ESP *4.2.2. Perspectives on irrigation in Galicia (NW Spain)*

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1. Introduction

The northwest of Spain is a territory characterized by a great economic dependence on the agricultural sector. This economic activity is strongly conditioned by high rainfall and the existence of numerous surface water streams of low flow that favour rainfed agriculture (Cuesta et al., 2005). Despite this availability of water resources in agriculture, the need for irrigation is justified by the interaction of several factors of different natures (Neira et al., 2005). We find a physical environment characterized by a peculiar topography, a relative abundance of water resources, a great dispersion of the rural population and a significant fragmentation of ownership (Crecente et al., 2002).

In important rural areas of Galicia, despite having significant rainfall, there is a need to resort to irrigation given the low average depth of agricultural soil (Cancela et al., 2006a), the low capacity for water retention in the soil (Martínez et al., 2011) and the irregular rainfall that affects a practically generalized summer shortage (Mirás-Avalos et al., 2009), and according to the predictions of the Intergovernmental Panel on Climate Change (IPCC) in the context of current anthropic climate change, this irregularity will increase (Kong et al., 2022).

As it appears in law 147/1963 of the Civil Law of Galicia, irrigation waters have a reduced and abnormal flow that prevents the creation of communities of irrigators (CCRRs). Despite this restriction, in 2003, there were a total of 397 CCRRs in Galicia, distributed throughout the territory (Image 4.2.2.1), based on the records available from the water agencies, Confederación Hidrográfica del Norte and Aguas de Galicia (Cancela, 2004).

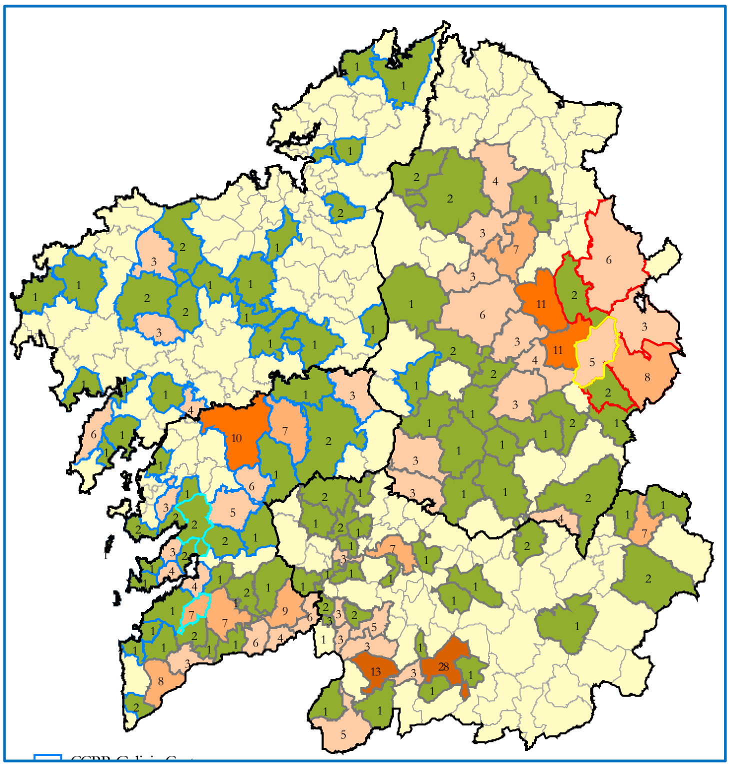


Image 4.2.2.1. Distribution by municipality of the irrigation communities in Galicia (Cancela, 2004)

According to Pérez García (2003), the importance of irrigation is clear in the modern history of Galicia. In the coastal regions, irrigated areas have a remarkable distribution in land growing cereals, judging by the high percentages of Salnés or Ulla. In some areas in the west of the province of Ourense, they also represent important areas, while in the Galician interior, the presence of irrigation has been associated with the development of permanent pastures. According to Bouhier (1979), in the Cadastre of Ensenada of the year 1752, reference was made to the irrigated domains in Galicia; among the most noteworthy data, it can be highlighted that almost all of the current province of Pontevedra and the southwest region of the province of Ourense were covered by irrigated areas. These provinces had more than 2% of their utilised agricultural area dedicated to irrigation.

In the traditional form of irrigation, namely surface water irrigation, water resources are obtained from small dams in water streams, pools, springs, or horizontal pits such as traditional "water mines" (Image 4.2.2.2).

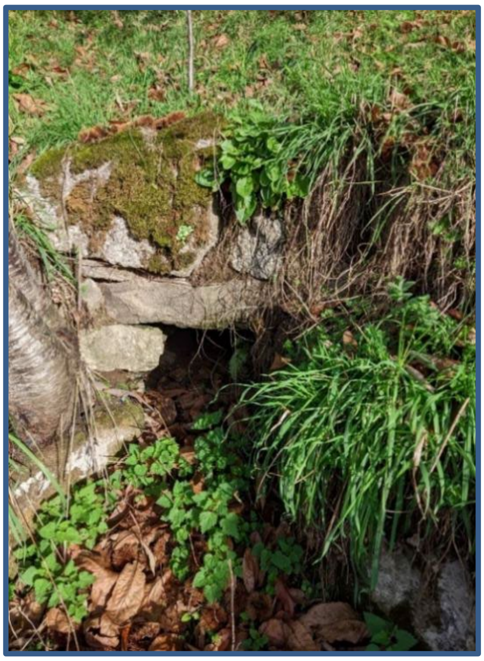


Image 4.2.2.2.Traditional water mine in Galicia

According to Neira et al. (1994), the amount of land dedicated to irrigation is highly variable in Galicia. In the province of Pontevedra, irrigation represents around 25% of the cultivated area; on the contrary, in the province of Lugo, it barely represents 1.9%. Most irrigation is carried out on natural meadows (80,000 ha), with irrigated arable land (not grassland) reaching 55,000 ha in area. In the studies carried out within the preparation of the final document of the National Irrigation Plan (PNR-2000), the irrigable area in Galicia was estimated at 134,027 ha, compared to the 85,490 actually irrigated, and map number 20 in PNR-2000 shows the distribution of irrigated areas in Spain.

