2006). In this setting, the Latin American and Caribbean Initiative for Sustainable Development (Iniciativa Latinoamericana y Caribeña para el Desarrollo Sostenible, ILAC) was launched, reflecting the singularities, visions, and goals of the region and taking into account, first and foremost, the application of the principle of common but differentiated responsibilities of States. This initiative aims at incorporating an environmental dimension into economic and social processes; ensuring the sustainable use of natural resources; contributing to alleviate poverty; increasing social equity through capacity building and technology transfer; strengthening support for economic development; and expanding access to international markets, thus fostering regional cooperation. Nevertheless, the “Globalization Project” (McMichael, 2011) has left these interests aside in pursuit of capital, denying the contradiction between environment and growth, while deepening the legitimization of the appropriation of nature (Leff, 2008).

The recently held Conference on Sustainable Development, also known as Rio +20 (Rio de Janeiro, Brazil, 2012) proposed the goal of redefining pathways towards a safer, more equitable, cleaner, greener, and more prosperous world for everyone, rethinking economic growth with greater social equity and securing environmental protection vis-à-vis the few objectives achieved since the previous Summit. To that end, two main topics were discussed: 1) the vision of a Green Economy in the context of poverty eradication through sustainable development, and 2) the institutional framework necessary for the achievement of this sustainable development. For its preparation, seven priority areas were considered: decent jobs, energy, sustainable cities, food security, agriculture, sustainable water and oceans, and disaster readiness. The adopted resolutions include the document “*The Future We Want,*” which promotes a sustainable economic, social, and environmental future for the planet characterized by fairness for both present and future generations. In general, it advocates holistic and integrating approaches to sustainable development which would guide humanity to a life in harmony with nature and would drive efforts to restore the health and integrity of the Earth’s ecosystem (General Assembly of the United Nations, 2012). In this sense, it considers the following aspects, among others: “Green Economy” as one of the available means to achieve sustainable development and as a tool for public policy-makers; the need of a more powerful institutional framework able to respond coherently and effectively to present and future sustainable development challenges at different scales, from global to local; and the achievement of the Millennium Development Goals from the perspective of the Sustainable Development Goals and as part of the post-2015 Development agenda. Additionally, it sets out the need to standardize and expand methods that contribute to the measurement of progress made around the Sustainable Development Goals (United Nations Environment Programme [UNEP], 2012).

Also necessary are urgent integrated actions from the local and national levels to the global level, which cover businesses, the civil society, and every actor involved, and that said actions be carried out at the appropriate scale, acknowledging each and every dimension of sustainable development. All countries, local governments, businesses, and civil society organizations are a part of the sustainable development framework and its four integrated goals: economic development (including the end of extreme poverty), social inclusion, environmental sustainability and good "governance" (including security). This last dimension is added to signal conditions facilitating sustainable development, including transparency, effective institutions, rule of law, involvement and personal security, accountability and adequate financing of public property, applicable to both the public and private sectors and civil society. Each of these four dimensions of sustainable development contributes to the other three and all of them, as a whole, are necessary for both social and individual well-being (Sustainable Development Solutions Network, SDSN, 2012).

Sustainability Indicators

The previously outlined concepts entail the acknowledgment of the need to have indicators that reflect and appraise the interrelations between socioeconomic development and ecological-environmental processes. This constitutes a baseline for the assessment of sustainability, and contributes to solve tensions among actors and their context in a more effective and efficient way. Previously developed sustainability indicators and measurements can be found in numerous pieces of work, especially at a global scale, which use national or regional aggregated data. Other studies have been carried out at country and city level, and also at the level of corporative and non-governmental entities (Global Reporting Initiative [GRI] 2011). The main differences between these indicators lie in what is to be sustained, what is to be developed, and for how long (Kates et al., 2005). Also, the number of proposed indicators goes from 6 to over 250, and its aggregation is not done in a single way, thus defining alternative visions on sustainability.

In Latin America, the Economic Commission for Latin America and the Caribbean (ECLAC) Sustainable Development and Human Settlements Division, through the Sustainability Assessment in Latin America and the Caribbean (Evaluación de la sostenibilidad en América Latina y el Caribe, ESALC) Project, proposed the generation of a Sustainable Development Indicators Database (Base de Datos de Indicadores de Desarrollo Sostenible, BADESALC) as an organized system of indicators, within a systemic and integrated framework, based on the concept of socioecological system. This database contains country-scale indicators which provide information related to Economic and Demographic Efficiency (*sic*), as well as indicators of Performance, Sustainability and Physical Flows Evolution and information for four main subsystems: social, economic, environmental, and institutional. These subsystems align with the sustainable development dimensions set out by the United Nations Conference on Sustainable Development (UNCSD, 1995, 2001, 2007). In 2008, the countries assessed the indicators proposal waiting for the institutionalization of their generation, considering the measurement of environmental, social, and economic indicators. The ECLAC Statistics and Economic Projections Division defined the Environmental Statistics and Indicators Database (Base de Datos de Estadísticas e Indicadores Ambientales, BADEIMA), which covers the measurement of air, water, oceans and coastlines, lands and soils, biota, energy, natural disasters, urban environment, and environmental management (Schuschny and Soto, 2009).

Prominent precedents in Argentina include the proposal of the Ministerio de Salud y Ambiente de la Nación (Ministry of Health and Environment, 2004) for the creation of a System of Sustainable Development Indicators in Argentina (Sistema de Indicadores de Desarrollo Sostenible de Argentina, SIDSA) with the purpose of assessing and monitoring sustainable development at country level on an integrated and continuous basis, and of applying such indicators to the decision-making process and the definition of public policy. This system has been implemented on a regular basis since 2004, and its last measurement dates back to 2010. The SIDSA considers the social, environmental, economic, and institutional dimensions, the interrelations among them (such as the impact of production aspects on the environment, the influence of the environment on human health), causal links between the different subsystems, and control signs, among others. The underlying criterion of this conceptual framework is the improvement of the population's quality of life and of the environment on which it depends. For each of the subsystems, there are two types of indicators: development indicators —accounting for a directional and progressive change—, and sustainability indicators —intended to reflect the change process and, consequently, the ability to maintain the development trend—. What is desirable in order to attain sustainable development is that the system's value, measured through the improvement in the quality of life, does not decline in the long run.

As a complement of the SIDSA, in 2006, the Ministerio de Salud y Ambiente de la Nación builds the indicators proposed by the Latin American and Caribbean Initiative for Sustainable Development (ILAC, 2006), which acknowledges the importance of regional activities in the promotion of sustainable development. Its goal is to adopt measures in areas such as biological diversity, water resources, sustainable cities, social aspects (including health and poverty), economic aspects (including energy), and institutional arrangements (including the promotion of capabilities, indicators, and civil society involvement), taking into account the ethics of sustainable development.

There are also pieces of work with sectorial and subnational scopes. Among them, Cantú *et al.* (2008) developed a methodology for the assessment and monitoring of the environmental sustainability of agroecosystems at a regional level, through the use of indicators and indexes assessed in different regions of Argentina throughout a network of universities and research centers. These include indicators for the resources land and water at both unit and system level. Loewy (2008), in a study carried out at the National Institute of Agricultural Technology (Instituto Nacional de Tecnología Agropecuaria, INTA) Bordenave experimental station on social indicators of production units for rural development in Argentina, postulates six premises that must coexist in every sustainable production system: social equity, production stability, production ethics, environmental efficiency, spatial efficiency, and agronomic efficiency. For his part, Calvo Moscoso (1999) proposes to develop a methodology for the assessment of the sustainability of agricultural production systems at the northwest region of Argentina through the use of an index which allows to monitor the condition of sustainability –considering the ecological or environmental, sociocultural, and economic-productive spheres–.

Based on the above mentioned precedents, this work presents a methodological proposal for the assessment of the sustainability of production systems within the Central-West Region. The proposal is based on the conceptual framework of sustainability that acknowledges the interactions among the ecological, economic, social, and institutional dimensions, as well as the complexity of production systems. This work was carried out by a group of researchers from different disciplines belonging to national universities located in the region under analysis.

First of all, the work addresses the characterization of the region under study from an ecological, economic, social, and institutional perspective to give way to the methodological proposal that allows the integration of these dimensions. Thus, the prevalent production systems within the target territory are identified and characterized, catering for their inherent social, environmental, economic, and institutional aspects. The identified production systems lead to a set of indicators to be considered when assessing sustainability. Second, the work designs a sustainability matrix, which is a tool that considers the observed convergences, organizes the information, and enables the assessment of the indicator. Finally, it lists some of the identified limitations and proposes lines of political action to ensure the feasibility of this methodological proposal.

Chapter 1.

Characterization of the Central-West Region

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In this chapter, the Central-West Region of Argentina is characterized on the basis of the four dimensions: ecological, economic, social, and institutional. Said dimensions form the conceptual foundations of sustainability, as assumed in the following sections of this work, which briefly describe some of their components.

The Ecological Dimension

The ecological dimension is associated with the supply of natural resources, biodiversity, and ecological processes, and the impacts of economic or population growth on all of them. The geographic area associated with the different ecoregions is used for the characterization of the soils and the biodiversity of the various environments within the Central-West Region. The region's climate is also taken into account, as well as the projections of climate change and variability for the decades to come.

Ecoregions

An ecoregion is

> ... a geographically defined area in which there prevail certain relatively uniform or recurring geomorphological and climatic conditions, characterized by a vegetation physiognomy made up of natural or seminatural communities sharing a significant group of prevalent species, an overall dynamics, and general ecological conditions, and whose interactions are essential to their long-term persistence (Burkart *et al.*, 1999).

The map of the ecoregions under study was based on the phytogeographical regions of Argentina (Cabrera, 1994) and was developed with the concurrence of a panel of experts on the flora and fauna of the country's different regions (Brown *et al.*, 2006). These are considered to be the most appropriate organizational level to assess the main ecological processes maintaining biodiversity and ecosystem services. It is even possible to find sociocultural, productive, and economic features inherent to an ecoregion which enable the interaction with the economic, social, and institutional subsystems. It is also deemed useful for the development and implementation of specific policies, as shown by the adoption of this concept by national and provincial organizations.

Eight of the eighteen ecoregions describing our country are represented in the Central-West Region (Brown *et al.*, 2006). They are: Pampa, Espinal, Dry Chaco, Monte of Plains and Plateaus, Monte of Hills and Valleys, High Andes, Puna, and Patagonian Steppe (Figure 1.1).

Pampa Ecoregion

This ecoregion extends geographically across the southern third of the province of Córdoba, comprising the departments General San Martín, Unión, Marcos Juárez, Presidente Roque Sáenz Peña, eastern portion of Juárez Celman and General Roca, and across the southern area of the province of San Luis, partially including the departments Gobernador Dupuy, General Pedernera, and Juan Martín de Pueyrredón.

The nature of this ecoregion's soils is given by the parent materials from which they have evolved and by the climatic conditions that define an increasing east-west water deficit gradient.

Figure 1.1. Ecoregions of the Central-West Region of Argentina

Source: Adapted from Brown *et al.* (2006).

In general, soils have developed from materials rich in sands with relative geochemical stability and little horizon differentiation. From a functional perspective, they are shallow, excessively drained, poorly structured soils without aggregates and with low levels of organic matter. Material weathering is barely incipient and carbonates have only been washed off the upper portion of the profile. Arable soils have been characterized as Class III and IV, as per the U. S. Department of Agriculture (USDA) land-capability classification system, with over 40.0% of the region's soils being entisols.

The natural vegetation of the Pampa ecoregion is characterized by the genera *Nassella* and *Jarava*, among others. It has been so deeply modified by agricultural and livestock activities that it could be argued that natural ecosystems have been replaced, almost completely, by cropland. Within the ecoregion, there persist particular environments such as lakes and wetlands, with a low degree of degradation, where the associated flora consists mainly of reed beds ("juncales" and "totorales") at permanent lakes, as well as tall grasslands of esparto ("espartillo"), or salt prairies of inland saltgrass ("pelo de chancho"), across the peripheral areas.

Espinal Ecoregion

This ecoregion covers the central and southwest areas of the province of Córdoba, partially including the following departments: San Justo, Río Cuarto, Marcos Juárez, Juárez Celman, and Unión, and also the central-south area of the province of San Luis, partially including the departments Gobernador Dupuy, Coronel Pringles, and Juan Martín de Pueyrredón.

In Córdoba, there is a marked contrast between foothills and the vast flatlands. This can also be seen in San Luis, which also features large sand dune areas. The characteristics of the soils are variable. Towards the northeastern area of the ecoregion, soils, formed on loessic deposits, are argillaceous and imperfectly drained. Towards the central-western and southern areas of the region, they are moderately to poorly developed, with coarse textures and low contents of organic matter and clay, and, particularly southwards, exhibiting petrocalcic horizons and sand dune areas.

At the Juárez Celman department, in Córdoba, temporary watercourses are not enough to form solid water networks due to the high permeability of the area's soils, giving rise to wetlands. In the central area, within the province of Córdoba, the most important watercourses are the Tercero (Ctalamochita) and Cuarto (Chocancharava) rivers, which belong to the Paraná basin, the Quinto (Popopis) river, which flows into an inland basin and whose sources are located in San Luis, and the Segundo (Xanaes) river, which flows into Mar Chiquita (Ansenusa) lake.

The ecoregion's vegetation is characterized by the prevalence of the genera *Prosopis* and *Acacia,* along with other genera, such as *Celtis, Schinus*, and *Geoffroea* (Cabrera, 1994).

Dry Chaco Ecoregion

This ecoregion expands across the northwest area of the province of

Córdoba, covering, either in full or in part, the departments San Javier, Cruz del Eje, Ischilín, Minas, Pocho, San Alberto, Sobremonte, and Tulumba; across the northern area of the province of San Luis, including, either in full or in part, the departments San Martín, Ayacucho, Belgrano, Chacabuco, and Junín; and across the eastern area of the province of La Rioja, covering, either in full or in part, the departments Capital, Chamical, General Ángel Vera Peñaloza, General Belgrano, General Quiroga, General Ocampo, General San Martin, Independencia, and Rosario Vera Peñaloza.

This region features the northwest valleys (“bolsones”), characterized by sedimentary basins of tectonic origin gently undulating with closed drainage basins (central point of the valley), where fine materials build up or saltwater deposits are formed. Its soil order is 40.0% aridisols, 25.0% entisols (poorly-evolved young soils, particularly torriorthents at the converging point between the foothills and the central area of the valley), and 35.0% haplustolls towards the hills (more developed soils with organic horizon) with a prevalent loam to silt loam texture.

The short course of the region’s rivers is due to scarce precipitation, the inherent characteristics of the materials (high infiltration), and the high evaporation rates. The main rivers on the north slope of the Sierras Grandes hills are: Cruz del Eje (dammed for the supply of drinking water, irrigation, and power), Soto, Guasapampa, and Pichanas (dammed). The main rivers on the west slope of the Sierras Grandes, Sierras de Pocho, and Sierras de San Luis hills are Los Sauces river (dammed for the supply of drinking water and irrigation) and other smaller rivers, such as the Chancaní and Luján rivers; the rivers of the Sierras de San Luis hills have small dams for the irrigation of confined areas. The most important river on the east slope of the Sierra de Velazco hill is the Río Grande river, also known as La Rioja river, with its numerous tributaries, some of which have temporary courses, which infiltrates into the alluvial fill of the Sanagasta valley. This river flows into the Dique de los Sauces dyke, whose dam ensures the availability of drinking water, power generation, and irrigation water. Lastly, the most important river on the east slope of the Sierras de los Llanos hills is the Anzulón river, which is used for irrigation purposes.

Underground waters, associated with the salt lakes basins, are quite shallow (6-170 m) and good-quality, with volumes of flow ranging from 1,700 to 4,500 l/hour. The Conlara basin has quite shallow groundwater, with eventual water springs (phreatic: 15-50 m and deep: 150 m), which are devoted to irrigation.

The Dry Chaco area has three districts: Chaco Serrano, Semiarid Chaco, and Arid Chaco, which roughly correspond to Chaco Serrano and

Occidental Chaco (Cabrera, 1994). This ecoregion's natural vegetation is represented by the xerophytic forest, characterized by a sparse low tree stratum (8-15 m high). In general, natural vegetation has been modified by human activities such as felling, grazing, browsing, trampling, and fire application for resprouting purposes.

The Chaco Serrano district is characterized by forests of "quebracho colorado" (*Schinopsis marginata*) and grasslands with "molle" (*Lithraea molleoides*) (Biurrun *et al.*, 2012). On the shrub-herb stratum there are several species from other biogeographical districts. At greater heights, the forest is replaced by grasslands or gramineous steppes with a predominance of species from the genera *Stipa* and *Festuca* (Torrela and Adámoli, 2006). The Semiarid Chaco district features "quebracho colorado santiagueño" (*Schinopsis quebracho-colorado*) and "quebracho blanco" (*Aspidosperma quebracho-blanco*). On the ecoregion's eastern border, these species also coexist with the "quebracho colorado chaqueño" (*Schinopsis balansae*). The Arid Chaco features open forests of "quebracho blanco" with a floral composition similar to that of the "quebracho colorado santiagueño" (*Schinopsis lorentzii*), but with a more xerophytic physiognomy, with some species typical of the monte *Larrea* spp. and an absolute absence of "quebracho colorado" (Torrela and Adámoli, 2006; Biurrun *et al.*, 2012).

Monte of Hills and Valleys and Monte of Plains and Plateaus Ecoregions

The Monte of Hills and Valleys ecoregion covers the western area of the province of La Rioja, including the departments Coronel Felipe Varela, Famatina, Chilecito, Sanagasta, Castro Barros, Arauco, and San Blas de los Sauces; and a significant portion of San Juan, including the departments Jachal, Ullum, Angaco, Caucete, Albardón, and San Martín.

The Monte of Plains and Plateaus ecoregion consists of the southern area of San Juan, including the departments Zonda, Rivadavia, Chimbas, Capital, Santa Lucía, Pocito, Rawson, 9 de Julio, Sarmiento, and 25 de Mayo, and a large portion of Mendoza, including the departments Lavalle, Guaymallén, Maipú, San Martín, Junín, Rivadavia, Santa Rosa, La Paz, and part of the departments Tupungato, Tunuyán, San Carlos, San Rafael, and Malargüe, as well as the northwestern area of San Luis, partially including the departments Ayacucho, Belgrano, and Juan Martín de Pueyrredón.

Morello (1958) divides the phytogeographical province of this ecoregion into two sectors: the septentrional, located north of 37° south latitude, and the austral (or meridional), extending south of the 37° line of latitude. Both sectors roughly coincide with the ecoregions Monte of Hills and Valleys, and Monte of Plains and Plateaus, respectively (Pol *et al.*, 2006).

The floral composition of these two ecoregions is very similar, while their geomorphological features stand out as the main difference between them. The Monte of Hills and Valleys ecoregion features longitudinal valleys which are continued southwards by closed basins (known as "bolsones") and intermontane valleys. On the other hand, the Monte of Plains and Plateaus ecoregion exhibits a more homogeneous landscape, with plains and vast plateaus of heights ranging from 0 to 1,000 m ASL (Burkart, 1996; Pol *et al.*, 2006).

The Monte of Plains and Plateaus ecoregion is characterized by a large depression filled up with degradation materials from the surrounding hill ranges; deep sandy torrifluvent soils of eolic and fluvial origin, and the existence of significant areas with sand dunes and halomorphic systems.

There are large rivers originating in Andean and pre-Andean thawings, with systems of collector rivers which may drain into the sea, like the Desaguadero-Colorado system. These water resources have enabled the great agricultural development of the region at irrigation oases. There are also temporary water courses which are not generally exploited by man. However, they occasionally hold low-cost structures, such as watering troughs for livestock. These ecoregions also have underground waters, such as the Mendoza and San Juan basin, which refills at the Andes mountain chain and has a low volume of flow on the upper aquifers that increases at around 80-150 m.

According to the physical and chemical characteristics of their soil and topography, these ecoregions can hold different plant communities: the well-drained soils of the intermontane valleys and bolsones are perennial foliage shrub steppes between 1.5 and 3 m high, with a predominance of "jarilla" (*Larrea divaricata, L. nítida and L. cuneifolia*); "mata sebo" (*Monttea aphylla*), and "monte negro" (*Boungaivillea spinosa*). Other abundant shrubs are the "pichana" (*Cassia aphylla*), the "tintinaco" (*Prosopis torquata*), and the "alpataco" (*Prosopis alpataco*). Other zygophyllaceous genera, such as *Bulnesia* and *Plectrocarpa,* are only found on the northern area (Morello, 1958; Cabrera, 1994; Burkart, 1996; Pol *et al.*, 2006).

At the *bottom* of the bolsones, there develop halophile communities ("jumeales" and "zampales"). Lastly, on river banks or on wet subsoil areas with shallow water table levels there are mesquite areas of “algarrobo negro” (*Prosopis flexuosa*) and “algarrobo blanco” (*P. chilensis*) (Morello, 1958; Cabrera, 1994, Burkart, 1996; Pol *et al.*, 2006). Also present are “tintitaco” and, in some areas with saline soils, creeping screwbean, also known as “retortuño” or “mastuerzo” (*P. strombulífera*).

On the hill slopes, at around 2,000 m, plant life becomes more stunted and jarilla is replaced, in part, by other xerophilic shrubs, such as cardons, which can reach heights of 4 to 5 m, and other cacti (Burkart, 1996; Bertonatti, and Corcuera, 2000). Some authors refer to this community, which extends up to about 3,500 m ASL, as “Pre-Puna” (Cabrera, 1994).

Puna and High Andes Ecoregions

Westwards and above 3,500 m ASL, there extend two intermingled altitude landscapes: the Puna and the High Andes ecoregions. Even though they share many similarities, the essential difference between these two environments is that the first has a basically plain relief, while the latter is characterized by its pronounced slopes (Reboratti, 2006). The predominant vegetation within the Puna ecoregion are shrub steppes, while the High Andes ecoregion features gramineous steppes and chamaephytes. Water draining off mountainsides forms “meadows” (also known as “vegas”) or “swamps” that hold greater biodiversity due to water availability (Cabrera, 1994; Bertonatti and Corcuera, 2000).

The High Andes ecoregion extends on the western area of La Rioja (departments Vinchina, General Lamadrid, Coronel Felipe Varela, Chilecito, and Famatina), San Juan (departments Iglesia and Calangasta), and Mendoza (departments Malargüe, San Rafael, San Carlos, Tunuyán, Tupungato, Luján de Cuyo, and Las Heras). It has a high-mountain geomorphology, with soft and steep slopes and also plateaus with heights between 3,500 and 4,500 m ASL, although decreasing southwards to as little as 2,200 m ASL. In general, soils are developed on rocky or gravelly material and exhibit low pedogenetic development.

The High Andes ecoregion is an important solid water reservoir, with a good number of glaciers and snowfields, although in permanent retreat as a result of global warming. Owing to its state of isolation and its harsh climate, it is a relatively unaltered environment (it could be thought of as the least modified in the country) (Reboratti, 2005). Natural vegetation consists of steppes or high grasses, and low woody mattress-shaped shrubs with a thick top, small leaves, and sizable root development, and an open and discontinuous distribution. The ecoregion features thatch-like vegetation, with a predominance of the genera *Nassella, Jarava, Festuca*, and *Poa*. Shrub steppes are also abundant, with predominance of the genus *Adesmia*.

The Puna ecoregion covers, within the province of La Rioja, the departments Vinchina, General Lamadrid, and Coronel Felipe Varela, and within the province of San Juan, part of the Iglesia department. It extends across the northwestern plateaus and mountains between 3,400 and 4,500 m ASL. It is a geomorphology of high plateaus, hills, and ravines, with immature soils with little organic matter which are commonly sandy or gravelly. Vegetation essentially consists of low shrubs like the “tola” (*Paraestrephia* spp.), the “añagua” (*Adesmia horridiscula*), and the “yareta” (*Azorella yareta*), of which hundred-year old specimens have been found. Land is not fully covered by shrubs and is largely barren. Grasses appear only occasionally at the “vegas”, and spore associations of “esporal” (*Pennisetum chilensis*) can be seen at some sheltered slopes. Larger trees are very scarce. Among them are the “queñoa” (*Polylepis tomentella*), which clusters in copses at sheltered sites, and the “churqui” (*Prosopis ferox*), which can only be found at the lowest eastern edges (Reboratti, 2006). Besides facing the threats inherent to high lands, these environments are arid and at high risk of desertification and, in spite of their biodiversity being relatively low (Morello, 1958), they exhibit a high degree of endemism (Bertonatti and Corcuera, 2000).

