Un-covering irrigation canals as an urban renewal mechanism. The eastern edge of Zaragoza (Spain)

Re-descubrir acequias como mecanismo de regeneración urbana. La orla este de Zaragoza (España)

PABLO DE LA CAL NICOLÁS

Pablo de la Cal Nicolás, "Un-covering irrigation canals as an urban renewal mechanism. The eastern edge of Zaragoza (Spain)", *ZARCH* 15 (diciembre 2020): 110-121. ISSN versión impresa: 2341-0531 / ISSN versión digital: 2387-0346.
https://doi.org/10.26754/ojs_zarch/zarch.2020154811

Recibido: 10-06-2020 / **Aceptado:** 04-10-2020

Abstract

With two dense districts and a large adjoining expanse of metropolitan orchards, the eastern edge of Zaragoza (Spain) is a perfect example for analyzing water flows in "irrigated cities", where a major functioning irrigation infrastructure has survived, generally in arid climate conditions. The basic premise of water–city challenges is analyzing these agricultural systems' potential for spatial and functional transformation strategies within a necessary urban renewal framework. The starting parameters are similar to those of other international examples whose urban strategies implemented to combat climate change have focused heavily on issues such as the storage capacity of rainwater and its urban reuse. However, in the example in question and, in general, in "irrigated cities", more attention should be paid to "making the city's agricultural structure more visible" by creating ecological corridors inside the city and by correcting the urban microclimate in highly dense areas with significant levels of compactness.

Keywords

Irrigation canals, urban agriculture, water cycle, urban microclimate.

Resumen

La orla este de Zaragoza (España), con dos barrios densos y una extensa huerta colindante, es un perfecto ejemplo para analizar los flujos de agua en las condiciones de las 'ciudades irrigadas', en las que pervive una importante infraestructura de regadío en funcionamiento, generalmente en condiciones de aridez climática. Precisamente, los retos de integración agua-ciudad exigen, como premisa básica, analizar el potencial de estos sistemas agrícolas para plantear estrategias de transformación espacial y funcional en el marco de una necesaria regeneración urbana. Los parámetros de partida son análogos a los que presentan otros referentes internacionales, que han implementado estrategias urbanas contra el cambio climático muy centradas en cuestiones como la capacidad de almacenamiento de la precipitación de aguas de lluvia y su reutilización urbana. Sin embargo, se requiere en el ejemplo que se plantea y con carácter general en las 'ciudades irrigadas' una mayor atención a las operaciones de 'visibilización de la estructura agrícola en la ciudad', en la creación de corredores ecológicos en el interior de la ciudad y en la corrección del microclima urbano en zonas de gran densidad y elevados índices de urbanización.

Palabras clave

Acequias, agricultura urbana, ciclo hidráulico, microclima urbano.

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Presentation

Many Mediterranean and Central European cities contain urban areas that expanded around an agricultural basis and their irrigation systems are still partially operating today. Incorporating these irrigation systems into the urban water system has attracted increasing interest in theoretical studies and in recent urban renewal actions.

International examples of urban planning integration and comprehensive water management are generally found in urban contexts with a prominent permanent presence of water (canals, ponds, etc.), in climates with high rainfall levels where flood protection is needed, and so on. However, there is less experience in urban areas in highly urbanized arid contexts with traditional irrigation systems.

Nevertheless, many urban areas that have expanded "on" metropolitan orchards can be recognized as "orchard districts". In these areas, urban renewal actions primarily based on restoring dynamics related to the still active water system underground can be taken.

The example of the eastern edge of Zaragoza clearly illustrates the condition of these "orchard districts" or "irrigated cities". This article offers an analysis of development and landscape plans recently drafted in this area and their features relating to other current examples.

