Traditional water management in contemporary urbanity:
Traditional water management suggests possible ways of managing the hydrographic basins of contemporary urbanity

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ABSTRACT: The main effects of climate are related to water variations in ecosystems. One of the keys to adapting to climate change is to build up the resilience of these ecosystems in the face of these changes by implementing nature-based solutions. Generally speaking, contemporary urbanity is located in low-lying areas and depends on terrains found upstream as much for the supply of water of sufficient quality as for the prevention of flooding in periods of excessive rainfall. In the case of Galicia, in addition to the increase in rainfall, the rise in sea-level will exacerbate the problems. The traditional knowledge of the functioning of ecosystems in terms of social-natural interaction, a knowledge possessed by the local population, is an important asset: this knowledge shows the process of adaptation to changing climate and socio-cultural conditions, where an understanding of the overall management of the water flow is essential. It is very important that this knowledge is better incorporated into the decision-making process, given that it can be used to design new strategies to address the challenge of climate change. This knowledge can also be used in the study of downstream zones in contemporary urbanity characterized by the dispersal of urban objects.
KEYWORDS: Floods, Managed aquifer recharge (MAR), Underground Taming of Floods for Irrigation (UTFI), Hydraulic space, Integrated water flow management

1. INTRODUCTION

The main effects of climate change in a territory manifest as changes related to water and alterations to its distribution in ecosystems. One of the keys to adapting to climate change is to strengthen the resilience of the ecosystems to the changes by implementing nature-based solutions.

In general, contemporary urbanity is located in low-lying areas and depends on terrain in higher areas to supply water of adequate quality as well as prevent flooding in periods of excessive rainfall. (Fig. 1).

In the case of Galicia –the region located in the North-West of the Iberian Peninsula forming part of the European Humid Area and which is subject to some of the highest annual rainfall in Western Europe- the majority of aquifers arise from systems of fractured impermeable rock. These aquifers have a low storage capacity and their levels are heavily dependent on rainfall frequency. They are thus sensitive to climate variation and very vulnerable to extended periods of drought. Climate change predictions for Galicia suggest that there will be a fall in the total volume of rainfall as well as a lower frequency of events which will intensify the already frequent droughts in the summer periods [1].

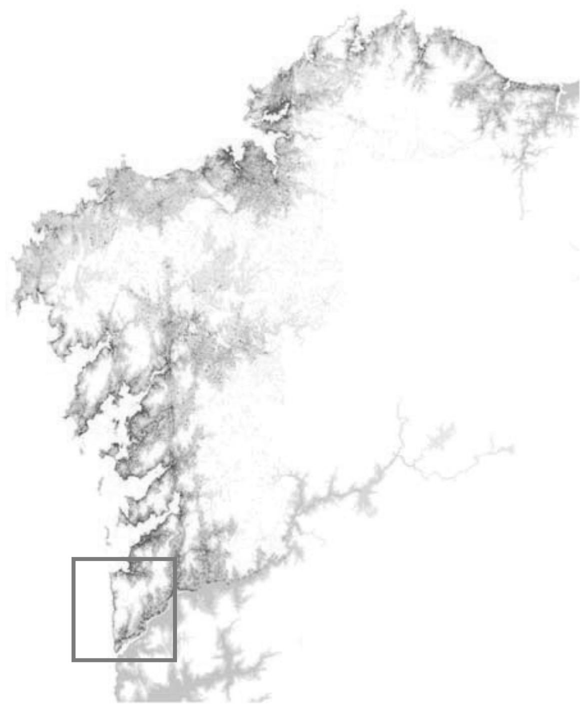

Figure 1: Galicia built-up areas located below +100m. The area which is subject of study is marked. Source: Authors´ image

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On the other hand, the forecasted rise in sea level due to climate change suggests a very considerable impact on Galicia where 2/3 of the population live on an extended seaboard of more than 1.500 km and is generally low-lying and accessible. This population size reflects the depopulation of the rural interior of the region. This coastal area is especially sheltered in the interior of its characteristic "*rías*". [2].This singular new coastal urbanity has grown in recent decades. It is based on pre-existing cites, small towns and minor ports in addition to transport infrastructure (motorways, roads) and rural smallholdings. The urban objects follow one another without a continuity solution in the low-lying areas of the seaboard. These characteristics of the urbanity only reduce the possibility of drainage of rivers and water flows at times of high tides as has already been seen on occasions.