In Image 4.2.2.3, an example of sprinkler and surface irrigation in the “Terra Chá” irrigation area in the province of Lugo is shown.

a)

b)

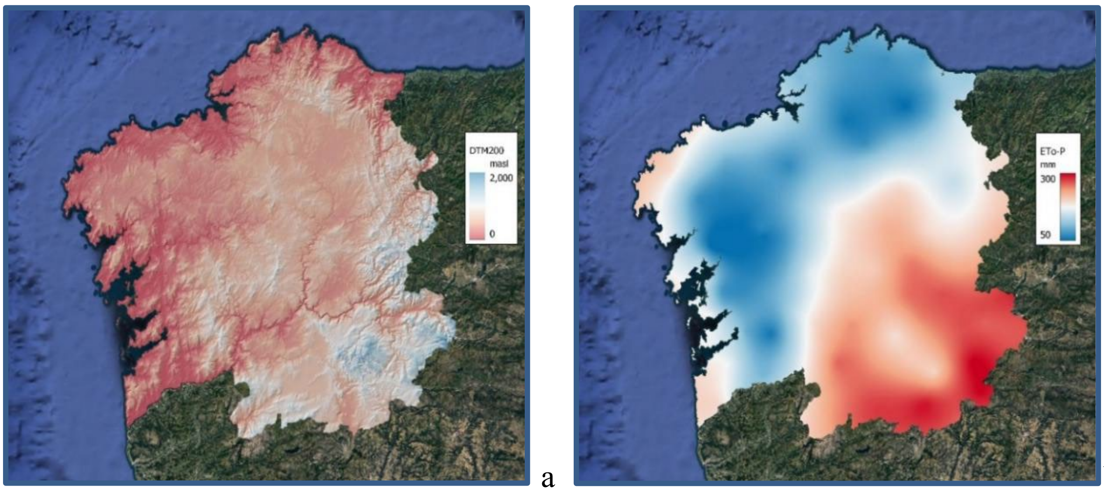
c

Image 4.2.2.3. Sprinkler a), and surface b) irrigation plots in “Terra Chá”

The orographic characteristics of Galicia, according to the data derived from the 200 m digital terrain model (DTM) of the National Geographic Institute (IGN), has an average elevation above sea level of 503 m and an average slope of 12.6%. This orography can be seen in the digital elevation model combined with the shadow map (Image 4.2.2.4), which provides us with an idea of the complicated orography for irrigation. The area of Galicia is 29,575 km², of which the area classified as agricultural is approximately 9000 km² according to data from the CORINE Land Cover (2018).

It should also be noted that of the entire agricultural area, only 2070 km² has a slope of less than 5% and 5263 km² has a slope between 5 and 10%. These topographic characteristics greatly limit the existence of large irrigable areas in Galicia.

In terms of climatology, the region is located in an oceanic climate, with an average rainfall of 1180 mm and a reference evapotranspiration of 712 mm (Naranjo and Pérez Muñuzurri, 2007). To demonstrate the existence of a water deficit in Galicia during the summer season (May–August), estimates of precipitation and reference evapotranspiration were performed using the method of Penman–Monteith. These data came from the stations belonging to the network of Meteogalicia (Conselleria de Medio Ambiente, Territorio e Vivenda), and the climatological data corresponded to the period of 2006 to 2020 inclusively. For the special interpolation, the techniques of ordinary kriging and residual kriging were used; in the latter case, X, Y and elevation were used as secondary variables. A more extensive description of the methodology used in the special interpolation is found in Rangel-Parra et al. (2023).



a b

Image 4.2.2.4. a) DTM 200 and b) difference between the values of precipitation and ETo for the months of May–August for the period 2006-2021

As a result, a map of the difference between precipitation map and reference evapotranspiration (ETo) for these months was obtained, as shown in Image 4.2.2.4b, in which the height of the water deficit ranges from 50 to 300 mm, being higher in the southeast area, corresponding to areas with lower summer rainfall and higher ETo values. This justifies the need for irrigation in Galicia. There is also a water deficit along the western coast.

2. Irrigation in Galicia

Cancela et al. (2004) pointed out that, for some time now, in countries belonging to the temperate-humid area of Europe, supplemental irrigation has been accepted as a necessity to improve the competitiveness of their crops. This irrigation, called a complement because of its subsidiary nature in the set of factors that affect plant production, became a widespread practice as agriculture was modernized in Galicia. Water is one of the fundamental factors that can limit the future of a livestock alternative based on the production of forage, as in fact it has been until now in the framework of traditional agricultural practices (Álvarez et al., 2014).

a

b

c

Image 4.2.2.5. a) Use of groundwater for irrigation in A Limia b), irrigation head in Quiroga in vineyards and c) irrigation wheel in maize field in Terra Chá

This situation explains why Galicia has been described as a "land of small irrigated areas". These small irrigated areas, mostly the result of private initiatives, have a combined surface area close to 16,500 ha, according to the Ministry of Agriculture, Food and Environment (MAPA, 2021). In addition, it is worth noting the existence of almost 12,000 ha of irrigated natural meadows and meadows, along with more than 1500 ha of vineyards (Image 4.2.2.5).