Water–city integration strategies in "irrigated cities"

Three general stages have been identified in the analysis of recent interferences between urban construction processes and the role of water flows in the city.[1] The first stage corresponds to transformations resulting from urban industrialization, whereby rivers, converted directly into urban sewers, became the focus of health and environmental problems. In the second, urban modernization tried to control natural water flows. Technological advances in water supply and wastewater treatment involved a gradual distancing from natural dynamics. Consequently, many natural and artificial watercourses were abandoned and replaced by new pipes and most of the preindustrial city's water system was completely covered or closed. After discrediting the excesses and abuses of this development stage, we are now immersed in the third stage—involving renewal processes of the city's water system based on environmental parameters and the restoration of watercourses that had been devalued, hidden or closed.

Watercourse restoration actions, initially based on renaturing strategies and the esthetic and functional restoration of river or coastal ecosystems, have included other urgent and global agendas in recent years, such as measures to mitigate the effects of climate change. Some cities have drawn up climate change adaptation strategies, for example Delft and Rotterdam, and they have coined the term "water sensitive city". The city is viewed as a single water system in which not only singular natural spaces play a crucial role, but also secondary watercourses, which form part of a capillary system comprising hydraulic filaments branching out along streets and urban spaces.

More recently, work has revolved around concepts such as "sponge city",[2] which refers to rainwater storage and reuse strategies, and "closed city", a term coined by some authors to identify cities that have no negative impacts on their surroundings resulting from drawdowns of water resources or discharges of polluted water, and their aim is to improve the storage, reuse and recycling capacity of rainwater and graywater.[3]

1 The sequences related to water infrastructures have been expounded in classic works, such as general studies published by Joel A. Tarr and Gabriel Dupuy (1988), Terje Tvedt and Terje Oestigaard (2014), and Maria Kaika (2005), and more specific research, such as the study published on Munich by Winiwarter, Haiddvogl and Bürkner (2016).

2 Government programs in China use the term "sponge city" for the group of cities that must attain a rainwater retention capacity of 70% for urban reuse by 2030.

3 Fransje L. Hooimeijer et al., "Hybridity vs Closed City. A study about the impact of applying 'Hybridity' as a concept of understanding in designing a decentralized water circulation urban model called 'Closed City'", Delft University of Technology, 2019, 5.

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In these approaches, urban environments are considered "hybrid constructions" created with interconnected human and natural systems linking together all living beings, resources and spaces. Recent studies quantify the "hybridization" indicator in a city to assess the relationship between human and natural systems. This "hybridization" has an environmental dimension—referring to the relationship between the city's three spheres (geosphere, biosphere and technosphere) and their participation in the water system—and a spatial dimension—including the analysis of all elements and surfaces that make sense of all the spatial elements forming part of the water system and water transfer mechanism, such as green roofs, storage tanks, bioswales, irrigation canals and urban community gardens.

The use of green infrastructures has been consolidated in all urban and landscape innovation models and "nature-based solutions" managing natural processes proactively to achieve water-related objectives have been applied.[4] These green infrastructures have been implemented with three basic principles in mind[5]: planning urban areas that maximize rainwater infiltration; encouraging runoff retention where possible; and, lastly, seeking and creating opportunities to reuse infiltrated and/or retained water.

Incorporating the urban agriculture agenda in town planning in the past two decades has consolidated the importance of agriculture as a hybrid space between city and nature, and the idea is for production areas to interconnect with each other within cities and also with external areas.[6] Enric Battle has the same view when he says that "the only reasonable solution for our nearby open spaces is for us to eat them",[7] suggesting that the urban food system needs to be planned jointly with other urban and regional sustainability strategies.

Assuming that these action criteria and principles are generally applicable, cities whose growth has been supported by millenary agricultural constructions and that preserve important traditional irrigation systems in their urban areas or nearby have a different profile and can be identified as "irrigated cities". In the Spanish context, we could refer to Granada, Valencia, Murcia and Zaragoza as well-known examples; in other latitudes, we could mention many other "irrigated cities" such as Mendoza (Argentina), which has a network of urban irrigation canals stretching over 500 kilometers, and Talca (Chile), which has an agricultural heritage recently perceived as a great opportunity for adopting an ecological focus in town planning.[8]