Patagonian Steppe Ecoregion

This ecoregion occupies a more reduced surface area than all the other previously described ecoregions in the Central-West Region. In Mendoza, it covers the departments Malargüe and San Rafael. The Payunia district extends across the volcano region in the southern area of Mendoza. The region’s typical geomorphology includes volcanoes, deposits of volcanic ashes, high plateaus, and peneplains. Soils are lithosols or incipient soils, always highly sandy, and/or saline soils, as in the case of Llancanelo. The typical vegetation is shrub steppe with small shrubs, such as the “quilimbai” (*Chuquiraga avellanedae*) and the “colapiche” (*Nassauvia axillaris*), as well as hard grasses.

Climate

Considering the reduced latitudinal extension of the Central-West Region in comparison with that of the country, it features no significant gradients of climate variables in the north-south direction. In terms of precipitation, there is an important east-west variation: humid on the east, subhumid and semiarid on the central area, and finally arid on the west area of the region. Normal thermal conditions are generally moderate during summer and winter, except for the northwestern portion of the region and the high areas on the west, which exhibit higher temperature ranges. However, the absolute values of climate variables, the duration of events, the extreme values, the seasonal variability, and their interaction with other physical variables in the environment are significant and determine the subregional characteristics, thus defining the region's productive potential, the year-by-year yield of crops and grasslands, the quality of natural resources, and regional economies.

Radiation, temperature, and water availability are the most limiting climate variables which determine the response of vegetation and crop yield, and whose variability and change in time are responsible for the variability of, for instance, agricultural production and the increase of production risk. Temperature and water variability are also accountable for the risks posed by frost, heat waves, floods, hail, and droughts, phenomena that manifest and affect the different ecoregions in distinct ways.

Due to the small latitudinal amplitude previously referred to, average annual solar radiation does not exhibit significant variation across the region. Sunshine hours determine mesothermal conditions along the year, with differences between the winter and summer seasons.

Temperature and Moisture Conditions

Thermal gradients within the Central-West Region generally vary latitudinally, except for the western pre-Andean or Andean areas, where there is a highly marked east to west temperature change driven by the altitude variation. Maximum average annual temperatures range from 26 °C to 28 °C on the northern area of the region; from 24 °C to 26 °C on the central area; and from 22 °C to 24 °C on the southern area. Towards the western area of the region, maximum annual temperatures range from 20 °C to 22 °C (Figure 1.2).

Minimum average annual temperature ranges from 12 °C to 14 °C on the northern area of the Central-West Region; from 10 °C to 12 °C on the central area; and from 8 °C to 10 °C on the southern area (Figure 1.3). Thermal gradients on the high areas of the west show averages ranging from 2 °C to 8 °C.

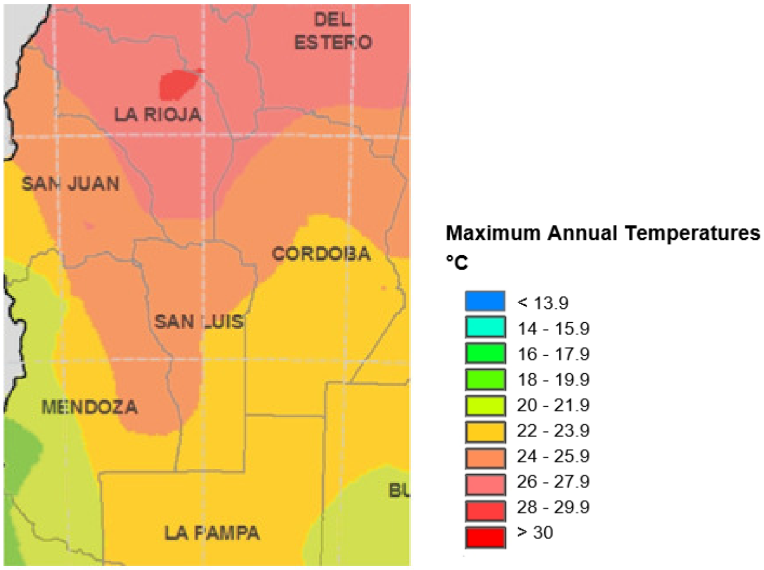

Figure 1.2. Variation of maximum annual temperatures on the Central-West Region, average for the 1971-2000 series
Source: Modified from INTA (2008a).

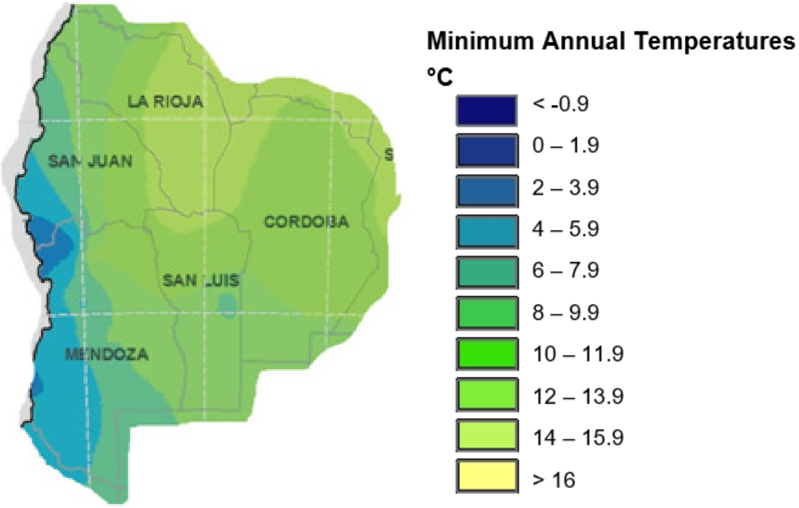

Figure 1.3. Variation of minimum annual temperatures on the Central-West Region, average for the 1971-2000 series
Source: Modified from INTA (2008b).

The moderate pattern of the region’s thermal conditions contrasts with the great variation in precipitation, which shows a pronounced gradient of east to west decrease. This results in the exacerbation of water deficits and availability, and positions precipitation as the most limiting climate element for a large number of production activities and to meet human requirements. Average annual precipitation varies from 900-800 mm on the eastern area of the region to average records of 200 mm on the western area, and even below 200 mm in certain areas of San Juan, the west portion of La Rioja, and the northwest of Mendoza (Figure 1.4). The seasonal distribution of precipitation throughout the region is typical of a monsoonal regime (concentrated during the warmest period, from October through March), with winter being the driest season (Ravelo and Seiler, 1979). Climate balance of water within the region suggests a small surplus on the east of the province of Córdoba, and different magnitudes of deficits on the rest of the region as normal or permanent situations. Nevertheless, interannual climate variability still causes imbalance situations departing from what is considered normal in a given area, with occasional droughts of differing severity and frequency.

The precipitation regime influences the water balance of soils, the replenishment of underground reservoirs, and surface water systems, including floods in areas exposed to this phenomenon, such as the southeast of Córdoba.

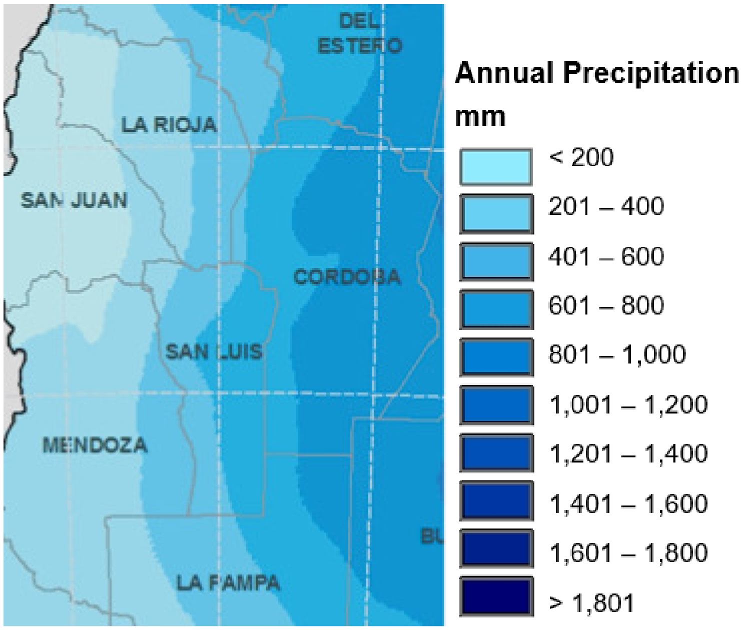

Figure 1.4. Variation of annual precipitation on the Central-West Region, average for the series 1971-2000

Source: Modified from INTA (2008c).

Climate patterns and climate variability across the region and the different subregions become increasingly complex based on their interaction with soils (depressed and flood-prone areas, saline soils, drainage issues, etc.) and their topographical variations, thus causing different environment responses due to the variation in precipitation efficiency and to changes in the environment potential for production.

Another element that climatically defines the Central-West Region is wind. Simplifying its analysis and focusing on its environmental effects and meteorological consequences, two behavior patterns can be pointed out. One of these patterns is more representative of the eastern area of the Central-West Region, while the other is more characteristic of the western portion of the Region, towards the Andean area. The first one, with a northeast/northwest and southwest direction, is the permanent and normal "northern wind-southern wind" alternation, responsible for precipitation and its yearly distribution, but also for heat waves, dessication, and soil erosion processes and the resulting environmental degradation. The latter is the characteristic "Zonda wind", a normal phenomenon of the western area climate, accountable for stress situations affecting living beings and negative, and even destructive, effects for the environment and its components.

Climate Change and Climate Variability

The preceding description of weather and climate elements applies to what could be referred to as "a stable climate state". However, there is plenty of evidence and references of climate change and its variability, situations that put pressure regarding change and response on the environment, on production systems, and on adaptations oriented to the search of new balances or sustainability conditions.

Climate changes on a permanent basis and climate variability is also a normal climate condition. These fluctuations can be attributed to factors referred to as external including, among others, solar radiation, volcanic eruptions, El Niño-Southern Oscillation (ENSO); and also to internal factors, such as greenhouse gas emissions, land-use change, deforestation, the advance of agriculture, desertification, etc. On regional analyses like this one, the consideration of both internal and external factors bears special significance for sustainability conditions.

One piece of evidence of climate change lies on the change in the planet's temperature. Global temperature has risen with respect to the past, and continues to rise at a ratio as projected in the last two reports of the Intergovernmental Panel on Climate Change (IPCC) (Rahmstorf *et al.*, 2012) (Figure 1.5).

Climate change and variability are very important factors for ecological processes. The environment's biological responses to changes in climate tend to bear significant relevance for socioeconomic aspects such as agriculture, forestry activities, biodiversity, and human health, and, at the same time, they play an important role in awareness-raising and environmental education around climate change.

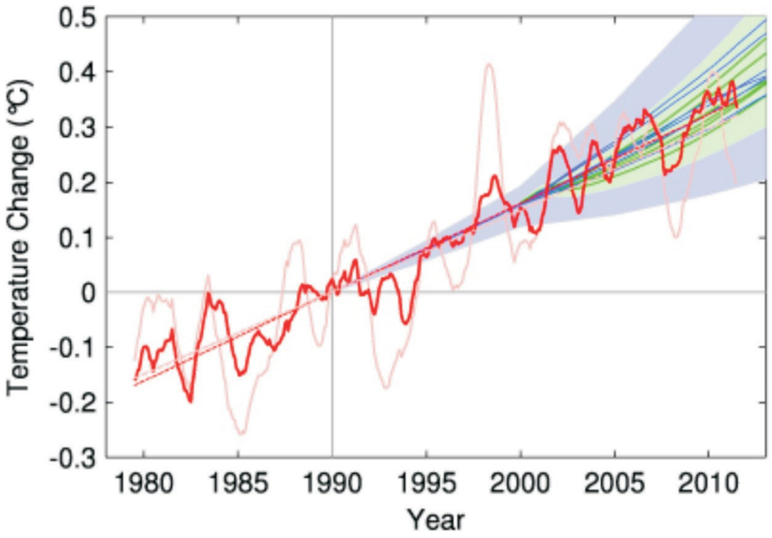

Figure 1.5. Global temperature evolution in the last 30 years

Note: The observed annual global temperature, unadjusted (pink line) and adjusted according to short periods of variations in solar radiation, volcanic activity, and ENSO (red line), as per Foster and Rahmstorf (2011). Linear trend shown as a 12-month moving average and compared to the IPCC's scenarios (blue lines and shades for Third Assessment Report; green lines and shades for Fourth Assessment Report). Projections are aligned in the chart so that they start (in 1990 and 2000, respectively) on the trend line of observed adjusted data.

Source: Rahmstorf *et al.* (2012).

Results confirm that the global warming projected by scientists in the 60s and 70s continues with a trend of 0.16 °C per decade closely following the IPCC's projections (Rahmstorf *et al.*, 2012). For 1979-2000, trends on the southeast area of South America are generally weaker than in other areas of the continent, yet positive (Camilioni, 2005). In the same study, and extensively applicable to a large part of the Central-West Region, there stands out a positive trend of average annual temperatures from the 1920s onwards, as well as a predominance of positive anomalies from the 1980s onwards.

At a regional level, within Argentina's agricultural areas, climate variability has become a very relevant aspect for agricultural production systems. In the analysis of impacts on the eastern and southeastern areas of the Region and using experimental data, crop development, and yield simulations for corn and peanut with different climate scenarios, it was shown that an increase in temperature variability causes a decrease in average crop yields, as well as an increase in their interannual variability, among other changes (Vinocur *et al.*, 2000a, b, c; 2001, and Vinocur, 2008). De la Casa and Seiler (2003), when comparing average climate variability for 10 years (1941-1990), found that climate changes tended to trigger changes in livestock production capacity within the province of Córdoba.

The IPCC's Third Assessment Report also records changes in precipitation. There is evidence that, during the 20th century, precipitation has increased between 0.5% and 1.0% per decade at most medium and high latitudes in the northern hemisphere continents, and between 0.2% and 0.3% per decade in tropical areas (IPCC, 2001). Within the Argentine territory, north of 40º south latitude, the increase in average annual precipitation was between 10.0% and 40.0% during 1956-1991 (Castañeda and Barros, 2001). A vast surface area, located between 20º and 40º south latitude, east of the Andes, and covering the Central-West Region shows significant positive trends, mainly in summer.

Future Climate Scenarios

On the IPCC's Fourth Assessment Report (IPCC, 2007), the projections for changes in average temperatures and precipitation were based on the results of simulations from a set of 21 atmosphere-ocean coupled general circulation models (AOGCMs) for emissions scenarios A to B and for 2080-2099, as compared to 1980-1999 (Christensen *et al.*, 2007). For the southern area of South America, the projected changes in average annual temperature indicate an increase in thermal values within a range of 1.7 °C and 3.9 °C and an average value of 2.5 °C, while in the case of precipitation, responses exhibit marked regional variability.

For the region under study, average summer temperatures (December, January, and February) show projections of temperature rises between 2.5 °C and 3.5 °C, while for winter (June, July, and August), temperature will rise between 1.0 °C and 2.0 °C. Precipitation projections show 15.0% to 30.0% increases for subtropical plain areas in summer, and a decrease of similar magnitude at the Central Andes, while winter projections forecast a 10.0% to 20.0% decrease within the Central Andes and few changes in the central area of the country (IPCC, 2007).

For the Cuyo region, climate change scenarios based on the MM5/CIMA high-resolution model and the A2 emissions scenario for 2021-2030 projected an increase in average annual temperature of 1.3 ºC to 1.5 ºC, and a 100 mm decrease in precipitation, as well as an average isotherm rise of 0 ºC at 130 m and 150 m altitudes (Nuñez and Solman, 2006). The changes in these variables would cause a 13.0% to 29.0% drop in the average annual volumes of flow of the rivers located in the northern area of the region, and a 10.0% to 12.0% drop in the ones on the south (Diamante and Atuel). The rise in the 0 ºC isotherm would bring about a contraction of snow cover up to 47.0% during the winter, with southern lower basins (Diamante and Atuel) being the most affected. It would also cause a reduction in snow persistence during the summer. The main consequences of these changes will be lower water supply in the oases of the Cuyo region (particularly along the rivers San Juan and Mendoza), the advance of runoff peaks, the reduction of summer volumes of flow (more pronounced at the basins of the rivers Diamante and Atuel), and the gradual disappearance of glaciers, with the resulting loss of the regulating and water reserve capacity associated with them (Boninsegna and Villalba, 2007).

For the province of San Luis, Barros *et al.* (2010) developed scenarios for 2011-2030 and 2046-2065, and for A1B emissions scenario, based on PRECIS regional climate model simulations (25 km resolution) forced with limit and starting conditions by the HadCM3 AOGCM. As compared to the 1980-1999 baseline period, percentage changes in average annual precipitation for 2011-2030 show a 5.0% rise with seasonal fluctuations, increases in summer, fall, and winter, and decreases in spring. For 2046-2065, these changes intensify, in excess of an annual 15.0% at the central and northwestern areas. Changes are not as marked towards the northeast portion of the province, with a widespread increase in summer, reaching values between 50% and over 30.0% at the central and southwest areas, and up to 20.0% in winter at the central and northern areas.

Expected changes in average annual temperature for 2011-2030 are 0.5 ºC to 0.6 ºC throughout the southern and central areas of San Luis, while, in the north, they could exceed 0.6 ºC. If seasonal changes are considered, the largest increases occur in summer (0.7 ºC to 0.8 ºC) in the central and northeast areas, while during winter values above 0.7 ºC can be observed on the northeastern end of the province. The projection for average annual temperature change for 2046-2065 shows a south to north increase from 1.5 ºC to 1.9 ºC, with seasonal values over 2.2 ºC in the northern area during the summer, and up to 2 ºC during the winter.

According to these results, in a 50-year scenario, water stress would increase on the northern area and a large part of the hill area, and would decrease on the south. A similar, yet more moderate, trend would also be observed on a shorter time horizon (Barros *et al.*, 2010).

For southern Córdoba, Vinocur (2008) developed climate change scenarios for 2020 and 2050 considering emissions scenarios A2 and B2 and AOGCMs HadCM3 (H), ECHAM4/OPY3 (E), and GFDL-R30 (G). For 2050, relative to the 1961-1990 baseline period, projections indicate a rise in air temperature for every month, ranging from 0.1 °C to 2.4 °C, with larger increases during spring and summer. Precipitation projections for 2050 show a 35.0% to 61.0% rise in April on four out of six scenarios (E-A2, E-B2, H-A2, and H-B2), as well as drops in June (5.0% to 23.0%), July (6.0% to 16.0%), and September (5.0% to 11.0%). This increased projected precipitation for April may increase flood risk on the southern area of the region, which is more prone to this kind of phenomenon due to its topographical and soil conditions. For October and December, all scenarios project precipitation increases with higher values in December. As September and October mark the beginning of sowing time for coarse-grains crops, projections for these months are very important for agricultural production. It should also be noted that all scenarios assume a decline in precipitation in January, thus exacerbating the water deficit typically occurring during this month in the region under study. Projected changes in seasonal precipitation show rises of different magnitude for summer, fall, and spring, depending on the considered scenarios and years, and peaking for 2050. For winter, four out of six scenarios indicate precipitation decreases ranging from 0.5% to 6.0% for 2020, and from 2.0% to 13.0% for 2050.

The Economic Dimension

The Central-West Region’s climatic, topographic, edaphic, and biological characteristics further the development of various primary production activities, such as agriculture, stockbreeding, and tree and fruit harvesting, among others. These are complemented by industrial development, which is mainly oriented to the metallurgical and agroindustrial fields, as well as by a significant level of tourism, business, and extractive activities. Next, gross geographic product and exports are considered as synthetic measurements of the region’s economic activities.

Gross Geographic Product

In 2007, the last year for which there is unified information available for all the provinces making up the Central-West Region, Gross Geographic Product (GGP) reached ARS 109,240 million at current market prices, with a per capita value of ARS 17,300. This accounted for around 13.5% of Argentina's level of economic activity, representing the most significant share following the province of Buenos Aires and the City of Buenos Aires (Capital Federal).

Table 1.1. contains a GGP breakdown by production industry and by province. Goods-producing industries account for 47.7% of the region's aggregate economic activity, while the remaining 52.3% is in the hands of service-producing industries. Among the first ones, the manufacturing sector (19.7%), the agricultural and livestock sector (13.6%), and extractive activities (6.4%) stand out. These three sectors as a whole account for about 40.0% of the economic activity, thus becoming the main production sectors within the Central-West Region.

An analysis of the region shows uneven contributions from the different provinces, with Córdoba contributing a 58.2% of the GGP, followed by Mendoza, with a 26.1%. Córdoba leads all sectors, with the exception of extractive activities, headed by Mendoza. No data by province department are shown as such information is unavailable from the relevant data sources.

Exports

According to the provincial statistics departments, the region's exports reached USD 11,392 million during 2007, accounting for 20.3% of the country's sales overseas. Table 1.2 contains an exports breakdown by major industry group and by province.

Industrial products (IP) account for 17.1%, while external sales for agricultural products (AP) represent 41.8%. Hence, this region's agricultural and agroindustrial sectors contributed, as a whole, 76.4% (USD 8,646 million) of total overseas sales revenues, thus being the largest source of foreign currency for the region's economy.

Table 1.1. Gross Geographic Product

In thousands of current 2007 ARS

PROVINCE	**LA RIOJA**	**SAN LUIS**	**SAN JUAN**	**MENDOZA**	**CÓRDOBA**	**TOTAL**	**%**
SECTORS TOTAL	**3,670,691**	**6,874,613**	**7,563,679**	**30,890,200**	**60,240,531**	**109,239,714**	**100.00**
Goods-producing sectors	***1,171,073***	***4,145,187***	***3,825,372***	***15,981,116***	***26,938,253***	***52,061,001***	**47.66**
A - Agriculture, Cattle-Raising, Hunting, and Forestry	182,906	892,284	1,090,664	2,551,050	**10,180,058**	14,896,963	**13.64**
C - Mining and Quarrying	7,008	69,742	89,379	**6,787,806**	82,365	7,036,300	**6.44**
D - Manufacturing Industry	794,131	2,846,230	1,749,257	4,421,430	**11,753,403**	21,564,451	**19.74**
E - Power, Gas, and Water	52,557	65,101	177,532	471,371	**974,463**	1,741,024	**1.59**
F – Construction	134,471	271,828	718,540	1,749,459	**3,947,965**	6,822,263	**6.25**
Service-producing sectors	***2,499,617***	***2,729,427***	***3,738,307***	***14,909,083***	***33,302,278***	**57,178,712**	**52.34**
%	**4.37**	**4.77**	**6.54**	**26.07**	**58.24**	**100.00**	**100.00**

Source: Dirección de Estadísticas y Censo (Statistics and Census Department) of the provinces of La Rioja, San Luis, San Juan, Mendoza, and Córdoba.

Table 1.2. Exports in the Central-West Region

In thousands of USD (FOB prices) Year 2007

INDUSTRY GROUP	**LA RIOJA**	**SAN LUIS**	**SAN JUAN**	**MENDOZA**	**CÓRDOBA**	**TOTAL**	**%**
Primary products	1,489	35,200	144,157	1,334,500	2,394,000	3,909,346	34.53
Agricultural products	100,035	196,900	274,458	737,500	3,428,000	4,736,893	41.84
Industrial products	66,832	288,100	-	168,700	1,412,000	1,935,632	17.10
Mining by-products	-	-	545,842	193,000	1,000	739,842	6.53
TOTAL	168,356	520,200	964,457	2,433,700	7,235,000	11,321,713	100.00
Percentages	1.49	4.59	8.52	21.50	63.90	100.00	

Source: Dirección de Estadísticas y Censo of the provinces of La Rioja,
San Luis, San Juan, Mendoza, and Córdoba.