2.1. Large irrigation areas in Galicia

The history of irrigation in Galicia is marked by the abundance of river streams that cross the entire territory, which together with the population dispersion and the high fragmentation of the territory have led Galicia to be covered by small farms (Casal, 1984). The study of the different dynamics that exist in Galician irrigation have been analysed by Bouhier (1979), who stressed that climatic conditions make irrigation necessary in these areas.

Table 4.2.2.1. Irrigable areas planned in Galicia

Denomination	Province	Date Declaration of National Interest	Date of Approval of the General Transformation Plan	Total irrigation area planned (ha)
Antela Lagoon	Ourense	27/12/1956 30/12/1958	06/07/1972	4.000
Lemos Valley	Lugo	01/12/1966	16/08/1969	5.500
Terra Chá	Lugo	18/08/1972		2.869
Sarria	Lugo	13/08/1971	20/07/1076	3.304
Lorenzana Valley	Lugo	13/08/1971	20/07/1976	3.304
Ulla Valley	A Coruña	-	-	1.150

From the year 1950 onwards, due to the push developed in the rest of the peninsula, the Ministry of Public Works undertook the transformation of some Galician areas into large irrigable areas. The areas that were decreed to be transformed into irrigated areas were the Ulla Valley, in the province of A Coruña, Sarria, Terra Chá, the Lemos Valley and the Lourenzá Valley in Lugo and the Antela Lagoon in the province of Ourense (Cancela et al., 2006b) (Table 4.2.2.1 and Image 4.2.2.6).

Among all the planned areas, only four were able to carry out infrastructure works and only three are irrigated by taking advantage of the existence of the distribution network (Antela Lagoon, Valle de Lemos and Terra Chá).

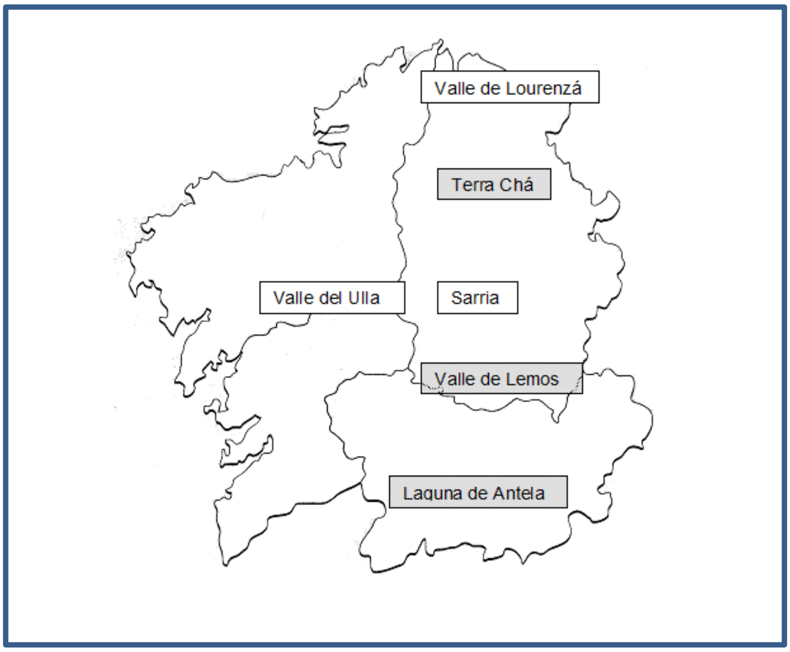


Image 4.2.2.6. Irrigable area in Galicia, with those that were developed in grey.

Only three of the six planned irrigation areas are currently irrigated: Lemos Valley, Antela Lagoon and Terra Chá. There are irrigation communities in the last two of these. At present, the area of the Lemos Valley is in the process of the creation of a community of irrigators, of which its statutes have recently been approved.

The action carried out in the Antela Lagoon, after its desiccation, consisted of the transformation of 2500 ha of the lagoon itself and 1500 ha of the surrounding perimeter. The current irrigation system allows the irrigation of 600 ha under pressure based on the water stored in the sanitation channels of the lagoon (MAPA, 1993). Undertaken in the early years of the 21st century, the modernization of irrigation consisted of two actions, directed by the Ministries of Agriculture and the Xunta de Galicia, covering a total of more than 2600 ha. The great difference of this irrigation area with respect to the other irrigation areas in Lugo is the origin of the water; in this area, it is obtained from the extraction of groundwater and the use of ponds to store water (Image 4.2.2.7), while in the other two areas, it comes from surface water resources.

Image 4.2.2.7. Water storage pond in the 'A Limia' region. Irrigation modernization actions

The irrigable area of the Lemos Valley is delimited by three main channels and a ditch that comprise the valley of the Mao River and the Cabe River. The initial area to be irrigated was initially 5500 ha. At present, the irrigation that we can observe in the area is a form of gravity irrigation of low cost and low efficiency, practiced in an area much lower than that projected (Image 4.2.2.8).

The lack of facilities as well as the lack of interest on the part of social agents are the main causes of this case of irrigation misuse in the area (Cuesta, 2001). Several studies are currently being carried in this area by our research group to modernize the irrigation system and improve water use efficiency in irrigation.

Image 4.2.2.8. Example of the misuse of water in the Lemos Valley irrigation area, with low efficiency

Finally, the Terra Chá area is divided into three sectors, with about 1900 ha of irrigation, with 50% of the irrigable area being irrigated by sprinklers (Image 4.2.2.9). One of the irrigation sectors (Sector II) undertook the modernization process in 2008, implementing a modern irrigation network on demand, covering a total of 777 ha (SEIASA del Norte).

Image 4.2.2.9. Elevated irrigation channel in Arneiro, Terra Chá

In addition to the areas of action mentioned in Table 1, in the 1960s, technical studies were carried out that reflect the need to transform land from other regions into irrigated land (Table 4.2.2.2).

