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Poverty Assessment in Degraded Rural Drylands in the Monte Desert, Argentina. An Evaluation Using GIS and Multi-criteria Decision Analysis

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Abstract The work aims to contribute to the construction a local-scale poverty indicator, which contemplates multiple dimensions and allows for spatialization of socioeconomic data for a rural area in the Monte Desert. Given the evident and widely studied relationship between desertification processes and poverty, and aiming to contribute to integrating socioeconomic information to desertification assessment and monitoring, there arises the need for spatializing poverty by addressing its multiple dimensions, aspects poorly developed thus far. For this purpose, a data model was designed, which enabled integrating quantitative and qualitative information within the scope of geographic information systems (GIS) with multi-criteria decision analysis (MCDA), whereby it was possible to spatialize in detail the degree of poverty in the study area, laying the foundations for up-scaling the assessment to different scales. This work demonstrates the usefulness of GIS and MCDA as an instrument that enables progressing in new integral, interdisciplinary, multi-scale and multi-temporal approaches.

Keywords Socioeconomic indicators · Multidimensionality · Integrated assessment · Desertification · Mapping

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1 Introduction

The close relationship among areas undergoing desertification processes and poverty, primarily affecting rural populations, is evident and has been widely studied. In the framework of combating desertification and mitigating its effects, it is very important to integrate socioeconomic information to the assessment and monitoring of desertification (Abraham et al. 2006). The United Nations Convention to Combat Desertification and Drought, especially in Africa (UNCCD 2007) states that there is a growing need for appropriate and reliable information to support the action of desertification-affected countries. In this respect, there are various shortcomings related to availability, reliability and comparability of the information, because each country characterizes poverty with its own methods, which hinders spatializing information and integrating it with biophysical data.

According to the definition adopted by the UNCCD (1994, art. 1 [a]), desertification is “land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities”. Currently, this process is affecting over 250 million people in over 150 countries across the world. In Argentina, 75% of the country’s surface area corresponds to drylands (arid, semiarid and dry sub-humid regions) which are vulnerable to being affected by desertification processes. Reversing this process is central, not only because of its environmental connotations but also because desertification is a social phenomenon that accentuates conditions of poverty and marginality in drylands (Abraham 2003). The social impacts of desertification are notably related to increased poverty and political instability. For this reason, the need stands out to provide viable alternatives to dryland inhabitants for them to maintain their means of subsistence without causing desertification (EEM 2005).

This situation is particularly visible in the drylands of Latin America, whose rural areas are mostly home to small peasant or family farms and are characterized by low availability of water resources and low land productivity. These conditions of poverty generate permanent or temporary migration towards agricultural areas and cities. Thus, it becomes evident how, in the region, from the social viewpoint, desertification favors poverty, breaking social and family structures and bringing about economic instability. These restrictions result in large-scale migration processes which are typical of degraded drylands and which are part of a cycle of depletion of natural resources (Morales 2005).

Starting from the multidimensional nature of the concept of poverty—which is generally established in relation to availability of data for its measurement- at present strong debates persist over its definition and measurability. From the perspective of human development, poverty is not only understood in terms of income but mostly in terms of lack of opportunities for persons and groups to fully develop those capabilities that allow them to achieve their life projects (Hopenhayn 2003).

The Economic Commission for Latin America and the Caribbean (ECLAC) has defined poverty as a situational syndrome that associates under-consumption, malnutrition, precarious housing, low education levels, poor sanitary conditions, an unstable insertion into the production structure and little participation in mechanisms of social integration (Altimir 1979). In this sense, Hopenhayn (2003) indicates that poverty derives from restricted access to property, low income and consumption, limited social, political and labor opportunities, poor educational achievements, limited access to health and nutrition services, restricted access to the use and control of natural resources and to other development areas. The present study adheres to the concept of poverty proposed by ECLAC.

An important question is how multidimensionality should be reflected in measures of poverty (Alkire and Foster 2011a; Alkire and Santos 2013). Once the definition of poverty to be adopted is agreed upon by consensus, it is necessary to select a proper method to measure it (Alkire et al. 2014). The multidimensional measurement methodologies have advanced considerably in the past years. Altogether, these advances have created new possibilities to measure multidimensional poverty at different spatial scales (Alkire 2011). Measuring poverty requires quantifiable indicators which relate to the definition selected; besides, the indicator or indicators used should contemplate identifying those people that consider themselves poor and aggregating the welfare of those individuals in poverty measurements (Feres and Mancero 1999).

In Argentina, poverty can be measured through two approaches; a direct approach and an indirect one. The former is addressed by the method of Unmet Basic Needs (UBN), and the human development index, its derivative, the human poverty index, and the household material deprivation index, the data for which are obtained from the National Population and Housing Censuses of Argentina, conducted every 10 years. The indirect approach is associated to the method of the poverty line, whose construction derives from the Permanent Household Survey, which is carried out in urban areas only.

The UNB method is the most widely used in Latin America to characterize poverty, and to draw comparisons between time periods and between countries. It was proposed by ECLAC in the 1970s and attempts to identify households and people that fall short of meeting a set of needs deemed indispensable according to welfare levels accepted as universal, basically using census information. In this regard, it is important to highlight that this methodology is based on the current notion of human dignity and on the universality of basic human rights, irrespective of the context of situation of the population. The method is based on defining the needs included in the measurement, and on establishing satisfaction thresholds. From the definition of a minimum set of satisfiers related to education, employment and housing, the amount of population that has no full access to them is measured. For a household to be considered to have UBN, it must present at least one of the needs defined as basic. In Argentina, the National Institute for Statistics and Census establishes that homes with UBN are those being under at least one of the following deprivation conditions: overcrowding, housing, sanitary conditions, school attendance and subsistence capacity (INDEC 2000).