These "irrigated cities" share common features. On the whole, they have preserved highly valuable large-scale landscape and production areas. Their climate conditions, generally with low natural precipitation and marked aridity parameters,[9] have led to an expressive contrast between the urban landscape and the irrigated landscape. This contrast has a spatial as well as a cultural dimension, since urban modernization in the twentieth century has managed to erode, and, in some cases, erase most of the city's "agricultural footprint". Nevertheless, to a certain extent, these cities have preserved a network of irrigation canals in survival mode, in an open struggle against implacable development processes, and against sectoral actions exclusively promoting irrigation system optimization.[10] One last point is that water distribution systems transport high volumes of water, especially when compared to the volumes circulating in the rest of the city's water network.

In this situation, faced with the challenge of implementing current city–water integration paradigms, merely superficial, esthetic or nostalgic visions of a "lost hybridization" need to be left behind. Instead, we ought to identify the arguments supporting efforts to reverse the current conditions of irrigation infrastructures that are still hidden.

4 Sustainable drainage systems (SuDS) aiming to correct unsustainability in our cities, identified by a high level of impermeability, with an intensive occupancy model, and ongoing expansion of sewer systems, are just one example of this type of approach that has become widespread, although far less than it should be, in more recent actions.

5 Rodríguez-Rojas et al., "El cambio de paradigma en la gestión del drenaje urbano desde la perspectiva del planeamiento. Una propuesta metodológica", Boletín de la Asociación de Geógrafos Españoles no. 75, 59.

6 One of the pioneering studies in this field was conducted in 1991–92 by Jac Smit, Joe Nasr and Annu Ratta, funded by the United Nations Development Programme and published in 1996 with the title *Urban Agriculture: Food, Jobs and Sustainable Cities* (later republished in 2001). Another interesting line of research is the study by Katrin Bohn and André Viljoen, who coined the term "continuous productive urban landscape" (CPUL) in "The Edible City: Envisioning the Continuous Productive Urban Landscape (CPUL)", Field 4, 2011, 149–61.

7 Enric Battle, "Fusionando ciudad y agricultura", in Renaturalización de la ciudad (Barcelona: Diputació Barcelona, Colección Estudios, Serie Urbanismo y Vivienda, 2019), 304.

8 In this respect, we must consult research conducted years ago by J. M. Ponte on the irrigation canals in Mendoza (Argentina) and other far more recent studies, such as the doctoral thesis by Catalina Madrid Stevenson entitled "La Línea del Agua. Infraestructura del paisaje para la resiliencia urbana ante extremos hídricos: el caso de Talca. Chile" (2019).

9 Annual average precipitation in Rotterdam (782 mm) and New York (1,114 mm), to give just two examples, is clearly higher than rainfall in cities such as Valencia (445 mm), Zaragoza (357 mm) and Murcia (293 mm).

10 Irrigation infrastructure managers seek to improve efficiency based on a sectoral vision that promotes the construction of concrete box culverts or pipes for irrigation courses to improve irrigation flow performance, thereby minimizing water loss and increasing circulation speed.

A first sound argument is the urban heat island's capacity for correction. An increase in permanent water surfaces with the subsequent rise in evapotranspiration would manage to reduce the high temperatures reached in the central areas of some districts, especially if the pavement permeability conditions were corrected, and the number of plants bordering the irrigation canals rose.[11] A second important aspect to consider is the opportunity for qualitative transformation of the urban space, which is consolidated by heritage and historical memory recovery actions and the collective identity of certain memorable places.

The restoration of irrigation canals as visible city watercourses paves the way to review the role played by crop areas in the city and to design scenarios with more hybridization between gray and green infrastructures. The challenge posed by these "irrigated cities" involves considering traditional irrigation systems as "landscape infrastructure". As Pierre Bélanger suggests, we must implement projects for operational systems addressing all the complexity of biodynamic processes and resources along the entire footprint in the city and throughout the infrastructures' lifecycles.[12]

Zaragoza: the opportunity to un-cover main irrigation channels

Zaragoza is the fifth most populated city in Spain (674,997 inhabitants in 2019). It is in the center of the north-eastern part of Spain in a region where the rivers Huerva and Gállego flow into the main course of the River Ebro, on its right and left banks, respectively. These rivers encouraged the first water supply and irrigation pipes built by the Romans and, later, the formation of the agricultural area in Muslim times. Using weirs and a dense system of distribution—or main—irrigation ditches, the Muslims constructed an extensive irrigation network to take advantage of the rivers' water. The scant rainfall[13] in this arid land and the irregular flow in the rivers limited the productivity of the metropolitan orchards.

