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"Gheorghe Asachi" Technical University of Iasi, Romania

BRIDGING THE GAP BETWEEN LANDSCAPE THEORY AND PLANNING: THE GTP MODEL IN A PYRENEES MOUNTAIN AREA

Josep Maria Serra-Diaz[1,2*], Ana Vera[2], Albert Pelachs[2], Enric Mendizàbal[2]

[1]*Departament of Animal Biology, Vegetal Biology and Ecology. Universitat Autònoma de Barcelona*
[2]*Research Group in Mountain Areas and Landscape, Departament of Geography,*
Universitat Autònoma de Barcelona, 08193 Cerdanyola del V., Spain

Abstract

The concept of landscape in Europe has moved from a scale analysis towards a holistic concept defined by laws and a European directive. In economically depressed mountain areas, the landscape represents both a resource and an opportunity for development, and the task facing managers of natural parks is not easy. The present study applied a geographic model that interprets landscape holistically using three subsystems (*G-T-P*): Geosystem or natural environment (G), Territory or socioeconomic environment (T) and Landscape or symbolic perceptions and values (P). We apply this methodology to possible rural development in a Pyrenean valley within a Natural Park. We showed that livestock and crop production activities have a significant role in the forest environment of the valley with no significant landscape impact. Overall, we show that GTP model enables to work within the legal definition of landscape and also identify landscape-friendly development strategies. Further research should focus on the interaction between these subsystems from the managers' perspectives.

Key words: GTP model, natural protected areas, landscape conservation, mountain areas, landscape valuation

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1. Introduction

The concept of landscape, traditionally understood in many scientific fields as a scale of analysis, has been replaced by the European Landscape Convention (European Council, 2000), in which the human perception of landscape forms part of the definition (article 1) and the objectives for landscape quality (article 6). Planning is a complex task in natural protected areas and is usually conditioned by multiple legislative interventions. For instance, in Spain there are European directives, Spanish laws, and laws passed by the Autonomous Communities. Specifically, in this case, the Autonomous Community of *Catalunya* enacted Law 8/2005/June 8 on the protection, management and control of the landscape, which defines landscape as "any part of the territory, as perceived by the community", language that emphasizes the multiple dimensionality of the concept.

However, it is important to recognize that a multi-dimensional analysis could have important methodological difficulties, partly due to a lack of a theoretical base concerning the concept of landscape (Read, 2005), but also due to enormous diversity of opinion about how to define the concept of landscape (Azevedo, 2008; Milani, 2001; Nogué, 2010; Roger, 1995; Wylie, 2007). In addition, this multi-dimensional analysis requires the use of multiple quantitative and qualitative methodologies.

Geographers' efforts to end the duality between landscape on a natural scale and landscape understood as a subjective perception led French geographer Georges Bertrand to formulate a framework for landscape studies, called *géosystème, territoire, paysage* (Geosystem, Territory,

* Author to whom all correspondence should be addressed: email: Josep.serra@uab.cat; Phone: 0034-93-581-2985

Landscape) or the *GTP* model (Bertrand, 2000; Bertrand and Bertrand, 2002). This model presents a progression of "artificialization" or human intervention (anthropization) affecting the territory (*T*), from the natural or physical elements (*G*) to the social or metaphysical aspects of the landscape (*P*). Many studies have highlighted the tension that arises when the natural environment is considered in isolation from socioeconomic development (Turner et al., 2003) and it is widely accepted that landscape studies must be broadly multidisciplinary (Farina and Naveh, 1993; Naveh and Liebermann, 1994), even in natural protected areas. Therefore, the GTP model meets the identified needs of landscape researchers.

The *GTP* model explains the three different but complementary time/space categories of the landscape. The Geosystem (G) dimension consists of the system's basic natural elements that have a useful function as a resource (i.e., a river). This time/space dimension of landscape is characterized by the behavior of the natural system, similar to the German concept of *Naturraum* (Haase, 1979) or natural space, i.e., biophysical units of landscape. This system is especially important to the managers of natural parks because most of their policies are mainly concerned with this domain. Territory (T) incorporates the socioeconomic registers of the geographic space, such as the resources captured from the environment (i.e., a bottle of mineral water). This is the time/space dimension that measures the degree of artificialization and explains the system's behavior based on the implementation and evolution of human activities, which in the case of the Pyrenees has produced changes in the spatial configuration of the traditional rural landscape (Rescia et al., 2008). Finally, the *paysage (P),* a multifaceted "landscape" concept, represents the sociocultural entrance to the environmental system, the natural *resourcement* filtered through the culture that acquires a series of perceptions and symbolic values (e.g., holy water in Catholic churches); it is based on a process of *artialization*, or aesthetic transformation. The consideration of cultural and heritage values in assessing a landscape has also been proposed in the context of management, such as the Cultural Values Model (Stephenson, 2008).

The present application of the GTP conceptual model was undertaken in the High Pyrenees Natural Park (HPNP; *Parc Natural de l'Alt Pirineu* in Catalan), near Spain's borders with France and Andorra in the northeast Iberian Peninsula (Figure 1). In the Pyrenees, the current landscape is the result of strong interaction between the natural environment and human beings seeking to take advantage of natural resources throughout history. Evidence of human influence can be seen in natural systems for more than 6000 years (Galop, 1998; Pèlachs et al., 2011) and especially the past 3300 years (Bal et al., 2011; Ejarque et al., 2010). Nonetheless, the traditional system has been in crisis since the 1960s and the current configuration of the landscape is the result of a double process: abandonment of the traditional system (agriculture, livestock, forest management, and mining) and rural exodus (Aldomà et al., 2004; MacDonald et al., 2000; McNeill, 1992; Weissteiner et al., 2011) together with intensification of a specialized tertiary economy, such as the development of Alpine ski facilities, which has transformed traditional uses (Garcia-Ruiz and Lasanta,1993; Lasanta et al., 2007). Currently, the cultural capital and landscape resources offered by the natural environment have led to activities such as ecotourism and hiking, which are multiplying and leading to a reassessment of cultural values (Moulin and Boniface, 2001). Therefore, a decision support system (DSS) used to manage the HPNP in this case, but generalizable to any natural park, must take into account the multiplicity of factors and interactions that make up the Pyrenees landscape and must also meet the objectives for landscape quality established by European, Spanish, and Catalan laws. The main objective of this study is the implementation of the *GTP* concept using spatial and statistical methods. We further exemplify its application as a decision support tool for the strategic development of a Pyrenean Valley within the HPNP.