Table 1.3 reports each network's share in the region's total and how it is allocated within the region itself. Major exported categories are oleaginous seeds and fruits and their by-products (oils and pellets), followed by gold, the automobile industry, and grains. Other relevant categories are machinery and equipment, dairy products, legume and vegetables by-products, and meat and its by-products.

Table 1.3. Export networks within the Central-West Region

In thousands of USD and percentage share, of the network in the total and of each province in the network. Year 2010

Network	CÓRDOBA	LA RIOJA	MENDOZA	SAN JUAN	SAN LUIS	TOTAL	%
Soybean	99.31				0.69	3,672,960.00	28.43
Gold (1)				100.00		1,604,866.00	12.42
Automobiles	98.77				1.23	1,595,565.00	12.35
Corn	94.80				5.20	1,012,884.00	7.84
Juice, wine, stum, vermouth, and others (2)			83.99	14.13	1.88	830,698.00	6.43
Vegetables			63.19	23.83	12.98	357,853.00	2.77
Peanut preparations	94.96				5.04	289,892.00	2.24
Dairy products	100.00					267,914.00	2.07
Fruits		1.34	96.67		1.99	219,659.00	1.70
Cellulose-Paper		52.48			47.52	190,192.00	1.47
Peanut	100.00					157,763.00	1.22
Meat	62.18				37.82	127,688.00	0.99
Petrochemical			100.00			126,400.00	0.98
Wheat	89.32				10.68	117,010.00	0.91
Grape				100.00		115,078.00	0.89
Leather		55.31			44.69	108,874.00	0.84
Iron and steel			54.56	20.23	25.21	88,902.00	0.69
Peanut oil and by-products (3)	100.00					86,781.00	0.67
Other grain exports	94.90				5.10	58,021.00	0.45
Sunflower	100.00					42,301.00	0.33
Oil and gas			100.00			36,711.00	0.28
Other forestry exports			100.00			11,612.00	0.09
Other networks		100.00				6,840.00	0.05
Cotton, textile		100.00				5,340.00	0.04
Remaining exports	58.91	2.10	18.82	9.13	11.03	1,786,763.00	13.83
						12,918,567.00	100.00

NOTE: (1). Includes raw gold, semiprocessed gold, gold dust, and scrap gold. (2) Includes grape brandy. (3) Includes peanut oil by-products.

Source: National Institute of Statistics and Censuses (Instituto Nacional de Estadística y Censos, INDEC) (2010).

The Social Dimension

The social dimension considers aspects related to the population of the Central-West Region: demography, health, education, and living conditions. This information is presented in a disaggregated way for each of the constituent provinces.

Demographic Aspects

The Central-West Region's aggregated population is 6,494,812 inhabitants, accounting for 16.2% of the country's population. Population density is 11.4 inhabitants/km^{2,} above the national value of 10.7 inhabitants/km^2. Over half the population (50.9%) is concentrated in the province of Córdoba, where density figures reach 20.0 inhabitants/km^2; whereas in the remaining provinces, density is below 12 inhabitants/km^2.

The region's masculinity ratio –reporting the number of men per hundred women– is 94.97, as compared to a national 94.3. This ratio exhibits extreme values in La Rioja and Córdoba, with 98.0 and 94.2, respectively, as compared to 97.5 in San Luis, 94.9 in Mendoza, and 95.8 in San Juan. Table 1.4 reports each province's absolute dimension and their relative share within the region.

Table 1.4. Population and density within the Central-West Region

By province, year 2010

Province	**Population 2010 (number of inhabitants)**	**Surface area (km²)**	**Density (in./km²)**	**Share within the Region**	
				Population	**Surface area**
Córdoba	3,308,876	165,321	20.02	50.95	28.99
La Rioja	333,642	89,680	3.72	5.14	15.73
Mendoza	1,738,929	148,827	11.68	26.77	26.10
San Juan	681,055	89,651	7.60	10.49	15.72
San Luis	432,310	76,748	5.63	6.66	13.46
Total	6,494,812	570,227	11.39	100.00	100.00

Source: Censo Nacional de Población y Vivienda (National Population and Housing Census) (2010)

The georeferenced population density in Figure 1.6 shows little urban concentration. The largest range (1,730.5 to 3,637.4 inhabitants/km^2) includes the department Capital of the province of San Juan (3,637 inhabitants/km^2); the city Córdoba Capital (2,365 inhabitants/km^2); and the departments Godoy Cruz (2,558 inhabitants/km²), Capital (2,130 inhabitants/km²), and Guaymallén (1,730 inhabitants/km²) in the province of Mendoza. The second density range (526.4 to 1730.5 inhabitants/km²) includes the departments located in the vicinity of the most densely populated capital cities. The remaining departments feature lower population densities, and a high share of low-density areas can be observed.

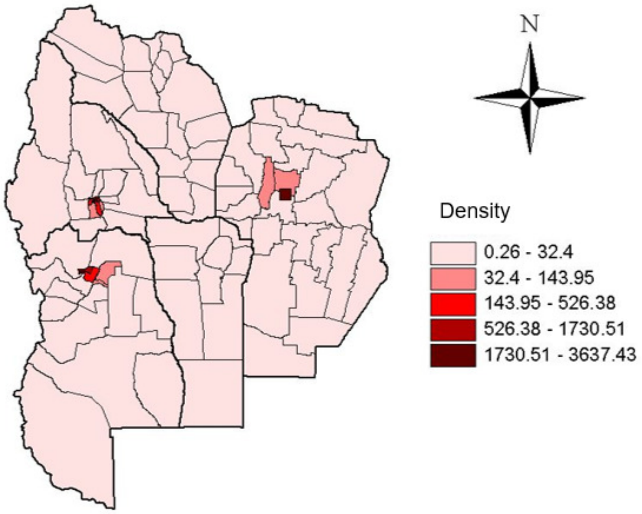

Figure 1.6. Population density within the Central-West Region, by department

Source: Censo Nacional de Población, Hogares y Viviendas (INDEC, 2010).

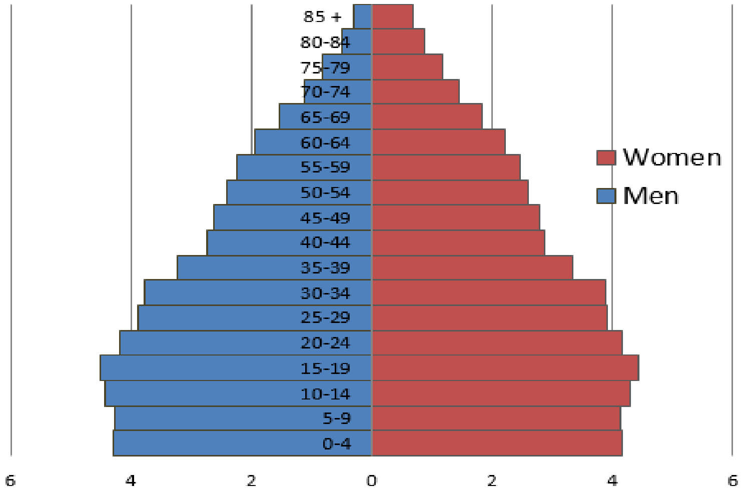

Figure 1.7. Percentage distribution of population by sex and age groups within the Central-West Region 2010

Source: Censo Nacional de Población, Hogares y Viviendas (INDEC, 2010).

In Figure 1.7, the graphic representation of percentage distribution of population by sex and age groups reveals that the population structure of the Central-West Region is stabilizing the proportion of the first age groups; it is also observed a decrease in fertility rates in the last decade. The structure describes a population with a higher female-male ratio, particularly from middle age onwards, and a trend towards aging.

In the 9-year intercensal period, the population of the departments of the Central-West Region has grown or decreased very unevenly, as can be observed in Figure 1.8. The ones exhibiting greater relative growth are the departments Junín in San Luis (42.7%), Iglesia and Pocito in San Juan (35.1% and 29.8%, respectively), Colón in Córdoba (31.6%), Capital in La Rioja (23.6%), and Malargüe in Mendoza (20.2%). In this same period, the departments that have lost the largest number of inhabitants, by province, are General Juan Facundo Quiroga (9.6%) and Famatina (8.0%) in La Rioja; Libertador General San Martín (9.3%) in San Luis; Capital in San Juan (3.2%), and Minas in Córdoba (3.2%), among others.

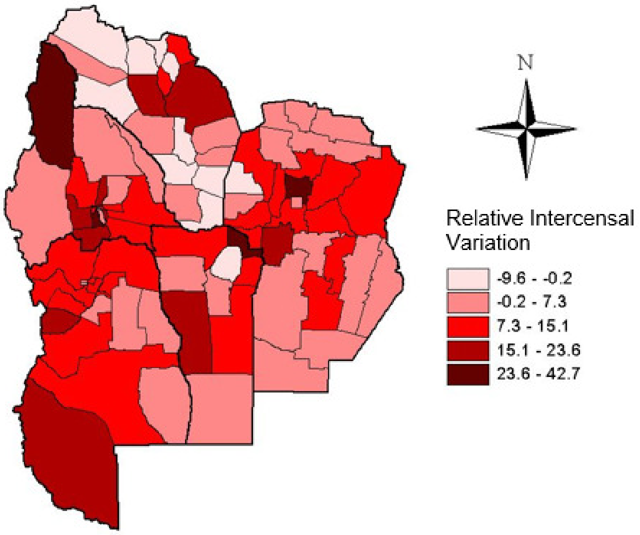

Figure 1.8. 2001-2010 relative intercensal variation, by Central-West Region department

Source: Censo Nacional de Población, Hogares y Viviendas (INDEC, 2010).

Population Characteristics

In the censuses, education is assessed through three different aspects: literacy, schooling, and highest level of instruction attained by the population.

Table 1.5 shows that 1.7% of the Central-West Region's population above 10 years old is illiterate (answered that they are unable to read or write). Córdoba is the province with the lowest illiteracy rate, but the highest number of illiterate people (32,678). On the other hand, Mendoza is the province with the highest illiteracy rate (2.8%), although the total number of illiterate people is low (7,229).

Table 1.5. Illiterate population within the Central-West Region

In number of people and percentage over total population aged 10 years and older by province, year 2010

Province	Population aged 10 years and older		
	Total	Illiterate	% of illiterate population
Córdoba	2,302,618	32,678	1.4
La Rioja	339,553	7,563	2.2
Mendoza	257,074	7,229	2.8
San Juan	646,544	13,157	2.0
San Luis	412,006	6,633	1.6
Region	3,957,795	67,260	1.7

Source: Censo Nacional de Población y Vivienda (2010)

The schooling situation of the 3-24 year-old population allows to find out the degree of compliance with compulsory preschool education (5 years old), elementary education (6-11 years old), and secondary education (12-17 years old) schemes. Schooling of 3-4 year-old children is also provided for in the National Education Act, although not on a compulsory-basis. Ideally, the 18-24 year-old range would correspond to higher education level. It is worth mentioning that this analysis considers only the answers provided by people during the census process (Are you currently attending any school?), without regard for whether they are actually at an age-appropriate educational level or not.

According to Table 1.6, within the region, the highest school attendance rate (99.2%) corresponds to the 6-11 age range, whereas the lowest corresponds to the 18-24 age range (38.2%), followed by the 3-4 age range. Issues become evident at the 15-17 age group (compulsory attendance period), where approximately 20% of young people are not schooled, which means that if they do not return to the education system in the future, they will be virtually excluded from the formal labor market. La Rioja is the province with the highest school attendance rates from 15 years old onwards.

Table 1.6. Schooled population by age within the Central-West Region

In percentage over total population aged 10 and older by province, year 2010

Province	**School attendance percentage, by age group**					
	3-4 years old	5 years old	6-11 years old	12-14 years old	15-17 years old	18-24 years old
Córdoba	57.2	95.9	99.3	95.8	79.5	38.8
La Rioja	51.4	94.8	99.0	96.6	82.0	42.5
Mendoza	43.0	91.9	99.4	96.9	81.4	38.5
San Juan	32.3	87.4	98.9	95.9	78.6	35.4
San Luis	44.5	92.5	99.0	96.4	80.5	32.5
Region	49.0	93.5	99.2	96.2	80.1	38.2

Source: Censo Nacional de Población, Hogares y Vivienda (2010)

According to the information provided by the 2010 population census, 35.9% of the population of the Central-West Region does not have health coverage.

Table 1.7. Population by health coverage status, Central-West Region

In percentage over total population by province, year 2010

	Public health scheme	Private-public health scheme	Private health scheme (voluntary)	State health programs and plans	No health insurance
Córdoba	47.4	11.9	6.1	1.7	32.9
Mendoza	50.4	7.9	3.4	1.3	37.0
La Rioja	48.1	9.5	2.3	2.0	38.1
San Juan	39.8	12.9	5.3	2.0	39.9
San Luis	40.7	11.8	4.8	1.7	41.1
Central-West Region	47.8	10.1	4.5	1.7	35.9

Source: Censo de Población, Hogares y Vivienda (INDEC, 2010)

Table 1.7 shows that this lack of coverage affects 41.1% of the population of San Luis, and 32.9% of the population of Córdoba, while the remaining jurisdictions fall in between these two figures. Public health schemes are associated with salaried work, while private ones are related to self-employment. Lack of health coverage is the result of unemployment and informal labor. Health indicators, which may reflect inequalities in the access to and the quality of health coverage and, at the same time, are the most representative of a population's health situation, are shown in Table 1.8.

Infant mortality rate is an indicator that is highly sensitive to the mother's living conditions and to mother and child health programs; hence, it is considered to be representative of a population's social situation. This indicator reaches its maximum in La Rioja, with 12.6 deaths –of infants under one year old– per 1,000 live births. This province also has the highest percentage of live births by mothers under 20, and the largest number of maternal deaths per 10,000 live births, an indicator which more than doubles the registered figures for the region as a whole. San Luis features the lowest infant mortality rate, with 10.7 deaths per 1,000 live births, a high percentage of which are born to mothers under 20 (18.4%). Crude mortality rates (CMR) adjusted by age do not show significant differences among the region's provinces. Total fertility rates –the average number of children born per childbearing age woman–, for the analyzed provinces are between 2.2 and 2.7 children per woman, with La Rioja featuring the minimum rate and San Juan featuring the maximum.

Table 1.8. Selected health indicators within the Central-West Region

Classified by province, year 2010

Province	Infant mortality rate (IMR) per 1,000 LB	Total fertility rate TFR	CMR adjusted by age per 1,000 in.	Mother mortality rate per 10,000 LB	Percentage of LB of mothers under 20 years old
Córdoba	11.1	2.3	6.58	4.8	14.7
La Rioja	12.6	2.2	6.95	11.4	18.5
Mendoza	11.7	2.5	6.35	4.4	15.5
San Juan	11.0	2.7	6.73	4.2	16.6
San Luis	10.7	2.3	6.53	3.8	18.4
Region	11.3	2.4	6.70	5.0	16.0

Note: LB= live births. in.= inhabitants

Source: Dirección de Estadísticas e Información en Salud (Health Statistics and Information Department). Ministerio de
Salud de Argentina (Argentine Ministry of Health)

It is hard to measure a population's level of poverty because there is no consensus around the actual meaning of the term "poverty" or the variables it involves. In Argentina, there are two preferred methodologies: measurement based on the relationship between income and basic food basket cost and total food basket (extreme poverty line and poverty line), and the unsatisfied basic needs indicator.

According to information provided by the Permanent Household Survey (Encuesta Permanente de Hogares, EPH), between 2010 and 2011, the proportion of population living below the poverty line and extreme poverty line has tended to decrease. Table 1.9 shows the share of population living below the poverty line and extreme poverty line on the main urban clusters in the Central-West Region. San Juan urban cluster features the highest indicators in the region for the second quarter of 2011 for both poverty line (11.1%) and extreme poverty line (2.4%), whereas La Rioja, with 0.5% of its population living under the extreme poverty line, and Mendoza, with 3.9% of its population living under the poverty line, are the provinces with the lowest rates.

The Unsatisfied Basic Needs (UBN) indicator for households considers the following factors: overcrowding –more than three people per room–, unsuitable housing, inadequate sanitary conditions –lack of water-flushed toilet–, at least one school-age child not attending school, and livelihood capacity –more than three to four people per employed household member whose employer is undereducated–. Each of these characteristics is considered household deprivation, and the presence of a single one of them is enough for the household to be rated as an UBN household. As of the date of this report, 2010 Population Census data for UBN indexes are unavailable, so the indicator of households without a toilet or water-flushed toilet is used as a proxy.

The Central-West Region –with 8.12% of households– is below the average national rate, which amounts to 12.69% (Table 1.10). The provinces of La Rioja and San Juan feature the highest percentages of households without a toilet (over 12%), while Córdoba has a 6.65% of deprived households. The number of households without toilet or water-flushed toilet access is widely scattered across the region.

Table 1.9. Poverty and extreme poverty within the Central-West Region

Classified by major urban clusters, 2010-2011 period

Urban cluster	Percentage of the population living under the extreme poverty line				Percentage of the population living under the poverty line			
	1st-2010	2nd-2010	1st-2011	2nd-2011	1st-2010	2nd-2010	1st-2011	2nd-2011
Greater Mendoza	1.8	1.6	1.0	1.6	7.6	7.0	3.6	3.9
Greater San Juan	2.2	4.1	2.5	2.4	14.4	15.3	12.8	11.1
San Luis - El Chorrillo	2.9	1.2	1.3	1.8	12.3	9.7	7.8	5.2
La Rioja	2.3	1.8	2.1	0.5	15.1	9.7	12.0	4.4
Greater Córdoba	3.4	1.6	1.3	1.7	10.0	7.7	6.1	6.3
Argentina	3.1	2.5	2.4	1.7	12.0	9.9	8.3	6.5

Source: INDEC-EPH. 2010-2011.

Figure 1.9 offers a georeferenced map for this indicator by department, ranging from 2.7% in Capital (San Juan) to 53.8% in Libertador General San Martín (San Luis). Departments with 30% to 53.8% of households without a toilet or water-flushed toilet include Minas and Pocho (Córdoba), Belgrano (San Luis), and Independencia (La Rioja). Ten departments of the province of Córdoba feature the lowest lack of toilet rates (2.7% to 7.5%). The remaining departments have intermediate rates ranging from 7.5% to 30.0%.

Table 1.10. Households without toilets or water-flushed toilets (proxy for UBN) within the Central-West Region

In total households and percentage over total households by province, year 2010

Province	Households		
	Without toilet or water-flushed toilet	Total	% without toilet or water-flushed toilet
Córdoba	68,586	1,031,843	6.65
La Rioja	11,468	91,097	12.59
Mendoza	43,351	494,841	8.76
San Juan	21,821	177,155	12.32
San Luis	10,859	126,922	8.56
Region	156,085	1,921,858	8.12

Source: Censo de Población, Hogares y Vivienda (INDEC, 2010)

The Institutional Dimension

The term “institution” generally applies to rules of conduct and common practices considered important to a society, such as the unique formal organization of government and public service. The operation of an institution emphasizes the creation of numerous rules or standards.

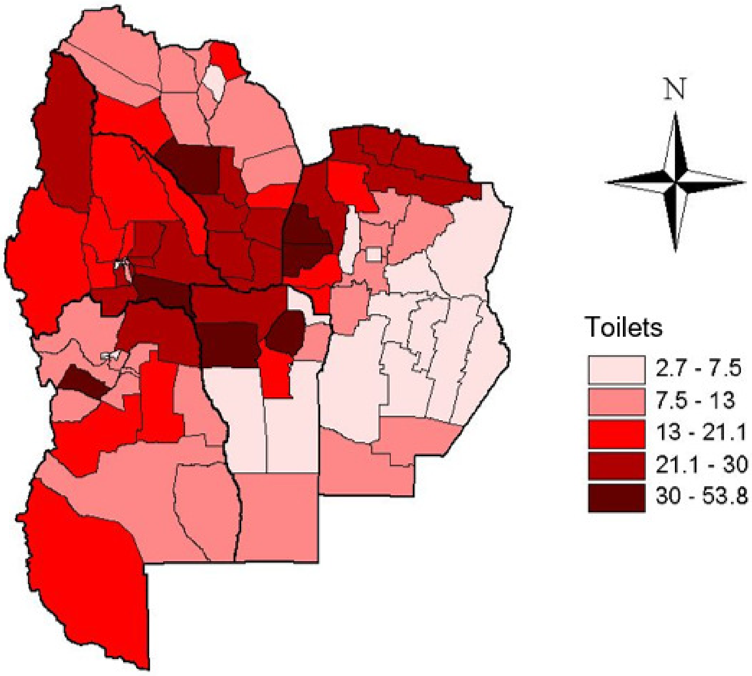

Figure 1.9. Households without toilets or water-flushed toilets
In percentage over total households within the department
Source: Censo Nacional de Población, Hogares y Viviendas (INDEC, 2010).

The National Constitution establishes that the provinces reserve to themselves all the powers not delegated to the Federal Government, and enact their own Constitutions under the republican representative form of government, by virtue of which they elect their own officers, ensuring municipal autonomy and ruling its scope and content regarding the institutional, political, administrative, economic and financial aspects.

As stated in article 124, the provinces are empowered to set up regions for their economic and social development, and have the original dominion over the natural resources existing in their territory. By virtue of this power, the province of Córdoba and Santa Fe signed the Tratado de Integración Regional (Regional Integration Treaty) (1998) “with the purpose of promoting economic, social and human development, as well as the development of health, education, science, knowledge, and culture...” and the Acta de Integración de la provincia de Entre Ríos al Tratado de Integración Nacional (Treaty of Adhesion of the Province of Entre Ríos to the Regional Integration Treaty) (1999), thus creating the Central Region.

Considering the different provincial constitutions across the Central-West Region, they all cover social, economic, environmental, and institutional aspects that would enable their territorial development. For instance, the Constitution of the province of Córdoba dedicates its third chapter to the ecological dimension. In the province of San Juan, environmental legislation in effect is the first of its kind in the country. Its Constitution (1986) granted the ecological dimension (environment and quality of life) the status of unalienable right –which must be preserved by the provincial State itself, or by means of an appeal or a popular initiative) (Art. 58)– in line with the ideas on human environment proclaimed at the Stockholm Conference (1972).

In Argentina there are regulations which cover the legislative aspects of various issues inherent to sustainability, such as the Código de Minería Argentina (Argentine Mining Code) (Law 1919/1886), the Ley General del Ambiente (General Environmental Act) (Law 25675/2002), and the Ley de Preservación del Medio Ambiente (Environmental Preservation Act) (Law 5961/1992) of the province of Mendoza. State reform processes sanctioned, as of 1993, a set of legislations including the reform of the Mining Code and of Law No. 24.585/95 (environmental protection of the mining sector).

In turn, the Ministerio de Cultura y Educación (Ministry of Culture and Education), in its Resolution 602/95, amended the designation, composition, and grounds of the Consejos de Planificación (Planning Councils). The resolution provides for the creation of the Consejos Regionales de Planificación de la Educación Superior (Regional Councils of Higher Education Planning) made up, in the Central-West Region, by the universities of the provinces of Córdoba, La Rioja, Mendoza, San Juan, and San Luis. The purpose of these councils is “to promote the integration of higher education institutions in the regional context, exchange and joint reflection among said institutions, the provincial states' representatives, intermediate social institutions, and production sectors within the region" (MR 602/95 - Annexes I and II).

At the end of 2009 (11/3/2009), the national universities of Córdoba, Tucumán, Nordeste (Northeast) , Salta, Jujuy, Santiago del Estero, Chilecito, Misiones, Chaco Austral, Formosa, Universidad Tecnológica Nacional (National Technological University), and Instituto Universitario Aeronáutico (Aeronautical University Institute), members of the Grupo de Universidades del Norte Grande Argentino (Group of Universities of the Great Argentine North), made up the Argentine Network of Universities for Sustainability and the Environment (Red Argentina de Universidades por la Sustentabilidad y el Ambiente, RAUSA), whose essential mission is to promote and support academic and scientific cooperation in the environmental field among the participating universities.