The main drawback of this method in addressing poverty at local scale, and particularly in rural areas, is the level of resolution: the data are fed into provincial, departmental and district administrative units and ratio-fraction (census minimum units); besides, census data take years to be published. This method is unable to recognize the population affected by the pauperization processes occurred over the last decades; the indicators used are best adapted to urban areas; the method incorporates indicators that only capture extreme situations and do not allow distinguishing different degrees of satisfaction, a situation that becomes evident mostly in rural areas, where fulfillment of needs has different particularities than in urban areas (INDEC 2010).

The case study chosen for building a poverty indicator is a territory representative of vast areas of Latin America: the non-irrigated lands of the Lavalle department in the heart of the Monte desert. At this site, affected by accelerated desertification processes, impoverishment accentuates social and political marginality of the local population, primarily due to lack of policies for local-scale development of the region and to remoteness from decision-making centers. Lavalle is a clear example of poverty as an outcome of desertification and in turn shows how poverty is a factor that feeds back the system, stressing the demand for and pressure on natural resources such as pastures, firewood, water for human and animal use, among others.

The spatial distribution of socioeconomic inequalities is conditioned by natural, demographic, cultural, economic and social factors which make up a network of close links, so their spatializing is fundamental for addressing environmental relationships in an integrated manner (Buzai 2015). The multiple dimensions of social data, together with the complexity of their spatialization, hinder their incorporation into the proposals for an integrated assessment of land degradation. This article aims to contribute to overcoming these shortcomings, laying emphasis on building a model of data that allows integrating qualitative and quantitative information to the field of geographic information systems, with multi-criteria decision analysis, and thus achieve detailed spatializing of the degree of poverty in the study area. In addition, it allows addressing the issue from the temporal scale, since baselines can be built from which to monitor changes and set up assessment and monitoring systems. This will help finish building a method for an integrated land desertification/degradation assessment and provide scientific knowledge to decision-makers.

In this sense it is worth clarifying that this contribution is a specific input to the treatment of spatial data related to poverty at the local level, and supplements the general procedure of integrated assessment of land degradation/desertification (Abraham et al. 2006) with a participatory strategy. This work especially considered the relationship between the different levels of factors, causes and consequences, from local to global.

In this context, the contribution from the geographic science and specifically from GIS to the study of poverty has been very significant. Various studies support the importance of incorporating the geographic dimension and of spatializing the phenomenon, plotted on a specific cartography (Deichmann 1999; Davis 2003). In this regard, worthy of mention are the great efforts made by different developing countries toward achieving a mapping of poverty, studies in which GIS have played a central role. It is pertinent to mention the studies conducted to estimate poverty in Vietnam (Minot and Baulch 2002; Minot et al. 2003), in India (Bigman and Srinivasan 2002); among others. However, these efforts are still incipient in South America (Hentschel et al. 2000; Farrow et al. 2005; Battiston et al. 2009).

Manalo Vista and Muruyama (2010) highlight the different approaches traditionally used to address the study of poverty. Some of them through an econometric methodology commonly called “small area estimation technique”, which is based on census data and surveys of a population sample. The objective of this kind of studies is estimating poverty levels for an as low as possible geographic disaggregation—such as for example a town or a city-, to then spatialize it on different thematic maps with use of GIS (Lanjouw 2004; Ivaschenko 2004). As specified by Bigman and Fofack (2000), this method has been widely spread and applied in different developing countries. Other studies adopt a methodology based on a set of indicators aimed to quantify basic needs, for which a series of non-monetary social variables are considered, in order to assess the welfare of households. In addition to social indicators, also demographic statistics, such as gender, age structure and household size, are included in the mapping of poverty (Henninger and Snel 2002). Finally, the approach based on the search for structural causes includes indicators linked to transport, infrastructure, and access to land and to resources in general, among them natural hazards.

2 Materials and Methods

2.1 Location and Characteristics of the Study Area

The Monte Desert is a South American subtropical to warm temperate desert and semi-desert located in western Argentina. The climate is semiarid to arid, with high evaporation.

Rainfall is scarce, with an annual mean ranging between less than 100 and 450 mm, much conditioned by relief, whereas mean annual temperature varies between less than 10 and 18 °C. These climatic features impact on production activities, where agriculture is confined to irrigated valleys, with intensive cultivation of fruits and vegetables (Abraham et al. 2009).

In the central part of the Monte, which corresponds to Argentina's central west, is the province of Mendoza. It is a territory with low rainfall—230 mm/year—(Abraham 2000), where rivers are the basic element for organizing the provincial space and allow irrigation for agricultural activities. Mendoza drylands currently represent fragile ecosystems, where desertification progresses swiftly, with its status ranging from moderate to very severe, and showing a growing trend (Roig et al. 1992). The three primary causes of desertification in Mendoza are overgrazing, deforestation and non-sustainable agricultural practices (Abraham 2002).

The population is concentrated in a highly fragile territory where competition for water use arises as one of the main environmental conflicts in the interaction between oasis and non-irrigated lands: depressed desert areas receive less and less surface water input, since river volumes are entirely used for irrigating the cultivated area and for consumption in urban settlements. The artificial oases represent 4.5% of the province's surface area and hold 98.5% of the population; they develop as “islands” in the vast non-irrigated drylands, which in turn represent 96.5% of the territory and where 1.5% of the population is basically devoted to subsistence livestock farming (Abraham et al. 2015).

This strong territory imbalance has its origin in the adoption, as of the eighteenth century, of an agroindustrial model inserted within a market economy. In this context, non-irrigated drylands have historically behaved as providers of resources and labor to meet the needs of the oases (Prieto and Abraham 1994). This situation is consolidated by application of the provincial law of water—General Law of Water (1884)—directed to satisfying the demands of the winemaking sector, disregarding the demands of stakeholders in non-irrigated drylands (Abraham and Salomón 2010). Outstanding among these drylands is the department of Lavalle in northeast Mendoza, whose territorial configuration replicates the oasis-non-irrigated land duality, resulting from the province's production model. This department covers 10,242 km², 92.28% of which correspond to non-irrigated drylands versus 7.2% of irrigated lands.

