A methodology to Classify Irrigated areas: Application to the central Ebro River Basin in Aragón (Spain).

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Abstract

The large diversity of irrigated agricultural areas hinders the development of social consensus and complicates decision-making about the allocation of investments for irrigation modernization. A classification of irrigated areas permits the identification and mapping of different categories and reveals the strengths and weaknesses of each category regarding specific criteria. This paper proposes a binomial (genus and species) classification methodology of irrigated areas, which was designed based on a participatory approach. Four internal properties determine the genus: type of water source, type of water energy, on-farm irrigation method and water availability. Four external properties classify the variability within each genus into species: land tenure, crop type, existence of an environmental protection figure and socio-economic level. The words used for the genus and specific name arise from the concatenation of syllables representing the state or level of each property. The method was applied to the irrigated area of the Ebro river basin in the Aragón region of Spain (ERB-Aragón). A total of 435,851 hectares were classified. A large part of the irrigated land uses surface water (94%), does not have water availability problems (80%), is not affected by environmental protection figures (97%), is devoted to field crops (86%), and manifests a low (45%) or moderate (41%) socio-economic level. A total of 24 genera and 126 species were identified. The two most representative genera are *SurGraFloVe* (31%) and *SurPumPreVe* (27%), and the two main species are *SurGraFloVe DisCeNoLo* (19%) and *SurPumPreVe ConCeNoMo* (19%). These species received the local names of "*Ribera del Ebro*" and "*Alto Aragonés*" to facilitate policy discussions. The application of the method to the ERB-Aragón provides a privileged insight that can support policy analyses and guide institutional intervention. The proposed methodology can be adapted to other areas of the world by adjusting criteria and categories to local conditions.

Acronyms

AAU:	Aggregated area unit.
BS:	Bardenas irrigation system.
CAP:	Common Agricultural Policy of the European Union.
CAyC:	Canal de Aragón and Cataluña irrigation system.
Ce:	Extensive crop productive orientation (cereal and fodders). Second property defining the specific name.
Ci:	Intensive crop productive orientation (horticultural, fruit orchards, olives and vineyards). Second property defining the specific name.
Con:	Concentrated land structure. First property defining the specific name.
Dis:	Disaggregated land structure. First property defining the specific name.
ERB:	Ebro River Basin.
ERBA:	Ebro River Basin Authority.
ERWP:	Ebro River Water Partnership, a Cooperation Group of the Rural Development Programme of the Government of Aragón (Spain).
Flo:	Flood irrigation, also known as surface irrigation. Third property defining the genus.
GI:	Gross income.
Gra:	Gravity feed water movement. Second property defining the genus.
Gro:	Groundwater resource. First property defining the genus.
GWUA:	General water user association. An irrigation organization composed of several WUAs.

Hi: High level of the socio-economic property of the irrigated areas. Fourth property defining the specific name.

ICU: Irrigation Cartographic Units.

Jun: Conjunctive surface and underground water resources. First property defining the genus.

Lo: Low level of the socio-economic property of the irrigated areas. Fourth property defining the specific name.

MAPA: Spanish Ministry of Agriculture, Fisheries and Food.

Met: Mixture of on-farm irrigation methods, flood and pressurized. Third property defining the genus.

Mo: Moderate level of the socio-economic property of the irrigated areas. Fourth property defining the specific type.

Na: Irrigated area with a special environmental protection strategy. Third property defining the specific type.

NI: Net income.

No: Irrigated area with no special environmental protection strategy. Third property defining the specific type.

Pe: Permanent water availability problems for irrigation. Fourth property defining the genus.

Pump: Pumping is used to move the water. Second property defining the genus.

Pre: Pressurized on-farm irrigation method. Third property defining the genus.

RAA: Riegos del Alto Aragón irrigation system.

SIG-PAC: Spanish Geographic Information System of agricultural plots for use in the Common Agricultural Policy of the European Union.

Sur: Surface water resources. First property defining the genus.

Var: Variable use of gravity and pumping to move the water. Second property defining the genus.

Ve: Eventual water availability problems for irrigation. Fourth property defining the genus.

WUA: Water user association.

WUI: Individual water user.

Introduction

Classification has been defined as the "systematic arrangement in groups or categories according to established criteria" (Merriam-Webster, 2020). Classification can provide quick understanding of the diversity and of the properties present in the complete set. When applied to irrigated areas, classification can help to identify the strengths and weaknesses of each group of irrigated plots in the context of their assessment, organization, rehabilitation or modernization. A number of authors have attempted to classify irrigated areas for different purposes.

Focusing on technical aspects, Khatibi (2003) proposed a classification of irrigation supply systems based on modeling approaches and management factors. These modelling approaches are mathematically expressed as shallow water, kinematic characteristic, hydrodynamic flow conditions, inertial-governed flow, upstream/downstream control and composite commands. Such a classification provides useful information for the management of irrigation infrastructure, but does not provide insight on aspects related to the territory, such as land organization, agronomy, social and economic issues.

Using multiple satellite sensors, an Earth mapping platform and ground truth data, Thenkabail et al. (2009) proposed a comprehensive methodology to classify irrigated areas in 28 classes. Classes 1-10 used surface water, classes 11-15 used groundwater, and classes 16-28 conjunctively used both water sources. The final map labelled classes based on water source, crop intensity (single, double or continuous crop) and crop type (based on the spectral signature).

Results were obtained with low-resolution information, and proved useful to gain insight on very large irrigated areas, such as countries or major river basins. However, this approach lacks the detail required to address the characteristics of the basic units of agricultural water management.

Gómez-Limón et al. (2013) stated that – in order to provide useful information to policy makers – categories need to be based on a full array of variables covering the different dimensions of irrigated agriculture. They defined “aggregated area units” (AAU), the basic-decision-making unit regarding agricultural water management for public policy. In their approach, each AAU was characterized by 32 variables including structural, managerial and cropping aspects. Structural variables included water source, irrigation technology, and farm and plot dimensions. Managerial variables included water use and water pricing. Finally, cropping variables included crop distribution and acreage. The authors performed a Principal Component Analysis on the 32 variables of a set of AAUs. A cluster analysis was finally used to obtain homogeneous groups of AAUs.

Altamirano-Aguilar et al. (2017) proposed a classification of irrigation districts in Mexico. These authors used Principal Components Analysis to cluster the districts based on their climatic characteristics. Finally, clusters were evaluated based on performance indicators related to management, water productivity, economical productivity and environmental issues.

Previous efforts reported in the literature to classify irrigated areas are very well suited to specific purposes, and adapt to the available information and the goal of the classification. The research reported in this paper aims at developing an easy-to-implement methodology that can be applied at regional scale to identify the strengths and weaknesses of different geographical units of agricultural water management. Our goal was to determine through consensus of stakeholders a set of variables that qualify an irrigated area and that have qualitative levels or states.

The need to classify irrigation systems emerged at the meetings of the “Ebro River Water Partnership” (ERWP), a Cooperation Group of the Rural Development Programme of the Government of Aragón (Spain). This initiative is part of the European Innovation Partnership on Sustainable and Productive

Agriculture (EIP Agri). ERWP set out to develop an integrative, socially and technology-rich vision of water use in the Ebro Valley. The initiative focuses on the geographic domain of the region of Aragón, located in the central Ebro valley, and on the main regional water use: irrigated agriculture. ERWP is a multi-stakeholder platform composed (among others) by farmers associations, water users associations (WUAs), agricultural and irrigation specialists, policy makers and researchers.

A key step in the development of the ERWP vision is to set up an inventory of irrigated land. The inventory requires a classification method that can organize the irrigated farmland into categories that can be easily assessed and compared to other local or distant portions of farmland in terms of their natural resources, technology, productive orientation or socioeconomic traits. The required classification method included aspects that could not be found in the literature. A two-step method was devised, with simple, qualitative properties associated to the first step (defining the intrinsic properties of a piece of irrigated farmland), and more analytical properties associated to the second step (focusing on external properties associated to farmland).

Discussions at ERWP permitted to determine the properties that would be used in each step of the classification, and to establish their qualitative levels based on observations, existing cartography or numerical analyses of geo-referenced data. The classification needed to use key hydrological, structural, socio-economic and environmental features of the irrigated areas, since ERWP set out to facilitate the identification of strategic needs and opportunities of the territory.

While the goal was to address the needs of a target region, steps were taken from the beginning to ensure that the proposed classification also represented progress towards a general classification methodology of irrigated farmland. The two-step process facilitates rapid progress in the first step, and requires detailed analyses in the second. A general classification can provide a standard nomenclature of irrigated areas, facilitating the sharing of knowledge and experiences between the different irrigated regions of the world.

Material and Methods

A classification method for irrigated areas

The first step was to define the geographic units that constitute the subject of the classification. Irrigation Cartographic Units (ICU) were used for this purpose and were defined as a polygon containing those irrigated plots with uniformity in terms of administrative, hydrological and farming parameters.

We decided to use a binomial (genus and species) classification. This is the system used in biology to classify living things and generally applied to other purposes. For instance, the Soil Survey Staff (1999) used the categories used in biology to classify soils, from the Order to the Family and the Series. The current version of the Soil Taxonomy System is very rich in categorization, but it does not reach the genus level. The purpose of this research is much simpler in scope, and only uses genus and species to implement a two-step process.

In our classification of irrigated areas, the generic name identifies the genus to which an ICU belongs. Four internal properties were used in this work to determine the genus:

1. Water source.
2. Energy for pumping irrigation water.
3. On-farm irrigation method.
4. Irrigation water scarcity.

These variables are related to the physical aspects of the ICU related to water. Strong structural modifications of the ICU are required to modify them, such as building new water abstraction, pumping and storage facilities or irrigation rehabilitation / modernization activities.

A genus can contain plenty of variability in additional variables. The specific name defines a type of individual (a species) within the genus. In this work, the features separating the variability present in each genus - thus taking the classification to the species level - are four external properties:

1. Structure of the irrigation plots.
2. Crop productive orientation.

3. Environmental protection figure.
4. Socio-economic level.

These variables represent key features of the farming activities performed on the ICU: the structure of the land for irrigated agricultural production, the type of crops being cultivated, the existence of environmental laws affecting irrigation, and a compound assessment of the socioeconomic status of the local communities.