There are other organizations that make up the institutional dimension and contribute to the region's development: the so-called non-governmental organizations (NGOs). Within the Central-West Region, there are different NGOs which help promote territorial development and system sustainability, such as the following: "Techo" (Córdoba) whose purpose is to temporarily solve the housing deficit; the association "Manos Abiertas" (San Juan), whose mission is to promote and dignify the people in greatest need by improving the quality of life and fighting poverty; the Asociación "El Simbolar" (La Rioja), whose aim is to improve the situation of smallholder farmers; the "Asociación Civil Ateneo Rural" (La Rioja) which, by means of microloans, boosts small departmental economies, strengthening community bonds though popular education and community cohesiveness; "Unión de Trabajadores Rurales sin Tierra" (Mendoza), whose purpose is to guarantee access to water and land; and "Un lugar para crecer" (San Luis), aimed at supporting vulnerable children; among others. These NGOs need to be taken into account when implementing sustainable development.

Institutional Organization of the Central-West Region's Provinces

The Judicial Power

Corte de Justicia (Court of Justice), Suprema Corte (Supreme

Court), Superior Tribunal (High Court), and Tribunal Superior (Superior Court) are the different designations adopted by the Central-West Region's provincial constitutions to refer to the highest judicial body. The Superior Tribunal de Justicia de Córdoba (High Court of Justice of Córdoba) and the Suprema Corte de Mendoza (Supreme Court of Mendoza) have the largest number of members: seven (in Mendoza, this number can be higher). Both the Corte de Justicia de San Juan (Court of Justice of San Juan) and the Superior Tribunal de Justicia de San Luis (High Court of Justice of San Luis) have at least five members, whereas the Tribunal Superior de La Rioja (Superior Court of La Rioja) has five members.

To be a member of the Judiciary, all the provinces stipulate the following requirements: a candidate shall be a citizen of the Nation, shall be a lawyer, and shall have attained to the age of 30. Members of the Judiciary shall hold their offices during good behavior. The justices of the highest judicial body are appointed by the Executive Power with the consent of the Senate in the provinces of Mendoza and San Luis; in San Juan and La Rioja, they are appointed by the Cámara de Diputados (House of Deputies) according to a list submitted by the Consejo de la Magistratura (Council of the Magistracy), in the first case, and according to a list submitted by the Governor, in the latter.

The Legislative Power

The Legislative Power is composed of a single house in Córdoba, La Rioja, and San Juan, and of two houses in San Luis and Mendoza.

One-house Legislatures have representatives for each provincial department and for the people of the province considered as a single district. In all provinces, legislators hold their offices for a term of four years and may be re-elected. The province's Vice-governor is the chairman of the house and has no voting power, except in case of equality of votes. To be a legislator, a candidate shall be of legal age, i. e., they shall have attained to the age of 18 in Córdoba, and of 21 in San Juan. All the provinces require candidates to be Argentine citizens. In Córdoba and in La Rioja, they shall have two years of immediate residence in the province (in the case of Córdoba) or in the represented department (in the case of La Rioja). In San Juan, a candidate shall have been four years a fully qualified citizen, shall have three years of residence in the province and one year in the represented department.

Two-house legislatures are composed of a Cámara de Diputados (House of Deputies) and a Senado (Senate). Their members hold their offices for the term of four years and are renewed by halves every two years. In San Luis the Cámara de Diputados is composed of representatives directly elected by the people of the departments. The representation shall be appointed proportionally to the number of inhabitants in accordance with last census, with a minimum of two deputies. In turn, the Senado is composed of one legislator per provincial department directly elected by the people of each department, by simple plurality of votes. In Mendoza, the legislature is appointed by direct election by the representatives of the electoral districts the population is divided into. Each district shall elect at least eight deputies and six senators with a maximum number of 50 and 40, respectively, for the province as a whole. In both provinces, a legislator shall have been five years a fully qualified citizen. In San Luis, a candidate shall have three years of immediate residence in the represented department and shall have attained to the age of 21 to be a deputy and of 25 to be a senator for the province. In Mendoza, a candidate shall have two years of immediate residence in the province, and shall be of legal age to be a deputy and have attained to the age of 30 to be a senator for the province.

The Executive Power

In all the provinces of the Central-West Region, the provincial constitutions establish that the Executive Power is vested in two citizens, called governor and vicegovernor, who are elected simultaneously, for the term of four years, by simple plurality of votes. The requirements are also the same in every province: having attained to the age of 30 and being an Argentine citizen.

In all provinces, except for Mendoza and San Juan, governors and vicegovernors may be re-elected for only one consecutive term (if they have been re-elected, they cannot be elected for a third term but with the interval of one term). In the province of Mendoza, the governor and vicegovernor may not be re-elected for a second consecutive term for any executive position (i. e., the governor may not be appointed as vicegovernor, and vice versa); may not be succeeded by any relatives within the second degree of consanguinity or affinity, and the outgoing governor may not be elected as national senator for a year after the end of their term. In the province of San

Juan, the governor may be re-elected for three consecutive terms. In La Rioja, the members of the governor-vicegovernor ticket cannot be relatives within the fourth degree of consanguinity or affinity; in San Luis, they cannot be relatives within the fourth degree of consanguinity and second degree of affinity; and in Córdoba, they can be neither spouses nor relatives within the second degree of consanguinity. San Juan does not establish any requirements in this regard.

Chapter 2.
Macro-Zoning of Prevalent Primary Production Systems

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The natural environment provides sustenance and imposes restrictions on human beings' chances of development. Hence, livelihoods associated with the different production systems are subject to the characteristics of the particular environments (Ellis, 2000). This is why it is considered appropriate to focus the analysis on the specific environments in which production systems are embedded at an initial stage.

A production system is a set of interrelated resources that, by means of various processes, allow to obtain certain output. These resources, from the perspective of livelihoods, are seen as capital, and can be classified into natural, human, financial, social, and physical capital (Scoones, 1998). This way, livelihoods, either individual, family-based, or community-based, are conditioned by the ability to access these resources and by the income generated by the output obtained. However, and to some extent, these abilities may be modified by human action with the purpose of achieving a different outcome.

Production systems can be classified into primary (agriculture, fishing, forestry, and mining), secondary (manufacturing industry; electric power, gas and water production, and construction), and tertiary (financial services –both public and private– and non-financial services –both public and private–). From the economic point of view, they are associated with the production of goods and services to meet human needs. These production systems have evolved to meet new needs or to reduce the amount of resources necessary for their operation. Change processes in production systems are due to a large number of driving forces. According to Gutman (1999), technological and organizational advances, new competitive contexts, changes in consumption patterns, and new players, among others, are included among the major forces affecting primary production systems since the end of the last century. At the same time, the modification of production systems affects livelihoods, the populations relying on them, and the environment supporting them. In the case of primary production systems, natural resource base sustainability is an essential determinant of the performance of rural livelihoods and impacts the other economic sectors. That is, the ability of a system to maintain productivity when subject to disturbing forces, whether a 'stress' or a 'shock', will be decisive for the possibility of obtaining products or services able to sustain the livelihoods of a significant part of the population (Scoones, 1998). Nevertheless, this author notes that measuring natural resource base sustainability is not only difficult, but also critical to both system resilience and to meet the livelihood needs relying on it, by reducing their vulnerability and increasing their sustainability though adaptive processes in the face of changes and new circumstances.

Finally, it is essential to consider the existence of structures and processes that may mediate the process of determining the resilience of socioecological systems or the sustainability of production systems or of the livelihoods relying on them. That is, the existence of institutions (both formal and informal) and organizations (both public and private) mediating access to resources and influencing the composition of the different strategies at certain moments and times (Scoones, 1998). From the perspective of the natural environment, these structures and processes may result in strategies that allow to increase the flexibility of the natural and socioeconomic restrictions of production systems and livelihoods, but which, in turn, may bring about negative impacts, both social and environmental, at different space and time scales (Cash *et al.*, 2006). Considering the preceding, *sustainable development* is not only associated with environmental factors, technological status, or individual decisions, but needs to be examined as well from a socioinstitutional perspective (Lattuada, 2000).

In this work, some “representative” primary production systems of specific ecoregions will be analyzed, but provincial political divisions will be maintained, as needed, as they are institutional factors, both formal and related to public organizations, that may entail differences despite the presence of similar determinants in the natural environment. By “representative”, it is meant those systems that prevail in the different natural environments (ecoregions) of the Central-West Region, which contribute a higher proportion of a province’s Gross Geographic Product and, among them, those which cover a greater amount of lands and involve a higher number of actors.

Considering the incidence on the production of raw material for the manufacturing industry, as well as its surface area and its share on export levels, and with the purpose of illustrating the methodologies proposed for the assessment of sustainability indicators for the prevalent production systems within the Central-West Region, the analysis focuses on the primary production sector, namely agricultural and livestock systems.

Methodology for the Identification of Prevalent Production Systems

As stated in the preceding pages, the geographic area under study covers the provinces of Córdoba, La Rioja, Mendoza, San Juan, and San Luis, and is characterized, from an environmental perspective, by a variety of ecoregions associated with different provincial and departmental jurisdictions.

To perform a characterization that includes environmental variables and social, economic, and institutional aspects, in this case study, departments are the minimum disaggregated level for most of the data from secondary sources used in the analysis. The wide range of realities –within both the natural and the social environments– made it necessary to set priorities for the analysis that allow to focus the attention on the prevalent production systems in each region.

This also implies the need to set geographical boundaries within which the various production systems are developed.

In order to address these needs, *justify the choice of a particular system for the study,* and identify the region's distinctive environmental, economic, and social characteristics and their potential differentiation, an exploratory statistical analysis is done combining the following methods: principal component analysis, classification and segmentation of observation units by prevalent characteristics.

The data used correspond to available department-level information for 355 variables associated to the different dimensions of sustainability. Information comes from secondary sources, namely surveys and publications by the Instituto Nacional de Estadísticas y Censos (National Institute of Statistics and Censuses), provincial statistics departments, the Ministerio de Agricultura de la Nación (Ministry of Agriculture), provincial governments, and the Instituto Nacional de Tecnología Agropecuaria (National Institute of Agricultural Technology), among others.

The principal component analysis consists in the construction of factorial axes based on the combination of the quantitative variables contained in the base. Each factorial axis is the result of the linear combination of the variables, and represents a portion of total variability. The construction of the axes follows a hierarchical sequence in such a way that the first factor will have a higher explained variance (inertia) than any of the succeeding ones. The variables used in the analysis can be either active –used in the construction of the factors– or illustrative –not used in the construction of the factorial axes, but supplementing the analysis, mainly as regards groups description,– and the role played by each variable follows the adoption of *ad hoc* criteria.

To analyze the Central-West Region, the process for the selection of active variables considered the presence observed in the region and their share in a first joint analysis. First, as there is no information available for all the departments on all the variables –in some cases, due to the lack of information in the consulted sources and, in others, because it is not a locally observable characteristic,– the selected variables were those appearing on at least two thirds of the departments' records. Thus, the initial number of analyzed quantitative variables was 202. Second, the result of the first component analysis performed on the 202 variables led to the selection of the 43 variables that make up the factorial coordinates on the first top (bottom) plane at 0.60 (-0.60). Third, the principal component analysis is performed on the 43 most significant active variables, incorporating the remaining quantitative variables as well as qualitative variables to illustrate and enrich the analysis.

The following step is the classification and segmentation of the departments *to define* homogeneous spatial units. The classification method explores the similarities among individuals from the quantification of the differences on all observed characteristics. These differences are then hierarchically organized in ascending order, resulting in the segmentation and formation of the different groups. The segmentation criterion includes maximizing the distance between the groups and minimizing the distance between the group's components in relation to a common benchmark referred to as "center of gravity." The group's significant characteristics are those present in greater amount –both in average for quantitative variables and in frequency for qualitative variables– with respect to observations for the same variable across the analyzed base, which leads to discussing prevalent characteristics in the group description. The fact that a given characteristic is significant within a group does not mean that all of the group components shall have it; similarly, a group might contain a non-significant characteristic that is present in some of its components.

When describing the group's significant characteristics from the prevalence perspective, main associations from which to proceed with the analysis of sustainability are defined, where the identification of the production system owes to the highest relative share of such system within the set of production activities of the group.

Prevalent Production Systems in the Central-West Region - Empirical Evidence

As confirmed by the results of the exploratory statistical methods, the Central-West Region is composed of three prevalent production subsystems referred to as "Grain and Cattle-Raising", "Miscellaneous Cattle-Raising", and "Fruit and Vegetable".

Figure 2.1 shows the departments' dispersion across the factorial plane. The location on the plane owes to the greater association with the characteristics defining each of the three groups and differentiating them from each other. So, for instance, on the first factorial axis, the departments Juárez Celman and Calamuchita (in the province of Córdoba) and General Pedernera (in the province of San Luis) are opposed to the departments of Tupungato and Santa Rosa (in the province of Mendoza), and Pocito and Zonda (in the province of San Juan). Similarly, on the second factorial axis, opposition is observed between the departments Luján de Cuyo (in Mendoza) and Rivadavia (in San Juan) on one hand, and the departments Ayacucho (in San Luis), Río Seco (in Córdoba), and General Ocampo and Rosario Vera Peñaloza (in La Rioja) on the other. The greater proximity of the departments to the Cartesian point on the plain identifies the class that has a greater prevalence of the group's representative characteristics.

Figure 2.1 shows the proximity of Calamuchita, Colón, and Río Primero (in Córdoba) to the identifier of the Grain and Cattle-Raising class; of General Ocampo, General Peñaloza, and General San Martín (in La Rioja) to the identifier of the Miscellaneous Cattle-Raising class; and of Tunuyán, Rivadavia, and San Carlos (in Mendoza), and of Chilecito (in la Rioja) to the identifier of the Fruit and Vegetable class.

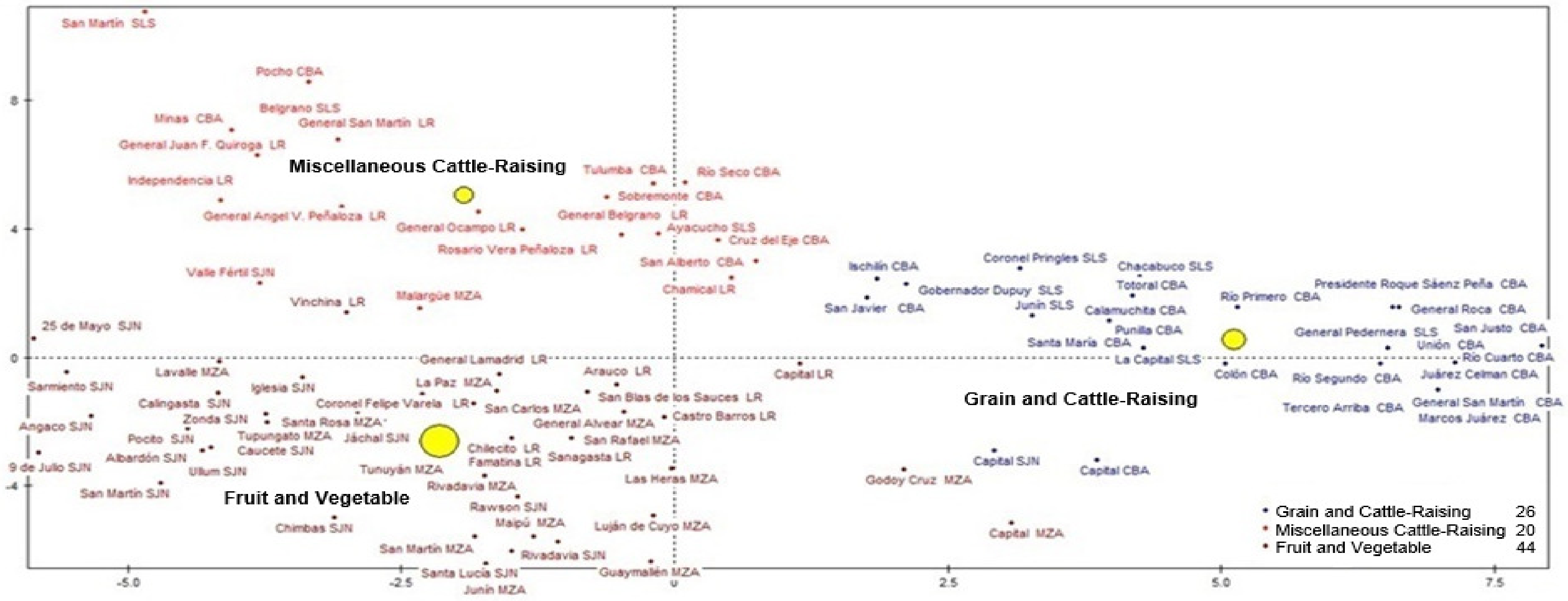
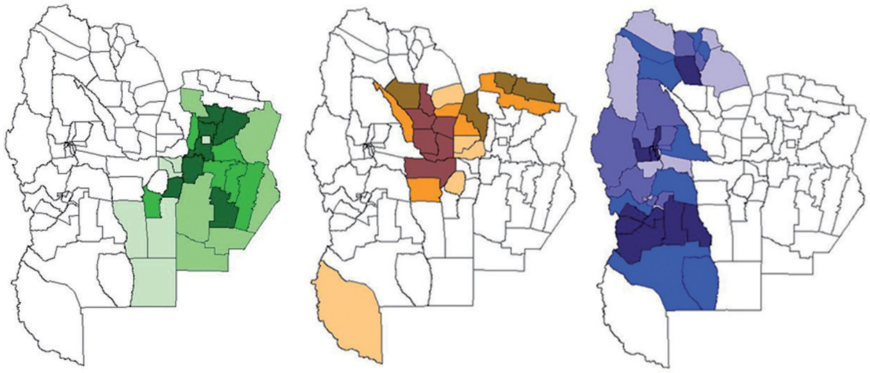


Figure 2.1. Classification of the Central-West Region departments as per environmental, economic, and social variables
(CBA: Córdoba; LR: La Rioja; MZA: Mendoza; SJN: San Juan; SLS: San Luis).

Figure 2.2 illustrates the presence of these production systems across the geographic area of the Central-West Region of Argentina, where each department is associated only with the prevalent production system. The different colors chosen for the departments of the Central-West Region within a system owe to the number of prevalent elements characterizing the system as compared to the remaining departments. Hence, the distinctive color for the Grain and Cattle-Raising system is green; brown for the Miscellaneous Cattle-Raising system; and blue for the Fruit and Vegetable system. The deepest shades of each color identify the most characteristic departments within the subsystem. For instance, around 50.0% of the province of La Rioja as well as virtually all of San Juan and Mendoza represent the Fruit and Vegetable production system. However, it is the departments La Paz, Rivadavia, San Carlos, Santa Rosa, Tunuyán, and Tupungato (in Mendoza), Albardón, Pocito, Rawson, and Zonda (in San Juan), and Chilecito (in La Rioja) the ones that prevalently exhibit the characteristics –as regards production system, social situation, and environmental aspects– that differentiate them from some departments from other areas of their respective provinces and from all the departments of the provinces of Córdoba and San Luis.



Prevalent areas in the Grain and Cattle-Raising subsystem

Prevalent areas in the Miscellaneous Cattle-Raising subsystem

Prevalent areas in the Fruit and Vegetable subsystem

Figure 2.2. Spatial estimation of prevalent areas as per classification presented on Figure 2.1

Note: The depth of the color shades within each area reflects the level of prevalence: the deeper the shade, the greater the prevalence of a production system across a given department. A greater prevalence is associated with a deeper color shade within each classified area.

Grain and Cattle-Raising Subsystem

The Grain and Cattle-Raising subsystem extends from the northeast of the province of Córdoba to the central-southern area of the province of San Luis, encompassing the central-southern area of the Central-West Region. It includes the departments Calamuchita, Colón, General Roca, General San Martín, Ischilín, Juárez Celman, Marcos Juárez, Presidente Roque Sáenz Peña, Punilla, Río Cuarto, Río Primero, Río Segundo, San Javier, San Justo, Santa María, Tercero Arriba, Totoral, and Unión (in the province of Córdoba); Chacabuco, Coronel Pringles, General Pedernera, Gobernador Dupuy, Junín, and La Capital or Juan Martín de Pueyrredón (in the province of San Luis). The Capital departments in both the province of Córdoba and the province of San Juan have a marginal share in this subsystem.

Located in the Pampa and Espinal ecoregions, it is particularly characterized by the environments identified as Loessic Pampa Altos de Morteros, Undulating Pampa, High Pampa, Plain Pampa and Arizona Pampa, Slopes and Interhill Depression and Concarán Depression, Sandy Pampa and Sandy Plain Pampa, Slightly Undulating Sandy Plain, Justo Daract Plain, with anthropogenic sand dunes, Anchorena Plain with sand dunes and isolated plains; with a prevalence of loam sandy and silt loam soil textures and 1.0% to 3.0% organic matter content. This geographic area features rainfall levels that double the average for the whole region, average temperatures of around 18.0 °C, and a predominance of original trees and grasslands.

This subsystem exhibits a prevalence, in terms of both spread and diversity, of edible grains and fodder crops, with the most prominent crops being wheat, corn, sorghum, oats, weeping lovegrass, and rye. Just as important are oleaginous seeds, which –in this geographic area– triple the dedicated surface area for the whole region, with soybean, sunflower, and peanut as its main crops. As regards cattle-raising, there is a prevalence of bovine and porcine cattle for breeding, with the number of head of bovine cattle per hectare doubling the average for the region. Bovine production is also devoted to rearing, backgrounding, cattle-breeding ranch, and dairy farm herds, while porcine cattle is mostly devoted to backgrounding, cattle-breeding ranch, and “full cycle” (breeding, rearing, and backgrounding) herds. The prevalent power sources are power generating sets, with the number of these pieces of equipment tripling the number for the whole region. Other power sources are wind and hydroelectric energy.

As for the sociodemographic aspect, there is a greater relative presence of people over 64 years old. There is also a prevalence of households with water availability inside the housing unit, water-flushed toilets, refrigerators, cell phones, and high-quality flooring. The preferred cooking fuel is gas, either in the form of bulk tank gas, cylinder gas, or mains gas.

At length, 98.9% of the farms and cattle-raising ranches of the Grain and Cattle-Raising subsystem are properly demarcated, whereas this indicator for the Central-West Region is 88.3%. The farms and ranches of the analyzed geographic area prevalently have property surface areas of 1,000 ha to 2,500 ha and of 500 ha to 1,000 ha, which, in average, account for 22.6% and 18.4% of the surface area of the departments making up this subsystem. By comparison, properties with these dimensions account only for 11.8% and 9.9% of the total surface area of the Central-West Region. In particular, farms and ranches of 1,000 ha to 1,500 ha cover, in average, 11.3% of the departmental surface area, and account for 5.0% of the total farms and ranches in the considered departments. By comparison, in the region as a whole, these characteristics account for 4.0% and 1.9%, respectively.

In this group, the varieties of edible grains grown amount to 6.5 units in average, as compared to only 3 for the whole Central-West Region (including durum wheat, bread wheat, buckwheat, corn, popcorn, barley, rye, and oats, among others). The average number of fodder crops is 20.7 to 10.7 (weeping lovegrass, oats, millet, fodder barley, fescue grass, alfalfa, lotus, melilotus, vetches, and chicory, among others). The surface area devoted to edible grains accounts for 23.5% of this subsystem’s departments (as compared to 9.6% of the region’s total area), whereas the area devoted to fodder crops accounts for 17.9% and 6.4%, respectively. In particular, out of the total surface area devoted to grain growing in properly demarcated farms and ranches, wheat covers 11.7%; corn 10.6%, and sorghum 0.9%, as compared to 4.1%, 4.9%, and 0.3%, respectively, of the region as a whole. Out of the total surface area devoted to fodder crops in properly demarcated farms and ranches, oats cover 3.4%, sorghum 3.6%, weeping lovegrass 7.5%, and rye 2.8%, as compared to 1.7%, 1.7%, 3.3%, and 1.3%, respectively, of the Central-West Region as a whole. In properly demarcated farms and ranches, the number of oleaginous seeds species grown is, in average, 3.4 by department (combining first and second-crop soybeans, peanut, confectionery sunflower, flax, canola, and others), as compared to 1.2 for the region as a whole.