2. Case study

The HPNP needs a DSS to choose the best strategy for the sustainable development of a public forest land called the *Ribalera,* taking into account landscape attributes. The Ribalera is managed by three decentralized municipal entities: Tírvia, which governs a 50% share of the municipality of the same name, and Farrera (25% share) and Burg (25%), both within the municipality of Farrera. In other words, all decisions must be negotiated by these three public owners of the land and therefore it is very important that planning efforts take into account the maximum number of different perspectives. The GTP model uses multiple methods to analyze the three subsystems (G-T-P) of the landscape and characterize and devise potential developmental strategies in accordance with landscape attributes, a holistic landscape approach that is defined by law.

3. Material and methods

The sources of available information determined the variables to be analyzed. These variables conditioned the spatial scale used to contextualize all the HPNP information related to the GTP model. The study area for the analysis of geosystemic variables (G) was larger than the HPNP itself, to accommodate the administrative boundaries of the municipalities involved. The territorial socioeconomic information analyzed (T) is only available at the municipality scale; we chose the highland regions of *Catalunya* (Law 2/1983/9 March, relating to high mountain areas) to properly contextualize the socioeconomic attributes of the HPNP. On the other hand, the administrative boundary defined by the Landscape Observatory of

Catalunya to draft the landscape catalog of the High Pyrenees and Aran region (per Law 8/2005/June 8, on the protection, management and control of the landscape) was used to define the landscape (P) values (Fig. 1 for further details on geographical boundaries of the G-T-P subsystems).

3.1. The geosystem

Geosystem analysis was based on a biophysical approach to studying the natural landscape (Bernert et al., 1997; Martin de Agar et al., 1995) because the objective is to establish a topoclimatic framework. The topoclimatic landscape (TCL) concept (Serra et al., 2011) that informed our methodology employs a multivariable statistical clustering approach to identify zones with similar physical and ecological features. The variables selected to characterize the topography are the slope and curve of the land, variables derived from a 30-meter Digital Elevations Model. Maps developed for the Digital Climate Atlas of *Catalunya* (Ninyerola et al., 2000) were used to calculate radiation and climatic variables. The climate variables selected were annual accumulated precipitation, annual hydric deficit, and temperature ranges. Hydric deficit was calculated from the difference between mean annual precipitation and potential evapotranspiration [MAP-ETP]. Evapotranspiration potential was determined using the Turc method (Allen et al., 1998).

The TCL concept also incorporates the characteristics of vegetation and land covers, using variables derived from remote sensing imagery: humidity, surface ground temperature, and normalized differential vegetation, indicating the phenological status of the land covers. Remote sensing indices were obtained by calculating annual composites, available from Landsat-5 TM and Landsat-7 ETM+ images from 2002 to 2006. Cluster analysis allowed us to group the pixels of each image, defining a group of pixels with high internal coherence with respect to the defined variables and therefore a homogeneous zone with respect to environmental conditions. In our study area, 11 TCL categories were identified (Fig. 2). In topographically complex terrain, climatic variables tend to change abruptly due to important changes in altitude and orientation. Therefore, both the categorization and cartographic shape of these landscapes have a high correlation with geomorphologic elements such as shady and sunny slopes, peaks, valley floors, or plains.

Each of the TCLs was also characterized using other ecological parameters considered relevant by the managers of the territory. The functional and structural organization of the landscape in each TCL was defined using information about the land covers (CREAF, 1993) and habitats (Generalitat de Catalunya and Universitat de Barcelona, 2005) represented. Based on these data, TCLs also provide information about various landscape metrics calculated using FRAGSTATS software (McGarigal et al., 2002), specifically the number of patches of each land cover and mean patch area.

3.2. The territory

The current and former socioeconomic profile of the study area was taken from two data sources: (1) territorial taxonomies and (2) changes in land use. Analysis of territorial taxonomies helps to interpret the current socioeconomic reality and create a group of Social Territorial Units (STUs) (Vera, 2007) based on factor analysis (Bosque and Moreno, 1994; Pallares-Barbera et al., 2004, Robinson, 1998) and cluster analysis (Lloyd, 2010). On the other hand, land use changes provide an idea of the historical dynamics of the landscape.

A combination of alphanumeric and spatial variables was used to identify territorial taxonomies. The alphanumeric variables of the agrarian census from 1999 and population census from 1991 and 2001 were taken from the Statistics Institute of Catalunya (http://www.idescat.cat). Spatial variables were provided by the Cartographic Institute of Catalunya (ICC) and databases publicly available online from the Catalan government's environmental agency (Generalitat de Catalunya, http://www20.gencat.cat/portal/site/mediambient). In each case the most recent data available were used in the analysis.

At the beginning of the study, 204 variables were considered; after data-cleaning, 127 variables remained available and were classified into 6 groups or sectors, which were then used in factor analysis: 1) demographic and economic, 2) social, 3) industrial and commercial, 4) agriculture, 5) livestock, and 6) spatial (Vera, 2007). The final factor analysis results are used in the cluster analysis to obtain groups of municipalities with similar socioeconomic and territorial dynamics. The STUs result from a reclassification of the cluster analysis (Vera, 2007).

Changes in land use were assessed by analysis of orthophotography from 1956-57, land cover maps from 1993, and geometrically adjusted military aerial photographs (Palà and Pons, 1995). These photographs were corrected using a 1-meter resolution and reprojected using the NUTM31 cartographic project system using an average of 16-20 control points obtained from ICC orthophotographs for each image. The root mean square (RMS) in the geometric correction was 2.5 meters. To compare the observed changes with the maximum precision possible, photointerpretation categories were established on the basis of a minimum digitalization area of 500 m^2, the cartographic criterion used when the land covers map was digitized in 1993. These categories were pastures, high-density forest (including the 1993 criteria for shoreline woods and reforestations), low-density forest (including the 1993 criteria for brush woods), urban areas, and two agricultural categories for 1956 images, active or abandoned, to allow us to quantify agricultural abandonment between 1956 and

1993. For purposes of comparison with the 1993 land covers map, agricultural abandonment was combined with low-density forest (Serra et al., 2008).