The construction of the Imperial Canal of Aragon, which runs along the southern side of the Ebro river valley, at the end of the eighteenth century considerably improved the provision and efficiency of irrigation water distribution systems. This landmark made it possible to irrigate areas on the right bank of the River Ebro from El Bocal, in Navarre, to Zaragoza, whose market garden covered a surface area of 10,000 hectares in its municipality organized into several irrigation communities.[14]

At the start of the twentieth century, the plot division structure of these irrigation communities, equipped with an efficient agricultural infrastructure of tracks and watercourses, fostered and made possible unplanned suburban growth. The later general development plans tried to solve the challenge of districts that had expanded on agricultural geometries unsuitable for densification, which had continued to intensify throughout the century.[15]

This water structure supporting the city's first suburbs (Delicias, San José, Oliver, Valdefierro, etc.) was gradually covered to enable development that could not be completed in the first stages. In the planned expansions, such as the district of Las Fuentes, the development involved artificially high levels compared with the agricultural land, which meant that the irrigation canals were also largely hidden.

This "hidden condition" did not, however, prevent the main channels from continuing to operate. They have never stopped transporting water from the Imperial Canal or from the River Gállego to the crop terraces outside the city. Irrigated land has reduced drastically since the mid-twentieth century, but, at the same time, the distribution systems have become more efficient and supply more water for irrigation.[16] [fig. 1].

11 Due to evapotranspiration, trees and plants absorb water from the soil and re-emit it into the atmosphere as water vapor, thereby triggering an evaporative cooling mechanism that corrects microclimate conditions.

12 Pierre Bélanger, "Landscape Infrastructure. Urbanism beyond Engineering" (PhD Thesis, Wageningen University, 2013).

13 Around 357 mm/year, half of the Spanish average.

14 The flow is constant throughout the year, with the only exception of the two "shutdowns" for three weeks in November and February to clean the channel. The Imperial Canal of Aragon is a system that withdraws 30 m^3/s from the River Ebro at El Bocal, near Tudela (Navarre), and distributes 50 m^3/s at several points by means of sluice gates, return ditches, and so on. The drawdown regime takes place from "sunrise to sunset" (14 hours), while water diversion from the River Ebro is almost constant for 24 hours.

15 As in many other cities, these unplanned growth processes combined with regulated actions, which, in Zaragoza's case (although relatively small in scale) required covering a stretch of the River Huerva to allow the city to expand towards Miralbueno (Gran Vía-Fernando el Católico sector) in the 1920s, and years later a second stretch was also covered to enable expansion towards Miraflores (Madre Vedruna sector).

16 The gradual covering of irrigation channels and the lining of traditional earthen watercourses with concrete have managed to minimize water losses from infiltration and evapotranspiration. Meanwhile, the abandonment of agriculture due to urban development has optimized the resources available for the land that is still set aside for crops. The water used for agriculture has to suffice to meet the deficit caused by evapotranspiration (766 l/m^2/year) and losses due to infiltration during transport, which in unlined irrigation canals is around 10-20% of the water volume (José María Marín, 1979).

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[Fig. 1] General plan of the water element system in Zaragoza superimposed with the hypsometric map. Source: Author, 2019, 508.

In the urban and agricultural space within the fourth ring road, Z-40, there is a 160.5 km water network, of which 23.48% corresponds to the four main watercourses (Ebro, Gállego, Huerva and Imperial Canal of Aragon) and the remaining 76.51% (around 122.8 km) to less important watercourses (main, ordinary and branch agricultural waterways). The irrigation system includes 50.2 km of covered canals.