For each of the eight properties used to establish the binomial classification, two or three qualitative levels or states were defined. The choice for two or three was dictated by the possibility of clearly differentiating them (Table 1). In binomial classification systems, genus and species names are often derived from Latin or Greek words. However, for irrigated areas, names were created by concatenation of selected syllables representing the levels of each of the properties. These syllables are marked in bold type in Table 1.

Regarding the properties defining the genus, the source of the water contributes with the first syllable. This property can present three states: irrigation with surface water (Sur), irrigation with groundwater (Gro) and conjunctive water use (Jun).

The source of energy moving water to the farms was divided in three states: gravity (Gra), when the water is gravity-feed and no external energy is applied; pumping (Pum), when water is pressurized in closed piping systems to lift water from the source; and a combination of both (Var, for variable).

Three states of on-farm irrigation methods have been considered for the third genus property: flood irrigation (Flo) representing traditional flood irrigation methods; pressurized irrigation (Pre) representing methods such as sprinkler, microsprinkler and drip; and a combination of the both (Met, for methods). In this work we use the term “flood” to refer to surface irrigation methods. We adopted this name to avoid confusion with surface water.

Combination states Jun, Var and Met are only used if each of the first two states of the property represents more than 30% of the ICU area.

The last property defining the genus is the water scarcity or the water availability level. Two stages were envisaged for this property: eventual (Ve) and permanent (Pe). Permanent water scarcity is associated with continuous or almost continuous problems of water availability for irrigation.

The first external property that defines the species refers to the size of the irrigated plots. This property presents two states: disaggregated (Dis) or concentrated (Con). An ICU is classified as disaggregated when more than 60% of its area is occupied by plots smaller than 5 ha. The 5 ha plot size threshold was proposed in the literature as the minimum size to be accepted in publicly subsidized irrigation modernization projects in the Ebro Valley of Spain (Esquiroz and Puig, 2001). Application of this methodology to other areas of the world would require an adjustment of this criterion, with additional and or different categories.

Two categories were defined for the crop productive orientation of an ICU: extensive crops (Ce) or intensive crops (Ci). The category “extensive crops” corresponds to field crops, such as cereals and fodders. The category “Intensive crops” corresponds to horticultural crops, fruit orchards, olives and vineyards. An ICU has an extensive productive orientation when more than 50% of its area corresponds to field crops.

The affection of an environmental protection figure on the ICU is the third internal property. In Europe, the Natura 2000 network (EEA, 2012) is a special environmental protection strategy commonly affecting irrigated areas. Natura 2000 delineates areas being protected by the Habitats Directive and the Birds Directive. The protection of Nature 2000 does not exclude human economic activity, but any activity needs to integrate with nature conservation. An ICU classifies as environmentally protected (Na) when more than 10 % of its irrigated area is located within one of these protected areas. It also classifies as Na if the complete protected area is included within the ICU. Otherwise, the ICU is classified as not affected by nature preservation figures (No).

The fourth and last property describing the species is the socio-economic level. We used three states for this property: high (Hi), moderate (Mo) and low (Lo). In this classification methodology, socio-economic integrates and expands the restrictive concept of per capita income taking into account other elements or variables that contribute to the quality of life of farmers in the ICU. The socio-economic level has been adapted to the particular conditions of the irrigated areas by using three types of indicators: economic, characteristics of the farming population and land, and characteristics of the total population of irrigated areas.

The selected economic indicator was defined as the average net farm income, expressed in € ha^{-1}, estimated by subtracting production expenses from the gross income. This indicator reflects differences between ICUs derived from the choice of crops, the interaction between natural resources and production technology, the economic objectives and the economic possibilities.

The variables involved in the characterization of the farming population and land include the age of farmers, the percentage of unemployed farmers (derived from Social Security databases), the educational level of farmers, farm size and value of farmland.

The variables used to characterize the demography of an ICU include age, time evolution of population, migration rate, natural growth rate, percentage of young people (less than 15 years old) and population density.

The variables used to characterize socio-economy are numerically diverse and use different units. The first step to reconcile them was to normalize them. The normalization process results in non-dimensional variables and restricts their values to the 0 – 1 range [Eq. 1]. Therefore, all normalized variables have the same weight, giving exactly the same importance to each of them. In the case of variables where a low value is good (e.g., age), the computation applied an inverse rule of three, so that a value of 1 was assigned to the lowest value of the series.

$$X_{new} = \frac{x_i - x_{min}}{x_{max} - x_{min}} \quad \text{[Eq. 1]}$$

The study area: the Ebro River Basin in Aragón

The Ebro river basin (ERB) is located in the north-west of Spain, has a total area of 85,362 km^2 and is drained by the 910 km long Ebro River (Figure 1). Ebro is the largest watershed in Spain, representing 17.3% of the Spanish mainland, and is one of the key European Mediterranean basins. Around 5.3 % of the active population is devoted to agriculture, slightly above the Spanish average (CHE, 2015). The basin has an important agricultural and livestock activity, with around 30% of the national meat production and about 30% of the national production of sweet fruits, fodder and vineyards. The irrigated area in the Ebro basin is 900,623 ha (i.e., 9% of its total area).

As previously discussed, the application of the proposed methodology is restricted to the ERB in Aragón (ERB-Aragón), roughly occupying 50% of the total watershed territory.

The Spanish Geographic Information System of agricultural plots for use in the application of the Common Agricultural Policy of the European Union (SIG-PAC) attributes 477,811 ha of irrigated land. According to the cadaster cartography of the Ministry of the Treasure, the area is 488,943 ha. Finally, the 2004 geodatabase of the Ebro River Basin Authority (ERBA), describes 518,628 ha of irrigated land. Part of the differences in irrigated area between information sources seem associated to the difficulty in keeping the database updated. SIG-PAC is a recent database (2015), and is updated periodically, while the cadaster and the ERBA seem to be only partially updated (changes in declared irrigated plots), and infrequently.

The geographical delimitation of the ICUs requires overlapping the cartography of irrigated land with the cartography of administrative concessions of the ERBA. The ERBA has a census of water rights with a thousand records related to irrigation. Data include the location (municipality) of the administrative bureau of the concessionaire. Attending to its organization, some ICUs represent Water User Associations, while others represent individual irrigation developments, Individual Water Users (WUIs). The latter correspond to holdings in which a WUA has not been created, but which are legally registered as farms belonging to individual water users.

The ERBA provides cartography of the delimitation of WUAs / WUIs, and a census of water use rights. The overlap of these two databases shows important differences due to the lack of effective updating. Differences were also found when combining ERBA information with the SIG-PAC geodatabase. The final delimitation of ICUs required and intensive labor of validation with different data sources and ground truth data.

Classifying the genus

Different procedures were used to obtain the data required to determine the values of the four properties defining the genus.

The water source was obtained from the ERBA database, where the origin of water is classified as surface, groundwater and mixed areas. Water source for ICUs not available at the ERBA database was obtained using other public data sources (cartography of soil geomorphology).

The source of energy to pump the water was also available at the ERBA geodatabase. This information was completed using the expertise of ERWP members. For instance, all recent irrigation developments at the central Ebro basin are water supplied from the Mequinenza reservoir using pump stations.

The on-farm irrigation system was obtained from the anonymized database of applications to the CAP subsidies. Every year farmers submit an application, detailing for each plot if it is irrigated or not, the on-farm irrigation method (flood, sprinkler, drip and others) and the type of crop, among other data. These records were not complete for each plot. For instance, the on-farm irrigation method was not declared in 14% of the plots. Missing information was extrapolated from existing data.

CAP applications present the information in tables without geographical representation. Plots were georeferenced using a common field in the application and in the SIG-PAC Geographic Information System: the plot identification code. Further, it was necessary to identify the ICU where the plot is included. This was done by overlapping the georeferenced plots with the ICUs geodatabase, leading to the determination of the on-farm irrigation methods present in each ICU.

Differences in water availability between the left and right banks of the river basin in Aragón are important. The main tributaries in the left bank of the river Ebro flow from the central Pyrenees and discharge large amounts of water to Ebro, particularly in spring. The tributaries in the right bank flow from the Iberian

System, and are characterized by variable flow with frequent shortages, particularly during the summer season. This information was combined with the experience of ERWP members to establish the water availability problems of each ICU.

Classifying the species

Plot size was determined from the SIG-PAC 2015 map of the irrigated plots. The percentage of ICU area corresponding to plots smaller than 5 ha was defined for each ICU.

The crop productive orientation was obtained in the same way as the on-farm irrigation method by combining the SIG-PAC map with the CAP application database (which includes the crop type). In the last step, results were overlaid with the ICU map.

The cartography of the areas belonging to the Natura 2000 Network was used to determine the ICUs with environmental protection figures. This information was downloaded from the Government of Aragon webpage and overlaid with the ICU map.

The socio-economic level of the ICU was described through net income, the characteristics of the farming population and farm land and the characteristics of the general population of the irrigated areas.

The net income (NI) was calculated discounting the production expenses from the gross crop income (GI). The acreage, the crop, and its average yield and market price are required for gross income determination. The acreage and the crop were obtained from the SIG-PAC 2015 geodatabase. Crop yields were obtained from the public databases of the Government of Aragon and the Spanish Ministry of Agriculture, Fisheries and Food (ESYRCE, 2015). In these databases, crop yields depend on the agroclimatic zones and on the water regime (dryland or irrigated land). However, yield estimates were not provided for different on-farm irrigation methods. Numerous research and technical works have highlighted the increase in field crop yield following modernization from flood to sprinkler irrigation (Playán and Mateos, 2006; Faci et al., 2010), and from flood to drip irrigation in fruit orchards, olives and vineyards (Assaf et al., 1984;

Rzekanowski and Rolbiecki, 2000; Liu et al., 2019). Modernization has also intensified farming by promoting double cropping of field crops in the same season (Stambouli et al, 2014; Jiménez-Aguirre and Isidoro, 2018). The increase and stabilization in crop yield have been attributed to the reduction of abiotic stresses. We resorted to scientific literature to introduce crop yield differences between on-farm irrigation methods

Crop prices were obtained from local markets of agricultural products (Lonja del Ebro, 2019). The average of all plots integrating an ICU provided the value of GI. Although income data change slightly from year to year (crop area, market price and average yield), the averaging and normalization processes provide stability to the socio-economic classification of the ICUs.