3.3. The landscape

Some authors (Bertrand, 2000; Bertrand and Bertrand, 2002) affirm that the landscape is landscape when a person looks at the surface of the Earth. For this reason landscape is not a pure scientific concept, because it is not a determined theoretical concept; because the diversity is difficult to analyze, and the landscape is diverse; and because the word landscape is used of a garbled way. Landscape is a panorama, a resource/literary speech where afterwards the scientists make science: the cartesian method that consists in dividing the things in parts increasingly small for comprise how works each one of them. But the landscape has to comprise a multiple scale form. From landscape's ideas that Bertrand writes, is easy to understand that the landscape has a sensory reality, since it could be perceived with the five senses, but also is the mental construction that the community has done of this landscape. The landscape is the representation of the things by a society (Mendizàbal et al., 2007).

In the application of such theoretical approach, landscape values were identified, mapped and described according to the six general categories of the Landscape Catalog of Catalunya (http://www.catpaisatge.net/cat/cataleg_prototipus.php): (1) natural values, 2) aesthetic values, 3) historical values, 4) social values, 5) production values, and 6) symbolic values and identity (see supplementary material 1 for the main points considered in the HPNP). All of these values were studied using written and graphic documentation, descriptions recorded during fieldwork, and cartographic analysis. Selection of each of the six values relies on the decision taken by the responsible of the research and therefore, empirical knowledge of the area is needed in together with citizen participation. It is important to point out that various quantitative and qualitative approaches can be used to assess these values and any one element of the landscape or setting can possess than one such value at a time. A systematic reflection about all five senses can provide an orientation to aspects of sight, hearing, smell, taste, and touch to be considered (Mendizàbal et al., 2007). In addition, processes for citizen participation using a variety of tools (interviews, web surveys, public exhibits, etc.) are essential to the correct identification of landscape values (Nogué et al., 2010; http://www.catpaisatge.net/cat/cataleg_participacio.php).

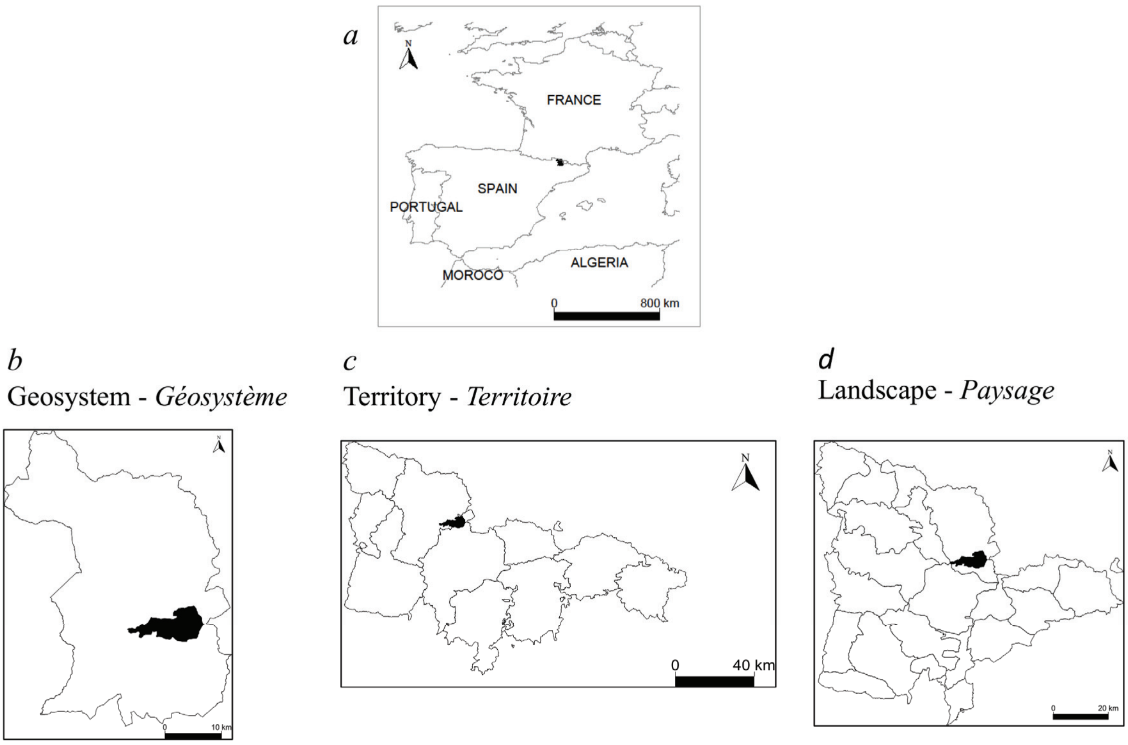

Fig. 1. (a) Study area and geographical boundaries of the landscape subsystems analyzed: (b) Géosystème: boundaries of HPNP; (c)Territoire: boundaries of highland regions of Catalunya (Law 2/1983/9 March, relating to high mountain areas); (d) Paysage: boundaries of the Landscape Catalogue of High Pyrenees and Aran (Law 8/2005/June 8 on the protection, management and control of the landscape).