Table 4.2.2.2. Possible irrigable areas in Galicia

Denomination	Main municipality affected	Province	Area (ha)
Xubia	Ferrol	A Coruña	300
Xallas	Cee	A Coruña	250
Umia Valley	Cambados	Pontevedra	4.100
Minho	Tui	Pontevedra	985
O Rosal	O Rosal	Pontevedra	107
Vega de San Clodio	Quiroga	Lugo	105
Arnoia-Tiaira-Maceda	Allariz	Ourense	1.745
Verín Valley	Verin	Ourense	6.300

Source: Consejo Económico Sindical Intersindical del Noroeste, 1964.

The distribution of irrigated farmland, as defined by the 1999 Agricultural Census Project, suggests that Galicia possesses less than 1% of the area of irrigated farmland in Spain, although the data presented above show that this value is clearly higher.

The following sections delve into the irrigable areas of the province of Lugo, as characteristic examples of large irrigable areas in Galicia.

2.1.1. Terra Chá irrigation district

The irrigation districts of Terra Chá are in Northeast Galicia, Spain. The average rainfall is 1027 mm, irregularly distributed by year. The area consists of seven irrigator communities, where the dominant crops are silage maize and grass pasture, which account for about 20% and 80% of the total irrigated area, respectively. Previous socio-economic studies in this region were performed by López (1979), Cardesín (1987) and, more recently, by Maseda et al. (2004), referring to the dairy farms in the region. Irrigation and water management practices were studied by Fernández-Lavandera and Pizarro (1980) and Neira (1994), while soils were characterised by Castelao (1989). Although the use of surface irrigation prevails in Galicia, sprinkler irrigation with lateral movement and a stationary distribution system is used in the study area, where water is pumped from the river Miño and its main tributaries. More information about the socio-economic situation of agriculture in Terra Chá can be found in Marín et al. (2010).

The area belongs to a livestock tradition, especially dairy cattle, and hence the existing crops are meadows and forage corn, having the second lowest weight in terms of area, although in recent years, the cultivation of corn has been increasing, at around 20% of the current producing area (Gómez et al., 2003), which today may reach 40% of the total irrigable area.


a)


b)


c)

Image 4.2.2.10. a) Irrigation infrastructures in Terra Chá: uptake water river section in Loentía, b) Loentia pumping uptake and c) Spillway Sector II

The poor state of the water collection and distribution network before the modernization of irrigation in 2008 can be seen in Image 4.2.2.10, Image 4.2.2.11 and Image 4.2.2.12.

Image 4.2.2.11. Water distribution channels, Terra Chá

Image 4.2.2.12. Obsolete water pumping equipment, River Lea

In 2008, the modernization works of the irrigation of the Community of Irrigators Río Miño-Pequeno-Franqueira were completed, which represented a relevant technological advancement, providing a pressurized network and all of the most advanced remote-control systems of the moment (Image 4.2.2.13.). The general irrigation network was built in cast iron and polyethylene, with a hydrant pressure of 65 m.c.a, such that it allows irrigation with an irrigation cannon. This energy aspect has meant an increase in the energy bill that the community members have to pay, in addition to the consequent wear of the mechanical elements of the installation (pumps, valves, etc.).

a)

b

c

Image 4.2.2.13. Terra Chá irrigation modernization project. a) PE pipe installation trench, b) basic project data, and c) Supervisory Control and Data Acquisition (SCADA)

2.1.2. Lemos Valley irrigation district

The Lemos Valley irrigation district, in the NW of Spain, is located to the south of the province of Lugo, in the Autonomous Community of Galicia. The establishment of this district in 1966 provided for the irrigation development of about 5300 ha by using natural flows from the river Cabe and regulated water flows from the river Mao. The design criteria used in 1996 were based on the limited capacity of the distribution network and on the lack of internal water storage (Neira et al., 2005).

The main distribution network consists of three main channels, with a total length of 78.5 km and flows ranging from 5.5 m^3/s at the inlet to 0.2 m^3/s at the outlet, directly before discharging into the river Cabe. A network of channels with different capacities and states of maintenance and with an approximate total length of 147 km branch off from these channels (Image 4.2.2.14 and Image 4.2.2.15).

Image 4.2.2.14. Irrigation channels in the Lemos Valley

a

b

Image 4.2.2.15. Infrastructures for passage of topographic obstacles in Lemos Valley: a) siphon and b) aqueduct

The area is characterized by a temperate Mediterranean climate, with an average annual temperature in the period of 2000-2021 of 13.7 ºC, which varies between the maximum average monthly temperature of 20.6 ºC (July and August) and the minimum average monthly temperature of 3.6 ºC (January). The actual annual rainfall recorded in this period was 387.2 mm. We can highlight the erratic nature of summer rainfall (from June 22 to September 23) in the study area: in the period of 2000/2021, we observe an average value of 95.8 mm, with a minimum of 11.5 mm, a maximum of 274.5 mm and a standard deviation that reaches a value of 51.3.

The traditional cropping pattern of the area consists of an annual rotation of artificial pastures and silage maize. This rotational scheme is characteristic of cattle-oriented agriculture in the region (Cuesta et al., 2004). Rotations of forage crops lead to the use of pastures and silage maize or to the combined rotation of both crops. Other patterns tested in previous studies are less suitable.

The main farm irrigation system is free draining borders, a type of surface irrigation. Irrigation is only applied to a small percentage of the surface of those fields bordering canals, due to the incomplete state of the distribution network within the irrigation perimeter. Therefore, water must be conveyed to many fields through furrows, leading to excessive water delivery, estimated at 12,500 m^3/ha (Cuesta et al., 2007).