Production expenses included direct costs and the payback of the investment on irrigation modernization. Direct costs were obtained from a public local database (ECREA, 2015) which provides cost estimates for different crops and cropping conditions (such as dryland and irrigated). Since the available data did not reflect differences in costs between the different irrigation methods, specific costs were added. For pressurized methods with pumping requirements, estimates of seasonal electricity costs were incorporated. For flood irrigation, estimates of the labor costs of the irrigation activity were included.

A distinction was made between the electricity costs of pressurizing surface water and groundwater. Four levels were established depending on the elevation to be overcome, from 0.25 kWh m^{-3} (for the surface water, Stambouli et al., 2014) to 1.15 kWh m^{-3} for the deeper watertable (Narvarte, 2018). The unit electricity cost was assumed constant at 0.09 € kWh^{-1}. Electricity cost was applied to the total area of the ICUs classified as Pumping (Pum) and to the pumping area of ICUs classified as variety of energy sources (Var).

The seasonal volume of irrigation water applied to each plot was estimated from crop water requirements and the irrigation system efficiency. Crop water requirements were obtained from the public local database of the Irrigation Advisory Service in Aragón (SIAR, 2019), which provides data from different agrometeorological stations located throughout the study area. Irrigation efficiency estimates for the different on-farm irrigation methods were obtained from the literature: 60% for flood irrigation (Playán et al., 2000), 80% for sprinkler irrigation (Hanson et al., 1996) and 90% for drip irrigation (Burt, 2004).

The labor cost of irrigation activity was only applied to flood irrigation, owing to the usual automation of pressurized irrigation methods. Costs differed with plot size: for disaggregate land tenure a value of 4 h ha^{-1} and irrigation event was used; for concentrated land tenure a value of 3 h ha^{-1} and irrigation event was applied. Further, an approximate water application of 1,000 m^3 ha^{-1} per flood irrigation event and a labor cost of 6 € h^{-1} were used to estimate seasonal costs.

The last step was to estimate the annual payback of irrigation modernization investments. Modernization plans were implemented in the target area at the national and regional levels. The total investment cost and the part supported by the farmers was obtained for each WUA (Zapata and Lorenzo, 2020). The following economic conditions were used for the loans subscribed by the WUAs: fixed annual payment, 25-year payback period and a fixed annual interest rate of 5.25%.

Total costs (direct costs, irrigation costs and irrigation modernization payback) were deducted from GI to estimate seasonal NI (€ ha^{-1}) for each ICU. The limits differencing the socio-economic level were established based on the local minimum and maximum values.

The farming characteristics and population specific variables were available from public sources at the municipal level. Farming land and farming population characteristics were obtained from the Department of Agriculture, Livestock and Environment of the Government of Aragón (DAGMA-GA, 2019). General population variables were obtained from the Synthetic Index of Territorial Development of Aragón (ISDT, BOA 2019), providing normalized values of the selected variable per municipality. Since an ICU can belong to one or several municipalities, the indicators values were determined as a weighted average, using the influence area of each municipality.

Results and discussion

Irrigation Cartographic Units in the ERB-Aragón

The processing of the different data sources (SIG-PAC, Cadaster and ERBA) in different formats resulted in the delimitation of 729 ICUs (641 WUAs and 88 WUIs, as seen in Figure 1). The area classified in ICUs amounts to 435,851 ha, 95% (414,841 ha) of which is organized in WUAs, while the remaining 5% (21,010 ha) belongs to WUIs. According to the analyses, 8% of the total irrigated area is not delimited in ICUs. The small size and dispersion of the plots or the lack of a legal registration at the ERBA census made it impossible to assign an administrative figure to these plots and to group them in ICUs.

One of the characteristics of the ERB-Aragón is that a large part of the WUAs belong to a higher organization figure called "General Water Users Association" (GWUA). This is the case of Riegos del Alto Aragón (RAA), Bardenas System (BS), Aragón and Cataluña Canal (CAyC), Aragón Imperial Canal, Tauste Canal and Lodosa Canal (Figure 2). GWUAs derive from large irrigation projects usually developed by the Spanish Government and representing 67 % of the target irrigated area. The first three GWUAs (RAA, Bardenas and CAyC) were built in the first half of the 20th century, have strong capacities in collective infrastructure management and enforce water conservation practices. The WUA and GWUA organizations also predispose to cooperation and mutual assistance, boosting economic growth and development (Gómez-Limón et al., 2014; Miao et al., 2018). The Aragón Imperial Canal, Tauste Canal and Lodosa Canal are ancient GWUAs (established before the 20th century), are located in the axis of the Ebro River and are not as active as the first three. GWUAs provide legal support to farmers and establish direct communication with the ERBA. Small irrigation projects (33% of the irrigated area) generally correspond to WUAs irrigated by ancient riparian canals located on the alluvial terraces of the Ebro River and its tributaries. These are characterized by relatively low water and infrastructure management standards.

The average size of the WUAs is 602 ha, showing an important variability (the coefficient of variation was 47%). The number of small WUAs (less than 500 ha) is very high (471), although they only represent 14% of the total ICU area. The

76 WUIs below 500 ha are also the most numerous, but they only represent 2% of the total ICU area. As the size of the ICUs increases, their number decreases. The 61 WUAs with an area between 1,500 and 5,000 ha represent 38% of the total area. The 14 ICUs with an area exceeding 5,000 ha are only of the WUA type, and represent 23% of the total area.

Analysis of genus in the ERB-Aragón

Table 2 presents the number and area of ICUs, WUAs and WUIs classified on the levels defining the four fixed properties of the genus for the ERB-Aragón irrigated area. Due to the characteristics of the ERB-Aragón, it was necessary to consider the three levels for the properties energy source and on-farm irrigation method (Table 1).

Most of the irrigated land in the ERB-Aragón uses surface water (94%), while groundwater use (6%) is limited to very specific areas of the right bank of the river (Figure 3a).

About half of the irrigated area uses gravity-fed water (52%, or 228,484 ha), about one-third uses pumped water (36%, or 155,127 ha) and the remaining 12% (12,239 ha) uses a mixture of gravity-fed and pumping water (Table 2 and Figure 3b). Regarding the on-farm irrigation method, 47% of the area (205,818 ha) uses flood irrigation, 46% (198,240 ha) uses a pressurized method and 7% (31,793 ha) uses a variety of methods (Table 2 and Figure 3c).

In general, flood irrigation uses gravity-fed water, while pressurized irrigation methods use pumped water. As a relevant exception to this rule, some ICUs using pressurized irrigation methods do not require pumping, since pressure due to elevation difference is sufficient to operate the irrigation systems. This represents approximately 9% of the area.

At the end of the 20th century, 70% of the irrigated land of the ERB-Aragón was flood irrigated. After the intense modernization process of the first two decades of the 21st century, this area was reduced to 47%. In any case, flood irrigation is more used in ERB-Aragón than in Spain (24%) (ESYRCE, 2018). The flood-irrigated area is commonly located on the alluvial terraces of the Ebro River and its tributaries (small irrigation projects and ancient GWUAs, Figure 2). Flood irrigation can also be found in areas located far from the riverbanks, such as in some WUAs of the GWUA of RAA and BS.

The degree of water availability problems for irrigation is eventual in 80% of the area (350,402 ha), while the remaining 20% (85,448 ha) has permanent water availability problems (Figure 3d). The ICUs located on the left bank of the basin and in the Ebro River alluvial terraces were assigned eventual irrigation water availability problems since water shortages are not frequent in these areas. The ICUs located on the right bank were assigned permanent water scarcity since they frequently present problems of water availability. This simplification does not take into consideration structural aspects, such as low storage capacity, conveyance problems or low on-farm application efficiency. A more detailed analysis would be required to characterize how the structural traits of each ICU interact with local irrigation water availability.

Figure 4 presents the ICUs of the ERB-Aragón classified at the genus level. Only the eight genera with irrigated area representation larger than 2% are individually presented on the map. The rest of genera, up to a total of 24 in the ERB-Aragon, were grouped and presented as "Other Genera" in the map legend. The main traits of the first two genera in the figure legend are as follows:

- The main genus, *SurGraFloVe* (136,569 ha, 148 ICUs or 31.3% of the irrigated area), is characterized by using surface water pressurized by gravity to perform flood irrigation in areas with eventual water availability problems. This genus is located on the alluvial terraces of the Ebro river and some tributaries, a large part of the ancient GWUAs (Aragón Imperial Canal, Tauste Canal and Lodosa Canal) and also in some WUAs of the GWUA of RAA (26,076 ha) and BS (50,374 ha).
- The second genus by area is *SurPumPreVe* (118,891 ha, 104 ICUs, 27.3% of the irrigated area). This genus uses surface water, requires pumping to use pressurized on-farm irrigation methods and only has eventual water availability problems. This genus is located in RAA and CAyC GWUAs, and in irrigation developments at the central Ebro basin. *SurPumPreVe* genus has been the main beneficiary of the modernization projects of the 21st century.

Analysis of species in the ERB-Aragón

Land structure is the first property defining the specificity of a genus. In the ERB-Aragón 59.4% of the land is disaggregated, while 40.6% is concentrated (Table 3). The average area of a concentrated ICU (1,295 ha) is more than three times that of a disaggregated ICU. The ICUs classified as concentrated are located in the RAA and BS WUAs, and to a lesser extent in CAyC (Figure 5a). Disaggregated ICUs are located on the riverbanks of the Ebro and some of its tributaries (Gállego, Jalón and Aragón), and correspond to the oldest local irrigation systems (Figure 5a).

Field crops (Ce) are grown in 86% of the total irrigated area. The remaining 14% is occupied with intensive crops (horticulture, orchards, olives and vineyards) (Table 3). The ICUs with intensive crops are, on average, smaller than the ICUs with extensive crops (309 ha vs. 710 ha). Intensive crops are mainly located in CAyC, in the Jalón river valley and in the recent irrigation developments at the central Ebro basin around the Mequinenza reservoir (Figure 5b).