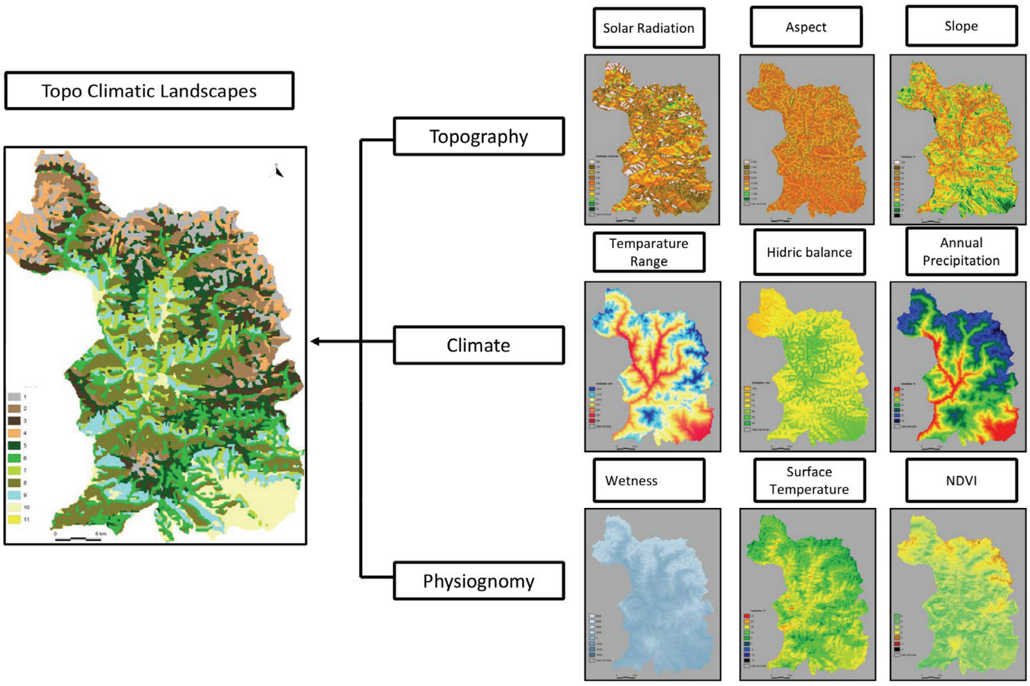

Fig. 2. Topoclimatic landscape (TCL) characterizing the geographic region of the Geosystem (G) in the GTP model. Eleven units result from the integration of 9 biophysical variables. (Physiographic taxonomy = 1: Summit areas;2: North face slopes at high elevation; 3: Sout faced mid-elevations;4: Plain areas at high elevations ;5: Mountain peaks; 6: Narrow valleys; 7: South facing mid-mountain summits ;8: Wide valleys slopes of mid-mountains;9: South facing slopes at lower elevations;10: plain areas;11: plain areas and very low elevation)

4. Results and discussion

4.1. Geosystem Analysis – nature and abiotic characterization

Topoclimatic conditions are dominated by the TCL6 (functioning of valley floors) and TCL7 (high mountain crest zones) categories, which together describe 63.3% of the surface area. Functional conditions are generally sunny or have a high thermic value but also have a definite forested character. Predominant land covers in the study area are high-density forest (50.15%), with a notable 16.64% low-density forest area (Table 1). Primary habitats are black pine (*Pinus uncinata*) groves (21% of the surface area), generally with alpenrose (*Rhododendron ferrugineum*), silicicole and mesophyll meadows (11.6%), and Spiny broom (*Calicotome spinosa*) habitats in sunny slopes (10.3%). Metrics for the landscape and its changes indicate an increase in the number of forested patches, reducing the mean area (Table 2). However, this pattern does not imply actual new fragmentation because these land covers have increased their area (Table 1). On the other hand, croplands and urban centers have experienced a slight fragmentation (Table 2) and present an overall scenario of decline when interpreted with land cover dynamics (Table 1). The largest patch, a high-density forest, has not undergone significant changes. Therefore, we conclude that the area is quite forested with no apparent danger to the habitats in this zone.

Geosystem classification made it possible to identify areas with similar environments and natural elements. In broad terms, this statistical approach to classifying biophysical variables has been used in the identification of large ecological regions as well as smaller zones (Haargrove and Hoffman, 2004; Monjeau et al., 1998), with a clear emphasis on resource management (Fairbanks and Benn, 2000; Rhee et al., 2008). However, the very categorization of continuous quantitative variables causes a degree of uncertainty that is difficult to incorporate it to management (Rocchini and Ricotta, 2007; Serra et al., 2011).

Table 1. Main land cover types of the Ribalera Valley for the two studied periods and their representativeness

	1956		*1993*	
LAND USE	**ha**	**%**	**ha**	**%**
Agriculture	253.85	5.66	59.1	1.32
Pastures	1122.03	25	1328.05	29.59
Forest (high density)	2339.26	52.13	2250.5	50.15
Forest (low density)	587.94	13.1	742.3	16.54
Urban areas	1.24	0.03	0.64	0.01
Non-productive	59.29	1.32	107.01	2.38
No data	124	2.76	0	0
Total	4487.6	100	4487.6	100

Our data confirm that the vegetation cover of the study area has undergone a transformation, particularly in the territorial dynamics that follow general trends in the Pyrenees resulting from a decrease in the population and in the activities of the primary sector, along with a certain degree of homogenization of the area's vegetation. However, the geosystemic and landscape analyses did not capture all aspects of the entire spectrum of these changes. Therefore, an analysis focused on the landscape's ecological resources or services could strengthen the Geosystem dimension (Groot et al., 2010).

Table 2. Landscape Metrics for each cover type in 1956 and 1993

	Number of Patches		***Mean Patch area***	
	1956	***1993***	***1956***	***1993***
Agriculture	27	15	9.41	3.93
Low-density Forest	138	319	4.26	2.33
High-density Forest	97	326	24.11	6.90
Pastures	113	372	9.93	3.57
Urban centers	4	3	0.31	0.22

4.2. Territory Analysis - territorial and socioeconomic dynamics

This zone is described as STU 3, which constitutes 91.84% of the HPNP area characterized by municipalities with steep slopes, ranging from 12º to >24º, and an altitude ranging from 900 to 1900 meters (supplementary material 2 and 3). The distribution of the working population trends toward tourism and services (50.12%), but the cluster is characterized by agrarian activity. Even with the presence of tourism, the primary economic activity in this territorial taxonomy is in the agrarian sector, specializing in raising beef, veal, and dairy cattle and also horses. There are also small local production systems related to agroindustry, primarily dairy products. The agricultural typology is large extensions of non-irrigated crops, pastures, and forest lands. Changes in land use clearly show the abandonment of agriculture (by approximately 5%), while livestock are being relocated in the zone and there has been a slight increase in recent years (ca. 5%). These two dynamics have led to an increase (>3%) in low-density forest in the study area (Table 1). It is important to note that the major changes are due to a shift from dense forest to pastures or low-density forest (Table 3) and to recall that fields abandoned in 1956 were considered low-density forest for purposes of comparison with 1993 data categories. The growing animal husbandry activity indicates that croplands are much more related to livestock than to any other type of farm product. We would point out the increase in pastures resulting from the loss of agricultural activity (Rank 5 in Table 4) as livestock has gained importance. In the study area, a large increase in forest cover and major decline in livestock and agricultural land use were observed over these 53 years. In general, however, this readjustment of activities has not produced major changes in land covers. The urban areas did not experience major transformations. We also observed that today's low-density forest areas that evolved from previous agricultural land use have development potential.

The **territorial units** that define the socioeconomic spaces of the Pyrenees have revealed how, even with the loss of population engaged in agriculture, growth in the tertiary sector and in construction, and the decrease in cultivated farmland resulting from abandonment of this sector, agriculture and livestock continue to be important to economic development in the Pyrenees.