A similar situation can be observed for surface areas devoted to first-crop oleaginous seeds in properly demarcated farms and ranches, which amount to 27.7 ha, as compared to 9.2 ha for the whole Central-West Region, out of the total surface area devoted to oleaginous seeds. In properly demarcated farms and ranches within the departments in this group, soybeans cover an average 23.7% of the devoted surface area, sunflower 2.1%, and peanut 1.9%, as compared to an 8.0%, 0.6%, and 0.6% share, respectively, within the Central-West Region.

A 54.7% of properly demarcated farms and ranches in the Grain and Cattle-Raising subsystem have bovine cattle and 33.3% have porcine cattle, as compared to 29.1% and 18.4%, respectively, in the Central-West Region. Particularly, 14.2% of the total properly demarcated farms and ranches have swine for breeding; 3.1% have swine for full cycle; 0.7% have swine for backgrounding; and 0.1% have swine for cattle-breeding ranches; whereas for the Central-West Region, the share is lower: 8.4%, 1.9%, 0.3%, and 0.1%, respectively. Out of the total bovine cattle existing in the departments that make up this group, the number of bovine cattle in breeding herds at properly demarcated farms and ranches accounts for 55.4%; another 10.3% of the head of cattle is devoted to rearing; 8.7% to backgrounding; and 6.8% to dairy farm herds. By comparison, the Central-West Region as a whole exhibits a lower share, with 39.8%, 5.2%, 3.0%, and 2.6%, respectively. In average, this geographic area features 40.3 head of bovine cattle per km^2, and 9.8% of properly demarcated farms and ranches have dairy production facilities, while these indicators for the Central-West Region are 19.9 head per km^2 and 2.8% of properly demarcated farms and ranches, respectively.

The prevalent power sources are power generating sets, available in 9.8% of properly demarcated farms and ranches, wind energy in 0.7%, and hydroelectric energy in 0.1%. By comparison, in the Central-West Region, these characteristics are observed in 3.7%, 0.3%, and 0.1% of properly demarcated farms and ranches, respectively.

As regards machinery, 23.9% of properly demarcated farms and ranches feature forage conditioning equipment; 12.7% feature combine harvesters, and 65.6% tractors; while, out of the total, these characteristics are observed in 8.7%, 4.0%, and 39.0% of farms and ranches in the Central-West Region, respectively. External technical advice contracts are observed in 50.0% of properly demarcated farms and ranches and machinery service contracts, in 44.5% of this group's properly demarcated farms and ranches, as compared to 28.0% and 24.5%, respectively in the Central-West Region as a whole. In those farms and ranches equipped with tractors, the average number is 2.2, while for the Central-West Region, it is 1.6.

In the farms and ranches of this group of departments, the share of rental and share-cropping is significantly higher than in the total departments of the Central-West Region: 25.0% versus 10.7% respectively. This group also features a higher share of incorporation in the form of corporations –de facto corporations, public limited companies, or others,– with an average 24.0% of the total properly demarcated farms and ranches, and a 42.7% of the surface area, as opposed to 17.6% and 34.5% respectively in the Central-West Region as a whole.

The sociodemographic aspect is reflected by means of population and housing indicators. People over 64 years old, referred to as "permanently non-working population" account for an average 11.3% of the population within the considered departments, whereas in the Central-West Region as a whole, they account for 9.7%. A 79.4% of housing units have high-quality flooring; 9.3% have slated or tiled roofs with ceilings; 3.4% have slated or tiled roofs without ceilings; 22.4% have slabbed or concrete roofs without ceilings; and 28.3% have slabbed or concrete roofs with ceilings. By comparison, in the Central-West Region, these characteristics are present in 61.4%, 4.9%, 2.1%, 14.3%, and 22.0% of the housing units, respectively.

In the considered departments, 46.4% of households have cell phones; 95.0% have refrigerators; 97.8% have toilets; 91.8% have water-flushed toilets; and 91.3% have water availability inside the housing unit; as compared to 35.6%, 90.4%, 94.7%, 84.4%, and 82.9%, in average, of the Central-West Region's households included in the census. As for cooking fuel, there is a prevalence of mains gas, available in 40.3% of the households; cylinder gas in 7.5% of the households; and bulk tank gas in 1.7% of the households; whereas in the Central-West Region the share is lower, with 27.6%, 5.1%, and 0.9% of the housing units, respectively.

Miscellaneous Cattle-Raising Subsystem

The Miscellaneous Cattle-Raising subsystem aligns mainly with the Arid Chaco ecoregion and exhibits a prevalence of cattle-raising ranches of over 1,000 ha devoted to caprine cattle for meat production and porcine cattle for breeding. The average number of ranches devoted to caprine cattle for meat production triples the average for the whole Central-West Region; and as significant are ranches devoted to cattle for leather and milk production, and for cattle-breeding ranches. The surface area of farms and ranches legally classified as undivided estate, the surface area devoted to fodder crops, and farms and ranches powered with solar energy nearly double the number in the Central-West Region as a whole. The prevalent characteristics in this subsystem's households are rainwater harvesting, water availability outside the housing unit and outside the premises, and housing units without toilet and with poor quality flooring. This subsystem encompasses the departments Río Seco, Sobremonte, Tulumba, Cruz del Eje, Minas, Pocho, and San Alberto, in the north and northwest of Córdoba; the departments General Ocampo, General Ángel Peñaloza, Rosario Vera Peñaloza, General San Martín, General Quiroga, Independencia, General Belgrano, and Chamical, in the south of La Rioja; the departments Ayacucho, Belgrano, and San Martín in the northwest of San Luis; the department Valle Fértil in the west of San Juan, and the department Malargüe in the south of Mendoza.

A 90.0% of the departments in this group belong to the Arid Chaco ecoregion, while the share of this ecoregion within the Central-West Region is only 25.6%. In particular, on 30.0% of the departments, the prevalent environments are chaqueño valleys and the fluvial–aeolian Candelaria Plain; 20.0% belong to the Dry Chaco and Chaco Serrano ecoregions; and 20.0%, to the Dry Chaco and Arid Chaco ecoregions and the Plains District. By comparison, in the Central-West Region, these characteristics are observed on the 7.8%, 4.4%, and 5.6% of the departments, respectively. In this geographic area, original vegetation takes up a 37.7% of the surface area, and 15% of the soils contain 0.6% to 0.8% of organic matter; while these characteristics are observed on the 20.2% and 3.3%, respectively, of the departments of the Central-West Region. Average temperature is

18.0 °C, similar to that of the Central-West Region, which amounts to 17.1 °C.

In this group of departments, 20.9% of properly demarcated farms and ranches have surface areas over 1,000 ha; 8.8% have surface areas of 1,000 ha to 2,500 ha; 5.9% have surface areas of

2,501 ha to 5,000 ha; and 15.1% have surface areas of 5,001 ha to 10,000 ha; whereas in the Central-West Region as a whole, these dimensions are observed on 10.3%, 5.0%, 2.6%, and 8.6% of farms and ranches, respectively.

In average, 48.4% of properly demarcated farms and ranches are devoted to caprine production in the departments making up the Miscellaneous Cattle-Raising subsystem, as compared to 17.9% in the Central-West Region. Particularly, 45.0% of properly demarcated farms and ranches within this subsystem have caprine cattle for meat production; 24.0% have caprine cattle for leather production; and 4.1% have caprine cattle for milk production. By comparison, in the Central-West Region, these characteristics are present in 14.8%, 6.5%, and 1.4%, respectively, of properly demarcated farms and ranches. Porcine cattle production for breeding is present in 13.4% of the subsystem's farms and ranches, as opposed to 8.4% of the Central-West Region's farms and ranches.

As significant is the production of donkeys and mules, present in 37.5% of this subsystem's farms and ranches, which nearly triples the 13.3% existence in farms and ranches of the Central-West Region. Horse and sheep production is also found on 68.3% and 24.1%, respectively, of properly demarcated farms and ranches. In particular, 66.6% are devoted to work horses; 3.0% to horses for meat production; 11.4% to sheep for wool production, and 18.4% to sheep for meat production. On the Central-West Region, these characteristics are observed on 40.6%, 11.5%, 38.0%, 1.2%, 4.4%, and 9.4% of farms and ranches, respectively. Bovine cattle is present in 49.7% of properly demarcated farms and ranches within the Miscellaneous Cattle-Raising subsystem, as compared to 29.1% of the farms and ranches within the Central-West Region. Cattle production gives rise to fodder crops, which cover 72.1% of the surface area of properly demarcated farms and ranches within this subregion. This more than doubles the figure reported for the Central-West Region, where the share of surface area devoted to fodder crops amounts to 32.9%. The share of natural and spontaneous woodlands and scrublands reaches 70.9% of the surface area of properly demarcated farms and ranches, as compared to 30.1% in the Central West Region.

In this group, there is also a significant share of inadequately demarcated farms and ranches, which account for 29.1% of the total farms and ranches in this subsystem, as compared to 11.7% of total farms and ranches within the Central-West Region. The prevalent legal form of organization of farms and ranches is unincorporated, covering 72.4% of the surface area and 86.9% of the properties of this subsystem, as compared to 57.9% and 80.4%, respectively, in the Central-West Region as a whole. A relevant characteristic is the share of surface area within properly demarcated farms and ranches that are legally classified as undivided estate, which represents 16.1% in this subsystem versus 7.9% in the Central-West Region. A 9.8% of farms and ranches have solar energy, as compared to 5.1% in the Central-West Region.

Regarding the sociodemographic aspect, 24.9% of the households of this subsystem’s departments have water availability outside the housing unit; 8.0% outside the premises, and 7.1% resort to rainwater harvesting. By comparison, these characteristics are observed in 13.5%, 3.6%, and 2.8% of the total households in the Central-West Region. In this subsystem, there is a significant share of households without toilets (11.0%) or water-flushed toilets (15.3%), as opposed to 5.3% and 10.3%, respectively, of households within the Central-West Region. A 42.7% of housing units have medium-quality flooring and 13.3% have poor quality flooring, versus 31.6% and 7.0% in the Central-West Region. Within this group, 17.2% of households have a computer and 78.5% have a landline phone, whereas in the Central-West Region, these characteristics are observed in 9.6% and 64.4% of households, respectively. The share of households using firewood or charcoal to cook amounts to 11.2% in this subsystem and to 4.4% in the Central-West Region as a whole. A 3.3% of the subsystem’s population is illiterate, a characteristic observed in 2.6% of the population of the Central-West Region. Within the Miscellaneous Cattle-Raising subsystem, there are, in average, 105.4 men per 100 women, while the masculinity ratio for the Central-West Region is 100.7. This characteristic is typical of geographic areas with scarcely populated urban centers which attract rural laborers.

Fruit and Vegetable Subsystem

The *Fruit and Vegetable* subregion extends across the Monte ecoregion, particularly the Monte of Hills and Valleys, with soils characterized by their silt loam texture, 0.4% to 0.8% organic matter content, and a prevalence of shrubs. It covers the departments Tunuyán, San Carlos, Rivadavia, Santa Rosa, Tupungato, La Paz, San Rafael, Luján de Cuyo, Lavalle, General Alvear, Maipú, San Martín, Las Heras, Junín, Guaymallén, Godoy Cruz, and Capital (in Mendoza); Rawson, Albardón, Pocito, Zonda, Caucete, Chimbas, Rivadavia, Calingasta, Ullúm, Angaco, San Martín, Jáchal, Santa Lucía, Iglesia, Sarmiento, 9 de Julio, and 25 de Mayo (in San Juan), and Chilecito, Coronel Felipe Varela, San Blas de los Sauces, General Lamadrid, Castro Barros, Famatina, Sanagasta, Arauco, Vinchina, and Capital (in La Rioja).

The surface area devoted to fruit trees and grapevine doubles the Region's as a whole. The same applies to unused arable land, surface irrigation, hiring of temporary labor, and 10 to 30 ha-properties. There stands out the production of drupe fruit (cherries, peaches, apricots) and pome fruit (apples, quince, pears), as well as tomatoes, olive trees, and onions. Irrigated land devoted to fodder crops is twice the average for the region. Also prevalent, but with a lesser difference as compared to the region as a whole, is irrigated land devoted to fruit trees and vegetables. The prevalent irrigation systems are surface irrigation with distribution through canals or ditches; gravity-fed irrigation, and subterranean irrigation.

As for the demographic aspect, there is a greater relative presence of foreign population as compared to the whole Central-West Region, inadequate housing –huts, shacks, rental rooms, hotels or room and board, spaces not intended for habitation, or mobile homes– and water supply through public network. Endocrine and respiratory diseases are the main cause of death in this subregion.

In detail, in this subregion, 87.2% of the surface area features original shrubs; 97.7% belongs to the Monte phytogeographical region (namely, the Monte of Hills and Valleys is present in 20.5% of the surface area), and the prevalent soil texture is sandy loam. By comparison, in the Central-West Region these characteristics are present in 60.9%, 51.1%, 10.0%, and 27.8%, respectively. Out of the departments that make up this subregion, 43.2% feature average annual precipitation of 100 to 200 mm; 29.6% exhibit average temperatures ranging from 14 °C to 16 °C; and 34.1% of the soils contain 0.8% of organic matter. On the other hand, in the Central-West Region, these characteristics are observed in 21.2%, 14.4%, and 18.9% of the departments, respectively.

78.3% of farms and ranches have surface areas of up to 25 ha, namely 46.3% have surface areas of up to 5 ha; 16.0% have surface areas between 5.1 and 10.0 ha; and 16.0% have surface areas between 10.1 and 25.0 ha; as compared to 45.0%, 25.6%, 9.5%, and 10.4%, respectively, in the Central-West Region. The share of surface area occupied by farms and ranches of up to 25 ha reaches 21.1% of the total occupied surface area, with 12.3% of the farms and ranches' surface area being non-arable land or wasteland, whereas in the Central-West Region as a whole, these characteristics amount to 10.5% and 7.3%.

The prevalent productive activity is fruit tree growing, which takes up 69.8% of the surface area. Also significant are grapevine on 43.2%, olive tree on 12.4%, drupe fruit (cherries, plums, apricots, peaches, and sour cherries) on 6.3%, and pome fruit (apples, quince, and pears) on 2.5% of the surface area; as compared to 35.1%, 21.1%, 6.6%, 3.3%, and 1.3%, respectively, in the Central-West Region. In average, there are 12.0 different fruit tree crops in the Fruit and Vegetable subsystem's departments, and 88.9% of the surface area devoted to these crops is under irrigation; while in the Central-West Region, these indicators are 8.8 and 71.3%, respectively. Also significant in this subregion is the surface area devoted to vegetables, including tomatoes, garlic, and onions, among other similar crops.

The rural electrical grid reaches, in average, 67.2% of the farms and ranches of this subregion; surface irrigation, 27.1%; and gravity-fed irrigation, 20.8% of the surface area, as compared to 48.9%, 14.0%, and 10.7%, respectively, in the Central-West Region as a whole. This subregion exhibits a greater rate of hiring of temporary labor, with 18.1%, and direct labor, with 43.2%, as compared to 9.4% and 35.9% in the Central-West Region. Similarly, the average number of people residing in farms and ranches amounts to 5.7 in this subregion versus 5.0 in the region as a whole.

Final Considerations

By way of warning, it is worth mentioning that factorial analysis methods are sensitive to the type and number of variables included in the data table. The introduction of additional analysis dimensions, the addition of further characteristics to the existing ones, or the absence in any subsequent study of the variables used in this one may, to some extent, alter the groups composition, mainly in those observation units with lower relative significance and accounting for a marginal share in the given cohort.

The heterogeneities existing in the agricultural and cattle-raising production facilities are well-known. Nevertheless, they cannot be fully seen when using departmental level data, hence the need to have information organized per production unit in order to adequately study these differences.

Chapter 3. Conceptual and Analytical Proposal towards Sustainability

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Sustainable Development assumes that reality is complex and dynamic, and involves social, economic, and environmental aspects. Commonly used indicators, such as Gross Domestic Product, Unsatisfied Basic Needs, and the Human Development Index, among others, fail to reflect this complexity in an integrated way, let alone can they be applied at a local scale. The analyses on development processes performed by various disciplines, contradictory as they might be, are all necessary contributions. For that reason, sustainable development calls for the articulation, at a single level of analysis, of the economic, the institutional, the ecological, and the social spheres.

Moreover, the negative effects at a local level of particular development models have already taken a global dimension. Different sectors of society are concerned about processes such as pollution, global warming, stratospheric ozone layer depletion, biodiversity loss, massive population movements, and malnutrition, among many others. The issue surrounding the Earth system's capacity to sustain a growing population under the current economic paradigm can be traced back to the local scale.

In response to the complexity and the approach of the concept from a political and scientific perspective, there began the differentiation between "environmentalists" and "economists", and, later on, "environmental economists". This gave rise to the concept of Ecodevelopment, coined by Ignacy Sachs (1980), who proposed an increase in productivity while respecting ecosystems. It is an intermediate approach between Malthusian pessimism, concerned about resource depletion, and abundance theorists' optimism, which conceives technological solutions as the sole way towards development. This concept paved the way for the subsequent emergence of the concept of sustainability, which came to replace its predecessor and to reconcile, at least temporarily, the conflicting interests around the direction of development. Thus, environmental economics detaches itself from ecological economics by virtue of the distinction between weak sustainability and strong sustainability. Ecological economics' concept of strong sustainability meant a major change as it asserted that man-made capital could not serve as a substitute for natural resources, and introduced the notion of natural capital in its production equations (Daly, 1997). Debates over what environmental sustainability means often focus on whether human-made capital can substitute for natural resources— whether human ingenuity will relax natural resource constraints, as in the past. (United Nations Development Programme [UNPD], 2011).

The United Nations Development Programme's report stands in favor of preserving basic natural assets and the flow of associated ecological services. This perspective aligns with human rights-based development approaches. *Sustainable human development is the expansion of the substantive freedoms of people today while making reasonable efforts to avoid seriously compromising those of future generations* (UNPD, 2011).

Thus, both economists and ecologists achieved their goals. The first, for development to involve continued economic growth (**sustained development**), and the latter, for development to consider the preservation of natural resources over time (**sustainable development**). These are some of the social processes that help explain the ambiguity and the multiple appropriations of the sustainability concept when attempting its application on actual and empirical situations (Left, 2008). This work conceptualizes sustainable development in a non-restrictive way, considering that the sustainability of development within a particular region can be influenced by both internal conditioning factors and external disturbances.

Contributions to Sustainability as a Science

In the 1980s and 1990s, the global sustainable development agenda became more of a social and political process than one involving the scientific and technological community. However, since the beginning of the 1980s, various scientific approaches have shown a growing interest in the relationship between nature and society. The new millennium witnessed the emergence of the so-called "new" sustainability science (Kates *et al.*, 2001). As a result, the scientific community gets involved by relating society and nature so as to enable an understanding of the interactions between global processes and social and ecological characteristics of particular places and sectors (Kates *et al.*, 2001:641).

Since its inception, this science required a new structure, methods, and contents to be able to answer a set of questions related to the dynamic interactions existing among the Earth system, human development, and sustainability; the determinants of both the vulnerability of specific systems and the resilience of systems jointly including nature and society; the setting of boundaries beyond which systems run a greater risk of degradation; and the incentive structures needed to enhance the social capacity of coping with those interactions in a sustainable way, among others. Essentially, the approach being pursued is a reverse approach, i. e., one that starts with the outcomes to be prevented and, from there, pinpoints dependable pathways for a transition to sustainability. As important are the long-term trends affecting this transition, which are characterized by their reshaping of nature-society interactions; may involve either human development processes or environmental processes; and are, in all cases, relevant for sustainability (Kates *et al.*, 2001).

Kates and Parris (2003) have identified at least ten trends with these characteristics: peace and security; population, migration, and urbanization; affluence/poverty; well-being and health; production, consumption, and technology; globalization, governance, and institutions; and global environmental change, including atmosphere, oceans, land, and freshwater systems. These long-term trends then become the central elements of vulnerability and resilience analyses. An exposed unit —a household, community, city or region—is vulnerable to a disturbance when it not only results in significant losses (demonstrating high sensitivity) but also when it lacks the capacity to regain a trajectory of social-environmental development, thus potentially creating a negative spiral of increasing loss (Watts and Bohle, 1993).

In a somewhat different language, the concept of resilience also theorizes loss and response to disturbance, but in reference to open, complex, and dynamic systems rather than specific units of exposure. Chapin *et al.* (2004), for example, define resilience as the magnitude of disturbance that can be absorbed by a system without fundamentally changing it. A more resilient system is one that is able to respond flexibly to change while maintaining its core functions and integrity (Folke, 2006). In some of the literature, a less resilient system is one for which disturbance in any of its component parts generates a shift into a less "desirable" domain, thus creating negative feedbacks into the system and subsequent shocks and impacts (Walker *et al.*, 2006). What is "desirable" or "undesirable" is ultimately subjective, and ideally determined by participants and actors within the system (Cumming *et al.*, 2005; Moreno-Pires and Fidélis, 2012) although part of the challenge for sustainability is reconciling the needs of diverse individuals, particularly vulnerable individuals, with the trajectory of change of the broader system. Persistence, adapting capacity, and transforming capacity based on *adaptive management* all concern the resilience of a socioecological system (Walker *et al.*, 2006) and the reduction of the vulnerability of production systems exposed to threats; thus, less vulnerable systems tend to be more sustainable in time and space.

Sustainability Conceptual Framework

This work considers sustainable development not as a state, but as a process that is built on a daily basis, based on past experiences and future uncertainty. Past experiences help us define the risks a system is exposed to and act accordingly, while uncertainty is the consequence of ignorance about what tomorrow may bring. Thus, the dynamics of a given system (country, region, or specific production) is signed by the steps already taken and by the chances of changes to come. It is a dynamic space continuously under construction, deconstruction, and reconstruction. As such, rather than a single ideal situation, it is a set of ideal situations redefined on a permanent basis as a consequence of the changes in the surrounding context.

Directing a development path towards sustainability depends, on one hand, on a system's internal conditioning factors. Overcoming the restrictions to attain sustainability will depend on the condition of said system in relation to its inherent diversity; its flexibility to adapt to changes; its management capacity, associated to factors such as power relationships, cultural competencies, and institutional characteristics, among others; and its ability to transform in order to reverse unwanted situations. On the other hand, every system is exposed to external disturbances coming from different dimensions. Among them, we can mention migrations (social dimension); market changes (economic dimension); impacts of climate change and other natural disasters (ecological dimension); or public policy changes, such as the implementation of a subsidy or restrictions on imports (institutional dimension) (Resilience Alliance [RA], 2010). An external disturbance reveals the resilience of a system and the vulnerability of its components, thus affecting, to a greater or lesser degree, its sustainability based on its internal conditioning factors.

In terms of systematization, sustainability is defined by four dimensions: economic, social, ecological, and institutional (Figure 3.1). These dimensions interrelate with each other creating synergies and trade-offs within a system, as a consequence of the multiplicity of feedback loops among its various components. These can either contribute to sustainability or put it at risk. This is why any intervention intended to help overcoming issues in one dimension must consider the results that such an action will have on the system as a whole.

Following the proposal made by the Sustainable Development Solutions Network (SDSN, 2013) –on which the new sustainable development goals for 2015-2030 are built–, there follows a summary of the main goals for each dimension, which will serve as a guide for the development of the analytical framework for the assessment of sustainability being introduced in the next section:

- From an ecological point of view, it is necessary to reverse the negative impacts on the environment. Sustainable development cannot be attained unless a “green” economy is pursued, i. e., by decoupling economic progress from man-induced environmental damage.