At present, this territory has low rural population density, estimated at approximately 4500 inhabitants distributed in 510 domestic units or scattered livestock stations. The settlement pattern is conditioned by presence of water: all settlements lie near the Mendoza and Desaguadero rivers—with temporary runoff-, mostly on their paleo-channels, with a close relationship to availability and quality of the groundwater aquifer (Abraham 1989), which is the main source of water for both human and animal consumption. It is worth mentioning that, in relation to water quality, most of the water available has high salinity levels and natural arsenic contamination (Pastor et al. 2005).

Economic activities are subsistence farming based on extensive cattle and goat rearing for meat and manure and, to a lesser extent, for apiculture and handicrafts. Woodland resources are also used for timber and firewood (Torres 2008).

Marginality and poverty conditions are accentuated by lack of access to infrastructure and to basic services such as drinking water, electric power, gas and roads.

Settlers are organized in Communities recognized by the National Institute for Indigenous Affairs as Huarpe Milcayac peoples from Mendoza. Land tenure and resource management are communal, with common problems of land ownership and low value of primary production.

The lack of sustainable land management practices and of development and land management policies have deepened conditions of desertification and poverty in the area.

2.2 Addressing Poverty by Applying Geographic Information Systems and Multi-criteria Decision Analyses

Decision makers frequently address territorial issues without basing themselves on reliable information or scientific criteria. This is due not only to lack of available scientific information, but also to the scarce mechanisms for information transfer and to the compartmentalized view which is usual when analyzing complex problems. This becomes evident, for example, in desertification studies, where analyzing the links among the different components of the complex system in an integrated fashion is fundamental (Entraigas et al. 2004). In this context, geographic information systems (GIS), constitute a powerful tool in environmental planning and land management, for the instruments they provide allow for land problems to be more easily solved (Bosque Sendra and García 2000).

Aiming to find solutions to complex spatial problems, GIS are linked to multi-criteria decision analysis (MCDA), directed to assist in decision-making processes (Colson and De Bruyn 1989). Their complementary use is a powerful, useful and valid tool (Bosque Sendra and García 2000), noted for its ability to describe, standardize, rank, select and assign weights based on an assessment that contemplates qualitative and quantitative data. Their operation relies on assessing alternatives following a series of criteria (Barredo Cano 1996). The joint use of GIS and MCDA is one of the ideal procedures for development of land management tasks, as they make it possible to implement simultaneous procedures of analysis, from a consideration of the two components of geographic data: spatial and thematic, cooperating in establishing solutions to complex spatial problems (Gómez Delgado and Barredo Cano 2005). In this sense, it is important to highlight that MCDA techniques provide a valid approach to the analysis of spatial processes that demand a specific assessment of value judgments through pondering of factors and evaluation of alternatives. They permit inventorying, classification, analysis and a convenient ordering of a series of alternatives based on those criteria that were deemed pertinent for the assessment (Barredo Cano 1996). Because of their high potential, over the last two decades their application has increased and results obtained have reinforced and validated their effectiveness, and these techniques have also made contributions to decision making (Voogd 1983; Barredo Cano 1996; Malczewski 1999; Bosque Sendra and García 2000; Dai et al. 2001).

In this study the challenge of representing the spatial dimension of the poverty phenomenon by applying GIS and MCDA techniques is addressed. In order to integrally study this problem and be able to get information that allows making decisions tending to reduce this scourge, it is necessary, in the first place, to have a mapping of poverty and a data model that includes its indicators and its spatial dimension. For this, it is indispensable to achieve standardization of the different kinds of data, which will allow incorporating spatial data into the assessment of poverty. This necessity to integrate geographic location to data models is not only limited to the poverty issue, it should also be included in the treatment of all multidimensional social problems (Akinyemi 2010).

The spatial dimension of socioeconomic problems does not come down only to geographic location, but also includes variables related to the physical or natural environment that play a major role in the condition of poverty (Manalo Vista and Muruyama 2010). Despite being a key aspect for understanding the poverty phenomenon and its spatial

extent, the geographic dimension has not been especially considered by most of the studies addressing the issue. In this respect, it is pertinent to mention the efforts to overcome these limitations, arisen since the approval of the Millennium Development Goals. According to the statement by Hyman et al. (2005) “The importance of poverty reduction to the world’s development agenda has motivated a greater interest in the geographic dimensions of poverty”; which is reflected in the worldwide promotion and development of different initiatives focused on poverty mapping as a key instrument for defining strategies that contribute to overcoming the problem.

These background data are included in the present article, allowing consolidation of a robust indicator of poverty, locally applicable and susceptible of being incorporated into a more general methodology for an integrated desertification assessment. Besides, the constructed indicator allows for the possibility of aggregation to meet the challenge of achieving a scaling-up from conclusions and studies carried out at local scale, and characterize the same processes at regional and national scale. This change in scale, based on scientific results, facilitates decision making at different levels of spatial and temporal resolution.

2.3 Analytic Hierarchy Methods

Among the techniques for MCDA, the “analytic hierarchy process” (AHP; Saaty 1980) was selected as the one allowing for the design of a poverty model for the study area, setting up valid and replicable assessment variables, and spatializing the socioeconomic conditions of the population. The AHP is a procedure associated with decision making, which works with judgments and assessments, it is based on ratio scales and allows combining the scientific and rational with the intangible to help synthesize human nature with the concrete and the objective contributed by science. It uses principles of hierarchical order to capture and generalize reality. And this process can be understood as a technique that enables resolution of multi-criteria, multi-environment and multi-factor problems, incorporating tangible and intangible aspects into the model, as well as the subjectivism and uncertainty inherent to the decision-making process (Moreno-Jiménez 2002).