Table 3. Characteristics of the socioeconomic territorial unit identified in the Ribalera Valley (subsystem T in the GTP model)

STU 3: Rural municipalities specialized in pastures and livestock				
Occupied Population			***Land use***	
Agriculture	1709 (31.70%)		Urban areas	792.2 (25.85%)
Industry	1830 (8.05%)		Industrial areas	52.2 (7.18%)
Building	2466 (22.72%)		Dry agriculture	235972 (66.13%)
Services	9571 (22.42%)		Irrigated agriculture	8631 (56.13%)
			Pastures	208568 (75.28%)
			Forest	161998 (46.67%)
			Natural Protected Areas	145479.44 (99.34%)
Livestock			Territory	
Cattle	47540 (47.77%)		Slope 6º	24337.9 (25.27%)
Sheep	10391 (42.66%)		Slope 6 - 12º	49822.4 (37.55%)
Goats	635 (38.58%)		Slope 12 - 24º	187556.6 (54.59%)
Pigs	16463 (10.81%)		Slope > 24º	269272.7 (69.19%)
Poultry	1848 (5.34%)		Altitude 30-60 m	3064.7 (3.14%)
Rabbits	190 (17.71%)		Altitude 60-90 m	36117.2 (17.45%)
Equin	4155 (74.68%)		Altitude 90-120 m	98130.2 (53.70%)
			Altitude 120-150 m	112441.3 (73.26%)
			Altitude 150-190 m	139979.8 (86.10%)
			Altitude > 190m	147681.4 (93.54%)

Table 4. Main changes in land cover types between 1993 and 1956 in the Ribalera Valley

Rank	*Land Cover 1956*	*Land Cover 1993*	*ha*	*%*
1	High Density Forest	Pastures	253.38	17.47
2	High Density Forest	Low Density Forest	243.48	16.79
3	Pastures	Low Density Forest	210.3	14.5
4	Low Density Forest	High Density Forest	191.17	13.18
5	Agriculture	Pastures	178.25	12.29
6	Pastures	High Density Forest	125.77	8.67
7	Low Density Forest	Pastures	118.25	8.15

The territorial units defined by the alphanumeric and spatial variables analyzed permit an assessment of inequalities between territorial environments (Romesburg, 1984) and the development of policies to appropriately address territorial needs.

4.3. Landscape Analysis – values and symbols

From the viewpoints of values analysis in this zone, several findings stand out:

1) ***natural values***: spaces of geological interest and humid zones are considered.

2) ***aesthetic values***: pastures are a key consideration, as is the shaded forest environment.

Therefore, if pastures need to be expanded, sunny areas and valley zones should be favored for this purpose, rather than shaded forests with deciduous trees. This contrast is a value to be taken into account. Continuing with the aesthetic values, the Ribalera is a zone with a concentration of mountain shelters (huts that have long supported the animal husbandry environment), which stand out as a unique physiognomy to be preserved. In the same manner, the geoforms are primarily schists and slates with a rounded shape and therefore do not exclude livestock activity. As an aesthetic assessment, the olfactory character of the Ribalera is an important consideration. The smells of mountain flowers and of dung – evidence of the long-time presence of active animal farming -- are valued. Herding helps to maintain open spaces and therefore supports fragrantly flowering vistas in high mountain areas. The quantities of cut grass available for animal feed can also be increased if pasture expansion is accompanied by an increase in managed prairies.

3) ***historic values***: transhumances roads have been found at the Ribalera, as well as historic fields and summer pasture zones. Therefore, the animal husbandry character of the zone is undeniable, despite the forested area. The remains of three populated sites abandoned in the early Middle Ages are also notable for their patrimonial and archeological value. We must ensure that the recovery of pastures does not harm these areas more than others, because they are currently abandoned with no hope of preservation.

4) ***social values***: the zone is divided by routes for motorized vehicles, with two points marked as a recreational area, and some specific areas have agreements to protect the territory. Therefore, to the extent possible the areas to be recovered should not include these specially designated spaces.

5) ***productive values***: the zone has summer pastures and forest development in a limited area between the Protected Geographic Indication (PGI), *Vedella dels Pirineus* (designated veal region of Pyrenees), and the Protected Denominations of Origin (cheese and butter from Alt Urgell and the Cerdanya mountains).

6) ***symbolic and identity values***: the zone contains religious hermitages associated with social and folk festivals, as well as abandoned Medieval town sites linked to the transhumances and other livestock and animal trails. Legends are told about a few specific sites near the river, and the natural beauty of the area has inspired generations of artists and writers.

The landscape values analysis relied upon indirect sources. Even though this assessment might have a high incidence of historical values and heritage, it leaves aside various dimensions of landscape that could be perceived (Stephenson, 2008). Research techniques such as interviews or ideal-type narratives (Rescia et al., 2008; Soliva and Hunziker, 2009) could contribute information about these changes that would differentiate between social perceptions of park users and of local residents.

4.4. Global assessment from the GTP analysis

The GTP approach reveals that livestock and crop production activities have a significant role in the forest environment of the Ribalera. None of the landscape dimensions analyzed show any conflict between such activities and the natural characteristics of the valley. Therefore, whenever the Natural Park managers place livestock activities in a central role of development, the landscape attributes of the valley will be preserved.

However, the analysis further indicated that crop production will need to be increased more than livestock production, with the intention of balancing the presence of these two activities in the landscape. Accordingly, these activities will have to take into account the productive values of the valley, using agricultural varieties suited to the area. Similarly, to strengthen historical values and the farming character of the valley, GTP analysis proposes to recover, to the extent possible, the ancient herders' paths leading to the Ribalera. In addition, the Landscape dimension (P) of the Ribalera includes values that show how heritage elements (e.g., animal trails) linked the roots of such activities (livestock and crops) in the past.

In general, GTP analysis should be used as an open DSS in which environmental and socioeconomic information and landscape values are aggregated and georeferenced to support management decisions (Volk et al., 2010). In our case, despite the study area's "natural" aptitudes to adapt to forestation, analyzing all landscape dimensions facilitated the consideration of agriculture and factory farm activities that offer great opportunities for economic and social development of the municipality, while revaluing historical aspects of the landscape.

According to our analysis using currently available data, this does not compromise any natural value. Even so, the methodology we used only permitted us to guide the decision process; more in-depth studies are needed to analyze the viability of the proposed landscape transformations. In this sense, it is important to note that the methods used, albeit suitable, do not fully capture the interaction between the systems (G-T-P) analyzed. However, the quantity of multiple networks of interactions between social, natural, and cultural systems (Walker et al., 2006) require a DSS designed to focus on the tools a user group (e.g., HPNP managers) must have to acquire the information they need to implement appropriate actions for different dimensions of the landscape and for the GTP model as a whole.