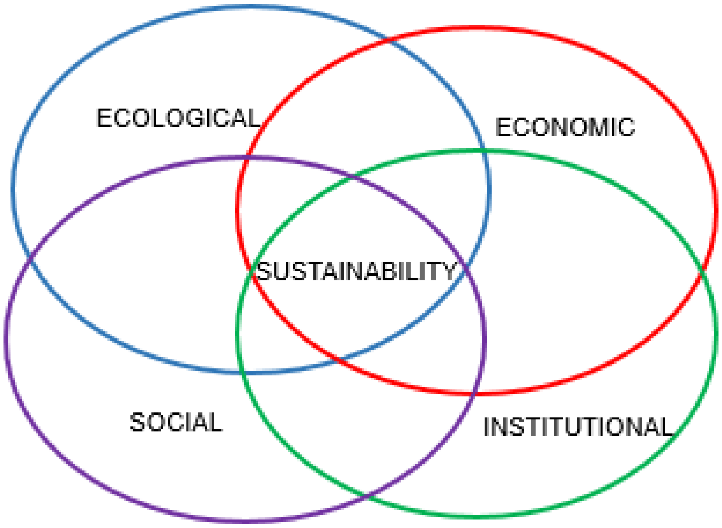

Figure 3.1 Sustainability dimensions and their interrelations

- From an economic point of view, sustainable development must aim at ending extreme poverty; providing adequate incomes, food security, education, basic infrastructure – such as water, energy, and access to health care–, and environmental stewardship; and reducing the vulnerability of communities or individuals exposed to disaster risks.
- As for social inclusion, the challenge lies on maintaining or increasing the quality of “social capital”. Social capital, considered a scarce resource contributing to economic productivity and human well-being, refers to rights and cultural practices; governments and companies’ transparency and reliability; and people’s ability to assert their opinions and pursue their interests in public decision-making processes, including those associated to the natural environment.
- Finally, the management of socioecological systems calls for

> the existence of an institutional context. Good governance is required of all sectors of society: governments, businesses, and civil-society organizations. Local governments need to build effective institutions and pursue sustainable development with transparency, accountability, clear metrics, and openness to the participation of all actors. The private sector must contribute to develop and deliver many of the new technologies, organizational models, and management systems that are needed for sustainable development. It must adopt transparent goals and hold itself accountable for those goals vis-à-vis its investors, customers, suppliers, and society at large. It should work with governments to address market failures, help mobilize the needed resources and secure private incentives, and it must be accountable for the social and environmental consequences of its actions. Civil society must also do its part to attain sustainable development. It includes voluntary organizations which oversee governments and businesses in terms of integrity and performance, mobilize communities, provide services, keep peace and security, and promote cultural activities. Progress on any of the four dimensions will require the adoption of advanced technologies already available. Universities and research institutions, therefore, play an important role as engines of basic scientific and technological research.

Sustainable development requires integrated pathways and must be applied at global, regional, national, and local scales. To that end, each region, each country, each city, and each rural locality will need to make its own situation analysis. Feasible pathways are highly complex, subject to great technological uncertainty, and likely to require substantial financial resources. They will often require changes in behavior and involve complex interactions across objectives, across time, and across actors (SDSN, 2013). Thus, the challenge of developing a methodology for the assessment of sustainability is still important.

Under the conceptual framework set forth hereinbefore, there follows the analytical framework supporting the methodological proposal for the generation of sustainability indicators for production systems that is being introduced in the following chapter.

Analytical Framework for the Sustainability Assessment of Production Systems

An analytical approach to the sustainability of production systems makes it necessary to define the criteria to guide the assessment of the four dimensions of sustainability: **Ecological, Economic**, **Social**, **and Institutional, and their interactions.** These criteria provide the basis for defining a set of components, which will enable the selection of the most appropriate indicators for both the analysis of the system's situation and the identification of the existing interrelations, be they positive or negative, stemming from the achievement of the goals set for each of the dimensions. It is also necessary to consider the external disturbances that might affect the system.

Criteria and Components of Each Dimension of Sustainability

In order to provide a rationale for the Sustainability Matrix that will be elaborated in the following chapter, this section proposes a set of components to assess the sustainability of the Central-West Region's production systems, which aligns with the criteria set forth for each dimension and exemplifies the postulates of sustainability. The analytical framework proposed hereinbelow is based on a general "demand-based" criterion: each dimension, in relation to its specific criterion, demands actions from the rest of the dimensions in order to achieve human well-being.

a) The Ecological dimension's criterion is **Preservation**. In this context, Preservation refers to both the quantity and the quality of ecosystemic processes, and its components are Water, Soil, Air, and Biodiversity. What is represented under the Preservation criterion is what the Ecological dimension demands from itself; that is the resources it has at its disposal, and with which it must meet both its own consumption and the consumption originated in the other dimensions. The Economic, the Social, and the Institutional dimensions pose demands on the Ecological dimension, considered "Ecosystem Services Demands."

b) The Economic dimension’s criterion is **Efficiency**, and it pursues the ideal use of productive resources in order to achieve the minimum impact (productivity), the independence from external supplies, and the competitiveness of the output (including market and production risks). Under the Efficiency criterion, understood as the optimal use of productive resources to meet needs, the components of the Economic dimension —Productivity, Independence from External Supplies, and Competitiveness— represent what this dimension demands from itself, that with which it must meet both its own demands and the demands posed by the other dimensions. The Ecological, the Social, and the Institutional dimensions pose demands on the Economic dimension, considered “Economic Resources Demands.”

c) The Social dimension’s criterion is **Equity**, and it refers to the fair allocation of the resources (natural resources and goods and services) generated by the system and contributing to the formation of the human, cultural, and social capital of both individuals and the community. Under the Equity criterion, defined as a set of practices aimed at addressing and overcoming all forms of exclusion and inequity, the components of the Social dimension — Human Capital, Cultural Capital, and Social Capital— represent what this dimension demands from itself as well as the demands originated in the other dimensions. The Ecological, the Economic, and the Institutional dimensions pose demands on the Social dimension, considered “Social Participation Demands.”

d) The Institutional dimension’s criterion is **Management Capacity**, and it refers to the adapting and transforming capacity in relation to both formal institutions and informal ones (customs, traditions, practices, among others), which allows adaptations in order to cope with risks threatening sustainability and encourage transformations within the system under analysis, assuming that its current status is undesirable for the socioecological system as a whole. Under the Management Capacity criterion, understood as the ability to manage tasks and processes in a fast and reliable way, the components of the Institutional dimension — Legislation, Enforcement, and Oversight— represent what this dimension demands from itself. All the Ecological, the Economic, and the Social dimension pose demands on the Institutional dimension, considered "Adaptive Management Demands."

Thus, the analytical framework for the assessment of sustainability indicates, on the one hand, the state of affairs of each dimension based on the identified components, which correspond to the criterion governing the dimension. On the other hand, the demands from each dimension are pinpointed, which, as a whole, make up the *ecosystem services demands* (those posed on the Ecological dimension); the *economic services demands* (those posed on the Economic dimension); the *social participation demands* (those posed on the Social dimension); and the *adaptive management demands* (those posed on the Institutional dimension). Nevertheless, these "Demands" by themselves do not guarantee the sustainability of production systems; hence, each dimension's set of components is introduced in order for them to contribute to a *Healthy and Productive Environment, Economic Progress*, *Prosperity and Equitable Social Opportunities, and Participatory Governance* (Independent Research Forum, IRF2015, 2013). Collectively, these contributions determine the state of "Human Well-being". Both Aggregate Demands and Human Well-being will guide the direction of the system under analysis in terms of sustainability.

The next chapter provides examples of the way in which each dimension contributes to Human Well-being, and introduces the methodology for the assessment of production systems based on this analytical framework. While the proposal is sort of a "photograph" in the sense of not allowing a complete identification of the system's future dynamics, it does enable a thorough examination of the interrelations among the different components of the four dimensions and, based on it, the definition of concrete lines of action.

The Importance of Analyzing Sustainability from a Resilience-Based Approach

As the methodology proposed in the following chapter relies on the incorporation of sustainability assessment from an approach based on the resilience of socioecological systems, it is necessary to consider the feedbacks (both positive and negative) and trade-offs occurring among the component elements of a system. These relationships take place among the different dimensions and across the scales (temporal and spatial) within each dimension, and among the dimensions or their components (RA, 2010; Cash *et al.*, 2006). Accordingly, for a production system to be sustainable, it needs to harmonize in a single productive act economic return on investment, nature preservation, and social justice attained by means of appropriate institutional management. However, more often than not, the goals of one dimension, or of any of its components, are in conflict with those of another dimension or its components. There follow some examples as applied to agricultural production systems.

At a spatial scale level, the achievement of economic goals (for instance, profitability in a productive cycle) demands less time than the achievement of social goals (such as food security); these, in turn, require less time than the achievement of ecological goals (for example, nutrient cycle optimization), which brings about mismatches among the involved aspects. This may lead to a situation that is unsustainable in time, unless there is an adaptive management process that allows not only to cope with these conditioning factors internal to the system but, at the same time, to anticipate the occurrence of external disturbances (such as an extended drought).

In a society, it is desirable for consumption to increase in order for production to increase, thus invigorating the economy. But this logic has environmental consequences, such as the overexploitation of natural resources to meet these growing levels of consumption and the sustained increase in waste disposal. Both these environmental consequences adversely impact the production system itself in the medium and long term.

At the agroecosystem level, and considering the goal of securing a steady or growing economic income, costs could be reduced by means of, for example, mechanization (by substituting labor for machinery or offering unfair working conditions), yet overlooking the social dimension. Also, land productivity could be enhanced by introducing chemical supplies (thus degrading the environment), which would mean overlooking the ecological dimension or even the economic dimension itself, thus generating an increasingly greater dependence on external supplies and exposing the system to the fluctuations in the price of such supplies.

Another example of conflicting relationships among the different dimensions of sustainability originates in the logic of the production modality itself, i. e., production activity is governed by the principle of profit maximization. One way of achieving this goal is to circulate a certain amount of available capital as many times as possible within a given time period. In this particular case, this could be exemplified by the development of short-cycle seeds which enable to reduce the exposure of crops to adverse climatic conditions, but which simultaneously allow the possibility of double cropping, thus putting an additional burden on the soils. Under this logic, in a farm with high land productivity, leaving land fallow, letting land rest, or devoting it to fodder crops to be ploughed back into the soil would be detrimental from the economic perspective. A similar situation would occur should such land and time be devoted to any other crop not maximizing profits, given the price difference in the market. This gives rise to a further conflict between the economic interest and the ecological interest of preserving the involved natural resources, either by letting a plot of land lie fallow, resorting to crop rotation, or using green manure.

One last empirical and current example illustrating this logic is the Argentine agriculturalization process that began in the 1980s and, later on, the monoculture of soybean and soybean-wheat double-cropping. These brought about a change in the management of agricultural systems that strongly conflicted with previous agricultural practices characterized by a prevalence of mixed agricultural/cattle-raising systems in the hands of a large number of small and mid-sized family farmers. While this change can be attributed to a combination of factors (new seed technologies, supplies and machinery, price of products in international markets, and domestic public policy), it has resulted in a significant movement of labor and producers (some found it more profitable to lease their land; others were uprooted due to indebtedness); air and water pollution owing to the use of harmful chemicals; increasing dependence on agricultural supplies; deforestation; and biodiversity loss as a consequence of the expansion of the agricultural border, among others. These problems have not yet found a management method that enables the sustainability of these production systems, given the resilience loss they entail for the socioecological system containing them.

These and other examples show the thin line that exists between sustainable and unsustainable. Therefore, it is equally necessary to define threshold values for those key variables within each dimension, and to continuously redefine such thresholds as a result of the changes affecting the context under analysis. There lies the need of an Institutional dimension that allow to develop an adaptive management of the system based on both individual and collective capacities, thus building trust and capital in its various forms (economic, cultural, human, natural, political, and social). Social capital can be expanded when the management of the system involves the greatest possible number of actors at all levels of governance, from local to global. To that end, investments must be made in order to secure the provision of ecosystem goods and services; incorporate ecological knowledge into institutional structures; create new social and ecological networks; combine different forms of knowledge; provide incentives for the participation of all actors; identify knowledge gaps and develop the experience required to address them (RA, 2010). As previously described, the enhancement of an aspect in one system may cause the worsening of the others. It is essential that these trade-offs be identified and that is why adaptive management must contribute to generate a greater degree of flexibility, inclusiveness, and innovation.

So far, this work has set forth and discussed the conceptual criteria for each dimension of sustainability, which serve as tools to obtain, through the application of the methodology that will be developed next, the most appropriate indicators for the identification of feedbacks, either positive or negative, not only within the analyzed production system itself, but also in relation to the means –social, ecological, and institutional– of the system in which it is embedded.

Chapter 4.

Production System Sustainability Indicator

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The assessment of the sustainability of a production system calls for the formulation of appraisal methodologies that, by means of the interrelation among indicators, allow an estimation of its level within a given geographical area and a given time frame, with the ultimate purpose of anticipating the future in relation to the involved processes.

The absence of conceptual agreement on sustainability is one of the aspects that have held up the development of an information base along with widely accepted indicators for its assessment. Similarly, the differences in terms of availability and access to base information for the creation of a generally applied measuring method compel the development of new methodological approaches on a continuous basis. These constraints differ not only along spatial and temporal scales, but also in relation to the goals for which the assessment is performed.

This chapter presents a proposal for the assessment, both qualitative and quantitative, of the sustainability of a production system –in the geographical area and temporal frame in which the system is embedded,– acknowledging the multidimensional nature of sustainability and the interrelations among its dimensions according to the conceptual framework set forth in Chapter 3. The rationale behind the selection of a primary production system is its greater scope in the spatial scale. However, the ultimate goal of this methodology is to enable its application on different production systems, both rural and urban, and their interrelations, from a perspective based on the resilience of socioecological systems.

Conceptual Aspects

For the calculation of the production system sustainability indicator (indicador de sustentabilidad del sistema productivo, ISSP), the dimensions (Ecological, Economic, Social, and Institutional) are initially organized in a matrix (Table 4.1) whose internal structure contains the relationships among them. By assigning a number to each dimension (1. Ecological; 2. Economic; 3. Social; 4. Institutional), it is possible to identify the relationship between any two of them as the position X_{ij}, for all $i,j=1,2,3,4$, symbolizing the relationship between the dimension *i* (table row) and the dimension *j* (table column). Thus, the position or cell X_{23} represents the relationships between the Economic dimension (located in a row) and the Social dimension (located in a column).

Table 4.1. Sustainability Matrix for a Production System

Relationships		**Human well-being**				**Aggregate Demands**
		Ecological (Preservation)	Economic (Efficiency)	Social (Equity)	Institutional (Management Capacity)	
Demands posed on the different dimensions	Ecological					Ecosystem Services
	Economic			X_{23}		Economic Resources
	Social		X_{32}			Social Participation
	Institutional					Adaptive Management
Contributions to human well-being		Healthy and Productive Environment	Economic Progress	Prosperity and Equitable Social Opportunity	Participatory Governance	Direction of the system in terms of sustainability

Conceptually, it reflects the demands from the Social dimension to the Economic dimension (for example, corporate social responsibility). Similarly, the demands from the Ecological, Social, and Institutional dimensions to the Economic dimension constitute the *Economic Resources Demands*. Hence, each **row** in the Matrix represents the demands posed on each of the dimensions. The demands posed on the Ecological dimension constitute the *Ecosystem Services Demands*; the ones posed on the Social dimension constitute the *Social Participation Demands*; and the ones posed on the Institutional dimension constitute the *Adaptive Management Demands*.

The principal diagonal represents the baseline or state of affairs of each dimension (positions X_{ij} such that $i=j$), based on which each dimension's components are defined. These components are originated in the governing criteria adopted for each of the dimensions according to *consensual* agreements on sustainable development.

The indicators defined for each component will be contingent upon such criteria. The first can change provided that different production systems are identified, while the latter will change whenever different goals are defined around the assessment of sustainability. In this context, the components will only change if the criteria are modified. Thus, for instance, indicators defined around the outcomes of a given policy would be different from indicators referring to a general assessment of sustainability.

The criteria –defined in the previous chapter and used in this one– obey to the ultimate goal of contributing to "Human Well-being", understood as the result of the development process based on the mutual interaction among a "Healthy and Productive Environment," "Economic Progress," "Prosperity and Equitable Social Opportunities," and "Participatory Governance" (IRF2015, 2013). This way, the components of each dimension must be such that they contribute to their defining criterion, and must relate, to the extent possible, to the components of the remaining dimensions for the purpose of examining the various synergies and trade-offs.

Each column of the table can be thought of as a specific function, where a dimension (located in a column) combines elements taken from the other dimensions (located in rows) in order to contribute to the achievement of Human Well-being. Thus, position

X_{32} stands for the contributions of the Social dimension to Economic Progress; for example, education and training to provide the production system under analysis with qualified labor in order to boost productivity.

Table 4.1 is a simplified representation of the sustainability building process in a production system. The different operations are organized in a **Sustainability Matrix** that encompasses the relationships of demands and contributions among the dimensions.

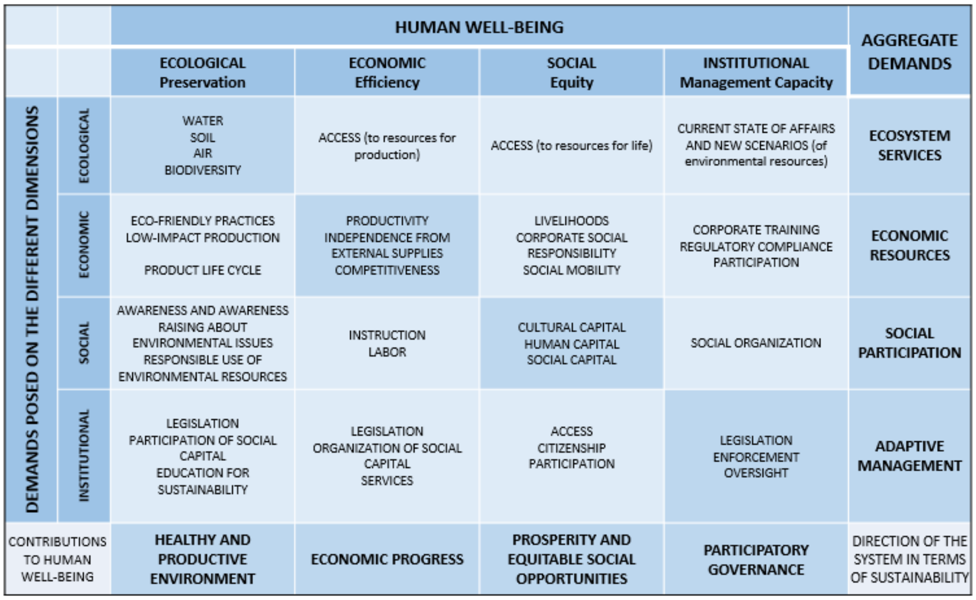
The Sustainability Matrix shows the relationships between aggregate demands and contributions to human well-being, allowing the assessment of the production system's state of affairs in terms of sustainability. The different **components** making up the Matrix are integrated by means of a set of indicators defined through variables. For example, the ecosystem baseline has four components: Water, Soil, Air, and Biodiversity. The Water component is made up by several indicators: Quality, Quantity, and Source, each of them relying on different variables for its assessment. Thus, if quantifying Quality, for instance, the considered variables could be Nitrates and Dissolved Salts, expressed in mg/L. However, the most relevant component as well as the specific indicator will be contingent upon the analyzed production system and its particular conditions and characteristics, and should be sensitive and effective enough to provide answers to the assessed questions.

The intertemporal comparison of these results will allow the assessment of the production system's path to sustainability. Also, going back to each of the components of the relationship matrix, the assessment will reveal the origin of both the actions contributing to the system's sustainability and those compromising any aspect of sustainability and, hence, requiring intervention.

Dimensions and Components

In order to provide examples for the Sustainability Matrix developed herein, this chapter proposes a set of components to assess the sustainability of the production systems in the Central-West Region shown in Figure 4.1, namely, intensive or extensive production systems associated with the (agriculture) primary sector. This is not a comprehensive list of components, as the specific sector or region's distinctive features may make it necessary to consider other components as well.

The principal diagonal shows the state of affairs of the dimension and the components under the prevailing criterion. The rest of the matrix represents the interrelations among the different dimensions of sustainability based on the criteria and components identified in Chapter 3.



		HUMAN WELL-BEING				AGGREGATE DEMANDS
		ECOLOGICAL Preservation	ECONOMIC Efficiency	SOCIAL Equity	INSTITUTIONAL Management Capacity	
DEMANDS POSED ON THE DIFFERENT DIMENSIONS	ECOLOGICAL	WATER SOIL AIR BIODIVERSITY	ACCESS (to resources for production)	ACCESS (to resources for life)	CURRENT STATE OF AFFAIRS AND NEW SCENARIOS (of environmental resources)	ECOSYSTEM SERVICES
	ECONOMIC	ECO-FRIENDLY PRACTICES LOW-IMPACT PRODUCTION PRODUCT LIFE CYCLE	PRODUCTIVITY INDEPENDENCE FROM EXTERNAL SUPPLIES COMPETITIVENESS	LIVELIHOODS CORPORATE SOCIAL RESPONSIBILITY SOCIAL MOBILITY	CORPORATE TRAINING REGULATORY COMPLIANCE PARTICIPATION	ECONOMIC RESOURCES
	SOCIAL	AWARENESS AND AWARENESS RAISING ABOUT ENVIRONMENTAL ISSUES RESPONSIBLE USE OF ENVIRONMENTAL RESOURCES	INSTRUCTION LABOR	CULTURAL CAPITAL HUMAN CAPITAL SOCIAL CAPITAL	SOCIAL ORGANIZATION	SOCIAL PARTICIPATION
	INSTITUTIONAL	LEGISLATION PARTICIPATION OF SOCIAL CAPITAL EDUCATION FOR SUSTAINABILITY	LEGISLATION ORGANIZATION OF SOCIAL CAPITAL SERVICES	ACCESS CITIZENSHIP PARTICIPATION	LEGISLATION ENFORCEMENT OVERSIGHT	ADAPTIVE MANAGEMENT
CONTRIBUTIONS TO HUMAN WELL-BEING		HEALTHY AND PRODUCTIVE ENVIRONMENT	ECONOMIC PROGRESS	PROSPERITY AND EQUITABLE SOCIAL OPPORTUNITIES	PARTICIPATORY GOVERNANCE	DIRECTION OF THE SYSTEM IN TERMS OF SUSTAINABILITY

Figure 4.1. Sustainability Matrix for a Production System

The Ecological Dimension

The governing criterion for the Ecological dimension is Preservation. Protecting natural resources means preserving ecosystem services for both human use and to ensure the functioning of ecosystems. Water, Soil, Air, and Biodiversity are the components of this dimension that will enable interactions with the other dimensions with the purpose of contributing to Human Well-being by means of a Healthy and Productive Environment.

Ecological-Ecological Relationship

The components of each dimension are made up of indicators and variables. For the Water component, the considered indicators are Quality, Quantity, and Source. The level of Nitrates and Dissolved Salts, among other substances, is what determines the Quality of Water; the available volume, along with the diversity of sources, acts as a determinant for the settlement of populations and the undertaking of productive activities in the area. Relevant aspects of the Soil component include Quality, Condition, Structure, and Subsoil Mineral Content, depending on the analyzed production system. The Air component is not circumscribed only to its Condition (Pollution, Particle Concentration), but also to Time and Climate as defined by their variables: Precipitation, Temperature, Atmospheric Pressure, and Wind, considering that the likelihood of production activities and human settlements is contingent upon them. The Biodiversity component includes Landscape Connectivity and Heterogeneity, Natural Environment, Vegetation, and Fauna. Biodiversity ensures the natural system's integrity by building a greater resistance to disturbances, thus securing the provision of ecosystem services. It is worth mentioning that the specific characteristics of a particular production system will call for greater (or no) emphasis on some of these components.