The AHP starts from setting a pairwise matrix (Saaty 1980) in which the number of rows and columns is defined by the number of factors or variables to be pondered. Thus, a comparison matrix is established between pairs of factors, confronting the importance of each one in relation to that of each of the others (a_{ij}). Then, the main vector is determined, which defines the weight (w_j) of each factor, and the standardized main vector provides a quantitative measure of the consistency of value judgments between pairs of factors. The measurement scale established for assigning value judgments (a_{ij}) is a continuous type scale (ratio) that ranges from a minimum value of 1/9 to a value of 9 (Barredo Cano 1996) (Table 1).

Once the comparison of matrix factors is made and value judgments are assigned, weight (w_j) for each factor is estimated, which accurately describes the characteristics of the value judgments considered. The procedure used to obtain the main vector consists in completing the comparison matrix with value judgments, and each column is summed. An auxiliary matrix is thus generated where each cell is completed with the result from dividing each value judgment by the sum of the corresponding column. Finally, the standard values of rows are averaged. This average corresponds to the main vector (Table 2).

Finally, the consistency ratio of the reciprocal matrix or main maximum vector ($r.i.$) is calculated. The value of this consistency ratio is defined by the consistency index/random

Table 1 Scale for assigning judgments

	Value	Assessment
	1/9	Extremely less important
	1/7	Less important
	1/5	Of little importance
	1/3	Moderately less important
	1	Equally important
	3	Moderately important
	5	Important
	7	Very important
	9	Extremely more important

The lowest value is extremely less important (1/9) up to extremely more important (9), indicating value 1 as equal in importance between pairs of factors (Barredo Cano 1996)

Table 2 Main vector calculation matrix

Factors	A	B	C	D	Standardized main vector (w_j)
A	1				$\Sigma A_{ij}/n$
B		1			$\Sigma B_{ij}/n$
C		a_{cb}	1		$\Sigma C_{ij}/n$
D				1	$\Sigma D_{ij}/n$

Where: $A_{ij} = \Sigma a_{cb}/\Sigma B$; finally: $(w_j) = \Sigma A_{ij}/n$ (Barredo Cano 1996)

index ratio. The composition of the matrix in question is compared with a hypothetical and random one. A **c.r.** higher than or equal to 0.10 indicates that value judgments have to be revised, for they are not consistent enough and may be affected by some degree of subjectivity. A **c.r.** lower than or equal to 0.10 indicates that the assigned value judgments can be considered satisfactory, and therefore the weights (**wij**) can be used in the final classification (Barredo Cano 1996).

3 Spatial Dimension of Poverty: Building the Composite Poverty Index

In analyzing the key processes operating in the current situation of poverty and marginality in the territory of Lavalley, the first obstacle to be overcome is the lack of socioeconomic data at local scale. Although there are population censuses, the minimum data publication unit is the census ratio-fraction, which does not match the administrative data and generalizes information in such a way that it masks the territory's particularities. Owing to this, the first research decision was to dismiss published census data and rely on the sole base of reliable data obtained from a thorough and georeferenced survey of livestock stations. In this way, the livestock station was used as the minimum unit of analysis.

The main source of information used was the thematic and spatialized database of livestock stations in the non-irrigated area of the department of Lavalley, developed by the Setting Roots Program of the Government of Mendoza and the Municipality of Lavalley. This database was subsequently enlarged and made consistent by the team at the Argentine Institute for Arid Land Research (IADIZA) of the National Council for Scientific and Technical Research (CONICET) for the LADA-FAO project (2007–2011). There were 477 livestock stations registered in the database, 285 of which had full information about the

number of livestock head and amount of population, a sample that represents 59.74% of the total universe. Other information layers were used as well: electric power network and “Aqueduct of the Desert”, both built based on field surveys conducted by IADIZA between 2007 and 2011. Moreover, the road network provided by the Territorial Environmental Information System (SIAT, Mendoza Government) was also incorporated. This network was adjusted by taking control points with GPS in the field and, based on a LandSat TM 5 satellite image of 2011, corrections were made and unsurveyed roads and tracks were digitized.

According to Ghamgosar et al. (2011) and Lee and Chan (2008), for building the composite poverty index, methodological steps were performed: initially the data model was designed in GIS (3.1) and the dimensions and criteria that allow addressing poverty in the study case were defined (3.2); later the relative importance of criteria was estimated (3.3); according to the benchmarks and scores defined, and all criteria were re-categorized and homogenized (3.4); finally, the dimensions were integrated and the results were mapped.

3.1 Definition of the Data Model in GIS

As a first step for setting the AHP into motion, the data model was defined in GIS, starting from identification of the decision criteria associated to the spatial dimension of poverty in the study area: five spatialized indicators were selected (number of goats per inhabitant, collection and marketing of jonquil, access to the road network, access to electric power and access to drinking water). These were structured in three dimensions: economic, of access to basic services and infrastructure, and of access to drinking water (Fig. 1).

3.2 Definition and Description of Dimensions and Criteria

3.2.1 Economic Dimension

Traditionally, the economic activities in the non-irrigated area of the department of Lavalle have been associated to extensive goat production as predominant activity, and secondly to the collection and marketing of jonquil (*Sporobolus rigens*). Notwithstanding, at present, progress has been made in identifying new forms of production that combine extraction and use of natural resources with other forms of income. As a strategy for surviving and staying in the area, goat producers have developed a pluri-active profile in their undertakings. The predominant activities are goat rearing, along with the supplementary activity of collecting and marketing manure; collection and marketing of jonquil; production of handicrafts; access to poverty amelioration programs; development of off-farm activities (mostly in the temporary vine harvest in irrigated areas) and, to a lesser extent, activities related to tourism and beekeeping for honey, among others (Torres 2008).

From identification of the pluri-active nature of livestock stations, and in relation to the goal of characterizing the economic component in the study area, two indicators that predominate in the area's economic processes were selected: number of goats per inhabitant and collection and marketing of jonquil per domestic unit.

3.2.1.1 Number of Goats per Inhabitant Extensive goat production is oriented toward self-consumption and, to a lesser extent, to selling of animals. Goats constitute the main capital for settlers, since they represent a source of cash income through their sale to

Fig. 1 Poverty model: dimensions and criteria of the Composite Poverty Index

private individuals or intermediaries, they provide irrigated areas with manure during autumn and winter months, they can be used for bartering for other necessary items and are fundamentally a basic source of food for the local people (Torres 2010).