We propose, through reference to a case study conducted in Galicia which reflects certain climate characteristics and hydrological particularities, to describe a traditional system of water management. The knowledge gained from this study might enable us to draw conclusions about how to design new nature-based infrastructures, which reflects a profound knowledge of the milieu in which it operates, is fully adapted to the natural water cycle and has sufficient flexibility to be adapted to the unpredictability of nature.

2. HYDROLOGICAL CHARACTERISTICS OF GALICIA

Weighted annual rainfall in Galicia is 1,180 mm and the period of highest rainfall is around the winter solstice.

The region has more than 21,200 water sources which make up a dense, uniformly distributed network that extends for over 32,000 km. This represents one water course to every square kilometre. As a result, it is difficult to travel more than 1 km in any direction in this region without coming across a running water course [3].

This dense hydrological network is the result of high levels of rainfall combined with the impermeable nature of the rocks (granite and schist) which form the substrate with fractured aquifers.

The territory of Galicia is thus a checkerboard of small heterogeneous aquifers of reduced volume and in which the water flow rate is elevated, as evidenced by the low levels of mineralisation and the frequency at which significant falls in volume occur in times of drought.

In the hydrological model (Fig. 2), the way in which the surface layers of granite-having been subjected to erosion and weathering-function like a sponge, absorbing a considerable volume of water which is effectively stored since it cannot drain away: the sub-surface rock is impermeable. The water thus retained in the winter and spring months drains away slowly during the dry summer season via numerous springs. This type of aquifer does not contribute greatly to the total water supply, but does retain water close to the surface throughout the dry season.

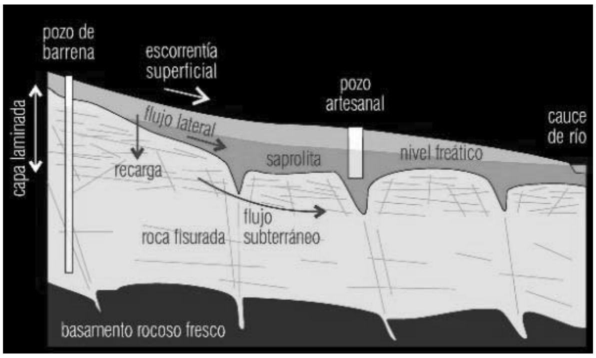

Figure 2: Concept of the hydrological model of rocky crystalline fractured aquifers. Source: Raposo, J.R.

3. THE ROSAL VALLEY

In these conditions a relevant case study was proposed: that of the upper zones of a small valley – the Rosal valley- in the south of Galicia. This valley, can be regarded as representative of many of the numerous small valleys comprising the dense hydrological network which precedes the urban areas on the valley floor and coastal areas.

The Galician coastal mountain ranges are zones of very high rainfall with a geographical element that combine to give rise to water run offs (Fig.3). The mountains are the first obstacle encountered by the high humidity cloud systems proceeding from far out in the Atlantic.

These mountains, although not of great elevation -little more than 600 m- are the primary rain water catchment areas in a region where the average annual rainfall is 1.800-2.000 mm. Springs and rivers arise and are sources of abundant surface water. These are the so-called "*castelos de agua*" (water castles) of the north of Portugal [4].

It is important to emphasize that the role played in these higher zones by the characteristic gentle slopes and rounded contours of these mountains, common features of old mountains subject to erosion. The almost flat surfaces *("chan, chaos, brañas, turbeiras…"*) and, above all, their porous alveoli, lie on layers of impermeable granite and so naturally store water. From pre-historic times, they were understood to be magical places and objects of cults, given their being reserves of life-giving water.

El Rosal valley, which is the object of our study, has the River Tamuxe, which arises in A Serra de A Groba, flowing along its floor. It runs into the River Miño 14 km from its source. At first, the river flows swiftly to then flow through a flatter and wider area of the valley near the point where it joins the River

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Miño. This area is the site of recent urbanization, as this process is favoured by its flat terrain and accessibility. This area is, however, precisely where the danger of flooding has been flagged up (Fig. 4).
We will centre our study on the upper reaches of the River Tamuxe´s valley. The choice of this zone was conditioned by the fact that here no concentration of plots of land has occurred. Thus, the plot layout has remained unchanged and water management structures are recognizable and indeed still in use.