The water source used for both maize (31.7% of the area) and artificial pastures (68.3% of the area) is the distribution channels. A high temporal variability was observed in flow measurements, conducted in different channels during the irrigation evaluations. The irrigation water supply largely depends on the capacity of the canal from which water is delivered and on the state of preservation of secondary and tertiary channels (Image 4.2.2.16).

Image 4.2.2.16. Secondary water distribution channel

Irrigation time and irrigation frequency data also show high variability. Results vary not only among different irrigation users, but also among different irrigation areas within the same field. During the studied season, the average irrigation times declared by farmers were significantly different depending on the type of irrigated crop; 7 hours per field in the case of maize, and 5 hours per field in the case of pasture. The application efficiency values obtained are low or very low, reaching a mean value of 35.2 %; however, the distribution uniformity (DU) values are acceptable.

The structure of land tenure limits the improvement and modernisation of this irrigation area. Land consolidation does not provide a solution to fragmented land ownership, because the consolidated plots would still be too small. The discharge and volume applied to fields and channels must be controlled by installing flowmeters. A significant improvement of the organisation of the irrigable perimeter requires irrigation on demand and the control of the water demanded by each user.

In addition to these actions, farmers must be given advice, and information about irrigation techniques must be diffused among them. This information was not provided when this area was established as an irrigation district.

3. Private irrigation: irrigation management

An alternative model of irrigation is the irrigation of small areas in Galicia, widely used for particulate uses and in small areas or linked to crops with a high added value such as vineyards or cut flowers.

An example of this type of management is the irrigation plot in Berlai-Guntín (Lugo), where the pit left by a clay mining operation (Image 4.2.2.17) was used to collect autumn and winter runoff water, performing supplementary irrigation in forage maize using a pivot.

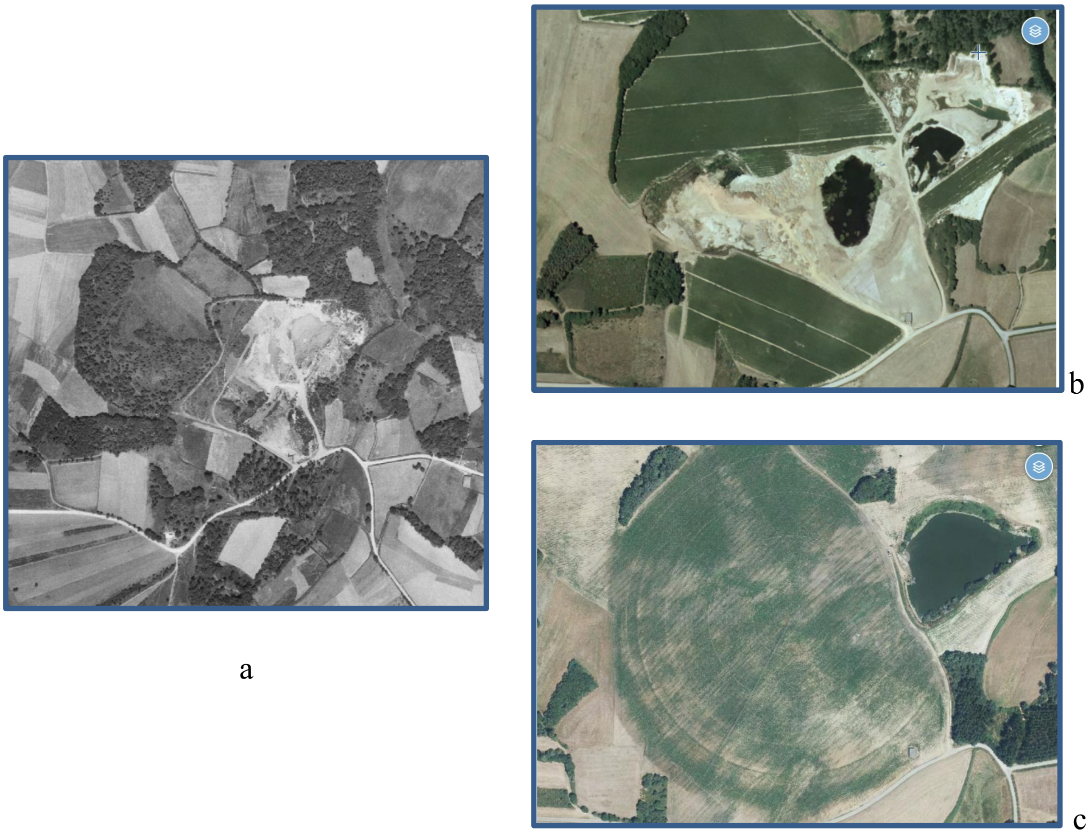


Image 4.2.2.17. Irrigation area in Berlai-Guntín-Lugo. a) Aerial photograph of July 1983, b) flight SIGPAC 2001 and c). Flight PNOA 2020

A second example, related to the irrigation of a vineyard, includes the installation of surface drip irrigation, while there are facilities with subsurface drip irrigation, that have been operating for more than 15 years, showing the relevance of providing the water needs required by the plant at critical moments of the cycle, as well as providing nutrients (fertigation) through irrigation water (Image 4.2.2.18).