From a social organization based on originating Huarpe communities, collective land ownership determines that extensive livestock production is carried out with no boundaries or fences, which results in a communal mode of harnessing resources. This practice is the fruit of a knowledge system that has been transmitted for generations and that has allowed the people to subsist, with limited possibilities of developing productive practices. Given this, it is considered that the greater the number of goats, the better the economic conditions of the population, since they constitute a sure source of income and food. Complementarily, it is important to state the number of inhabitants per livestock station relative to the size of the flock.

The analyzed livestock stations have from 1 to 13 inhabitants, with an average of 4.6 inhabitants per livestock station in the sample. On the other hand, with respect to the number of goats, there are livestock stations that have no animals, and one of them rears the maximum number, 800 head, with the average being 109 head of goats per livestock station. In this respect, in pondering, the highest score was assigned to livestock stations with a greater number of goats per inhabitant (Fig. 2; Table 5).

3.2.1.2 Collection and Marketing of Jonquil (*Sporobolus rigens*) *Sporobolus rigens* is a grass with very long rhizomes, which grows on sandy soils and has low forage value (Ruiz Leal 1972). This species grows in areas nearby the San Juan and Mendoza rivers. Its collection and sale is a source of cash income that supplements goat farming activities.

Fig. 2 Indicators of the economic dimension

While marketed through intermediaries, its sale makes it possible for producers to receive a flow of cash, as in general only social plans allow them to handle cash, Jonquil collection is one of the major extraction activities in the northern part of the study area, and is performed by families in an artisan-like manner. This species is harvested in sandy soils with a sickle and has the advantage of being harvested twice a year, causing no erosive impact because, not being rooted out, it maintains the stability of sand dunes. It is also used for brooms, baskets and handicrafts.

Considering the positive aspects of this activity, scoring for livestock stations was based on whether the activity was performed or not (Table 5). It is important to highlight that, while development of this activity is in the first place determined by availability of the resource, assessment revealed those livestock stations that, having availability of jonquil and therefore a flow of cash, stood out over the others (Fig. 2).

3.2.2 Dimension of Access to Basic Services and Infrastructure

3.2.2.1 Access to Electric Power Network There is a clear nexus between poverty, power and environment; however, the power factor is usually analyzed as an isolated element, whereby policies for development and poverty reduction do not generally include this aspect. According to ECLAC (2009), there are numerous studies in Latin America associating lack of access to power with the lowest Human Development Indices.

Lack of power limits opportunities for people and, therefore, their quality of life in relation to their economic productivity, education, food, health, and gender equality. Moreover, lack of access to electric services in rural areas brings direct impacts on the environment because of the constant need for forest resources to fulfill energy needs for heating and cooking, among others. At international scale, there are precedents where access to electric services is considered a parameter for characterizing poverty or living standards of the population, among them the Millennium Development Goals Reports devised by Panama, El Salvador, Honduras and Cuba (ECLAC 2009).

In order to characterize poverty in the non-irrigated area of the department of Laval, where most of the population has no access to electric power, it is proposed to analyze, together with other aspects, access to this service by local people. Livestock stations in the area are supplied through the laying of three-phase power cables, single-filament power or solar panels.

Three-power cables are laid mostly in the oasis area, with Asunción and El Cavadito being the only villages with access to them in the non-irrigated area. Connection to these cables is differential, given their short length in the area analyzed and their high cost to locals. The volume of electric power allows operation of household appliances, such as a microwave, refrigerator, television, even air conditioning equipments, in addition to the use of electric water pumps, which are much used for exploiting the groundwater aquifer.

The single-filament network extends from south to north up to the village of Lagunas del Rosario, and in the east sector, from El Puerto, running parallel to road no. 51, up to the village of Arroyito. Villages and groups of livestock stations which are close to this network can have access to it, which enables them to use household appliances, refrigerators and electric water pumps to collect water from wells.

The most scattered livestock stations in the territory, however, lack an extension of power lines, so most of them get energy through solar panels. These panels provide them with energy for some hours a day, which allows them to use appliances, but which is not enough to power a refrigerator. This mainly hampers storage and preservation of meat, dairy and fresh products which can be purchased in the villages or from a Street vendor who goes from livestock station to livestock station.

In order to identify those livestock stations with access to the power network, a 500 m buffer was calculated for the single-filament network, and a 1000 m buffer for the three-phase power network. Subsequently, scores were assigned, with the highest value corresponding to the three-phase power network, because it has a higher possibility of being used by the population, and the lowest value corresponding to solar panels (Table 5; Fig. 3).

Fig. 3 Indicators of the dimension of access to services and infrastructure

3.2.2.2 Access to Road Network Accessibility is a factor that has been little analyzed when studying poverty conditions, however, it is considered to play an important role in relation to access to markets, health services, education, urban centers, among others. Lack of accessibility, due to either lack of roads or bad road conditions, is an important limitation to the possibilities of diversifying local production and to people's living standards.

A clear example is the study conducted in Uganda, where the poverty-lack of accessibility relationship was analyzed in 5500 families (Pozzi et al. 2009). Among the main

conclusions, it is to be highlighted that welfare, measured by wealth indices, diminishes drastically as access to population centers grows worse.

In light of these relations, it is pertinent to analyze access to the road network by the people in the study area, taking the hierarchy of roads into consideration. Roads crossing the department of Lavalle are national routes (no. 40 and 142) and provincial routes (no. 34), all of them are paved and connect the territory with other provinces. Consolidated (dirt) roads connect localities within Lavalle and link the department to other departments in the province. Because of the characteristics of these roads, vehicle traffic has limitations. Tracks connecting livestock stations and villages are the most widely used means of communication. Due to the predominant soil texture, sandy-loam and clay, tracks become difficult to access, especially when it rains and they often become almost impassable. In the summer months, tracks are usually waterlogged, and sometimes they cause people to be isolated for weeks.