Despite its usefulness, implementation of the GTP model is very open-ended. Therefore, the resulting decisions, even if well informed, fall back on the expertise of the managers and may omit important processes of participation in making decisions about the landscape (Pedroli et al., 2006). In this sense, future refinements of the GTP model should explicitly incorporate the vision of the communities that occupy each landscape and rely less on evaluation by outsiders, which can have a strong influence on management decisions (Calvo-Iglesias et al., 2006).

Although this application of GTP analysis was strongly multi-criteria, it presents an aggregated and vertical interpretation of the data: it begins with the action to be taken on behalf of the geosystem (G). Even though it may seem to conflict with Landscape Diagnosis Assessment arguments in favor of sustainability and resilience (Bastian et al., 2006), this is because the margin of action and legislation available to natural park administrators is limited to the Geosystem dimension (Figure 3). Therefore, an open DSS framework must consider such constraints in order to avoid large gaps between a DSS designed by researchers and what planners and policy makers actually need (Giuponni et al., 2007; Van Kouwen et al., 2008). However, incorporating different dimensions in this case allowed DSS users to at least consider plausible interactions with other landscape characteristics.

It is important to emphasize the effect of integrating the various data models and the uncertainties of landscape analyses. At the data level, the various work scales normally are related to different research objectives. In our case, while economic and social data are aggregated at the municipal level, data on vegetation and climate are collected regionally and assigning scales of time and space to many of the values identified is difficult to quantify, to say the least. To this amalgam of data at different time and space scales, we must add the different techniques used in the data analysis, transformation, and aggregation required to construct a DSS. Therefore, the fusion of various data models and analyses means that the analysis of uncertainty in decision-making is still a difficult task; fortunately, in the field of ecology these efforts are on the increase (Keenan et al., 2011).

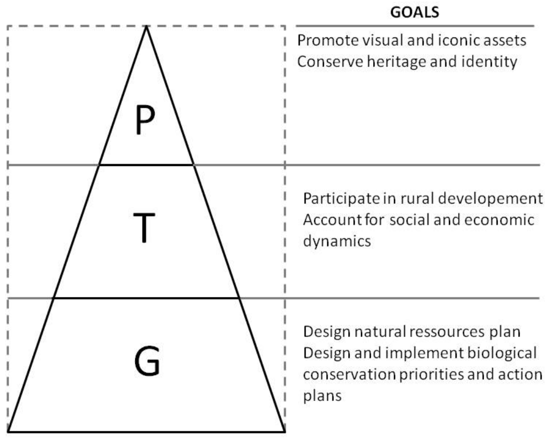

Fig. 3. GTP framework adapted and interpreted for natural reserves in Europe

5. Conclusions

The present study demonstrates the possibility of applying concepts derived from the geographic theory on the design of a structure to decision support for managers of natural parks. We conclude that research on the application of concepts like the GTP model that embrace a global understanding of landscape can assist in DSS design by encouraging global thinking about landscape management. We envision future methodological improvements for integration of data working with very different sources of data and different geographical scales.

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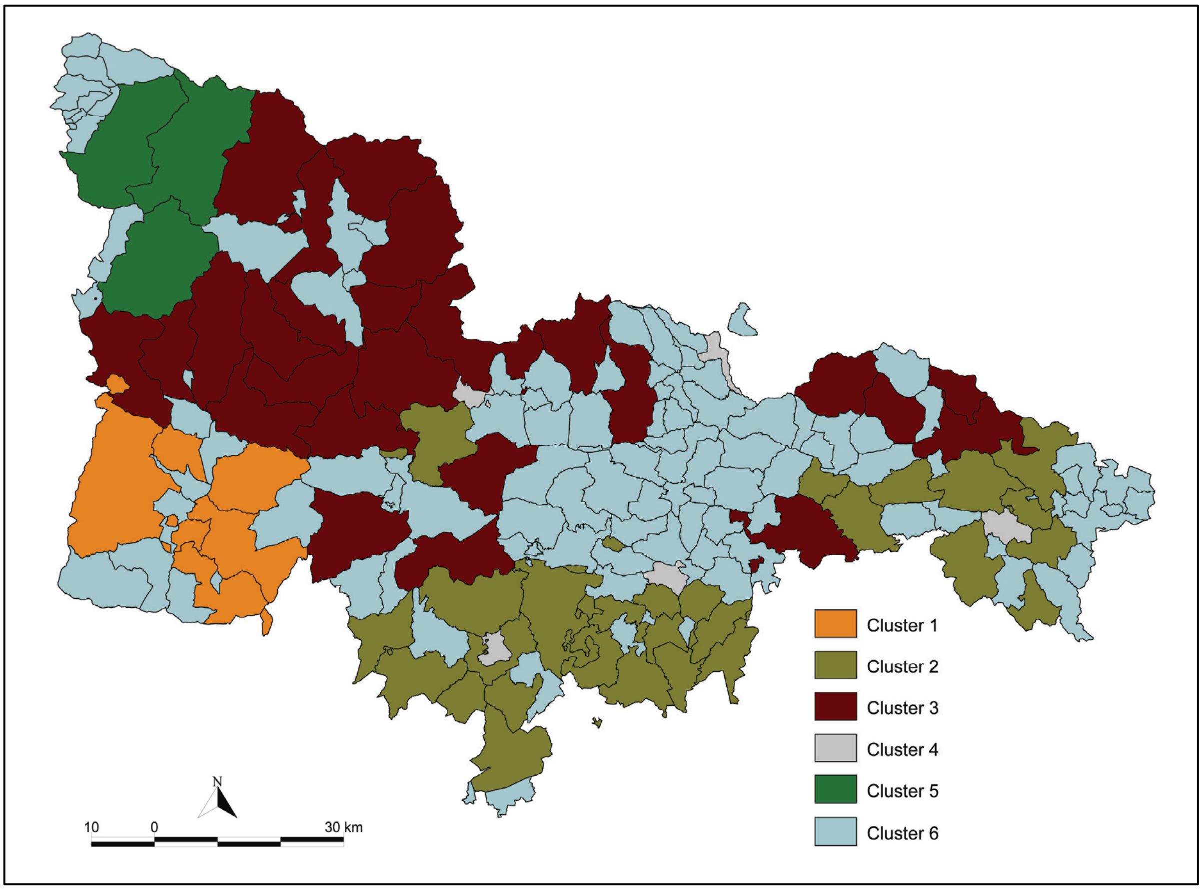
SUPPLEMENTARY MATERIAL 1. List of diferent landscape vàlues identified to characterize P subsystem in the GTP model