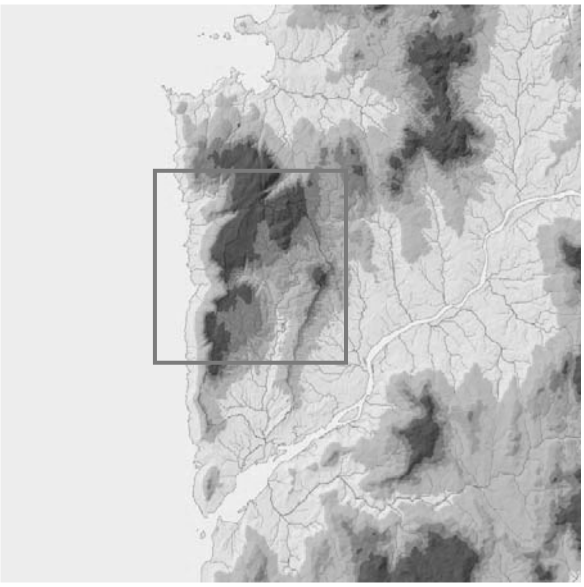

Figure 3: El Rosal valley sheltered from the Atlantic by the A Serra da Groba mountain range, 37 km x 37 km. Area highlighted are measures 12 x 12 km. Source: Authors´ image

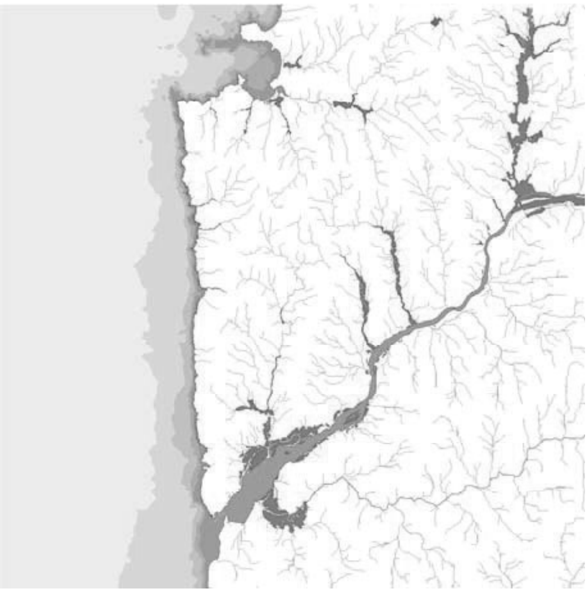

Figure 4: Zones at risk of flooding from rivers and the sea. Source: Own image using data from the Spanish Ministry of Agriculture, Fisheries, Food and Environment (MAPAMA) and Climate Central

This is not the case in the lower reaches of the valley where plot concentration has led to the loss of a significant part of the cultural rural landscape of Galicia –an element of which is its complex hydraulic network.

4. METHODOLOGY

We started by elaborating a cartography which enabled us to accurately represent the water´s geography. Intensive field work was combined with the use of a geographical information programme from digital terrain modelling MDT05 of the Spanish National Geography Institute. The work was complemented by microtyponym data from the PTG (Galician Typonym Project) [5]. This work made it possible to identify a graduated hydrological network with water courses that were either continuous or permanent (“*regueiros*”) or discontinuous, appearing only in periods of rainfall (“*regueiras*”).

Natural water courses, both continuous and discontinuous, facilitate drainage of the terrain, to which are added the managed water courses, the “*regos*” and “*levadas*” that with an inverted geometry and topology complement the natural network.

Data obtained from the tax assessment record from 1956, added to other sources of statistics (use, areas, ownership,…) and which reflect a “mature” moment in the functioning of traditional agriculture, were checked, complemented and broadened through the “*in situ*” study of water management throughout the whole year: “winter irrigation” and “summer irrigation”.

This developed cartography allows us to visualize water use and to clarify the relationship between the settlements and the management of the territory from the perspective of water resources.

5. TRADITIONAL NATURE-BASED SOLUTIONS

In the study, it was revealed that these territories had been settled after careful consideration of the sites for the hamlets which were conceived as the real logistic centres from which the hydraulic system was administered. This reflected a deep knowledge of the local hydrological conditions and the natural water cycle on the part of the settlers.

Each hamlet administers the water that falls on its territory, forming a hydrological space composed of small “*vales*” and “*valiños*” which concatenate with those of other hamlets. As they are nestle together, the laws of coexistence are respected with regard to the territories of the hamlets located upstream and downstream.