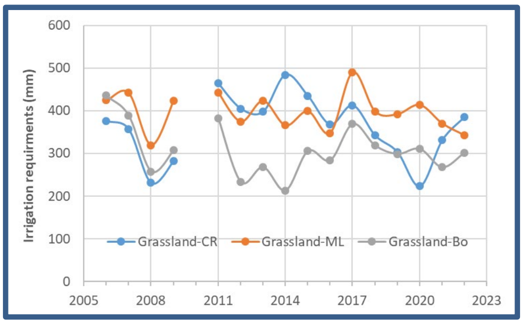
Image 4.2.2.18. Surface drip irrigation in Condado do Tea vineyards (protected designation of origin Rías Baixas-Pontevedra)

3.1. Irrigation modelling and programming

The changes in the dynamics of rainfall distribution, especially during the spring and summer months, has generated an incipient interest in water management in Galician irrigation, both in large and small areas. The programming of irrigation based on climate information, available throughout Galicia, facilitates irrigation management in a sustainable way. It is important to mention the existence of the SIAR (Advisory service to irrigators) network (http://www.siar.es/), regulated by the Ministry of Agriculture and Fisheries, Food and Environment through the General Subdirectorate of Irrigation and Rural Infrastructure, from which the farmer can perform estimates of the water demand of their crop.

The database available in the SIAR allows consultations of water needs from 2006 to the present to be performed. It is worth mentioning the low number of stations in Galicia—four in total, located in the provinces of A Coruña and Lugo. The stations of Boimorto (Bo), Monforte de Lemos (ML) and Castro de Rei (CR) were considered to extract information for the main crops: grasslands, maize, vineyard and potato. Image 4.2.2.19 shows trends in net water requirements over the past 17 years.

There are other platforms such as Climate Data Store in Copernicus (https://cds.climate.copernicus.eu/), which allow us to access aggregated historical climate data, with which we can make comparisons with different scenarios in the short, medium and long term.



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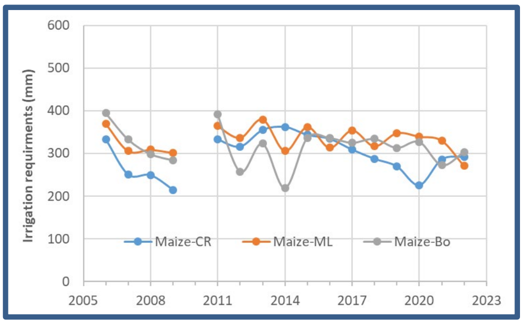

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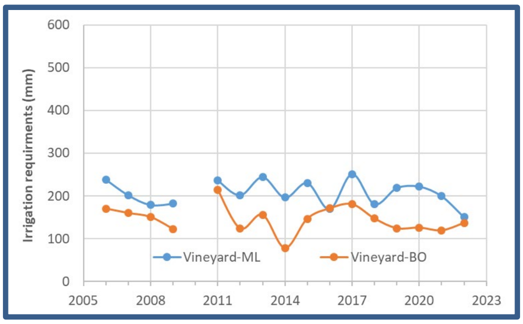

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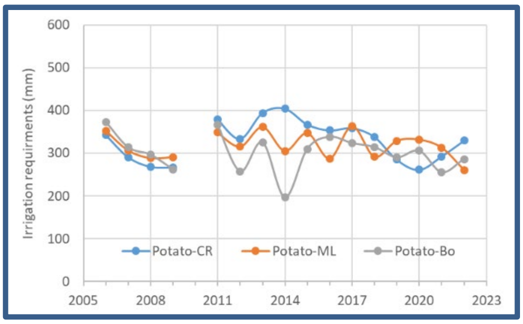

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Image 4.2.2.19. Evolution of crop water requirements from 2006 to 2022, for a) grassland, b) maize, c) vineyard and d) potato. Data from SIAR Boimorto (Bo), Monforte de Lemos (ML) and Castro de Rei (CR)

As an example, the variation of the average temperature in the summer months (June, July and August) in the centre of the province of Lugo is depicted (Image 4.2.2.20). The trend towards an increase in average temperature in the period of 1985-2020 can be observed, as well as the forecast of a continued rise in temperature in the short term. This aspect again highlights the importance of establishing tools that allow the management of irrigation in real time, as well as the importance of it in temperate regions, such as Galicia.

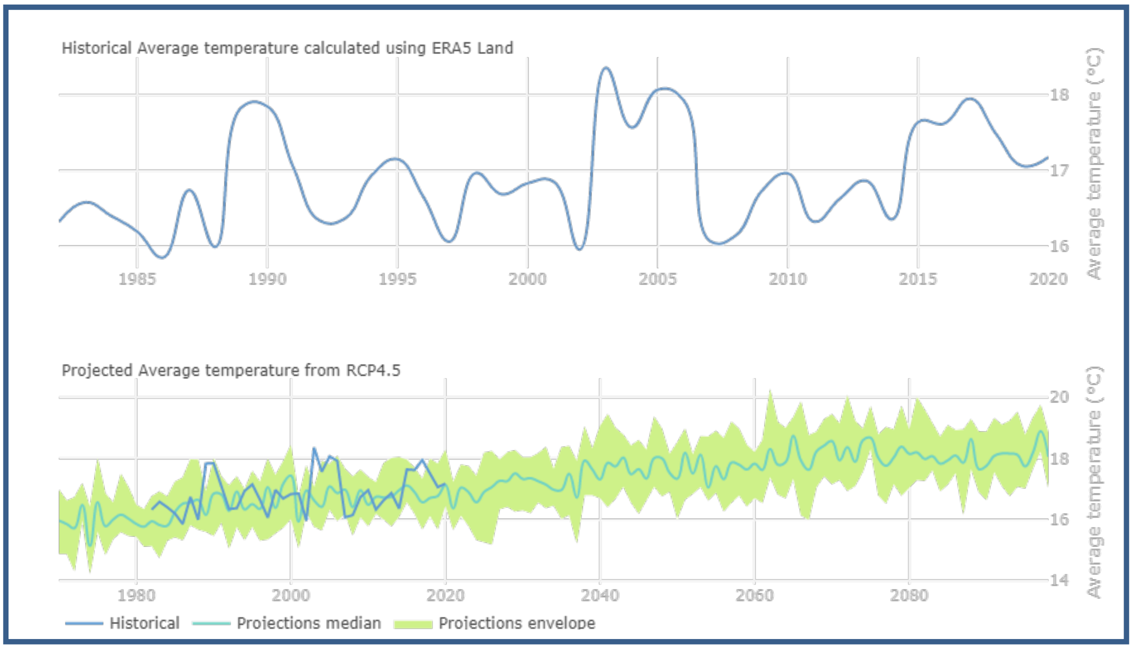
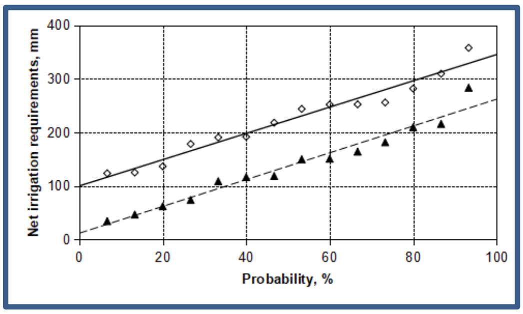