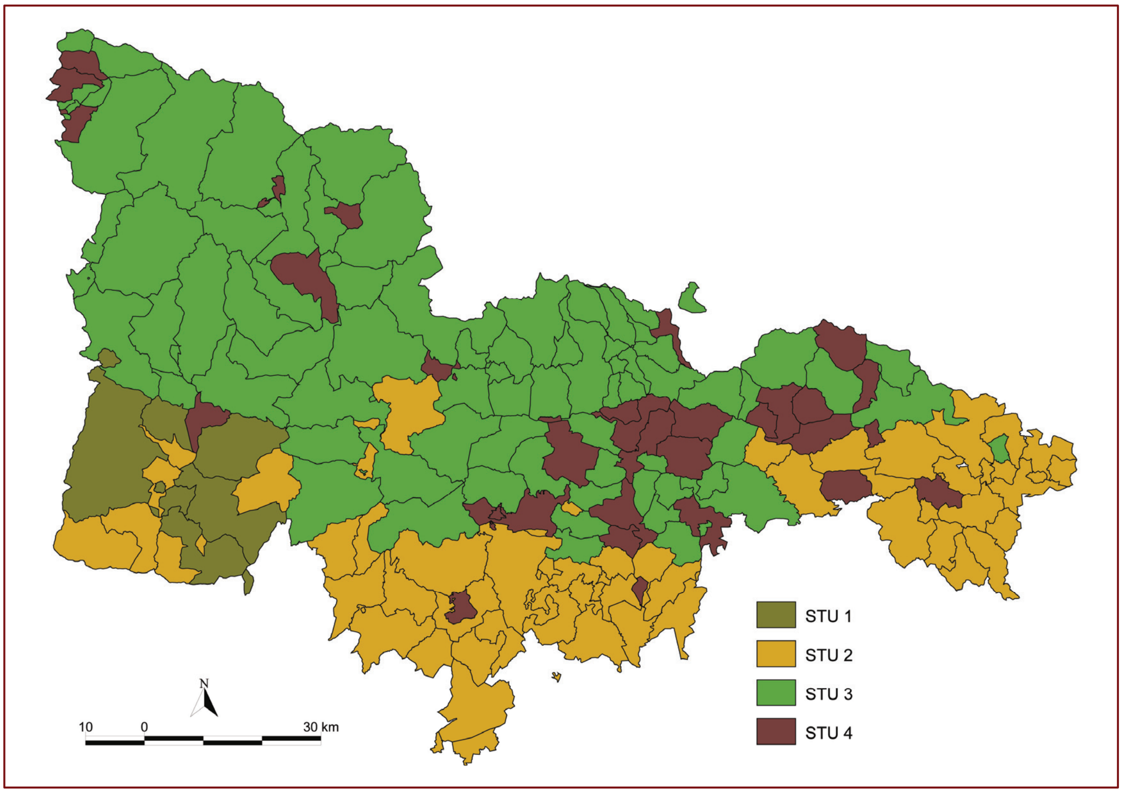
Values	***Main points considered***
1) Natural	Spaces of geological interest, Plan for Spaces of Natural Interest (PEIN), Humid zones and biological corridors
2) Aesthetic	Aesthetic highlights were considered from various standpoints: morphological (reference peaks, well-known scenery, mountain passes); climatic (clouds, blizzards, north winds); agricultural (gardens, cereal grains cultivation, fruit trees, high meadows and pastures) and forests (woods), noting their features (an emblematic dam, an area with shepherds' huts) and the fact that their centers are compact (mid-slope, valley floors, atop a ridge, sunny or under a rock wall). Other aesthetic values identified include the aromatic nature of the vegetation (mown grass, evergreen woods) and livestock. Different historical elements with a strong aesthetic presence (hermitages, medieval bridges, hydroelectric plants, castles, watchtowers, dams, irrigation canals).
3) Historical	Various elements were identified (a castle, medieval bridge, hermitage, church, mine, hydroelectric plant, border trail, rural fairground), lineal structures (Roman road, animal trails, river transport channel, irrigation canal) and scenic sites (*bocage,* civil war sites). Other elements include designated "heritage of humanity" sites, abandoned farm fields, summer pastures, and historic fields. Archaeological heritage was also considered (castles, towers, megaliths, paleontological sites).
4) Social	Areas of leisure enjoyment (fishing rivers, mushroom-hunting woods, and hunting areas), local initiatives for environmental protection, activities related to publicity and information (tourist information, museums, and recreational areas), popular and traditional activities (local festivals, fairs and markets with particular landscape characteristics), and activities related to enjoying and using the landscape (viewing spots, thermal springs, gardens, ski resorts, mountaineering huts, all-terrain bicycle trails, national and natural parks, Alpine and Nordic skiing).
5) Production	Distinctive high-quality agricultural products, tourist services (ski resorts, spas, golf courses, skiable terrain), and some elements associated with the productive capacity of the land (e.g., garden, sawmill, irrigation canal, *bocage, closa cerdana*, pasture, forest products) and water resources such as hydroelectric plants.
6) Symbolic and identity	Some natural symbols are highlighted (peaks, reference points, and local winds such as the *fogony* or blizzard effect and the *torb* or north wind). Knowledge of the territory has also made it possible to identify current symbols (National Park, Heritage of Humanity site) and some symbolic communication axes (border crossings, animal trails, historic river transportation). Religious spaces include hermitages, cathedrals and urban centers that have symbolism and identity because of a bell tower or a particularly elevated location on a ridge. In this group we also placed stories and legends about witches, mythological beings, the military, Moors, *minairons* (goblins), fire festivals, and local sagas or legendary songs, as well as traditional gastronomy: cheeses, and local dishes such as *girella, olha aranesa, patates figols, trinxat de la Cerdanya,* and *xolis*.