The water used by the hamlet community is understood culturally as a common good. A medium, a fertilization vehicle offered by nature, a good in constant use [6], which is used and left again in the cycle to other irrigators. The entire infrastructure is

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constructed in such a way that the replenishment of the aquifers can benefit other irrigators and the other hamlets downstream on the floor of the valley.

In coming to understand the system, two important observations were made regarding hydraulic resources: on the one hand, the considerable fluctuations in water availability over the course of the year; and, on the other, the high level of interconnectedness between the water resources.

The approach to the organization of the infrastructure reflects an understanding of the natural water cycle, and although Galicia is generally regarded as a region with plentiful water resources, the reality is that a substantial portion of its territory has a rainfall deficit in summer [7].

Starting from these natural conditions, a series of strategies have been implemented during the long period of anthropisation of this region. These strategies are examples of “Underground Taming of Floods for Irrigation” (UTFI) which in this case facilitates the re-filling of aquifers due to increased water flows during the wet season. This process mitigates the effects of flooding downstream. In addition, it reduces the effects of drought by making subterranean water available for all human needs, among these being increasing the productivity of the cultivated land.

The surface and subterranean water resources are administered in an integrated way which is highly effective. The subterranean aquifer is understood to be a buffer that can serve to overcome variations in the natural water supply (Fig. 5).

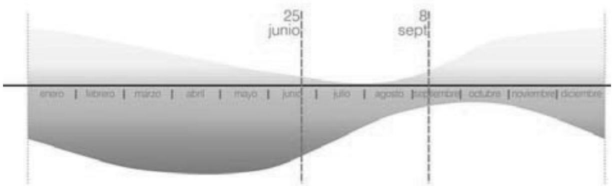

Figure 5: The extensive refilling of aquifers during the winter allows greater availability of water for irrigation at the beginning of the dry season. Source: Authors´ image

It is worth emphasizing that the water is managed by these farming communities throughout the whole year and two distinct periods are recognized: winter and summer.

The summer period coincides significantly with the moment of negative hydraulic balance, when water is scarce, measured and owned, according to rules of custom established within the community. Summer irrigation is intensive work, with the application of small water flows distributed as efficiently as possible. The water is shared, divided, measured and distributed and becomes the sole property of the plots that hold the rights.

Irrigation in the winter, more extensive, has another function closely linked to fertilization, when the water is free and abundant. It belongs to everyone and everyone can use it as they wish for as long as is desired, and always that the geometry allows water movement by gravity.

Blanket irrigation distributes the water over cultivated soil with absorbent species, favouring infiltration and filtration through the soil to fix the nutrients [8]. This happens at the beginning of the cold weather season to protect the crops in the meadows and “*lameiros*” from frost. “*Regas de lima*”, as J. Portela points out, “traditional irrigation “feeds” the crops in summer and “warms” them in winter, allowing forage production” [9].

The winter irrigation is also a technique of dispersal, for reducing flows, increasing filtration and reducing the water´s potential for erosion. It favors infiltration in order to store water in aquifers and groundwater, and will be useful for gradually recharging springs and wells.

For all this to be accomplished, three systems are employed that complement one another with the aim of facilitating water infiltration, water retention during the dry season, and avoiding of flooding downstream. These are:

a) The “*Lameiros*” (meadows): These are natural depressions irrigated in winter to counter frost damage. The “*lameiros*” are used to produce green grass. Their location upstream of the areas to be irrigated during the summer allows refilling of the aquifers throughout that season as well as reduction of water flow downstream and thus its erosive effect. Their location also means the water remains in the surface layers of granite which, as we have seen, function like a sponge by storing significant volumes of water which are retained by the lower layers of impermeable rock. The farming community has a perfect knowledge of the functioning of the system as well as of the high level of interconnectivity of the hydraulic resources; as a result, in summer when irrigation starts but water is scarce, they abandon the irrigation of the “*lameiros*” in order to maximize the availability of water downstream [9].

b) Las “*levadas*” (water channels): The water channels (“*levadas*”) conduct water in laminar flow at a low and constant flow rate which is controlled to reduce erosion. The “*levada*” –the most important of all the elements in the system- consists of channels which divert water for several kilometres from the main river, and which irrigates fields that have been designated to receive water from this source. The residents of the hamlets refer to this as a communal irrigation system. It irrigates most of the plots and every hamlet that due to its location can be irrigated from the Tamuxe will have a “*levada*” as its main source of irrigation. This “*levada*” will be

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supplemented by numerous dams and smaller water catchments. The hamlet is the basic community unit for administering irrigation via the "*levada*".