The total irrigated area with environmental protection is 11,131 ha (2.6%). However, given the small percentage needed to have an ICU classified as protected, 140 ICUs fall in this category. Figure 5c presents the spatial distribution of ICUs with (Na) and without (No) environmental protection. Protected ICUs are generally small (average area of 216 ha) and are either located on the boundaries of protected areas, such as the axes of the Ebro, Cinca and Alcanadre rivers, or contain protected lagoons (Sariñena) or playa lakes (Gallocanta).

The first step to characterize the socio-economic level was to compute the gross income. The values of GI were arranged in three levels: lower than 1,500 € ha^{-1}, between 1,500 and 2,500 € ha^{-1} and larger than 2,500 € ha^{-1} (Figure 5c). The ICUs with lower GI are all flood-irrigated and grow extensive crops. The ICUs with intermediate GI are, in general, WUAs with pressurized irrigation methods and with extensive crop orientation, and some flood irrigated ICUs located on the banks of the Ebro and Gállego rivers with extensive crop orientation and a considerable area devoted to horticultural crops (Figure 5c). The ICUs with the largest gross income correspond to areas with intensive crop and some WUAs with extensive orientation and on-farm pressurized methods that have a considerable area cropped with intensive crops. Intensive crops imply certain direct costs (particularly labor), but also provide potentially large incomes. Among the ICUs with extensive crop productive orientation, those using pressurized irrigation methods had larger gross income than those irrigated by flooding. Irrigation technology resulted in reduced abiotic stresses.

Figure 6b presents the results of the net margin per ICU, organized in three levels: low (lower than 700 € ha^{-1}), moderate (between 700 and 1,500 € ha^{-1}) and high (larger than 1,500 € ha^{-1}). In general, flood irrigation is associated with the lowest net margin, while pressurized irrigation for extensive crops shows moderate net margin, while pressurized irrigation for intensive crops (particularly fruit orchards) shows the highest net margin. ICUs with high net margin represent 15% of the ERB-Aragón irrigated area (65,188 ha, 108 UCRs), moderate net margin 40% (173,219 ha, 214 ICUs) and low-income ICUs account for 45% of the total irrigated area (197,063 ha, 407 UCRs).

The economic indicator only considers the income of the agricultural irrigation production, omitting other economic activities taking place in or around irrigated areas, such as livestock farming or agribusiness. Modern irrigated areas typically have a dependable water supply and adequate rural roads. This is fostering the installation of intensive livestock farms and agro-industrial plants. These effects have not been evaluated in this research, but their consideration will reinforce the traits observed in the socio-economic classification.

The second indicator that integrates the definition of the socio-economic property describes characteristics of the farming land and the farming population. Municipalities close to large urban areas (i.e. Zaragoza, Huesca, Barbastro and Fraga) have very high farmland prices compared with neighborhood municipalities. This is due to land speculation for activities other than farming. This variable should therefore be cautiously analyzed to avoid disturbances in the classification.

Only nine ICUs have a percentage of young farmers (less than 35 years old) larger than 20%, in the rest of ICUs young farmers have a lower representation, highlighting the significant ageing of the local farming population. The educational level of the farmers is in general low (only 8% having completed professional training or university education). ICUs with the highest share of young farmers, least farming unemployment (below 5%) and highest educational level (from 10 to 25 % of the farmers) are located in RAA and CAyC systems. These areas have the highest irrigation technology levels, improving farmers' quality of life and facilitating generational replacement. The most aged farmers can be found in areas with high farming unemployment (above 15%) and the lowest educational level (less than 5% of the farmers). These areas are located in ICUs located in the riverbanks of the Ebro and other tributaries.

The farming land and population indicator integrates the abovementioned variables, and is organized in three levels: low, moderate and high (Figure 6b).

The demographic indicator was available at municipal level and integrates data from the different economic sectors of the municipality (ISDT, 2019). Figure 6c presents the distribution of the population indicator arranged in three levels, low, moderate and high. High values of the indicator could be found around large urban areas (Zaragoza, Huesca, Fraga and Monzón), presenting the largest increments in population, positive migration rates, youngest population and the highest population density. This pattern is associated with the provision of social services (health and education) and with the presence of industrial sites. Hospitals, Universities and other social services are mainly found in urban areas. The lowest values of the population indicator are located in some WUAs of RAA and the WUAs of the right side of the Ebro river basin.

Consideration of the maps of the three indicators led the ERWP to use an equation giving different weights to the three variables. Stakeholders gave the largest weigh to the economic indicator, an intermediate weight to the farming indicator and a low weight to the demographic indicator. For example, an ICU with high economic indicator (net income), but with very low farming and population indicators resulted in a moderate socio-economic level; an ICU with low economic indicator but very high farming and population indicators resulted in a moderate socio-economic level.

Figure 6d presents the spatial distribution of the socio-economic indicator (three levels) for the different ICUs of the ERB-Aragón. The ICUs with low socio-economic level (197,970 ha, 412 ICUs and 359 WUAs, Table 3) mostly correspond to flood irrigated areas located in the alluvial riverbanks of the Ebro and other tributaries. The high socio-economic level (57,661 ha, 60 ICUs and 52 WUAs, Table 3) corresponds to ICUs with a productive orientation of intensive crops, mostly fruit trees. The moderate socio-economic level (180,219 ha, 257 UCRs and 230 WUAs) corresponds to pressurized irrigated areas with a productive orientation of extensive crops.

The application of the abovementioned properties to the ERB-Aragón ICUs resulted in 23 specific names. The seven specific names with the highest surface representativeness occupied 87% of the total area: *ConCeNoMo* (27.7%), *DisCeNoLo* (26.9%), *ConCeNoLo* (13.7%), *DisCeNoMo* (7.4%), *ConCeNoHi* (5%), *DisCiNoHi* (4.3%) and *DisCiNoLo* (2.6%) (Figure 7). The remaining 16 specific names had individual areas below 2% and together represented 13% of the area (see "Other specific" in Figure 7). The most extended specific name had concentrated plot structure (*ConCeNoMo*), while the second in importance had disaggregated plot structure (*DisCeNoLo*). Together, both specific names represent more than 50% of the total irrigated area in ERB-Aragon. The concentrated specific name has a moderate socio-economic level, while the disaggregated specific name has a low socio-economic level. Both have a productive orientation based on extensive crops (Ce) and are not affected by environmental protection figures (No).

The combination of genera and specific names resulted in 126 different species. Only eight of them have a representation above 2% in area, and jointly represent 63% of the total area. Figure 8 presents the most important species of the seven important genera of the ERB-Aragón, representing 89% of the total irrigated area. The main traits of the first two species in the Figure legend are as follows:

- The most extended genus, *SurGraFloVe*, has two key specific names: *DisCeNoLo* (19%) and *ConCeNoLo* (9.6%). The first species (*SurGraFloVe DisCeNoLo*) corresponds to the oldest traditional irrigated ICUs of the Ebro and tributaries riverbanks. The second species only differs in the plot structure, and corresponds to systems developed by Governmental initiative (National Colonization Institute) in the first half of the 20th century, so it was assigned the local name *Colonización* (equivalent to *SurGraFloVe ConCeNoRe*).

- The second genus, *SurPumPreVe*, has three principal specific names: *ConCeNoMo* (18.7%) *ConCeNoLo* (2.1%) and *ConCeNaMo* (1.3%). The first and third species correspond to recently modernized areas located in WUAs of RAA. The first species was assigned the local name *Alto Aragonés* (equivament to *SurPumPreVe ConCeNoMo*), while the specific *CoCenNaMo* (including an environmental protection figure, such as the areas surrounding the Sariñena lagoon), was assigned the local name *Sariñena* (equivament to *SurPumPreVe ConCeNaMo*). The second species in importance within this genus corresponds to pressurized irrigations that abstract water directly from the Ebro River and pump to high areas with a predominance of extensive crops. A characteristic WUA of this type is Loma de Quinto, leading to the local name of this species *Loma de Quinto* (equivalent to *SurPumPreVe ConCeNoLo*).

From classification to strategic needs and opportunities

Key features of the different species of the ERB-Aragón were revealed by the classification process. These provide nuanced insight on the irrigated systems that can support policy analyses and guide institutional intervention.

Species *Ribera del Ebro* (84,086 ha, 19%) and *Tarazona* (16,033 ha, 3.7%) are threatened by farmers' ageing and low educational level, a decline in WUAs organization, obsolete infrastructure, low-income production model, fragmentation of property and proximity to large urban areas. In the second species, the situation is more complex due to permanent water availability problems. These species have been the basis of local food security for centuries, and have environmental and heritage importance. They provide a number of ecosystem services and nature-based solutions, such as protection against flooding, support to biodiversity, interface with aquatic ecosystems and spaces of social recreation. Although these services increase the positive externalities in different rural socio-ecological contexts (Masseroni et al., 2017), it is difficult for farmers to take advantage of them when the economic model is not profitable.

The eventual valuation of the ecosystem services externalities could boost societal interest of maintaining these irrigated areas and guide the allocation of public subsidies for irrigation modernization that are compatible with the positive externalities. Solutions that have been successful for other species such as *Colonización*, based on replacing traditional flooding by pressurized methods, may not be adequate for these species. Masseroni et al. (2017) proposed technical solutions such as targeted rehabilitation measures based on the integrated use of decision support services, gate automation, remote and feedback controls and real-time flow optimization. Although a technical solution is required, the major challenge is to integrate the environmental issues and the social dimension (farmers and other stakeholders); otherwise, a solution will not present itself.

Additionally, the species affected by permanent water availability problems should have a strong WUA organization with very active water management measures. The objective is to harmonize water availability with water consumption. Controls on maximum crop evapotranspiration and water allocation to plots and farmers seem to be required. Additionally, these WUAs need to focus on crops that can lead to moderate to high income with low water requirements, or to crops in which income is not critically affected by water availability.