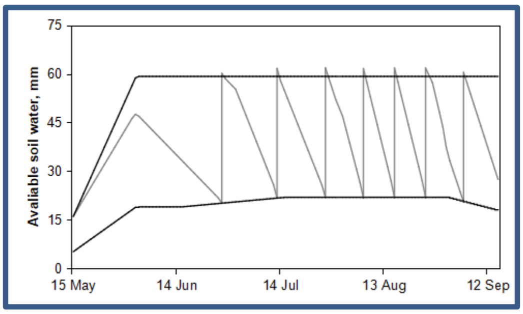
Image 4.2.2.20. Evolution of average temperature (top), and projected average temperature (bottom), using ERA5 Land and RCP4.5 scenario in Lugo province (Copernicus)

As explained by Pereira et al. (2021a), in an update to the method of estimating water needs established by FAO (Allen et al., 1998), for a correct assessment of irrigation needs, corrections of cropping coefficients (Kc) to local conditions are necessary. So, the water needs of the meadow in Galicia should be lower than those reported from the SIAR, considering a Kc = 0.8, with something similar happening in the remaining crops.

References to modelling water needs, adapted to the growing conditions and climate in Galicia, are limited. Adapted (calibrated) crop coefficients have been obtained for crops such as maize (Cancela et al., 2006a, 2013), potato (Cancela et al., 2007), meadows (Cancela et al., 2006a), vineyards (Fandiño et al., 2012 a, Fandiño et al., 2013, Cancela et al., 2015a, Fandiño, 2021) and hops (Fandiño et al., 2015), so there is a broad field of work to address, even more so if we take into account the fact that the option of introducing new crops is available, derived from the current climatic conditions.

The works of Pereira et al. (2021b, c) and Rallo et al. (2021) collected reference values for vegetable and field crops and trees and vine fruit crops, respectively, facilitating the adequacy of crop coefficients for the correct determination of water needs in Galicia. In Image 4.2.2.21, the net irrigation needs for maize and grassland in Galicia are presented (Cancela et al., 2006a). It is worth mentioning the importance of considering the fraction of soil cover and the height of the crop to obtain the water requirements without increasing or reducing them, assuming a total coverage of the crop, when this does not occur, or vice versa (Pereira et al., 2020). These authors also presented an example of using satellite image data, whose application, together with the basic information of the crop, allows us to recalculate in real time the water needs throughout the irrigation campaign, improving the use of water.



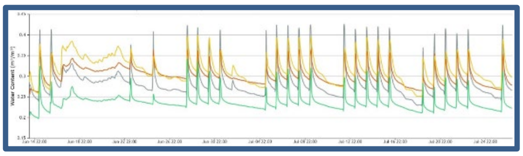


a b

Image 4.2.2.21. a) Empirical probability distribution of non-exceedance of the net irrigation requirements for silage maize (squares) and grass pasture (triangle) and b) variation of available soil water (grey line) for irrigated silage maize

3.2. Digitization of irrigation: images and sensors

Precision agriculture pursues the appropriate use of resources (inputs) to maximize agricultural production, involving the implementation of different processes, such as the opening and closing of irrigation sectors, as well as the application of artificial intelligence to help in decision-making processes by the farmer (Cancela et al., 2015b). Today, the availability of open satellite images (COPERNICUS) is a reality, as well as low-cost and solid sensors (Fandiño et al., 2012b), allowing efficient irrigation management and its implementation in small plots (Rodríguez-Fernández et al., 2021). In addition, unmanned platforms such as UAVs have the capacity to fly over crops at strategic moments throughout the crop cycle, obtaining high-resolution images, below 10 cm pixels, with which we can obtain vegetation indices (NDVI, PCD, SAVI,...) or physical parameters of the crop, feeding the decision support systems based on artificial intelligence processes (Rodríguez-Fernández et al. 2020). In relation to irrigation management, thermal cameras have provided a breakthrough in the detection of areas with greater water stress, using indices such as the Crop Water Stress Index (CWSI) (Cancela et al., 2021), either from satellite images or from images obtained by a UAV (Image 4.2.2.22).