Economic-Ecological Relationship

The contributions of the Economic dimension to the Ecological dimension are Eco-Friendly Practices, Low-Impact Production, and awareness about Product Life Cycle aimed at *Human Well-being* by means of a *Healthy and Productive Environment* under the Preservation criterion.

Eco-Friendly Practices consider, for instance, the biodiversity management within the production unit, crop rotation, diversity of agricultural practices among production units, the existence of natural vegetation borders, agrochemical use, greenhouse gas emissions, and energy efficiency in the case of agricultural production systems.

Low-Impact Production includes mainly the production of goods and services adapted to environmental conditions, but also the modality and magnitude of the use of natural resources. As regards Water, for example, relevant aspects include the volume of water secured by source type, as it defines the scale of impacts and potential risks associated to its use, either by the production system itself or by other users of the resource. As regards Soil, the type of soil management undertaken affects, to some extent, the system's productivity, but can also influence the water cycle. On the other hand, climate is a further determinant to be considered, inasmuch as any production failing to adapt to certain climatic conditions will result in additional pressure on natural resources, as previously mentioned for the Water component.

Product Life Cycle is assessed through different indicators of interest in relation to the production system in question, including, among others, energy use, greenhouse gas emissions, consumptive use of water, or pollution. These are explicit geographical indicators that not only show depletion, degradation, or pollution, but also reveal their location and clear the ground for assessing the impact that the production of a particular product, as well as its distribution, its consumption, and the waste generated have on natural resources, ecosystems, and the livelihoods of populations.

Social-Ecological Relationship

The Social dimension contributes to the Ecological dimension through the much needed Awareness and Awareness Raising about Environmental Issues and Responsible Use of Environmental Resources aimed at *Human Well-being* by means of a *Healthy and Productive Environment* under the Preservation criterion.

Awareness and Awareness Raising about Environmental Issues include, for instance, the appreciation of ancestral practices associated with a greater communion with nature and respect for its cycles, as well as of daily practices related to solutions having regard for the value of the environment. Responsible Use of Environmental Resources includes any use of environment components not specifically associated with the production of goods and services, such as per capita water consumption and the reduction of waste buildup.

Institutional-Ecological Relationship

The Institutional dimension contributes to the Ecological dimension through the approval, ongoing revision, and oversight of an adequately aligned Legislation that provides for the undertaking of any necessary assessments of environmental impact. It must also promote and ensure the Participation of Social Capital through consortia associated to the use of one or more natural resources. Moreover, it must provide Education for Sustainability through the dissemination –on the media– of practices of resource preservation and control, promoting the transdisciplinary scientific and technological development required to contribute to the generation of *Human Well-being* by means of a Healthy and Productive Environment under the Preservation criterion.

The Economic Dimension

As for the Economic dimension, the criterion to contribute to *Human Well-being* through *Economic Progress* is Efficiency, understood as the optimal allocation of economic resources subject to the actual availability of both environmental and economic resources, as well as to social requirements, and supported by institutional processes or structures favoring transformations in line with the defined goals.

Ecological-Economic Relationship

The Ecological dimension provides the Economic dimension with a certain availability of resources in order to develop production processes that allow it to contribute to *Human Well-being* through the generation of *Economic Progress* under the Efficiency criterion. Resources define not only an ecosystem's particular characteristics, but also the chances of development of production processes and their limitations.

Economic-Economic Relationship

Under the Efficiency criterion, the Economic dimension contributes to *Human Well-being* by generating *Economic Progress* based on the components Productivity, Independence from External Supplies, and Competitiveness.

The Productivity component covers both potential production (highest possible level of production yield, for instance, per cultivated hectare or volume of used water, given existing conditions) and actual production (real yield) for each type of product.

The Independence from External Supplies component refers to the share of resources and services that come from outside of the production system or geographic area in which it is embedded (supplies, financing, technologies). Generally, the greater the share, the longer the lead time, which may negatively affect both the availability and the accessibility of such resources and services –

especially in those localities that are farther away from urban marketing and distribution centers–.

The Competitiveness component covers different aspects relative to technology, planning, associations, and marketing strategies, which are all factors contingent on spatial and temporal variables, as well as on the type of activity being considered. For example, the potential introduction in the market of organic products or goods produced using alternative energy sources.

Social-Economic Relationship

The contributions of the Social dimension to the Economic dimension, for the generation of *Economic Progress* under the Efficiency criterion and towards *Human Well-being*, include Contextualized Instruction, which covers technological development and critical reflection. It is technological when it is directly associated to the productive process. Other contributions of the Social dimension to the Economic dimension are Labor with different levels of qualification and contribution to the consumption of goods or services locally produced in contrast to those coming from other sources.

Institutional-Economic Relationship

The Institutional dimension provides the Economic dimension with Legislation, Organization of Social Capital, and Services to contribute to *Human Well-being* through the generation of *Economic Progress* under the Efficiency criterion.

The Legislation component includes the existence of laws, decrees, or rules addressing emergency situations; enabling access to certifications (certificate of origin, organic products, good practices, and product traceability); and encouraging investment in Research, Innovation, and Development.

The Organization of Social Capital component includes the existence of nonprofit organizations, representative entities and public agencies, whose role is to strengthen productive processes through technical, commercial, and financial support.

The Services component encompasses ensuring the provision of both public and private services, including access to Insurance, Emergency Law, Energy, Communications, and Transport. In general, the Institutional dimension must contribute to the adaptive management of production systems, particularly in the face of the changing circumstances affecting production (environmental, market-related, technological) and marketing.

The Social Dimension

The criterion for the Social dimension is Equity, which consists in a set of practices aimed at addressing and overcoming all forms of exclusion and inequity, in the search of Prosperity and Equitable Social Opportunities. Equity is a precondition for sustainability from both an environmental and a social cohesion perspective.

Ecological-Social Relationship

This relationship entails implicit contributions made by the Ecological dimension to the Social dimension for the sake of *Human Well-being* through the generation of *Prosperity and Equitable Social Opportunities* under the Equity criteria.

The component to be analyzed in this relationship is Access to Resources, which contributes to quality of life. In this regard, the quality and quantity of the resources are as important as the guaranteed access to them and the participation in their distribution, in terms of the ways in which citizens can manage and decide what is to be done with such resources. The natural environment not only defines the particular characteristics of development in a society, but also acts as a source of physical threats for those populations exposed to, for instance, adverse climatic events such as droughts and floods, earthquakes, volcanic eruptions, and other disasters that affect the chances of economic development and put people’s health or life in peril.

Economic-Social Relationship

The Economic dimension provides the Social dimension – through the generation of *Prosperity and Equitable Social Opportunities*– with Livelihoods, Corporate Social Responsibility, and Social Mobility to contribute to *Human Well-being* under the Equity criterion. The Livelihoods component encompasses a population’s access to a production system or job with which to secure an income and ensure a sense of settlement. This means that the territory must allow a person's personal and family development and ensure they are not forced to move to a different geographic area in order to work.

In addition to generating and allocating economic value, a company's actions may influence space, with an impact that can go beyond the business sphere and expand across a greater spatial or temporal scale. These actions, which companies carry out despite not being legally bound to, are reflected in the Corporate Social Responsibility component, and include, among others, technological upgrading, relationships with trade unions and social organizations, good agricultural practices, job-related training, transport connections, water and power supply, community social equipment, sports centers, and health and social assistance centers. The Social Mobility component, understood as the chances of people going up the social ladder, includes income distribution as one of its main aspects to be analyzed.

It should be noted that most productive activities generate impacts that go way beyond the production unit, thus affecting social standards and local institutions, and hence requiring coordination activities, especially in the case of multiple small-scale production operations.

Social-Social Relationship

This relationship, contributing to *Human Well-being* by means of *Prosperity and Equitable Social Opportunities* under the Equity criterion, is analyzed in relation to the following components: Cultural Capital, Human Capital, and Social Capital.

What is meant by Capital –be it Cultural, Human, or Social– is the abilities developed by people, both individually and/or collectively. The Cultural Capital component refers to both the capital acquired through time at the family and community level and the institutionalized capital, associated with an educational background in environmental preservation, planning, management, consulting, and marketing, among others. The Human Capital component is related to the population's working conditions, educational attainment levels, and health condition, among other indicators of human development. The Social Capital component encompasses aspects related with the distribution of income and other characteristics inherent to the fulfillment of basic needs.

Institutional-Social Relationship

The Institutional dimension provides the Social dimension with the components Access, Citizenship, and Participation to contribute to *Human Well-being* through the generation of *Prosperity and Equitable Social Opportunities* under the Equity criterion.

The Access component is related with the media, schools, hospitals, and any other kind of services required by society, in general, and by the production system, in particular. The Citizenship component refers to the existence and use of participation channels. The Participation component encompasses the existence and use of representation channels.

The Institutional Dimension

Management Capacity, both adaptive and transforming, understood as the ability to manage tasks and processes in a fast and reliable way, is the Institutional dimension's governing criterion. The greater the Management Capacity, the greater the resilience and the lesser the vulnerability for the achievement of *Participatory Governance* contributing to the generation of *Human Well-being*. It refers to both individual and collective capacities, based on the building of trust and capital (economic, cultural, human, social, natural, and political) in order to guarantee the provision of ecosystem goods and services, the incorporation of different forms of knowledge, and the allocation of incentives for stakeholder participation. This dimension includes the rules and standards guiding the way people live, work, and interact in a society, and encompasses both formal and informal institutions. Essentially, institutions need to be flexible and encourage innovation in order to address internal conflicts and ever-changing environments.

Ecological-Institutional Relationship

The Ecological dimension provides the Institutional dimension with the information regarding the state and dynamics of the environment needed to assess the current conditions and the likely future scenarios, in relation to the goods and services contributed by ecosystems, aiming at the achievement of *Human Well-being* by means of *Participatory Governance* under the Management Capacity criterion. This component covers the analysis of the risks associated with changes in the natural environment. As an example, changes in precipitation and water availability patterns –affecting both populations and their production systems– give rise to transformations in the management of natural resources or systems. In this sense, there arises the need to assess current and future impacts resulting from climate change.

Economic-Institutional Relationship

The Economic dimension contributes to the Institutional dimension through Corporate Training, Regulatory Compliance, and Participation aiming at the achievement of *Human Well-being* by means of *Participatory Governance* under the Management Capacity governing criterion. The analyzed aspects regarding this relationship include the involvement of the corporate sector, in both environmental matters (responsible use of resources) and social matters (food security), production quality control, and the existence of inclusive forms of deliberation around the future of production systems. It is also convenient to assess the capacity to define the current production systems' adaptations or transformation options should they be considered vulnerable or affect other aspects of sustainability in the future.

Social-Institutional Relationship

The Social dimension provides the Institutional dimension with its participation in Social Organization, aimed at generating *Participatory Governance*, thus contributing to *Human Well-being* under the Management Capacity criterion.

This Social Organization is understood in terms of association and participation in trade unions, production cooperatives; non-governmental organizations; consortia associated with natural resource management; and networks that allow the building of trust and cultural, human, political, and social capital towards a comprehensive management of production systems.

Institutional-Institutional Relationship

This relationship encompasses all of the Legislation and the Enforcement and Oversight capacity required for the generation of *Participatory Governance* under the Adaptive Capacity criterion, thus contributing to *Human Well-being*. The Legislation component includes the revision of existing laws, as well as the creation of new instruments to guide the behavior of people and organizations around sustainability-oriented goals, that is, any regulation required for the adequate performance of each of the dimensions and their respective interrelations. The (legislation) Enforcement component covers the adherence to economic freedom, global competitiveness, corruption perception, freedom of the press and freedom of speech, accountability of public servants, and rule of law to contribute to institutional quality. The Oversight component includes monitoring and intervention while observing the existence and application of current law.

It is important to remember that the description of the dimensions, interrelations, and components of the Sustainability Matrix is not a comprehensive one, but is included as an example and as a guiding instrument to be taken into account when assessing the sustainability of a given production system.

Assessment of the Sustainability Matrix

When assessing the Sustainability Matrix, it is necessary to define the observation unit. A production system is associated with a geographic area with relatively defined boundaries. It may be confined to a restricted zone with a smaller surface area than the one demarcated by the provinces' internal administrative division. It may also extend across a single province, covering more than one department. Or it may encompass a larger area including several provinces. Regardless of the territorial extension of a production system, it is agreed that the basic observation unit is the minimum spatial dimension able to be considered within said production system. Accordingly, the observation unit to be considered is the primary production unit. By virtue of the differences in the units of measurement and the dimensions of the observed characteristics, the assessment of the Sustainability Matrix is performed by homogenizing and incorporating the answers from surveys (made on the production system's primary production units) or, alternatively, coming from secondary sources.

The assessment process begins with the collection of information at the primary production units, which may be made part of the study either through a census survey or a sampling procedure. If applying the sampling methodology, the heterogeneity of the various actors existing within the production system needs to be taken into account in order for the sample to be representative of the reality surrounding the systems in the observed geographic area. The answers provided at the primary production units are then organized by characteristics into the corresponding data table, and constitute the variables for the components of each dimension of sustainability.

Table 4.2 illustrates the observation on *n* production units, corresponding to a geographic area, of the *L* variables/indicators making up each of the *K* components of each dimension *ij* of sustainability.

Table 4.2. Components, Indicators, and Variables

	Components of the dimension ij													
	C_1				..	C_g				…	C_K			
	Indicators/variables					Indicators/variables					Indicators/variables			
Observation	V_1	V_2	…	V_L		V_1	V_2	…	V_L		V_1	V_2	…	V_L
1	$x_{1,11}$	$x_{1,21}$	…	$x_{1,L1}$							$x_{K,11}$	$x_{K,21}$	…	$x_{K,L1}$
2	$x_{1,12}$	$x_{1,22}$	…	$x_{1,L2}$							$x_{K,12}$	$x_{K,22}$	…	$x_{K,L2}$
m								$x_{g,lm}$						
n	$x_{1,1n}$	$x_{1,2n}$	…	$x_{1,Ln}$							$x_{K,1n}$	$x_{K,2n}$	…	$x_{K,Ln}$

The generic element $x_{g,lm}$ represents the answer of observation *m* for variable *l* of component *g*, part of a particular dimension *ij*. The trajectory of *m* goes from 1 to *n*, the total number of observed production units in the territory of the system under study; *g* ranges from 1 to *K*, the total number of components in the dimension *ij*; *l* ranges from 1 to *L* and shows the indicator or variable to be considered for the component of the dimension *ij*.

In Table 4.2, data are presented in the raw, that is, as surveyed, keeping their original unit of measurement and dimensions. To homogenize the information, the real value –as observed for each variable or indicator existing in each dimension within a given territory– needs to be related to reference measures, as follows:

$$\mathrm{X}_{g,lm} = \frac{x_{g,lm}\, real - X_{g,l}\, min}{X\ g,l\, max - \ X_{g,l}\, min}$$

where $X_{g,lm}$ *real* is the observed value for variable l of component g, in the survey; $X_{g,l}$ *min* is the minimum reference value for variable l of component g; $X_{g,l}$ *max* is the maximum reference value for variable l of component g. $X_{g,lm}$ is determined as the homogeneous value for variable l of component g observed at the analyzed production system's primary production unit m. $X_{g,lm}$ ranges between 0 and 1. Minimum and maximum reference values are determined for each variable of each component and for each considered production system according to, for instance, specific bibliographic references, the observation of maximum and minimum limits within the surveyed system, etc.

The homogenization of all observed attributes enables a balanced assessment of each of the components in question. Table 4.3 replicates the n homogeneous primary observation units for the L variables of component g, already shown in Table 4.2. The calculation of the average for the rows indicates the average value of the component for each of the production system's primary production unit; whereas the calculation of the average for the columns indicates the value assumed by variable l of component g for the considered geographic area.

Table 4.3. Component assessment

	Component g				
	Variable/indicators				Component value by production unit
Observation	1	2	…	L	
1	$X_{g,11}$	$X_{g,21}$	…	$X_{g,L1}$	$X_{g,.1}$
2	$X_{g,12}$	$X_{g,22}$	…	$X_{g,L2}$	$X_{g,.2}$
n	$X_{g,1n}$	$X_{g,2n}$	…	$X_{g,Ln}$	$X_{g,.n}$
Component value by variable	$X_{g,1.}$	$X_{g,2.}$		$X_{g,L.}$	I_g

Thus,

$$\mathrm{X}_{g,.m} = \frac{\sum_{l=1}^{L} X_{g,lm}}{L}$$

where $X_{g,m}$ is the average value of homogeneous variables of component *g* as observed at the primary production unit *m*; and

$$\mathrm{X}_{g,l.} = \frac{\sum_{m=1}^{n} X_{g,lm}}{n}$$

where $X_{g,l}$ is the average value of homogeneous measures of variable *l* of component *g*, as observed at the *n* primary production units. Based on these values, the index for component *g* is then calculated, as follows:

$$\mathrm{I}_g = \frac{\sum_{m=1}^{n} X_{g,.m}}{n}$$

The assessments for the components of dimension *ij* for each observation of a surveyed primary production unit are compiled in Table 4.4. The last row contains the index for each component within the territory of the considered production system.

Table 4.4. Dimension Assessment

Components of the dimension ij						
1	2	3	…	g	…	K
$X_{1,.1}$	$X_{2,.1}$	$X_{3,.1}$		$X_{g,.1}$		$X_{K,.1}$
$X_{1,.2}$	$X_{2,.2}$	$X_{3,.2}$		$X_{g,.2}$		$X_{K,.2}$
$X_{1,.n}$	$X_{2,.n}$	$X_{3,.n}$		$X_{g,.n}$		$X_{K,.n}$
I_1	I_2	I_3		I_g		I_K

These results are subsequently used to calculate the Relation Index, which is an average of the components' index value as per the following relation:

$$IR_{ij} = \frac{1}{K}\sum\nolimits_{g=1}^{K} I_g$$

where IR_{ij} is the Relation Index of dimension ij, I_g is the homogeneous value of each component of dimension ij, K indicates the number of existing components within dimension ij included in the calculation with an equal weight. For example, IR_{12} represents the Relation Index for the Ecological-Economic dimensions.

The aggregation of the IRs results in the assessment of the final demand and of well-being for each dimension of sustainability.

$$D_i = \sum_{j=1}^{4} IR_{ij}\,; \quad 0 \leq D_i \leq 4$$

$$B_j = \sum_{i=1}^{4} IR_{ij}\,; \quad 0 \leq B_j \leq 4$$

where D_i represents the demand of the dimensions included in rows, and B_j is the aggregated value of the dimensions included in columns, which results in well-being. Both D_i and B_j assume values ranging between 0 and 4.

The production system sustainability (sustentabilidad del sistema productivo, SSP) results from aggregating the final demand or the well-being attained by the four dimensions and ranges between 0 and 16.

$$SSP = \sum_{i=1}^{4} D_i = \sum_{j=1}^{4} B_j$$

The SSP value represents a quantification of the state of well-being and of the relative sustainability of the productive system in question.

The organized information on Table 4.5 shows the assessment of the Production System's Sustainability Matrix with the relations among dimensions (IR_{ij}), the demand (D_i) and the well-being (B_j) of each dimension *ij*, as well as the production system sustainability (*SSP*).

Table 4.5. Assessment of the Sustainability Matrix

Relationships		Human Well-being				Aggregate demands
		Ecological (Preservation)	Economic (Efficiency)	Social (Equity)	Institutional (Management Capacity)	
Demands posed on the different dimensions	Ecological	IR_{11}	IR_{12}	IR_{13}	IR_{14}	D_1
	Economic	IR_{21}	IR_{22}	IR_{23}	IR_{24}	D_2
	Social	IR_{31}	IR_{32}	IR_{33}	IR_{34}	D_3
	Institutional	IR_{41}	IR_{42}	IR_{43}	IR_{44}	D_4
Contributions to Human Well-being		B_1	B_2	B_3	B_4	SSP

The Production System Sustainability Indicator (*ISSP*) results from relativizing the value attained by *SSP* and its maximum potential of *16*.

$$ISSP = \frac{SSP}{16}$$

The *ISSP* ranges from 0 to 1: the greater the proximity to 1, the higher the sustainability of the production system.

This methodology proposed for the assessment of the sustainability of a production system is based on an *ex post* analysis of the results obtained from the set of economic, social, ecological, and institutional processes. In a given point in time and for a particular production system, it provides information about the system's state of affairs in terms of sustainability, yet not about the causal relation between the values. In this sense, it is sort of a "photograph" that, despite not allowing a complete identification of the system's future dynamics, enables an examination of the interrelations among the different components of the four dimensions and, based on it, the definition of concrete lines of action. Its repeated application over time will allow to monitor the progress and setbacks as regards sustainability.

It should also be noted that production systems are made up by diverse actors who relate with each other not necessarily in an equitable manner. These heterogeneities, while contributing differently to sustainability, can be analyzed using the matrix. The process consists in disaggregating the components into production unit strata, defined in accordance with the criterion that best represents said heterogeneities for a particular sector.

Simulation of a Particular Case

The application of the Sustainability Matrix model begins with the carrying out of a primary source survey aimed at determining the value assumed, at each observation unit, by the variables or indicators making up each component.

To illustrate the method, the response of 500 observation units is simulated for the Quality indicator of the Water component. The study carried out by Cantú *et al* (2008) concludes that the presence of nitrate levels over 45 mg/L and dissolved salt levels over 500 mg/L make water undesirable for human consumption. Considering this result, the answers of the 500 observation units are simulated by generating random numbers between 0 and 300, and between 0 and 3,000, respectively.

Table 4.6. The Ecological Dimension: Ecological-Ecological Relationship. Assessment of the Quality indicator for the WATER component

	Observed values Quality indicators		Homogeneous value Quality indicators		Water Quality indicator value by production unit X(g, . m)
Observation	Nitrate	Dissolved salts	Nitrate	Dissolved salts	
1	248	2,791	0	0	0
2	120	414	0	0.172	0.086
3	199	2,911	0	0	0
4	52	1,894	0	0	0
5	71	1,306	0	0	0
6	113	914	0	0	0
7	162	2,426	0	0	0
8	17	470	0.6222	0.06	0.3411
9	71	2,585	0	0	0
10	269	1,461	0	0	0
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
499	91	640	0	0	0
500	2	494	0.9556	0.012	0.4838
I(k)			0.0828	0.09146	0.0871

Table 4.6 shows part of the values observed in the simulation. The next step is the homogenization of the observed values in order to express them in a common unit of measurement.

It is necessary to consider the assumption that the higher the observed value for Nitrates and Dissolved Salts, the lower the sustainability level. Consequently, if observed values are higher than 45 mg/L and 500 mg/L, respectively, the indicator is assigned a value of 0; whereas in the case of observation units below these values, reference values are used [minimum value equal to 0 for both, and maximum value of 45 for Nitrates and of 500 for Dissolved Salts]. It is also important to include the consideration that the higher the value, the lesser the sustainability of the indicator, which is why the result is the one's complement of the homogenization process. Accordingly, the homogeneous value is obtained as follows:

$$\mathrm{X}_{A,N8} = 1 - \frac{x_{A,N8}\, real - X_{A,N}\, min}{X_{A,N}\, max - X_{A,N}\, min} = 1 - \frac{17-0}{45-0} = 1 - 0.3778 = 0.6222$$

where $\mathrm{X}_{A,N8}$ is the homogeneous value for observation unit 8, for the Nitrates variable (N) of the Water component (A).

The same procedure is applied on the Dissolved Salts variable

$$\mathrm{X}_{A,S8} = 1 - \frac{x_{A,S8}\, real - X_{A,S}\, min}{X_{A,S}\, max - X_{A,S}\, min} = 1 - \frac{470-0}{500-0} = 1 - 0.94 = 0.06$$

where $\mathrm{X}_{A,S8}$ is the homogeneous value for observation unit 8, for the Dissolved Salts variable (S) of the Water component (A).