The dominance of extensive crops (wheat, barley, corn and alfalfa) of the ERB-Aragón ICUs is a significant weakness in the current context of decreasing water availability. The strong dependence on volatile cereal markets (commodities with a track record of low prices) result in irrigated areas with low biodiversity and compromised economic balance. Introducing new crops in ICUs with extensive crops will improve the sustainability of irrigation. This is not an easy solution, because the economic, technical and social requirements for extensive cropping are completely different from those of intensive crops. The on-going automation of tedious and time-consuming farming tasks (such as pruning or planting) is providing opportunities for crop restructuring.

Conclusions

The methodology proposed in this research to classify irrigated areas uses a binomial structure (genus and species). The properties defining the genus and species and its levels were supported and validated by a multi-stakeholder platform. The first challenge of the classification was to define the geographic units (ICU) that constitute the subject of the classification. The ICU definition was adapted to local conditions, data availability and target of the classification. Data limitations arose when applying the methodology to the irrigated area of the Ebro River Basin in Aragón (ERB-Aragón).

The total classified area, 435,851 ha, is organized in 729 ICUs, 641 water users' associations (WUAs, 95% of the total area) and 88 private irrigators (WUIs, 5%).

Among the strengths of the ERB-Aragón irrigated areas:

1) Sufficient surface water resources to irrigate 94% of the area;
2) Few problems of water availability for irrigation (20% of the area);
3) Only 2.6% of the area is affected by environmental protection figures; and,
4) Strong leadership of the WUAs, providing solid capacities in collective infrastructure and water management (66% of the irrigated area is organized in General WUAs).

Among the weaknesses of the ERB-Aragón irrigated areas:

1) Moderate energetic dependence (more than 36% of the irrigated area requires water pumping);
2) Moderate irrigation technological development: only 45% have pressurized (and automated) on-farm methods;
3) Disaggregated land structure (59.6% of the irrigated land is in plots smaller than 5 ha);
4) Low crop diversity (86% of the area is devoted to extensive crops);
5) Aging and low educational level of the farmer population; and,
6) Low or moderate (45% and 41% of the total area, respectively) socio-economic level.

A total of 24 genera and 126 species were identified in the study area. Eight genera covered 91.4% of the ERB-Aragón irrigated area, and eight species covered 63% of the ERB-Aragón. Among them, the two most representative genera are *SurGraFloVe* (31.3%) and *SurPumPreVe* (27.3%). The two most common species are *SurGraFloVe DisCeNoLo* (19.0%) and *SurPumPreVe ConCeNoMo* (18.7%)

The method applied to the ERB-Aragón identified and mapped the different irrigated areas with specific key features and intervention requirements. Results can be used to support policy analyses and guide decision-making for institutional interventions.

The proposed methodology can be adapted to other areas of the world, adjusting criteria and categories to local conditions.

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Tables

Table 1. *Properties defining the genus (based on fixed or internal properties) and species (based on variable or external properties) of the Irrigation Cartographic Units. For each of them, two or three qualitative states ore levels are presented, the third being a mixture of the previous two. Finally, for each state or level the syllables that allow composing the genus name and the species name are presented.*

Table 2. *Number and area of WUAs, WUIs and ICUs of the different properties and states or levels defining the genus of the irrigated areas.*

Table 3. *Number and area of WUAs, WUIs and ICUs of the different properties and states or levels defining the species of the irrigated areas.*

Figures

Figure 1 *Location of the Ebro river basin (black line) and the Autonomous Region of Aragón (grey shadow) in the Iberian Peninsula map. The irrigated area by SIG-PAC 2015 and the ICUs of the Ebro River Basin in Aragón are presented in the map. ICUs represent either Water Users Associations (WUAs) or Individual Water Users (WUIs).*

Figure 2*. General Water Users Associations (GWUAs) of the Ebro River Basin in Aragón.*

Figure 3*. Classification of the state of the four properties defining the genus of the ICUs at the ERB-Aragón irrigated areas: a) Surface or Underground water source; b) Gravity, pumping or a variety of energy sources moving the water; c) Flood, pressurized or a mixture of on-farm irrigation methods; and d) Permanent or eventual water scarcity level for irrigation.*

Figure 4*. Classification map of genera in the ERB-Aragón. The genus name responds to the concatenation of selected syllables representing the state of each of the four internal properties (water source, energy source, on-farm irrigation method and level of water scarcity).*

Figure 5. *State or level of the first three properties defining the species of the irrigated areas of the ERB-Aragón: a) Disaggregated or concentrated land structure of the irrigated plots; b) Extensive or intensive crop productive orientation; c) Protected or not protected by an environmental protection figure. Subfigure d) presents the Gross margin of the ICUs arranged in three levels, high, moderate and low.*

Figure 6. *Variables defining the socio-economic level of the ICUs: a) Economic (Net farm margin); b) Farming population and land indicator; c) Population indicator; and d) Socio-economic level of the irrigated areas. Variables are presented in three levels: high, moderate and low.*

Figure 7. *Classification map of the ERB-Aragón specific names. The specific name is formed by concatenation of selected syllables representing the levels of each of the four external properties.*

Figure 8. *Classification map of the species in the ERB-Aragón. The name of the species responds to the concatenation of selected syllables representing the levels of each of the properties defining the genus and the specific names. Local names attributed to several species have been included in the legend.*

Table 1. *Properties defining the genus (based on fixed or internal properties) and species (based on variable or external properties) of the Irrigation Cartographic Units. For each of them, two or three qualitative states ore levels are presented, the third being a mixture of the previous two. Finally, for each state or level the syllables that allow composing the genus name and the species name are presented.*

Properties		States or levels			Name		
		I	II	III	I	II	III
Genus	Water source	**Sur**face	**Gro**undwater	Con**jun**ctive	**Sur**	**Gro**	**Jun**
	Energy moves water	**Gra**vity	**Pum**ping	**Var**iety energies	**Gra**	**Pum**	**Var**
	On-farm irrigation method	**Flo**od	**Pre**ssurized	Several **Met**hods	**Flo**	**Pre**	**Met**
	Water scarcity for irrigation	E**ve**ntual	**Pe**rmanent		**Ve**	**Pe**	
Species	Structure of the irrigation plots	**Dis**aggregated	**Con**centrated		**Dis**	**Con**	
	Crop productive orientation	**E**xtensive **c**rop	**I**ntensive **C**rop		**Ce**	**Ci**	
	Environmental protection figure	**No**	**Na**tura		**No**	**Na**	
	Socio-economic level	**Hi**gh	**Lo**w	**Mo**derate	**Hi**	**Lo**	**Mo**

Table 2. *Number and area of WUAs, WUIs and ICUs of the different properties and states or levels defining the genus of the irrigated areas.*

Genus properties	States ore levels	Number			Area (ha)		
		WUAs	WUIs	ICUs	WUAs	WUIs	ICUs
Water source	Surface	610	62	672	397,878	10,814	408,691
	Groundwater	31	26	57	16,963	10,196	27,159
Energy applied to water	Gravity	427	33	460	227,256	1,229	228,484
	Pumping	144	47	191	136,494	18,634	155,127
	Varied	70	8	78	51,092	1,147	52,239
On-farm irrigation method	Flood	425	53	478	200,112	5,706	205,818
	Pressurized	170	30	200	183,727	14,513	198,240
	Several Methods	46	5	51	31,002	791	31,793
Water scarcity for irrigation	Permanent	324	52	376	74,354	11,094	85,448
	Eventual	317	36	353	340,487	9,916	350,402

Table 3. *Number and area of WUAs, WUIs and ICUs of the different properties and states or levels defining the species of the irrigated areas.*

Species properties	States or levels	Number			Area (ha)		
		WUAs	WUIs	ICUs	WUAs	WUIs	ICUs
Structure of the irrigated plots	Disaggregated	138	35	173	208,873	15,146	224,019
	Concentrated	503	53	556	205,968	5,863	211,831
Crop productive orientation	Extensive	464	64	528	362,520	12,219	374,739
	Intensive	177	24	201	52,321	8,791	61,112
Environmental protection figure	Natura	117	23	140	23,422	6,847	30,269
	No	524	65	589	391,419	14,162	405,581
Socio-economic level	High	52	8	60	49,546	8,115	57,661
	Moderate	230	27	257	173,326	6,893	180,219
	Low	359	53	412	191,969	6,001	197,970