Information about the road network was spatialized areally by mapping buffers according to their hierarchy: dirt roads 800 m, consolidated roads 1500 m and paved roads 3000 m. Buffer distances were defined considering the actual distribution of the population in relation to access roads, analyzing the daily movements of the population, the willingness of livestock units, landforms, public transportation to urban areas and health centers and the possibility of local people moving on foot. Subsequently, this information was related to livestock stations and scoring was established according to the type of access they have. Livestock stations with access to paved roads show the best accessibility conditions, followed by those with access to consolidated roads, with access to tracks, and in the last place, with the lowest score, are those livestock stations without access to any means of communication (Table 5; Fig. 3).

3.2.3 Dimension of Access to Drinking Water

Drinking water is considered to be the basic service, a resource of vital importance that ought to be accessed by the entire population. The magnitude of its importance is reflected in the declaration on the human right to water and sanitation made in 2010 by the United Nations General Assembly (UN—Resolution 64/292 2010). This declaration reaffirms that both drinking water and sanitation are essential to the realization of all human rights. However, already in 2002, the Committee for Economic, Social and Cultural Rights recognizes the right to water, specifically stating that “The human right to water is indispensable for a dignified life” (UN—Observation No. 15 2002). This right is conceived as the right everyone has to sufficient, healthy, acceptable water, physically accessible and affordable for personal and domestic uses.

The study area has historically lacked a drinking water service. The so called “Aque-duct of the Desert”, meant to provide water to the villages in the Lavalle desert, started being built in 2010. Extending for 270 km, it is one of the largest aqueducts in Argentina. Building works are still underway, and installation of pumping stations is planned.

Works are not over yet, neither are the connections of livestock stations to the network, since farmers have to afford the costs. Once the network is finished, its approximate area of influence will extend for about 1000 m on either side of the aqueduct. Thus, around 200 livestock stations would be able to have access to drinking water. The distance from livestock stations to the network may vary from meters to kilometers, so purchasing the material for the connection becomes difficult for the farmers to afford.

Considering the vital importance of having access to drinking water, and its relevance in the various processes of desertification and poverty, in the multi-criteria method designed,

livestock stations were scored according to their present connection to the aqueduct -or the possibility of a future connection depending on their spatial location-. It is important to highlight that farmers likely to connect to the aqueduct in the future have been considered in the same category, bearing in mind that the process of connecting to the aqueduct is gradual and continuous—depending on the farmers' availability of financial resources and is expected to end in the short term (Table 5; Fig. 3).

3.3 Estimating the Relative Importance of Criteria

Once the criteria were defined, based on the knowledge the authors of this work have gained about the social and environmental dynamics of the study area, the main vector was estimated for each criterion, that is to say, the relative importance of items was estimated using the paired comparisons method with a pairwise matrix (Table 3; Fig. 4).

As can be seen, access to the drinking water dimension shows the highest relative weight compared to the other dimensions within the framework of poverty assessment in the study area.

3.4 Re-Categorization and Homogenization of Criteria

In order to homogenize information, all factors were structured in a hierarchic manner and, by scoring the classes of each indicator, the classes of spatialized variables were re-

Table 3 Pairwise matrix and main vector of Poverty dimensions

Dimension	Economic	Access to basic services and infrastructure	Access to drinking water	Main vector
Economic	1	–	–	0.2584
Access to basic services and infrastructure	1/3	1	–	0.1047
Access to drinking water	3	5	1	0.637

Consistency ratio = 0.03; the consistency is acceptable

Fig. 4 The weights of poverty dimensions

Table 4 Scores for economic and access to services and infrastructure

Condition	Score
Good conditions	4
Fair conditions	3
Poor conditions	2
Very poor conditions	1

Table 5 Benchmarks and scores for criteria

Criteria	Frequency	Score
<i>Number of goats per inhabitant</i>		
0–10	131	1
10–25	68	2
25–45	41	3
45–95	45	4
<i>Collection and marketing of jonquil</i>		
No	199	2
Yes	86	3
<i>Access to electric power network</i>		
Outside the area of influence of electric power network/solar panel (buffer 0 m)	225	1
Single-filament (buffer 500 m)	47	3
Three-phase (buffer 1000 m)	13	4
<i>Access to road network</i>		
No access to roads (0 m)	10	1
Dirt road (800 m)	179	2
Consolidated road (1500 m)	46	3
Paved road (3000 m)	50	4
<i>Access to drinking water</i>		
With no access to aqueduct	163	1
With access to aqueduct	122	3

categorized according to their benchmarks, depending on their impact on poverty in the study area (Tables 4, 5).

3.5 Integration of Dimensions and Mapping of Results

Once the variables were re-categorized, compound or global weights were obtained by multiplying the scores assigned in the previous step by the main vector to each criterion. Afterwards, a linear summation was performed of all hierarchized criteria or compound weights divided by the number of indicators composing the dimension, and this result was multiplied by the corresponding main vector, all within the scope of GIS (Fig. 5).

The poverty rate was designed thinking about its replicability on other study sites under other local conditions, so that the number of indicators for each dimension may vary. Taking this into account, it is necessary to divide the indicators of each dimension in order to relativize them.

$$\text{Composite Poverty Index} = \{[(\text{Number of goats per inhabitant} + \text{Collection and marketing of Sporobolus rigens}) / 2] * 0.2584\} \\ + \\ \{[(\text{Access to electric power network} + \text{Access to road network}) / 2] * 0.1047\} \\ + \\ (\text{Access to drinking water} * 0.637)$$

Fig. 5 Polynomial formula for poverty

Table 6 Livestock stations according to their economic conditions, and to their access to drinking water and basic services

Economic conditions and access to drinking water and basic services	Values	Frequency
Very poor conditions	1.12–1.38	100
Poor conditions	1.40–1.80	62
Fair conditions	1.81–2.74	76
Good conditions	2.75–3.13	47

4 Results

Application of AHP allowed integrating all five criteria corresponding to the three dimensions defined in the data model. Thus, the following results were obtained: out of the total 258 livestock stations, 47 present Good conditions, 76 Fair conditions, 62 Poor conditions and 100 Very poor conditions (Table 6; Fig. 6).