The "*levada*" marks the limits of the irrigated space and forces the location of the hamlet at a certain point, marking a stiff line above which there is no possibility of watering.

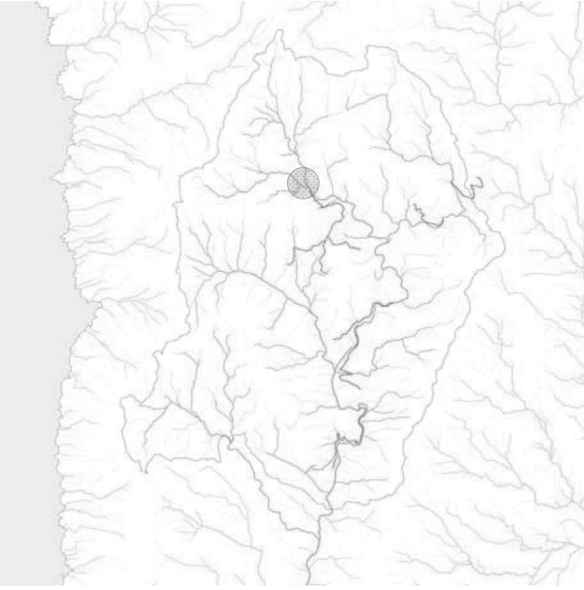

Figure 6: The River Tamuxe and each of the water channels that are distributed over the length of its flow. The red area marked in the higher zone identifies the zone of the "lameiro" upstream of the areas irrigated in summer. 12 x 12 km Source: Authors´ image

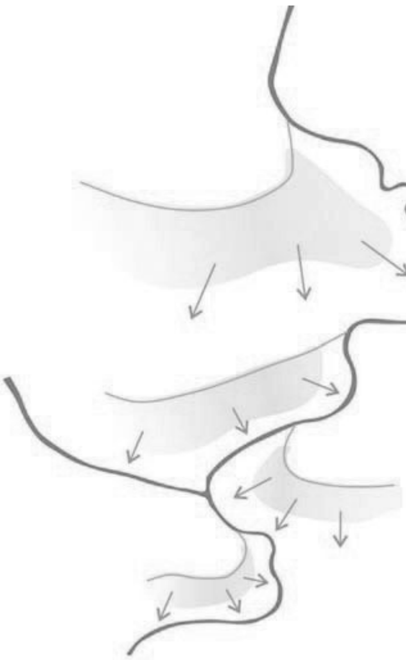

Figure 7: The different "levadas" (water channels) come off the main river at successive intervals. They attenuate flows and dissipate energy during the winter. Source: Authors´ image

It is dug out of the soil, and in addition to its irrigation function, it has an important role in winter in attenuating the flows of the main river, dissipating energy, dividing flows, watering them, recharging aquifers, and infiltrating meadows. The non-infiltrated "leftovers" are returned back to the river through the "*regos fureiros*".

c) The "*Regos fureiros*" These are drainage channels draining the run offs of surplus water in winter to the rivers and "*regueiros*". They are an important part of the infrastructure which are adjusted to bypass the areas when infiltration is not possible or when rainfall is very high. They also divert water towards points in the system where it will not have a damaging effect.

6. CONCLUSIONS

Every territory, taking into account its individual characteristics, must address the consequences of climate change by implementing policies, programmes, plans, projects and actions that, in an integrated manner, are capable of mitigating the pernicious effects of these changes.

An in-depth study enables an integrated understanding of the territory´s history and evolution, its geography and geomorphology, derived from each socio-cultural context in its development.

The knowledge of the cultural landscape that was exposed, and of the traditional elements and techniques described, allows us to propose its survival and the high likelihood of it needing conservation, maintenance and implementation. The described above techniques can be summarized as:

- Techniques of accumulation and storage of water in the higher zones of the coastal mountain ranges and communal "*baldíos*", avoiding uses in forests incompatible with its spongy edaphological properties.

- Techniques for the dispersion of natural effluent flows and of the copious run offs of rushing water, maintaining and/or implementing an inverse, arborescent network -using "*levadas*" and irrigation channels- that, from the management of the topography, take advantage and/or generate networks of water dispersion, with retention and regulation tanks, causing the dispersion of excessive flows, and minimizing water circulation speeds; favouring the infiltration capacity in cultivation terraces and/or in the "*lameiros*", retarding the concentration of waters downstream; and maintaining and improving the edaphology of the cultivated soils created with the carefully considered horizontalization of cultivated terraces, preferably irrigated and cultivated, as areas of retention and infiltration of rainwater.