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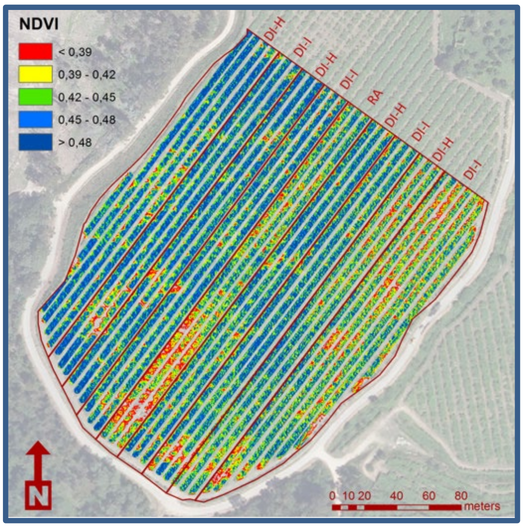
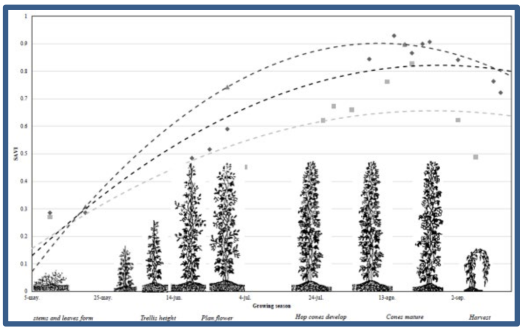




c

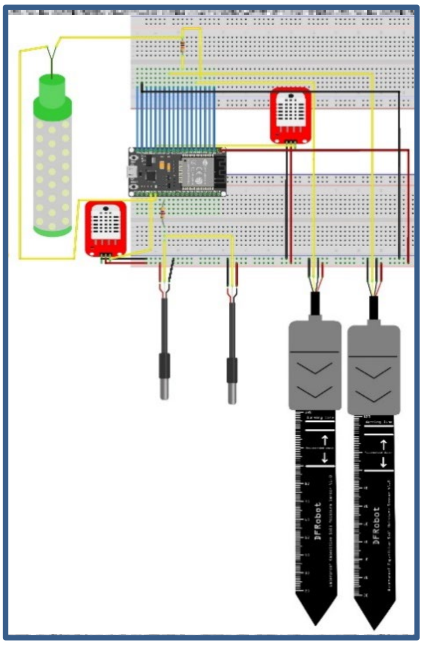
a

Image 4.2.2.22. a) NDVI in veraison for cv 'Albarino' grapevines under different irrigation treatments, b) dynamics of soil moisture content in a hop field, and c) evolution of SAVI index in a hop field in Galicia

Finally, it is worth noting the relevance of knowledge of the physical properties of the soil, where the zoning of the plot, based on the apparent electrical conductivity of the soil (Image 4.2.2. 23b), is very useful (Mirás-Avalos et al., 2020).

a)

b



c

Image 4.2.2.23 a) Soil water content sensors in a Galician vineyard, b) soil electrical conductivity equipment in the field, c) connections scheme of several soil and climate sensors with a low-cost microcontroller ESP32

In recent decades, considerable efforts have been devoted to process automation in agriculture. Regarding irrigation systems, the effort to address this demand has experienced several difficulties, including the lack of communication networks and the large distances to electricity supply points. With the recent implementation of LPWAN wireless communication networks (SIGFOX, LoRaWAN, and NBIoT), and the expanding market of electronic controllers based on free software and low-cost hardware (i.e., Arduino, Raspberry, ESP, etc.) with low energy requirements, new perspectives have appeared for the automation of agricultural irrigation networks (Fernández-Ahumada et al., 2019). In the figure below, you can see an example of an ESP32-based low-cost system with two air temperature and relative humidity sensors with a radiation shield, two capacitive soil moisture sensors, a watermark sensor for measuring water potential in the soil, and two soil temperature measurement sensors, powered by solar energy and with data transmission via the Lora protocol, to a gateway that sends the data via email and, in turn, registers them on a microSD card (Image 4.2.2.23c).

4. Challenges for the future of irrigation in Galicia

In the current global climate context, and in Galicia, where the increase in average temperatures in the summer period and the irregularity of rainfall is a reality, improving the efficiency of existing irrigation systems and introducing new irrigation systems is of vital importance in pursuing sustainable agriculture in rural Galicia. This aspect, linked to the changes in the CAP (common agricultural policy) (2023-2027), opens the door to decoupled payments from production with the introduction of different eco-regimes that make production more sustainable, although in these, it is necessary to apply deficit irrigation strategies to maintain productive and qualitative levels that make Galician agriculture and livestock competitive. It opens up the opportunity to expand the range of crops to be cultivated by improving the climatic conditions for their effective development, although again, they require the contribution of water through irrigation in a sustained way over time.

In addition, the existence of information technology tools such as sensors, satellites, drones, and platforms providing access to open climate data will allow the adequate management of irrigation systems, and therefore water, as a scarce resource, facilitating decision making considering parameters of the soil–plant–atmosphere complex and the productive objectives of the farmer, incorporating artificial intelligence into the final tools. In this sense, the modelling of the water needs of crops not studied so far, in the climatic conditions of Galicia, requires the support of public institutions that finance them and will allow for the completion of the database of cultural coefficients for the implementation in the medium term of a System of Help and Information to the Galician

Irrigator, as occurs in other Spanish communities. The existing meteorological network in Galicia (MeteoGalicia), together with the agrometeorological stations of private companies, would be a good starting point with which to advance with the purpose of providing farmers with a Galician SIAR, making their farms more competitive and sustainable, maintaining the population in the rural environment.

For all the above, the future scenario is encouraging because there are technical and human resources with which we can achieve efficient water management in Galicia, thus anticipating critical situations in the medium term, where the responses will not be effective. It is necessary to solve the current energy problems, where large irrigation systems have obstacles to their use, as their operation depends on the cost of the energy. This will involve developing water storage systems that allow the pressurization of networks using gravitational energy, as well as using photovoltaic and wind energy as a sustainable resource that allows for the feeding of pressurization/pumping units, reducing energy costs, in the face of the energy transition and the implementation of a circular economy in the Galician territory.

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