Studies published in recent years have highlighted the value of this hidden network under the city's streets and how it can be used to renew the public space by forming "water streets", and to consolidate the historical memory of certain historical areas. Although these studies have been conducted with a variety of approaches and viewpoints (archaeological, anthropological and heritage),[17] their impact on town planning or development documents has been minimal.

The most important document with this stance is the Green Infrastructure Master Plan of Zaragoza (2016), a planning tool promoted by the Environment and Sustainability Agency of the city, which adequately considers this irrigation system's potential as the primary element of a higher-ranking structural spatial system. By way of example, one of its main actions is the ecological corridor plan for Zaragoza's irrigation network, which envisions a review of the network's condition within the city to locate the cases or sections needing to be redesigned to meet the master plan's objectives.[18]

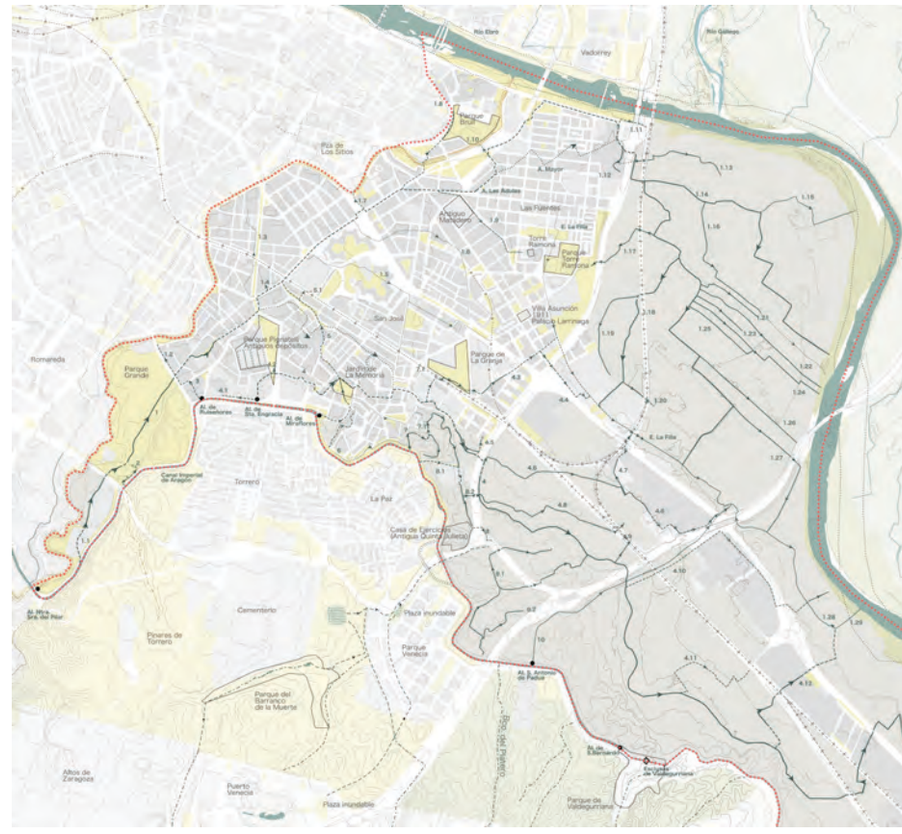
The eastern edge of Zaragoza: Las Fuentes and San José as orchard districts

The Miraflores irrigation area (around 1,014 hectares) is especially interesting as a case study to analyze the interaction between metropolitan orchards and cities in more detail. In this area there are still 26.6 km of uncovered irrigation canals within the fourth ring road, many threatened by urban expansion developments, and

17 Readers may consult the studies by Carlos Blázquez et al. (¿Agua pasada?: regadíos en el Archivo Histórico Provincial de Zaragoza, 2008), by Félix A. Rivas (Patrimonio hidráulico en la huerta de Zaragoza, 2016) and the author's doctoral thesis (Zaragoza: construcción urbana en un territorio de ríos y huertas. Dinámica fluvial, infraestructura hidráulica y ciudad, 2019).