The result obtained was classified into four categories, identifying livestock stations as being in Very poor conditions, Poor conditions, Fair conditions and Good conditions. To define degree of poverty for each livestock station, those presenting Very poor conditions and Poor conditions were categorized as poor. Finally, and given the need to spatialize poverty processes in areal manner for their future inclusion in an integrated assessment of desertification in this territory, a buffer 2.5 km in diameter around livestock stations was calculated. This distance was determined based on consultation with local people, who defined it considering both the average area where goats move around for grazing and the area where they collect firewood and other resources (Fig. 6).

5 Discussion

Despite the importance of socioeconomic studies for land degradation/desertification is globally recognized, socioeconomic variables have historically been given a superficial treatment or have not been addressed at all. This is explained on the one hand, by the lack of input from social scientists to a complex, multidimensional, and multidisciplinary problem, but also because of the great difficulty for systematizing the multiple dimensions of social phenomena in their interaction with physical-biological processes. Added to this is that social processes are often difficult to spatialize. In addition to these considerations, in drylands there is a lack of reliable data on multiple levels, particularly at the local scale, where usually direct survey or the data coming from geographic information systems and remote sensing must be used. To overcome this, use of proxies is generally necessary when addressing the socioeconomic dimension, although they may generate biases and hide the real conditions of affected populations and territories. In drylands, and particularly in

Fig. 6 Composite poverty index

developing countries, this problem is exacerbated by the fact that, in some cases, these kinds of studies are totally ignored.

In Latin America, especially in Argentina, socioeconomic aspects are usually approached from a qualitative point of view, which makes them very difficult to integrate into assessment models that allow for the construction of scenarios whereby decision makers and the scientific community would be able to measure the problem and propose solutions.

The aim of integrated assessment of land degradation is to identify and analyze the multiple relationships between the physical-biological and socioeconomic indicators, and

among the latter, those related to poverty become leading indicators. Unfortunately, recognized and commonly used indicators to measure poverty are subjected to economic factors and often focused on the urban environment. The clearest example of this is UNB, whose major limitations lie in the fact that the indicators dealt with have the same weight—irrespective of the particularities of each territory; classifying a home as poor independently of whether it has one, two or three basic needs unmet. Also, the use of service indicators for the rural area has conceptual problems: by using the same indicators for both the rural and the urban areas, poverty would be being overestimated in the former area (Feres and Mancero 2001). Moreover, working with information from the point-based measure of poverty, such as are UNB and PL, poses serious limitations that many a time mask reality, mistakes increase as this information is integrated into that coming from the physical-biological context, until reaching the stage where makers of territory-related decisions come to decisions based on such information.

Despite poverty is one of the issues receiving major attention by the UNCCD and a priority issue in its last scientific conferences, so far no position has been taken or a unified methodology defined for evaluation in party countries, much less if this evaluation is performed locally. Fortunately, at international level new experiences are arising relative to the multidimensionality of this phenomenon.

There are numerous frameworks for multidimensional poverty assessment (Alkire and Foster 2011a, b; Alkire et al. 2015; Santos et al. 2015), which are the theoretical and methodological bases for many countries which have changed their ways of addressing poverty, moving forward towards more complex analyses and which reflect each of the realities in a better, more precise way. Although these works find an accurate manner of assessing deprivations in the multidimensional approach, it is important to highlight the progress attained by the study by Alkire and Foster (2011b). This methodology combines two cut-off modes; one within each dimension, to determine whether a person is deprived of such dimension, and a second one, across the dimensions, which identifies poor people by “counting” the dimensions in which a person is deprived. This approach allows enriching poverty assessments and affords contributions that will surely be taken into account in future studies by the authors of the present work.

The analysis and comparison of the poverty index obtained with other indices that also address the multidimensionality of the phenomenon, such as the multidimensional poverty index (MPI) of Mexico, the Colombian multidimensional poverty index (CMPI) of Colombia and the MPI of Ecuador, raises a number of relevant aspects to be considered. On the one hand, such as is proposed in the present study, all experiences present different criteria to select dimensions, variables, and to define their units of analysis, however, all of them base their methodological approach on the proposals of Alkire and Foster (2007, 2011a, b). Beyond the methodological adaptations that each proposal incorporates, undoubtedly, a key distinguishing aspect is the multidimensional perspective under which they were built.

In the Mexican case, based on framework set forth by Alkire and Foster (2007), the MPI includes two dimensions, one referring to economic welfare and the other one to social rights. Also, to understand the social processes linked to poverty (CONEVAL 2010) the MPI incorporated their territorial context into the analysis. The multidimensional approach with which Mexico officially analyzes deprivations since the year 2009 includes education, access to health services, access to social security, shelter characteristics, access to basic services, access to food, and level of social cohesion. Outstanding among the advantages of its application is the capacity to assign relevance to problems related to the high indigenous

poverty rates (Alkire and Santos 2010), which come to light thanks to this multidimensional approach.

In Colombia, the CMPI is based on the approach of Alkire and Foster (2011b) and uses the household as the unit of analysis. This is a convergence with our work that, similarly, uses the livestock station, which may comprise one or more households. The use of this multidimensional approach responds to the need to overcome the limitations of classical measurements like UBN, and its analysis is enhanced by addressing the dimensions of educational conditions, childhood and youth, work, health, and housing and public services (Angulo Salazar et al. 2013).