- By-pass techniques, such as the "*regos fureiros"*, prevent the flow of "rough waters" through valuable

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areas needing to be protected and divert them along alternative routes. For them to be effective, it is necessary that they are regularly kept in use and maintained so that they can function as an integral part of the territory´s drainage system.

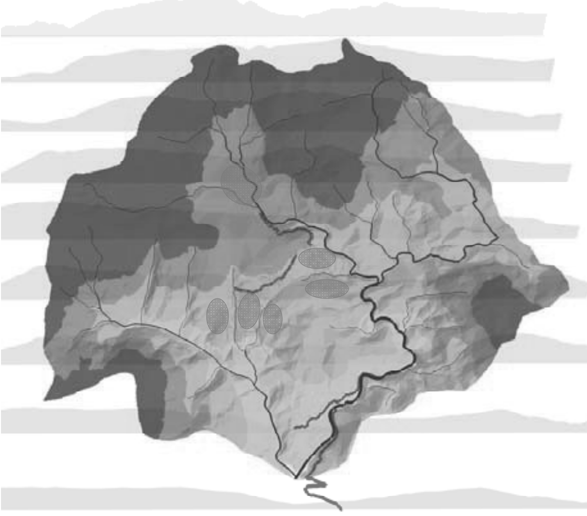

Figure 8: Area of "lameiros" in the upper zones and area under irrigation. The winter irrigation contributes to the refilling of the shallow phreatic alluvial layers which means water is available during times of scarcity in the summer period. Source: Authors´ image

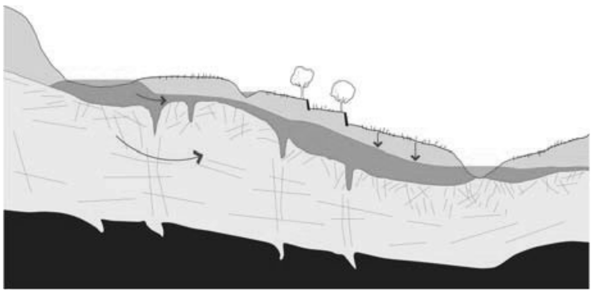

Figure 9: The traditional water management allows the comprehensive re-supply of aquifers which makes water available during the dry season. Source: Authors´ image

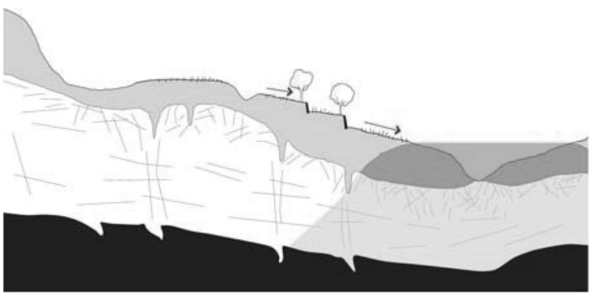

Figure 10: The lack of this management supposes the increase of the avenues in the rivers increasing the problem of flooding already existing downstream, aggravated with increase in sea level. Source: Authors´ image

It appears an opportune moment to, on the one hand, avoid the abandonment of the traditional hamlet of the high and medium zones of the valleys and "*valiños*" (small valleys) and thus reverse the gradual emptying of these peasant hamlets and the concentration of their former inhabitants in the urban and seaboard environments; and, on the other, to retain the previously constructed territorial elements that are still useful. These can be integrated into contemporaneity and implemented integrally with new networks and elements.

We can therefore define traditional water management in the small hamlet communities located in the small valleys of Galicia as "Sustainable Territorial Drainage Systems", capable of bringing a landscape that has been intensively anthropized close to nature; and this through the wise management of water (close to the water cycle) and cultivation.

The local community´s traditional knowledge of how ecosystems function in socio-natural interactions is a very important asset, demonstrating the process of adaptation –since the first human settlement of these territories- to both changing climate and socio-cultural conditions.

Today, it is necessary to improve the incorporation of this knowledge into the decision-making process. These is because it can be used to formulate new strategies to address the important challenges posed by both climate change and the indiscriminate occupation of low-lying areas by a contemporary urbanity characterized in these territories by the informality of urbanization and the dispersion of urban objects in coastal areas.

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