SUPLEMENTARY MATERIAL 2. Cluster summary and Distribution of social and econòmic clústers in the geographical region of analysis of the T subsystem (Territory) in the GTP model

	Frequency	***RMS Std Deviation***	***Maximum Distance from Seed to Observation***	***Radius Exceed***	***Nearest cluster***	***Distance between Cluster Centroids***
CLUSTER 1	4	1,4003	7,2725	> Radius	2	7,1752
CLUSTER 2	27	1,4480	10,4379	> Radius	6	3,2638
CLUSTES 3	25	0,7786	5,8635	> Radius	6	3,2863
CLUSTER 4	5	1,8252	13,0014	> Radius	2	9,3521
CLUSTER 5	3	0,8606	3,8592	> Radius	3	9,7155
CLUSTER 6	99	0,6027	12,5236	> Radius	2	3,2638
Pseudo F Statistic			19,77			
Approximate Expected Over-All R-Squared			0,16			
Cubic Clustering Criterion			55,13			

SUPPLEMENTARY MATERIAL 3. Social Territorial Units identified in the geographical region of analysis of the T subsystem in the GTP model





STU 1: Rural municipalities specialized in agriculture and sheep livestock			
Occupied Population		Land use	
Agriculture	439 (8.14%)	Urban areas	226.5 (7.39%)
Industry	307 (1.43%)	Industrial areas	10 (1.37%)
Building	408 (3.76%)	Dry agriculture	27213 (7.63%)
Services	1727 (4.05%)	Irrigated agriculture	1589 (10.33%)
		Pastures	16221 (5.86%)
		Forest	28333 (8.16%)
		Natural Protected Areas	102.22 (0.06%)
Livestock		Territory	
Cattle	1137 (1.14%)	Slope 6º	9374.9 (9.74%)
Sheep	3976 (16.32%)	Slope 6 - 12º	15418.2 (11.62%)
Goats	141(8.57%)	Slope 12 - 24º	28824.1 (8.39%)
Pig	16032 (10.53%)	Slope > 24º	16340.6 (4.20%)
Poultry	2097 (6.06%)	Altitude 30-60 m	9939.6 (10.19%)
Rabbit	14 (1.30%)	Altitude 60-90 m	29107.8 (14.06%)
Equin	22 (0.40%)	Altitude 90-120 m	20199.5 (11.05%)
		Altitude 120-150 m	7773.4 (5.06%)
		Altitude 150-190 m	2864.1 (1.76%)
		Altitude > 190m	204.6 (0.13%)

STU 2: Rural municipalities specialized in stabled livestock (pig. poultry. rabbit)			
Occupied Population		Land use	
Agriculture	2050 (37.33%)	Urban areas	942.6 (30.76%)
Industry	8608 (39.89%)	Industrial areas	366.9 (50.44%)
Building	2566 (23.56%)	Dry agriculture	67891 (19.03%)
Services	10507 (24.48%)	Irrigated agriculture	3471 (22.57%)
		Pastures	28743 (10.37%)
		Forest	113531 (32.71%)
		Natural Protected Areas	573.55 (0.39%)
Livestock		Territory	
Cattle	38374 (38.56%)	Slope 6º	52596.1 (54.62%)
Sheep	7668 (31.48%)	Slope 6 - 12º	55841.1 (42.08%)
Goats	529 (32.14%)	Slope 12 - 24º	93335.2 (27.17%)
Pig	106857 (70.19%)	Slope > 24º	58621.9 (15.06%)
Poultry	28302 (81.76%)	Altitude 30-60 m	79940.7 (81.97%)
Rabbit	792 (73.81%)	Altitude 60-90 m	124046.3 (59.93%)
Equin	912 (16.39%)	Altitude 90-120 m	36979.7 (20.24%)
		Altitude 120-150 m	11202.8 (7.30%)
		Altitude 150-190 m	2414.5 (1.49%)
		Altitude > 190m	77.1 (0.05%)

STU 3: Rural municipalities specialized in pastures and equine. cattle and sheep livestock			
Occupied Population		Land use	
Agriculture	1709 (31.70%)	Urban areas	792.2 (25.85%)
Industry	1830 (8.05%)	Industrial areas	52.2 (7.18%)
Building	2466 (22.72%)	Dry agriculture	235972 (66.13%)
Services	9571 (22.42%)	Irrigated agriculture	8631 (56.13%)
		Pastures	208568 (75.28%)
		Forest	161998 (46.67%)
		Natural Protected Areas	145479.44 (99.34%)
Livestock		Territory	
Cattle	47540 (47.77%)	Slope 6º	24337.9 (25.27%)
Sheep	10391 (42.66%)	Slope 6 - 12º	49822.4 (37.55%)
Goats	635 (38.58%)	Slope 12 - 24º	187556.6 (54.59%)
Pig	16463 (10.81%)	Slope > 24º	269272.7 (69.19%)
Poultry	1848 (5.34%)	Altitude 30-60 m	3064.7 (3.14%)
Rabbit	190 (17.71%)	Altitude 60-90 m	36117.2 (17.45%)
Equin	4155 (74.68%)	Altitude 90-120 m	98130.2 (53.70%)
		Altitude 120-150 m	112441.3 (73.26%)
		Altitude 150-190 m	139979.8 (86.10%)
		Altitude > 190m	147681.4 (93.54%)

STU 4: Urban municipalities specialized in services and industrial sectors			
Occupied Population		Land use	
Agriculture	1199 (22.24%)	Urban areas	1074.6 (35.07%)
Industry	10473 (48.63%)	Industrial areas	283.8 (39.02%)
Building	5419 (49.92%)	Dry agriculture	27217 (7.63%)
Services	20768 (48.66%)	Irrigated agriculture	1567 (10.19%)
		Pastures	25393 (9.17%)
		Forest	40939 (11.79%)
		Natural Protected Areas	257.00 (0.17%)
Livestock		Territory	
Cattle	12775 (12.84%)	Slope 6º	9429.4 (9.79%)
Sheep	2050 (8.42%)	Slope 6 - 12º	11481.1 (8.65%)
Goats	323 (19.62%)	Slope 12 - 24º	34342.1 (10.00%)
Pig	11407 (7.49%)	Slope > 24º	44936.4 (11.55%)
Poultry	2226 (6.43%)	Altitude 30-60 m	4264.3 (4.37%)
Rabbit	103 (9.60%)	Altitude 60-90 m	17879 (8.64%)
Equin	503 (9.04%)	Altitude 90-120 m	25805.8 (14.12%)
		Altitude 120-150 m	22092.6 (14.39%)
		Altitude 150-190 m	19115.3 (11.76%)
		Altitude > 190m	11158.7 (7.07%)