The construction of the MPI of Ecuador (period 2006–2010) responds to criteria closely linked to the principles of rights and social justice, enshrined in its Constitution, and focused on the concept of development based on the right to good living. The approach based on rights requires a multidimensional perspective, since rights cannot be understood through an aggregate measure or a unidimensional approach. Dimensions analyzed in this index are: food and water, communication and information, education, housing, health care and work and social security. Likewise, the multidimensional approach allows analyzing each dimension separately, minimizing the loss of information derived from analyzing only the global value of the index (Mideros 2012). In order to achieve a useful tool for public policy, the Ecuadorian index also includes the territorial dimension in its composition. One thing worth stressing in analyzing the changes detected by the MPI between 2006 and 2010 is that, although the index values show an overall diminishment, the rural population, indigenous and Afro-American women are the sectors showing the greatest inequalities (Mideros 2012). This allows surmising that the Ecuadorian MPI has a very detailed degree of disaggregation in its analysis since, like in the Mexican case, it achieves identification of situations of inequality that generally remain masked when using other indices.

Our work contributes to a multidimensional understanding of poverty at the local level, obtaining indicators and benchmarks through the use of GIS and AHP, and allowing spatialization of the identified processes. In this sense, numerous studies use both techniques combined in order to construct deprivation indices (Cabrera-Barona et al. 2015; Kumar and Pathinathan 2015), which affords the possibility to assign weight to the index components and, in turn, to link information about different dimensions. Currently, these methodological approaches have become more and more powerful and are envisioned as the most complex and complete ones at the time of spatially assessing deprivation. Another study conducted in Quito (Ecuador) (Cabrera-Barona et al. 2015) is a clear example in which emerging socioeconomic issues guide authors to select those key dimensions (education, health, housing and employment) that best represent the analysis situation. This study presents a very interesting alternative, by supplementing the AHP with ordered weighted averaging to create different deprivation scenarios, laying emphasis on health inequalities. The possibility of simulating, for instance, the implementation of a public policy and how it would impact the territory, through construction of scenarios, is one of the strengths of these methodological approaches. Besides, the use of GIS and AHP allows replicability of deprivation indices, as well as their being approached at multiple scales.

The present case study takes livestock stations as the unit of analysis, which is considered an original contribution. These are settlements that characterize the distribution of the population in most of the pastoral areas with subsistence economies in drylands. Therefore, it is possible to replicate this work in these territories, and in the case of analyzing other patterns of settlements, units of analysis may be the production units recognized in each case.

For the study area, this is the first experience where not only the indicators but also their benchmarks were established. Poverty conditions are also mapped. With this work we have helped fill a gap in the integrated assessment of land degradation/desertification. Having this information allowed us to move forward with a greater degree of certainty in the analysis of relations between the biological and physical subsystem and the anthropic use of resources in drylands. Also, identifying the affected population by poverty from a multidimensional viewpoint (UNDP 2015) allows adapting indices that have recently been developed by international organizations and need to be applied locally.

Among the limitations of the proposed methodology, subjectivity when defining the buffer distances, for example for road network, is highlighted. This subjectivity is relative and involves a methodological flexibility to become adapted to different situations, since the data emerges from the terms and extent of the case study and its spatial scale. In this very sense, it is important to reflect about the authors' bias affecting the construction of the pairwise matrix. Although they have a profound knowledge of the territorial dynamics of the study area, the subjectivity inherent to the method could have been reduced by the involvement of other experts at the time of selecting criteria and assessing their weights and relationships. Attainment of an acceptable consistency ratio could be masking the bias of the work team, a situation that no doubt constitutes a challenge to overcome in future works. The work opens important perspectives for application at local and national level, and their transfer internationally. In the case of Argentina, the authors participate in the National Observatory of Land Degradation and Desertification, which nucleates fifteen pilot sites, among which is the one that has been developed in this work. In this sense, participatory diagnoses made reveal the need to integrally address socioeconomic factors, especially poverty in rural areas, and their spatialization, both nationally and locally. This work aims to achieve this goal, and the links of the Observatory with international organizations, especially the UNCCD, could promote its dissemination and adjustment.

6 Conclusions

The work performed enabled building a local-scale, robust indicator of poverty, able to contemplate multiple dimensions and which clearly allows spatialization of socioeconomic data. Thus, a complex indicator was generated, composed of five variables structured into three components, appropriate for determining degree of poverty in the study area and replicable in similar areas. This is considered sufficient, and does not inhibit the possibility of incorporating further variables known to be important for the concept of poverty, such as migration, access to social plans, education, health, among others.

The obtained indicator opens multiple possibilities to studies addressing an integrated assessment of land degradation/desertification, and contributes to filling a knowledge gap in the treatment of socioeconomic data and their spatial representation. Moreover, the contribution made helps overcoming the limitations of territories that lack reliable databases and which are amongst the poorest in the world. The requirement to work exclusively with official statistics from population censuses or from other secondary sources is demystified, undertaking, instead, the systematization of original and reliable databases which may have been developed in the area for other purposes and which only require a consistent statistical treatment of the data, and probably an updating.

Having detailed information about the minimum units of analysis, in this case the livestock station, enables aggregation to larger units. This flexibility facilitates use of this

data at different spatial scales and by different stakeholders involved in decision making relative to land use management and improvement of living standards, within the framework of the combat against desertification and drought. The work done lays the foundations for further deepening a topic of great worldwide importance, as is scaling-up to achieve a comprehensive bottom-up approach, starting from the true local field in order to obtain more generalized results at other scales. In this way, progress can be made in the design of strategies, not only locally but also -at national and regional scales.

The usefulness of GIS and MCDA is demonstrated, not only as tools for research design but also as instruments in themselves that allow progressing in new integral, interdisciplinary and multi-scale approaches. A fundamental element in this respect is their contribution to the monitoring stage and to the spatial, as well as the temporal, dimension of processes. Therefore, they contribute to meeting the Millennium Development Goals, as well as the objectives set forth by the main international environmental agreements, such as the UNCCD and the United Nations Framework Convention on Climate Change. We believe that the work performed will contribute to filling a knowledge gap and will be able to be applied for determining the extent and degree of poverty in the drylands of Latin America.

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