18 Green Infrastructure Master Plan of Zaragoza. Written by: Atalaya team, Jaime Díaz Morlán, Oscar Miravalles Quesada and Irene Zúñiga Sagredo. City Council of Zaragoza, 2016. Although these actions were planned for the medium-long term, the master plan proposes a prior study that includes a review of regulations, recent integration cases and also non-integrated cases, an information and participatory campaign, regulatory integration in the PGOU (town development plan) and in irrigation regulation, and, lastly, a plan to upgrade the irrigation network in urban areas. See PDIVZ, Ficha A.03.00, Sistemas de regadío.

[Fig. 2] Water structure in Miraflores in the south-eastern sector of Zaragoza in 2008. Source: Author, 2019, Annex 2 SIG Map "Zaragoza desde el agua", Map 2.2.b.



almost 17 km are today covered under the districts of San José (66,665 inhabitants) and Las Fuentes (42,321 inhabitants). [Fig. 2]

This area stretches from the terraces east of Zaragoza, between the Imperial Canal of Aragon in the south and the River Ebro in the north. The main irrigation canals of Miraflores cross the districts of San José and Las Fuentes as they descend towards the deep level of Las Fuentes orchards, whose most representative space is the Meander of Cantalobos in the River Ebro, of around 300 hectares, which is disconnected from the district by major infrastructure barriers, such as the rail line and the third ring road, Z-30. Since the 1980s, residents have been clamoring for this space to receive suitable attention by the approval of a Special Protection Plan.[19]

Both this market garden space and the urban sectors of the east of Zaragoza (San José and Las Fuentes on the right bank of the Ebro, and Vadorrey on the left bank) have shown worrying signs of stagnation and deterioration in recent decades.[20] The lack of decisive public intervention in these districts contrasts with the plentiful series of town planning work and studies that have addressed the opportunity of creating new links between the city and the market garden. Firstly, we must refer to the study conducted in 2009 by the Official Association of Architects of Aragon, a concise document that highlighted the need for a global intervention in the eastern part of the city and the opportunity to reorganize intermediate sections between the urban facade and the third ring road and Las Fuentes metropolitan orchards.[21] [Fig. 3]

The "Study of Alternatives for the Location and Urban Integration of the International Horticultural Exposition, ExpoPaisajes2014" was drafted at the end of this same year.[22] It was a failed initiative that proposed an interesting solution for structuring the green ring of Zaragoza in the eastern part of the city. In 2010, the city council drafted an Amendment to the General Plan called "Eastern Districts",[23] which largely adopted most of the proposals incubated in previous years and joint management development proposals within the districts and in areas along the edge.

19 The socio-urban development study *Las Fuentes. Un barrio con futuro*, published in 2006 by the Zaragoza housing association Sociedad Municipal de Rehabilitación Urbana, describes the content of a necessary "special plan for the protection and improvement of Las Fuentes metropolitan orchards and the copse Soto de Cantalobos" on pages 86–94.