Once the homogeneous values for all the variables of the Water Quality indicator of the 500 observation units have been determined, there follows the calculation of the value of the Water Quality indicator for each observation unit.

$$\mathrm{X}_{\mathrm{A},.8} = \frac{\mathrm{X}_{\mathrm{A,N8}} + \mathrm{X}_{\mathrm{A,S8}}}{2} = \frac{0.6222 + 0.06}{2} = \frac{0.6822}{2} = 0.3411$$

where $\mathrm{X}_{\mathrm{A},8}$ is the average value of the homogenized variables of the Water component (A) observed in primary production unit 8; and also for each of the variables of the Water Quality indicator

$$\mathrm{X}_{A,N.} = \frac{X_{A,N1} + X_{A,N2} + \cdots + X_{A,N8} \ldots + X_{A,N500}}{500} = \frac{0 + 0 + \cdots + 0.6222 + \cdots + 0}{500} = \frac{41.3778}{500} = 0.0828$$

$$\mathrm{X}_{A,S.} = \frac{X_{A,S1} + X_{A,S2} + \cdots + X_{A,S8} \ldots + X_{A,S500}}{500} = \frac{0 + 0.172 + \cdots + 0.06 + \cdots + 0}{500} = \frac{45.73}{500} = 0.0915$$

where $\mathrm{X}_{A,N.}$ represents the average value of the homogeneous measures of the Nitrates variable (N) within the Water component (A) –as observed in the 500 primary production units– and $\mathrm{X}_{A,S.}$ is the average value of the homogeneous measures of the Dissolved Salts variable (S) within the Water component (A) –as observed in the 500 primary production units–.

The values of the index of the Water component are calculated based on either: a) the indicators, or b) the observation units:

$$\mathrm{I}_g = \frac{\sum_{l=1}^{L} X_{g,l.}}{L}$$

$$\mathrm{I}_g = \frac{\sum_{m=1}^{n} X_{g,.m}}{n}$$

$$\mathrm{I}_{A,CAL} = \frac{X_{A,N.} + X_{A,S.}}{L} = \frac{X_{A,.1} + X_{A,.2} + \cdots + X_{A,.8} + \cdots + X_{A,.500}}{n} = \frac{0.0828 + 0.0915}{2} = \frac{0 + 0.086 + \cdots + 0.3411 + \cdots + 0.04838}{500} = \frac{0.1742}{2} = \frac{43.5539}{500} = 0.0871$$

where $\mathrm{I}_{A,CAL}$ is the index of the Water component (A) for the Water Quality indicator (CAL).

Table 4.6 shows the values observed in the simulated primary source survey, the homogeneous values calculated based on reference values, the indicator value by surveyed unit, and the index value by variable and by component.

The results obtained by repeating the procedure for the total number of indicators of the Water component within the Ecological-Ecological relationship are included in Table 4.7.

Table 4.7. Value of indicators of the Water component

Indicator	Index
Quality	0.0871
Quantity	0.8126
Source	0.5163

The next step is to average the value of the indicators to obtain a value that is representative of the Water component, as follows:

$$\mathrm{I}_A = \frac{\mathrm{I}_{A,CAL} + \mathrm{I}_{A,CAN} + \mathrm{I}_{A,F}}{L}$$

where I_A is the index of the Water component (A), $\mathrm{I}_{A,CAL}$ is the index of the Water Quality indicator, $\mathrm{I}_{A,CAN}$ is the index of the Water Quantity indicator, $\mathrm{I}_{A,F}$ is the index of the Water Source indicator, and L refers to the number of indicators of the component. For this particular case:

$$\mathrm{I}_A = \frac{0.0871 + 0.8126 + 0.5163}{3} = \frac{1.4160}{3} = 0.4720$$

Following the same procedure, the value of the components Soil, Air, and Biodiversity is calculated. These components, along with the Water component, make up the Ecological-Ecological relationship. Table 4.8 shows the value obtained for these components.

Table 4.8. Value of the components within the Ecological-Ecological relationship

Component	Index
Water	0.4720
Soil	0.2811
Air	0.9619
Biodiversity	0.5617

The Relations Index is the representative value between any two dimensions of sustainability, and is calculated as follows:

$$IR_{ij} = \frac{1}{K}\sum_{g=A}^{K} I_g$$

For the Ecological-Ecological relationship, it is:

$$IR_{11} = \frac{I_A + I_S + I_{AI} + I_B}{4} = \frac{0.4720 + 0.2811 + 0.9619 + 0.5617}{4} = 0.5692$$

where IR_{11} is the Relations Index between the dimensions Ecological and Ecological, I_A is the value of the Water component, I_S is the value of the Soil component, I_{AI} is the value of the Air component, I_B is the value of the Biodiversity component, all of which make up the Ecological-Ecological dimension.

The values obtained by repeating the procedure for the remaining relationships among the different dimensions of sustainability for this particular case are included in Table 4.9, and, after being reorganized, are included in the Sustainability Matrix shown in Table 4.10.

The demand and the well-being of each dimension of sustainability are assessed as follows:

$$D_i = \sum_{j=1}^{4} IR_{ij}$$

$$B_j = \sum_{i=1}^{4} IR_{ij}$$

In this context, the ecosystem services demand is

$$D_1 = IR_{11} + IR_{12} + IR_{13} + IR_{14} = 0.5692 + 0.5560 + 0.6957 + 0.2575 = 2.08$$

And the well-being generated by means of a healthy and productive environment is

$$B_1 = IR_{11} + IR_{21} + IR_{31} + IR_{41} = 0.5692 + 0.8438 + 0.8761 + 0.4916 = 2.78$$

Table 4.9. Interrelated dimensions

Relationships	Index
1.1. Ecological-Ecological	0.5692
1.2. Ecological-Economic	0.5560
1.3. Ecological-Social	0.6957
1.4. Ecological-Institutional	0.2575
2.1 Economic-Ecological	0.8438
2.2 Economic-Economic	0.8984
2.3 Economic-Social	0.3792
2.4 Economic-Institutional	0.9842
3.1 Social-Ecological	0.8761
3.2 Social-Economic	0.4139
3.3 Social-Social	0.8409
3.4 Social-Institutional	0.2998
4.1 Institutional-Ecological	0.4916
4.2 Institutional-Economic	0.0157
4.3 Institutional-Social	0.8705
4.4 Institutional-Institutional	0.2961

Table 4.10. Sustainability Matrix

Relationships		Human Well-being				Aggregate Demands
		Ecological	Economic	Social	Institutional	
Demands posed on the different dimensions	Ecological	0.5692	0.5560	0.6957	0.2575	2.08
	Economic	0.8438	0.8984	0.3792	0.9842	3.11
	Social	0.8761	0.4139	0.8409	0.2998	2.43
	Institutional	0.4916	0.0157	0.8705	0.2961	1.67
Contributions to Human Well-being		2.78	1.88	2.79	1.84	9.29

The production system sustainability (SSP) is obtained by aggregating the demand and the well-being for each dimension

$$SSP = \sum_{i=1}^{4} D_i = \sum_{j=1}^{4} B_j$$

In our example, the aggregate demands and the generated well-being result in the following sustainability level:

$$SSP = 2.08 + 3.11 + 2.43 + 1.67 = 2.78 + 1.88 + 2.79 + 1.84 = 9.29$$

The state of affairs (Sustainability Indicator) of the Production

System is obtained by relativizing the calculated value to 16, which is the maximum attainable sustainability potential provided for by the model for this particular case

$$ISSP = \frac{SSP}{16} = \frac{9.29}{16} = 0.5805$$

Table 4.10 shows the distance separating each dimension from the desirable values and which are the weakest dimension interrelations. The application of this methodology has both short-term and long-term effects. In the short term, it allows to identify weaknesses and strengths in a production system, while in the long term, by means of regular measurements, it enables an intertemporal comparison of the levels attained by the different dimensions and interrelations, and by sustainability as a whole.

Figure 4.2 illustrates the state of affairs of a production system in terms of sustainability. The maximum sustainability potential is attained when the demands posed on each dimension and the well-being generated by each of them lie close to the external line (level 1). Particularly, this diagram allows to observe the greatest deficits, in terms of generated well-being or of demands, influencing the level of sustainability. However, once these deficits have been identified, the actions required to enhance the sustainability level of the production system under study are not as straightforward, owing to the multiple interrelations existing among the different dimensions.

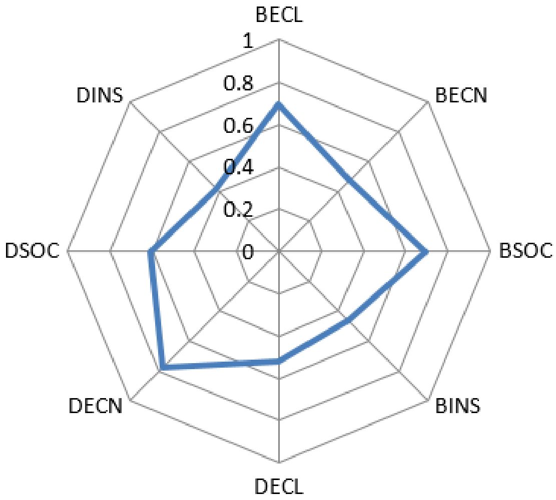


Figure 4.2. Contributions of Aggregate Demand and Human Well-being to sustainability

[DECL: Ecological Demand; DECN: Economic Demand; DSOC: Social Demand; DINS: Institutional Demand; BECL: Ecological Well-being; BECN: Economic Well-being; BSOC: Social Well-being; BINS: Institutional Well-being].

Chapter 5. Restrictions and Recommendations

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This chapter addresses the restrictions encountered during the development of a methodology for the assessment of the sustainability of production systems within the Central-West Region. It also provides a set of recommendations to be considered when applying the proposed methodology.

Restrictions

The methodological proposal of Indicators for the Assessment of Production Systems Sustainability set forth in this work is not exempt from both conceptual and analytical restrictions inherent to the execution of interdisciplinary and transdisciplinary actions. In this regard, each discipline brings in its own analytical perspectives, as well as its priorities, when defining the actions needed to overcome the obstacles to sustainability identified by each of them. This is why such a proposal will call for recurring future discussions oriented to reaching an agreement on what to do, the instruments available or to be created for the analysis, and the actions to be carried out. However, this entails a commitment towards a joint learning effort aimed at attaining a vision and a language that allow the effective integration of the various disciplines, without overshadowing any of them individually. The following section lists some, but not all, of these restraining aspects identified throughout this proposal development process.

Conceptual Restrictions

As anticipated, one of the obstacles encountered during this methodology development process has been the absence of a common language among the different disciplines involved. While this situation hinders consensus building when it comes to defining the components, it also promotes the ability to think from “the other’s” point of view and to make progress towards an interdisciplinary perspective. Without underestimating the progress made, it is important to be warned of the need to continue to develop the theoretical and conceptual content, other than the employed terminology.

The Ecological dimension components include not only those ecosystem resources which are important to humans, but also those upon which the survival of the very ecosystems depends.

The Economic dimension components encompass new approaches to production systems, in such a way that they represent more equitable situations, consider the great variety of ecosystem services users, and, consequently, address their own growth from an integral perspective of development. This conceptualization also involves the development of cooperation and articulation strategies aimed at strengthening each production chain within the region.

The Social dimension components are, first of all, among the most complex ones in terms of their conceptualization, especially when it comes to viewing them through the lens of other disciplines; moreover, such conceptualization ultimately depends on the involved social actors, which exceeds the scientific approach of this proposal.

The Institutional dimension components represent an additional challenge due to the multiplicity of theoretical-conceptual standpoints through which they can be approached. This work intends to identify those associated with the ability of public, private, and civil society organizations to contribute to the provision of goods, services, and infrastructure, as well as legislation and participation. Nevertheless, it is essential to conceptualize and identify those inherent to the capacities of the region as a whole to adapt management to the changing and uncertain future circumstances.

Methodological Restrictions

When it becomes necessary to decide on a methodology for the assessment of development sustainability, one may come across various goals underpinning this process and, hence, defining its basic guidelines. These goals can be summarized (although not in a restricted sense) in three broad groups: 1) those intended to become acquainted with the "state of affairs" of a system in a general way; 2) those oriented to assess the "response" of a system after specific interventions; and 3) those aimed at diagnosing the capacity of a system to tackle any unforeseeable situations that might be encountered in the future. This work refers to the first kind of goals: to become acquainted with the state of affairs of a given production system in a broad sense; that is, considering it as a part of a broader system in which it is embedded.

The multidimensional nature of the proposed assessment allowed to indefinitely multiply the number of variables or the amount of information according to that which was considered relevant by each discipline. In response, the generated components establish relationships among the dimensions of sustainability based on a set of defined criteria with the purpose of narrowing down the number of variables for each production sector to be able to assess sustainability. The main methodological aspect consists in specifying priorities for the addition of variables into the defined components, so that they are, at the same time, representative of what the assessment intends to find out.

In the process leading to the creation of the Sustainability Matrix, the components intrinsic to each dimension interact both with each other and with the other dimensions, thus giving rise to a number of synergies that may occasionally result in conflicts which converge, are subject to change, and deepen the complexity of the whole issue.

Moreover, related literature has enabled the identification of some questions that need to be decided and specified when applying the proposed methodology. Among them are those related to determining what are the most appropriate indicators and variables to address the defined components; what is to be considered a sufficient number of indicators for the intended analysis; how to decide on the relevance of a particular type of weighing in the construction of compound indicators or aggregate indexes to facilitate a comparative analysis; how are the heterogeneities among the different production units reflected; how to assess the performed application; and how to effectively convey the obtained results to the different actors involved.

Finally, it is important to bear in mind the little systematized information available for the implementation of the proposed methodology. The availability of an appropriate data set is the foundation for the construction of indicators that endow the performed assessments with applicability and credibility.

Political Restrictions

The provinces making up the Central-West Region are not integrated in a single formal cooperation framework addressing this or other development-related issues. However, these types of frameworks do exist among some of the Region's provinces, or among a province within the Region and others outside of it. Except for very specific cases, there are not participation instances that allow to take into account the opinions of all the actors affected by a particular issue. There is also little cohesion among the members of the academic community, civil society, the public and private sectors, and professionals devoted to the study of development.

Institutional realms find it difficult to grasp the multidimensionality of sustainability, which prevents a transdisciplinary vision that allows to draft strategies for overcoming specific issues that focus on every dimension of the territory.

There is neither enough awareness on the seriousness of the environmental problems created by humans, nor a strong articulation between formal and informal educational institutions as regards this situation.

Last but not least, the lack of regulations and the absence of a comptroller prevent the enforcement of the specific provisions included in the different provincial constitutions regarding the environmental, social, economic, and institutional functions in each province.

This context makes it necessary to continue reinforcing interdisciplinary nodes or networks to address the issue in question.

Recommendations for Sustainable Development in the Central-West Region

The Central-West Region's socioenvironmental situation, socioeconomic perspectives, and institutional aspects are outlined next in order to make the recommendations resulting from the research carried out.

The Central-West Region features quite varied socioenvironmental situations. This variability is contingent upon, among other things, environmental characteristics, economic development models, populations' sociocultural values, and policies implemented in the different provincial spheres, but essentially upon the interaction among those factors. That is why, on one hand, it is necessary to perform a thorough study of the Region's current state of affairs and future prospects focusing on its ecological, economic, social, and institutional aspects as a whole. On the other hand, it is essential to have an adequate methodological framework for carrying out the study, as well as to define who will be responsible for its implementation, assessment, and conveyance to the different social actors, in order to build a learning mechanism as well as a procedure that allows to materialize the achievement of concrete goals.

The Central-West Region's situation, across all of its dimensions, is shaped by a wide range of external conditioning factors. From a socioeconomic perspective, processes such as globalization and recurring global economic crises, on one hand, negatively influence local production systems and their population's income distribution, mediated by large corporations' strategies and the lack of governmental strategies aimed at changing and articulating them. On the other hand, global environmental change, in its different manifestations, has repercussions on the local arena, thus affecting ecosystems that support human activities and define their well-being. Besides, effective practices to boost these systems' or companies' production levels cause pollution and environmental degradation. Specifically, climate change impacts represent a great challenge for the upholding of the Central-West Region's main production systems and the sustainability of its most vulnerable populations. Among others, they may affect the hydrologic cycle and water quality, and intensify desertification processes and loss of biodiversity and ecosystem services. These conditioning factors threaten the resilience of the whole socioecological system defined as the Central-West Region.

As for the institutional aspect, it is important to underscore the role of the various instances of public policies at their different scales, from global to local, of businesses, and of civil society, educational and scientific organizations in relation to addressing the emerging problems. International agencies are showing growing concern about the negative social and environmental aspects of current development patterns and about what are the most appropriate mechanisms for overcoming them. In our country, this concern has also taken root among the national and the provincial governments, along with the inadequate technical and financial capability to deal with new challenges. Members of the business sphere are casting more and more doubt on the restrictions imposed on business development by both social and environmentalist organizations. In relation to the foregoing, most of the pressure exerted in pursuit of a qualitative change in socioecological systems comes from civil society organizations. Moreover, it is the sectors involved in the generation of knowledge and technology that can provide possible solutions to these conflicts, which have become exacerbated in the last decades. In this context, it is evident that there is concern among the Central-West Region's actors, yet the inadequacy of management –sustainability-wise– results in isolated actions that are not enough to fulfill the proposed goals, something that calls for broader coordination and cooperation efforts among all of the sectors involved.

This work brings to light the relevance of undertaking policy proposals oriented to promote sustainability in line with the considerations described in the preceding chapters. These suggest that sustainability is a multidimensional process guiding the path or direction to be followed.

Bearing in mind that the components of the Sustainability Matrix are dependent on the criteria selected to approach each dimension, defining them will require the consideration of the opinion of every actor within the Central-West Region (institutions, companies, NGOs, etc.). It is a social learning process involving the greatest number of actors possible; that is, defining the criteria to be developed by the components of the matrix entails overcoming the technical proposals.

By virtue of the dynamism and complexity of socioecological systems, the existence of feedbacks and trade-offs within and across spatial and temporal scales, and the fact that there is no such thing as *a priori* optimal indicators, but these need to be developed, assessed, and adapted according to pre-established criteria, there follows a list of recommended actions:

- Be aware of the condition of the region's socioecosystems, namely local production systems.
- Determine the main change driving forces which, in the last few years, have had an impact on the region's ecological, economic, social, and institutional variables, such as processes of distribution of wealth.
- Define a set of relevant variables for the future monitoring of the condition and evolution of socioecosystems.
- Assess the possible impacts of uncertain future events.

For these actions to be materialized, *bridging organizations* should be created with the purpose of promoting cooperation and shared knowledge production among the various groups involved in the management of socioecological systems (Crona and Parker, 2012). These organizations have proved to be, in many cases, able to ensure the continuous monitoring of indicators, promote the coordination of policies and actions among different agencies and actors, build capacities, and facilitate the implementation of specific public policies and private actions.

The goal of bridging organizations is to provide an arena for learning, trust building, and conflict resolution, where "bridges" can be built between science, other forms of knowledge, governments, and nongovernmental actors (Crona and Parker, 2012). They can serve as a gathering point for sectoral interests and demands, thus contributing to the coordination of policies to promote the sustainability of the region's production systems as a whole.

Actions led by these organizations must seek to include the multiplicity of standpoints surrounding the characteristics of current processes and their future outcomes and drive continuous learning processes –with systemic, inter and transdisciplinary approaches– which encourage integrated thinking and collaborative governance. This fosters the contribution, conveyance, and application of new knowledge aimed at solving conflicts affecting the four dimensions of sustainable development at a regional scale.

Conclusions

This work is geographically focused in the territory of the Central-West Region of Argentina and is driven by the need to address conflicting situations resulting from the development of its production activities. Its general goal is to provide an adequate methodological proposal for the assessment of the sustainability of its production systems.

The search of an assessment method based on sustainability indicators for the Central-West Region started with the characterization of the ecological, economic, social, and institutional aspects of the Region. This detailed account allowed to access indicators and variables that describe different aspects of the Region's reality in an isolated way, but fail to represent the complexity of the relationships intertwining among them, which is inherent to the concept of sustainability.

The complexity of this reality poses great challenges when it comes to developing a methodology capable of integrating all four dimensions of sustainability. This understanding and the acknowledgment that partial indicators do not lead to the resolution of the problems observed in the Region –through exploratory statistical methods– enabled the identification, first of all, of the prevalent production systems and the delimitation of the geographic area where they are embedded. Next, there followed the development of a methodology for the definition and subsequent management of indicators associated with the different dimensions of sustainability.

Sustainability-related issues are usually analyzed based on significant, yet partial or isolated, scientific aspects, which keeps researchers from obtaining significant results towards the generation of (systemic) sustainability on our production systems. In an academic context, disciplinary perspectives are prioritized over complex articulations, as disciplines have been developed based on the division of epistemological labor. It can be observed that the usual procedure consists in obtaining simple indicators –pertaining to a single dimension, either ecological, social, economic, or institutional–, which, despite representing some progress, are insufficient to interactively address the inner fabric of the inherent complexity of production systems.

The absence of integrated indicators towards the stated goal, adapted to a regional scale such as the Central-West Region, led to the examination of different alternatives –for a new methodological view– based on the use of complex indicators that consider the four dimensions of sustainability. The approach is built around a systemic and holistic view based on the multidisciplinary nature of the participant groups, but in a great effort to bring about transdisciplinary progress for addressing such a complex issue as the assessment of sustainability.

This integral view along with the complex (and many times dichotomous) dimensions of sustainable development give rise to the central ideas for the creation of a sustainability index to assess production systems within the Central-West Region. To develop this compound indicator, a production system was first represented within a matrix integrating the ecological, economic, social, and institutional dimensions of sustainability. This heuristic tool considers the interactions among the components of each dimension, and among each dimension and the others. The resulting model leaves behind the narrow and restricted nature of an economic, business-centered proposal, or of an exclusively environmental one, which, more often than not, have guided important public policy decisions to mobilize or develop a given territory.

Each strategy or proposal for public policy and private action –identified with the help of the results rendered by the Sustainability Matrix– will be contingent upon the criterion or method used to work on each dimension and its components. Nevertheless, ecological, economic, social, and institutional conditions will directly influence the interrelations among the dimensions within the matrix, which should pave the way for the alignment of management towards sustainable development. Hence, the proposed sustainability index and the guidance provided for its development can be adapted for the assessment of any production system, allowing to acknowledge the various distinctive features without losing sight of sustainability in terms of the group of activities within the region.

This type of assessment needs to be performed through time on a systematic basis in order to pinpoint the dynamics and the patterns of change in the considered systems. The complexity of the dimensions and, even more, of their interactions calls for the adoption of a continuous interdisciplinary learning process. These are inescapable considerations since the results of the proposed assessment method can be used by decision-makers as a regulatory and management tool.

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e-book

Methodology for the Generation of Sustainability Indicators for Production Systems

Central-West Region of Argentina

Roberto Ángel Seiler
Ana María Vianco
Responsible Editors

This publication is the result of a joint initiative among researchers from seven National Universities geographically associated with the provinces of Córdoba, Mendoza, San Juan, San Luis and La Rioja, all of which make up the Central-West Region of Argentina.

It arises in the context of a Targeted Scientific and Technological Research Project managed by the Agencia Nacional de Promoción Científica y Tecnológica (National Agency for Scientific and Technological Promotion) with the general objective of "establishing operational frameworks that allow a tangible assessment of the sustainability of different production systems within the Central-West Region, articulating ecological, social, and economic processes in an integrated and interdisciplinary way, with the purpose of generating specific recommendations for the management of public policies in the Region".

Sustainability is a concept widely used in the public sphere; it is almost overused and, in many cases, quite inaccurately. It is mostly associated with ecology or the environment, and, many times, under an extreme conservationist idea, without any regard for the uses in such an environment. Considering this understanding, the originality of the proposed work lies in an attempt at an integrated analysis of sustainability, based on the simultaneous interaction of its four constituent dimensions -ecological, economic, social, and institutional- and with the human being as the holder of sustainable well-being. The analysis aims at the assessment of the sustainability of primary production systems; however, its conceptual flexibility allows for its application on any production system.

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