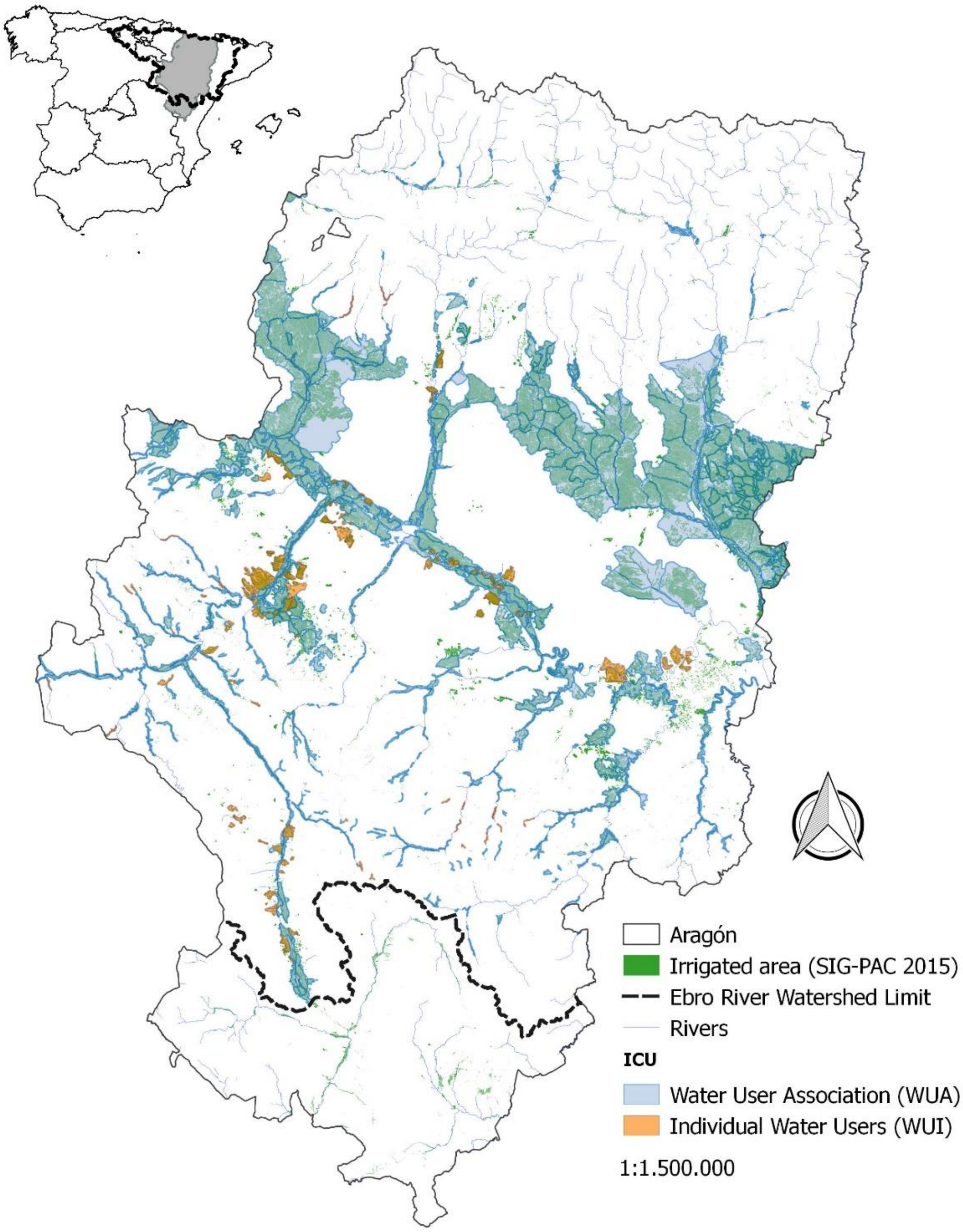

Figure 1 *Location of the Ebro river basin (black line) and the Autonomous Region of Aragón (grey shadow) in the Iberian Peninsula map. The irrigated area by SIG-PAC 2015 and the ICUs of the Ebro River Basin in Aragón are presented in the map. ICUs represent either Water Users Associations (WUAs) or Individual Water Users (WUIs).*

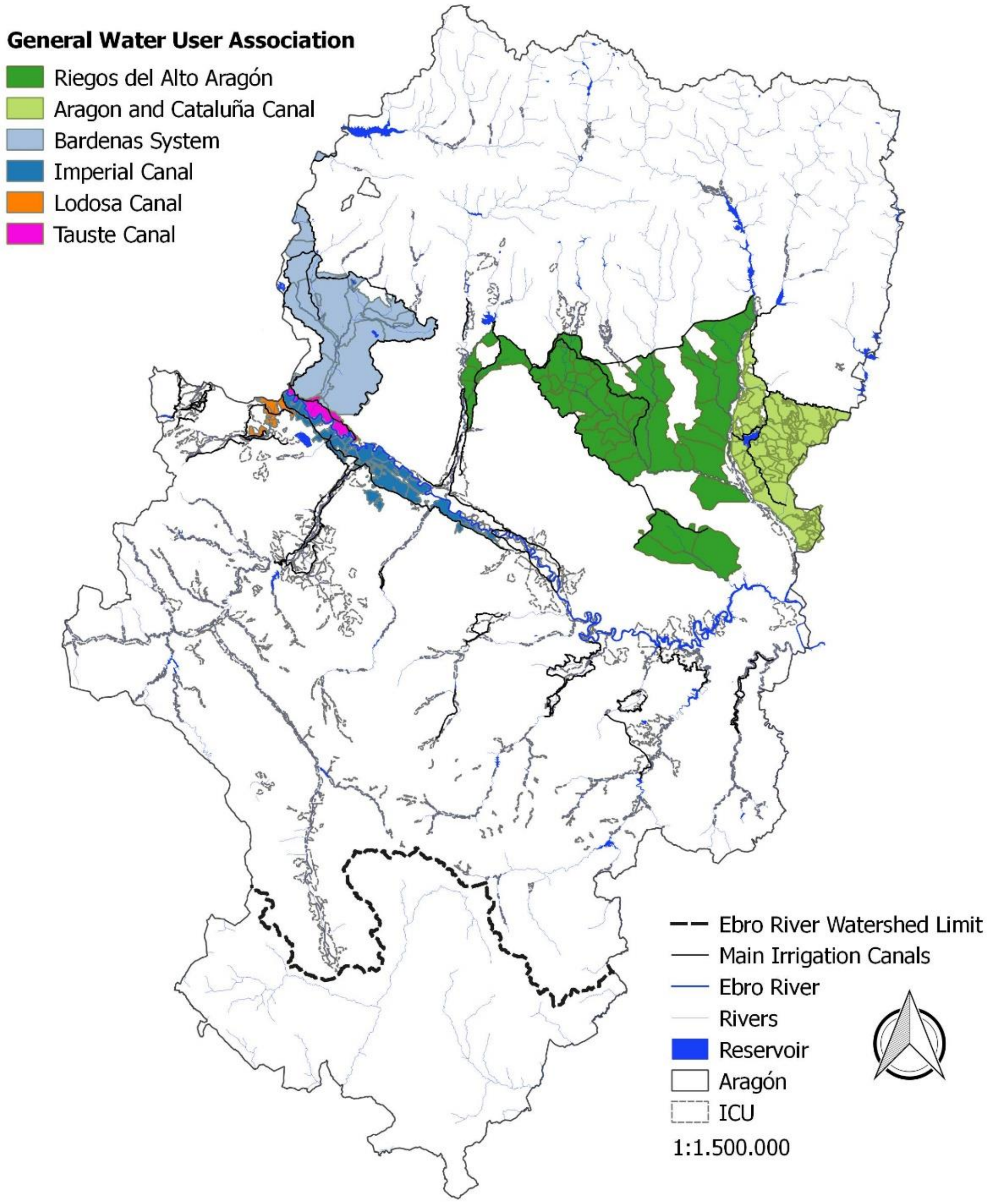

Figure 2. *General Water Users Associations (GWUAs) of the Ebro River Basin in Aragón.*

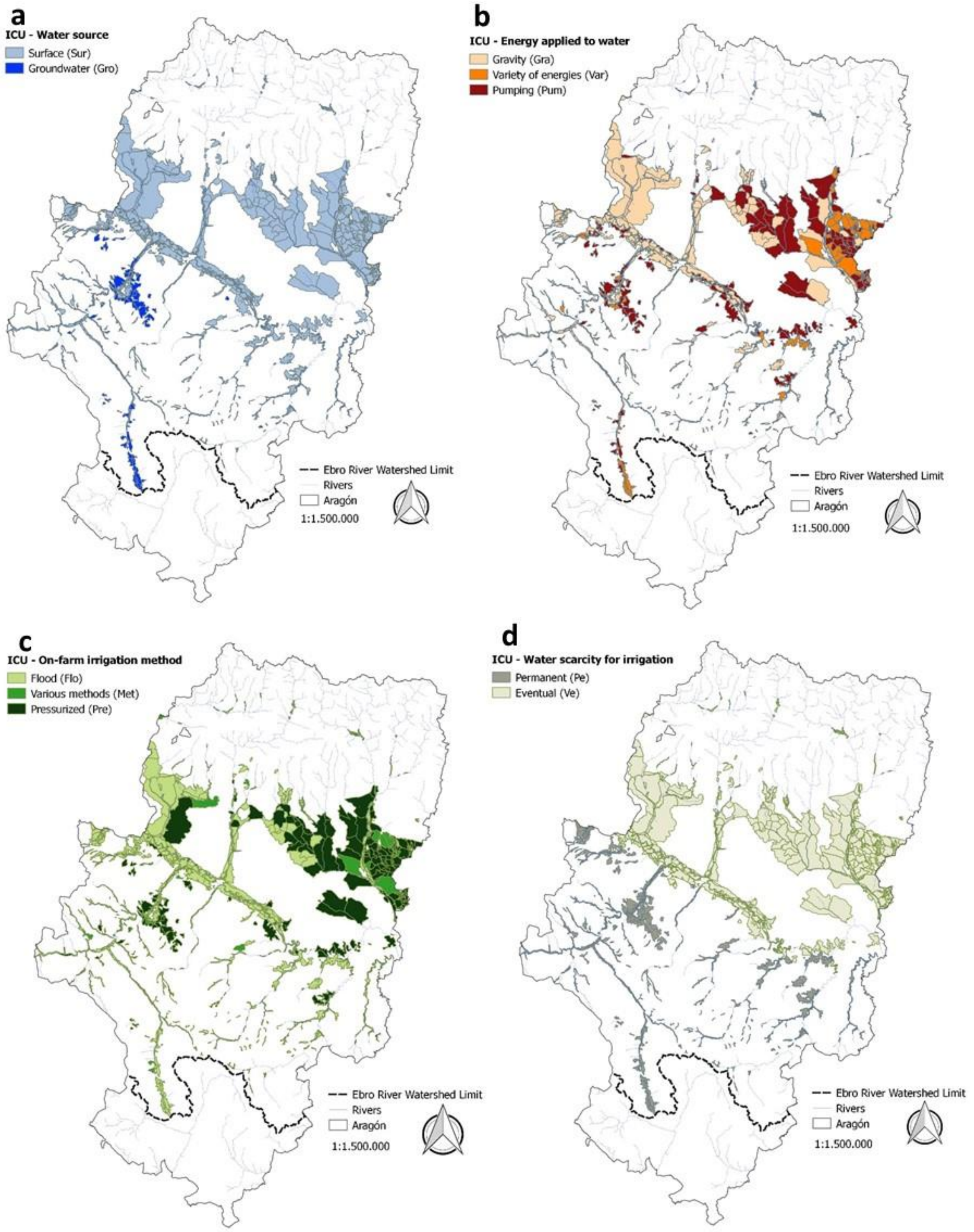

Figure 3*. Classification of the state of the four properties defining the genus of the ICUs at the ERB-Aragón irrigated areas: a) Surface or Underground water source; b) Gravity, pumping or a variety of energy sources moving the water; c) Flood, pressurized or a mixture of on-farm irrigation methods; and d) Permanent or eventual water scarcity level for irrigation.*

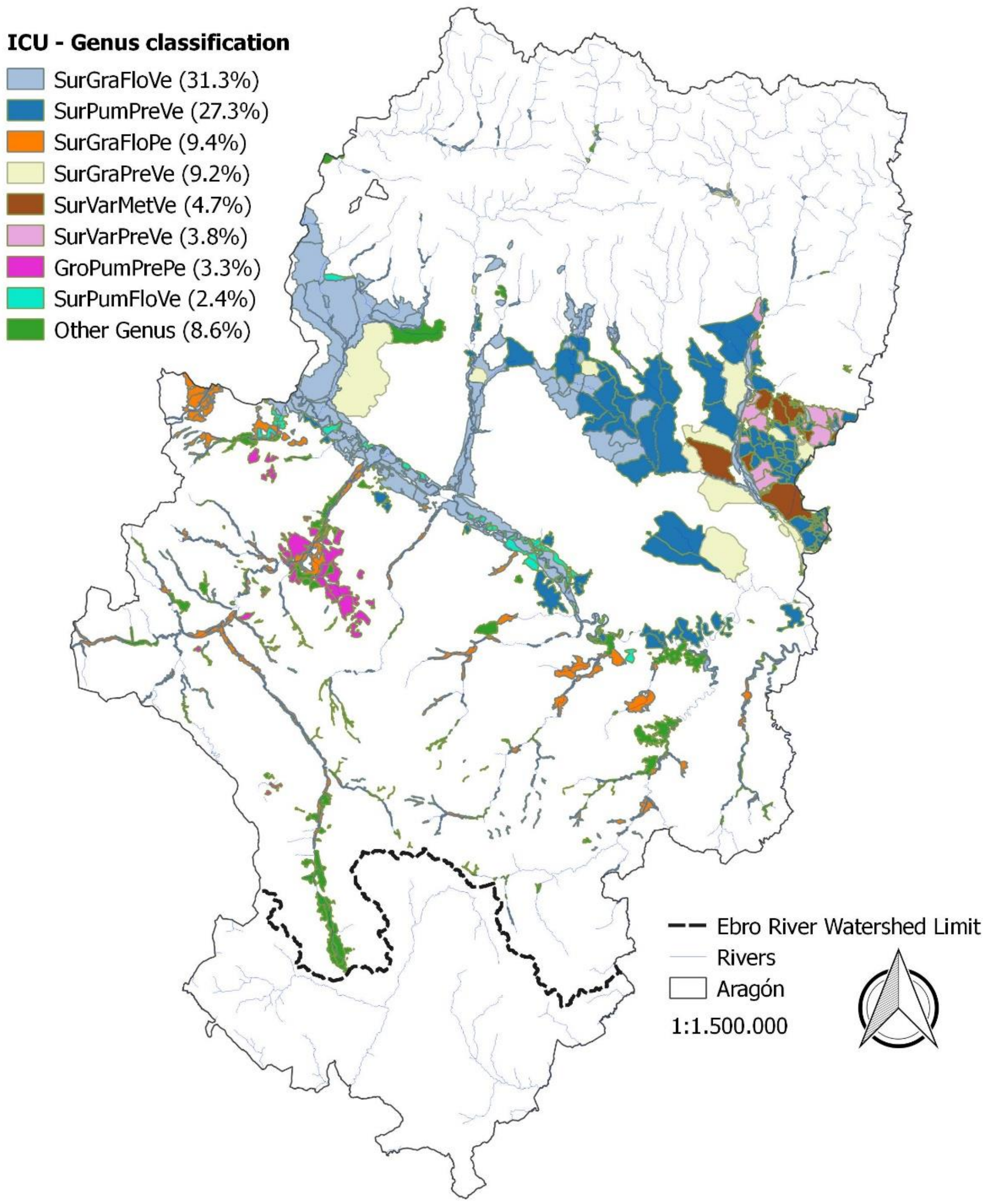

Figure 4. *Classification map of genera in the ERB-Aragón. The genus name responds to the concatenation of selected syllables representing the state of each of the four internal properties (water source, energy source, on-farm irrigation method and level of water scarcity).*

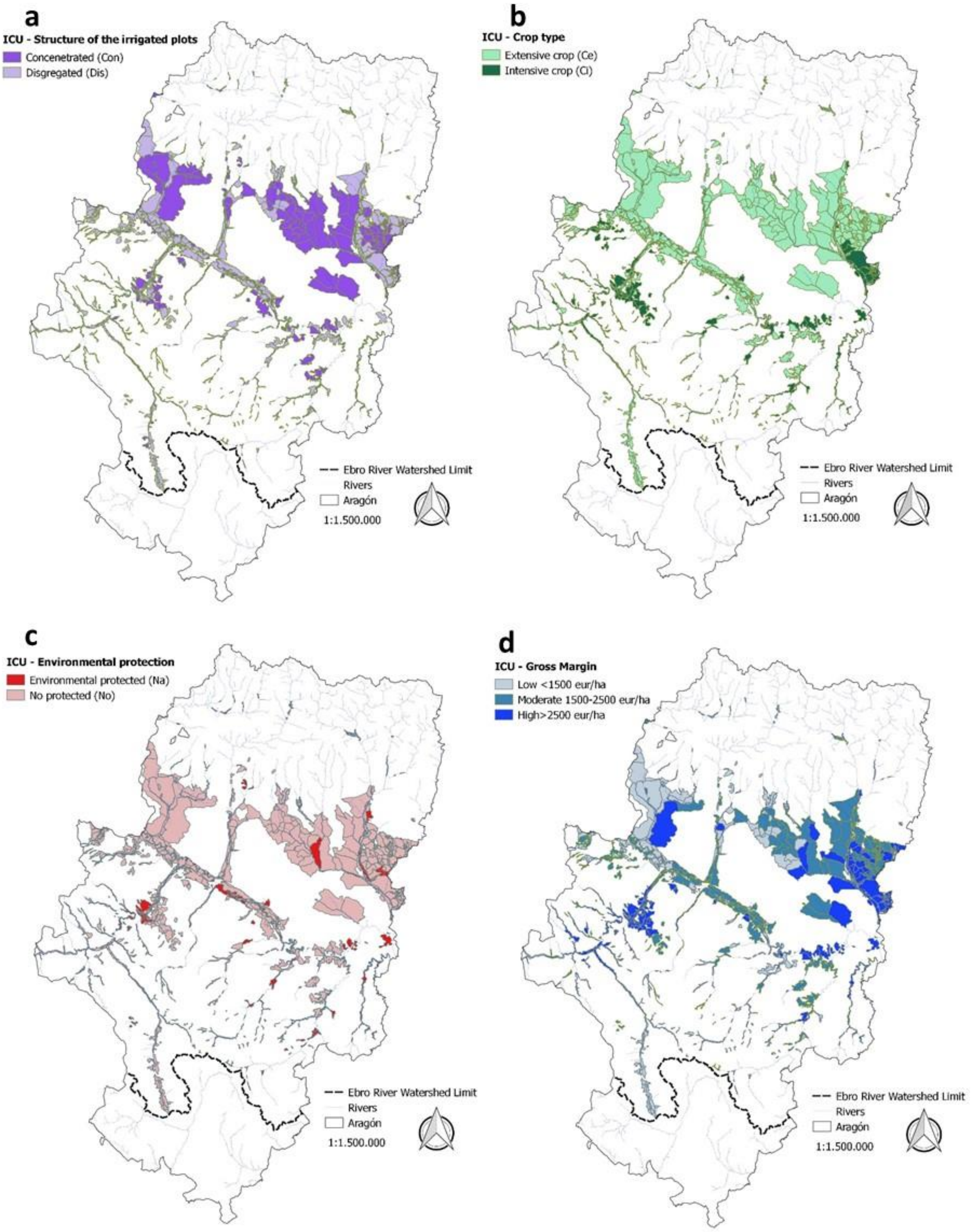

Figure 5. *State or level of the first three properties defining the species of the irrigated areas of the ERB-Aragón: a) Disaggregated or concentrated land structure of the irrigated plots; b) Extensive or intensive crop productive orientation; c) Protected or not protected by an environmental protection figure. Subfigure d) presents the Gross margin of the ICUs arranged in three levels, high, moderate and low.*

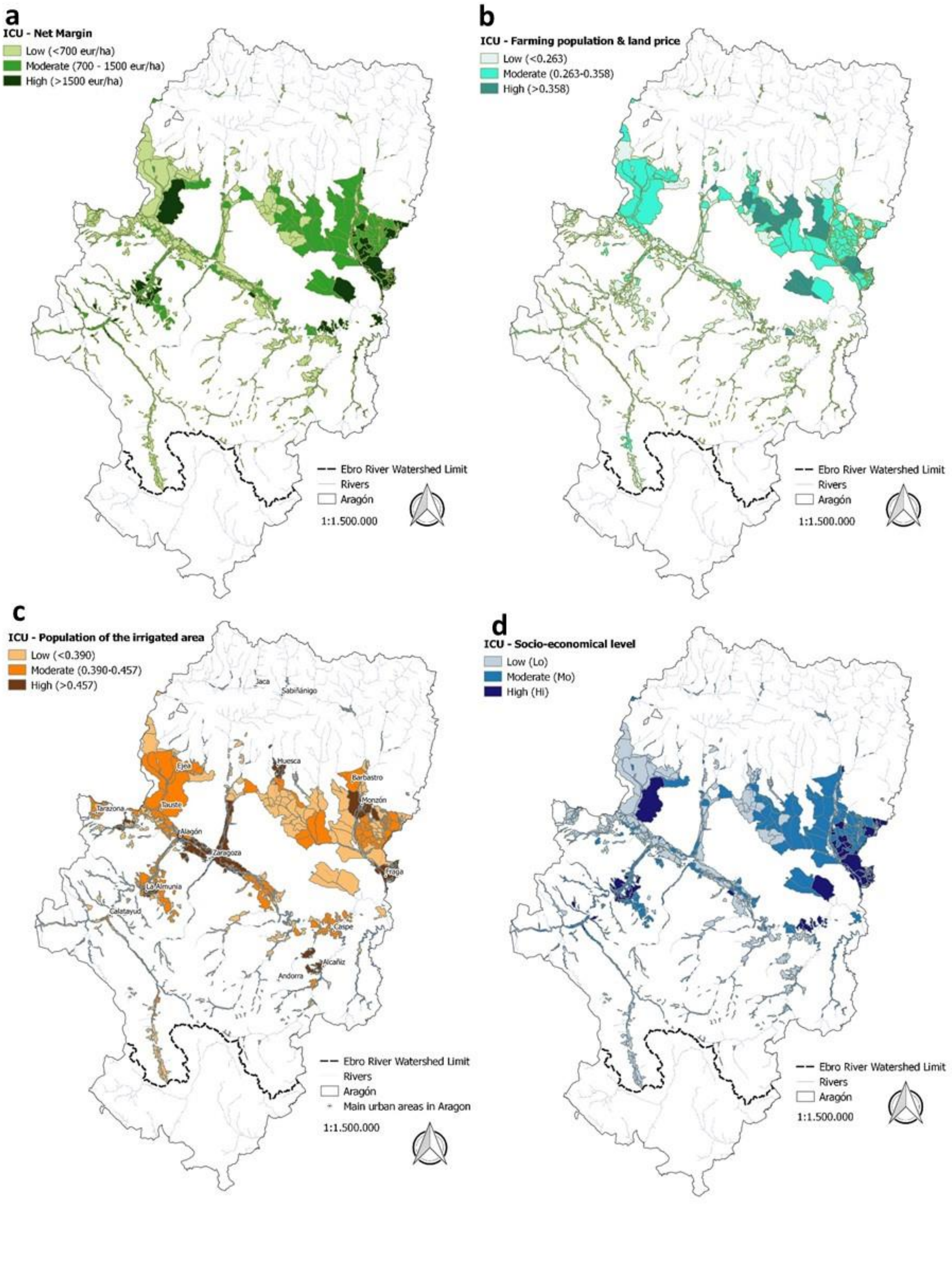

Figure 6. *Variables defining the socio-economic level of the ICUs: a) Economic (Net farm margin); b) Farming population and land indicator; c) Population indicator; and d) Socio-economic level of the irrigated areas. Variables are presented in three levels: high, moderate and low.*

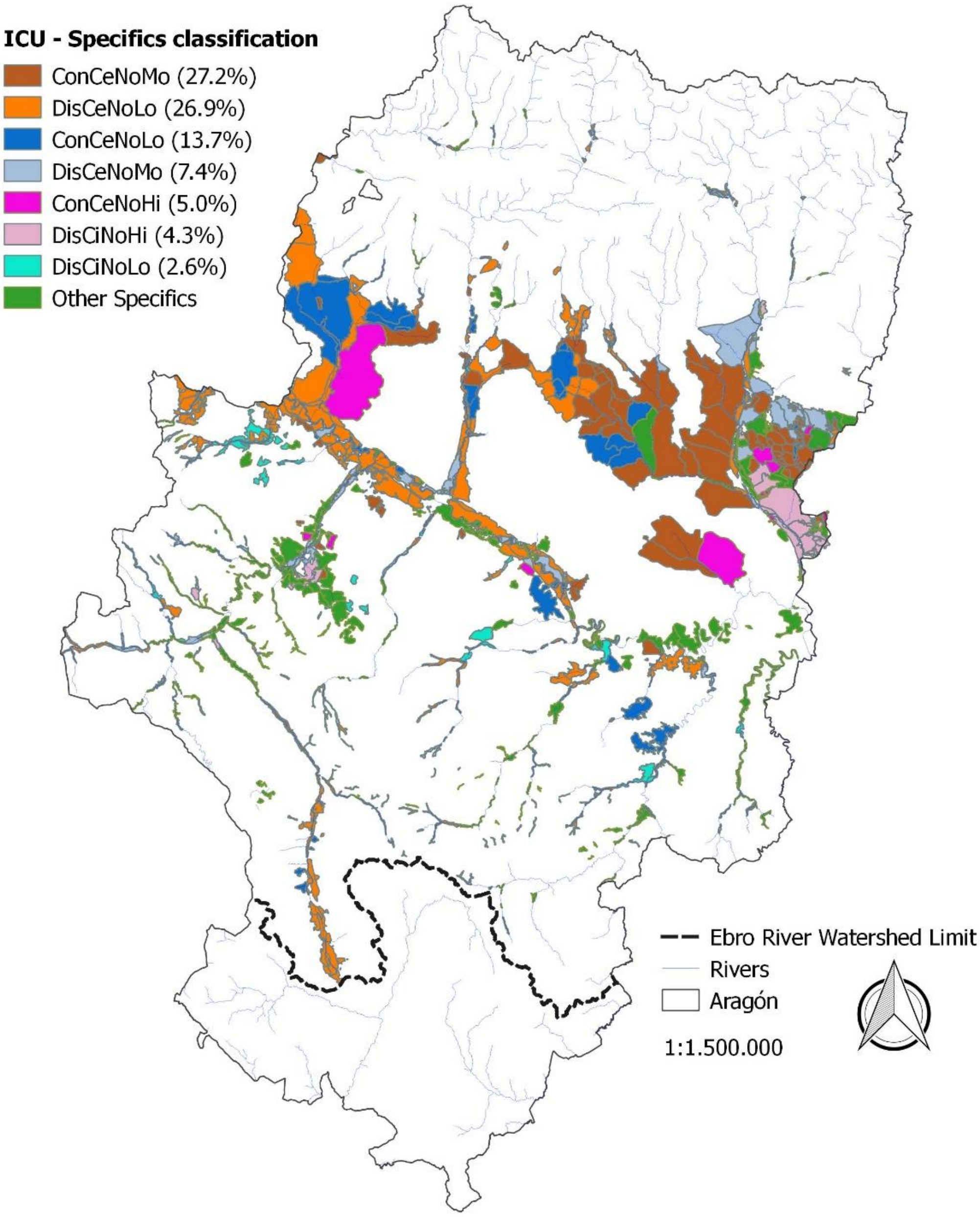

Figure 7. *Classification map of the ERB-Aragón specific names. The specific name is formed by concatenation of selected syllables representing the levels of each of the four external properties.*

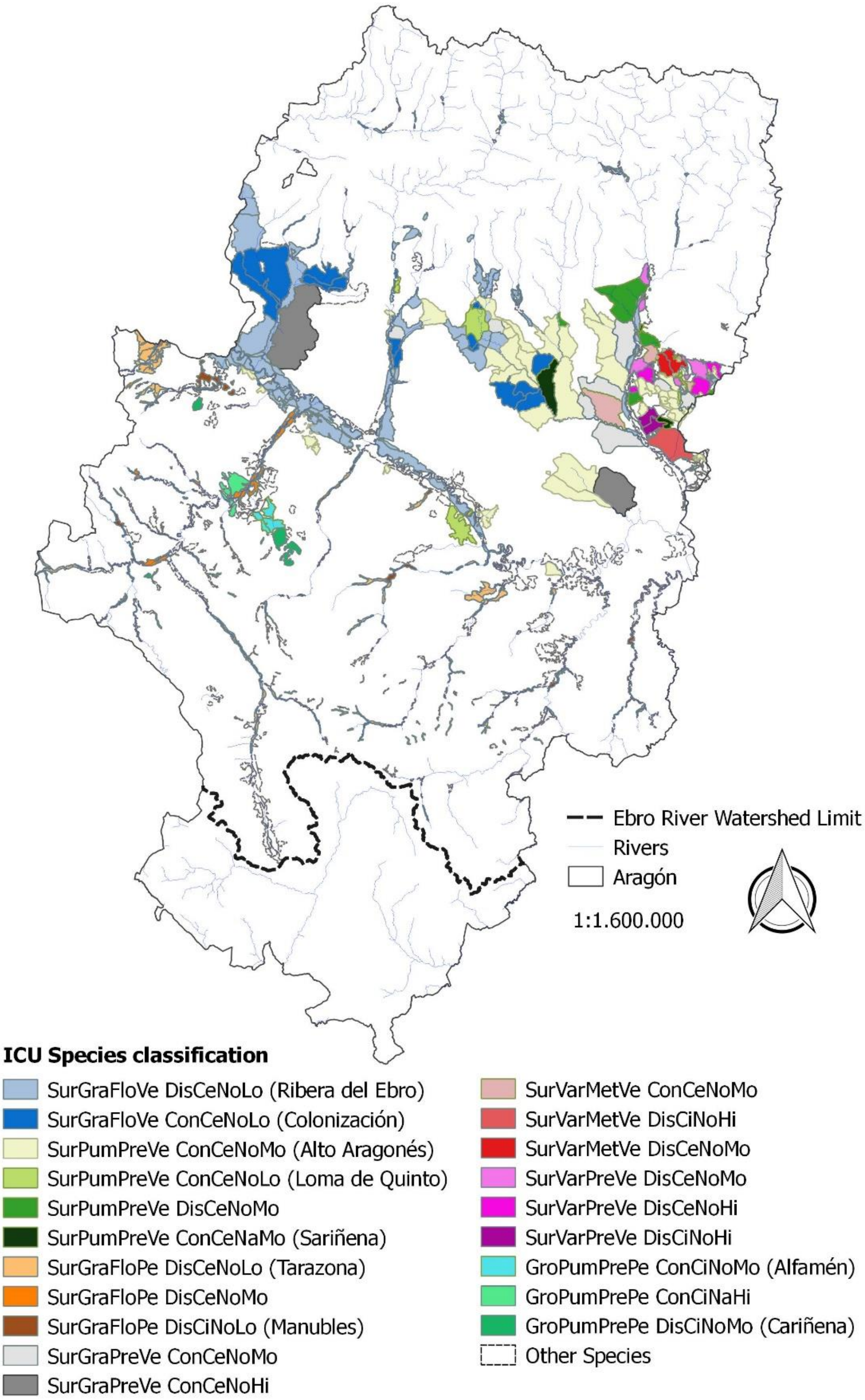

Figure 8. *Classification map of the species in the ERB-Aragón. The name of the species responds to the concatenation of selected syllables representing the levels of each of the properties defining the genus and the specific names. Local names attributed to several species have been included in the legend.*