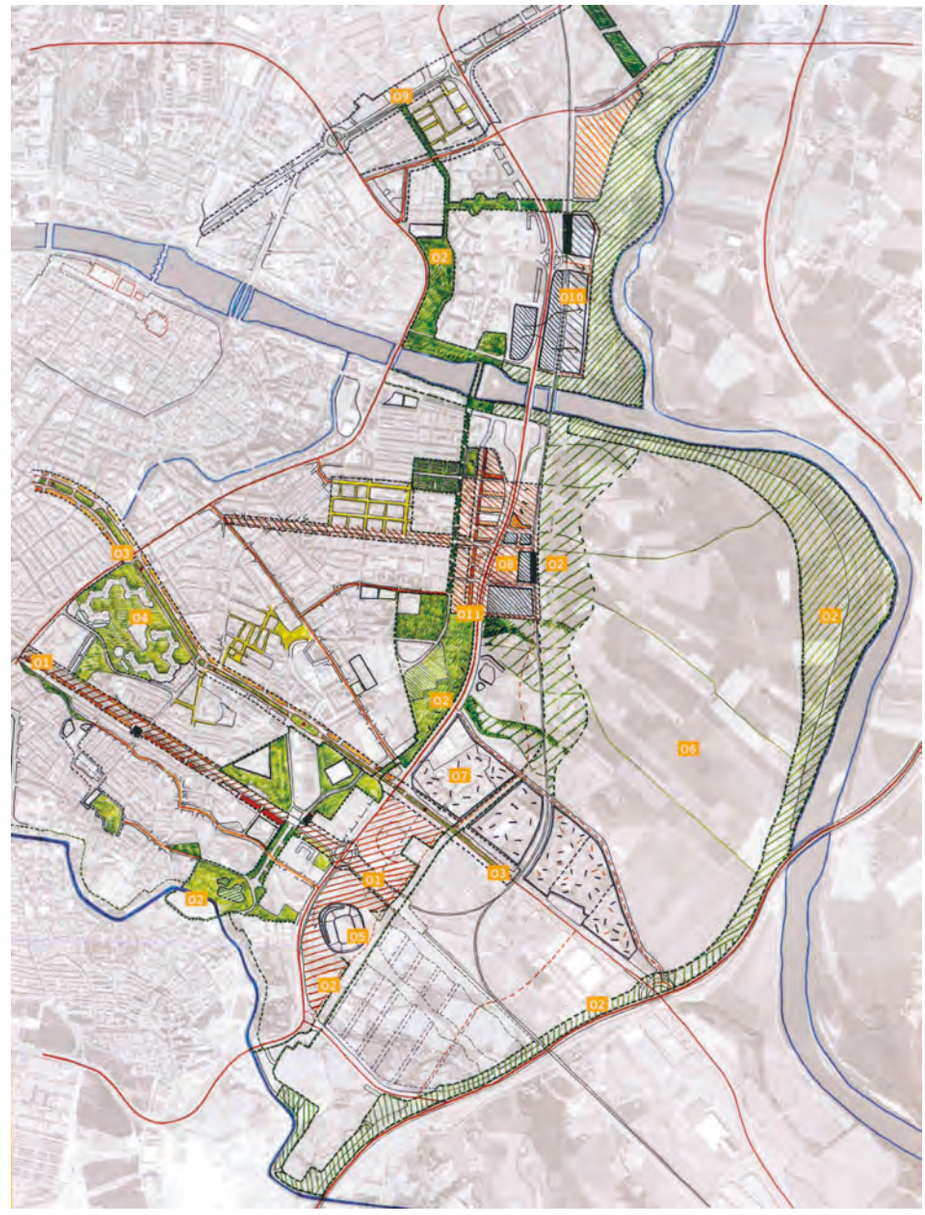
20 In the first decade of the twenty-first century, Zaragoza completed highly important development work in the western sector (new intermodal station, 2008 International Exposition site, etc.), but strategic projects such as the extension of Tenor Fleta Avenue or the need to "close" or connect the "green ring" in the east have not yet been implemented, even though they have been requested repeatedly for years and are considered "urgent" by all municipal governments.

21 This is a study published in Zarquitectura no. 14–15 Year 2010: Ciudad [dos] Talleres Zaragoza Este, which also includes the results of the research conducted by three schools of architecture in 2007 (ETSA of Navarra in La Jota-Vadorrey, ETSA of Vallés-Barcelona in Las Fuentes and ETSA of Valladolid in San José).

22 The study of location and development integration alternatives for Expo Paisajes 2014 was written in December 2009 by the joint venture between Idom Zaragoza and Cerouno Arquitectos, commissioned by the City Council of Zaragoza.

23 Amendment no. 71 of the PGOU of Zaragoza, drafted by Ramón Betrán, head architect of the city council's town planning services, was not approved due to lack of political will.

[Fig. 3] Proposal for the renewal of the districts in the eastern edge. Official Association of Architects of Aragon. 2009. Source: ZArquitectura, no. 14–15, 2010, 83.



In 2011, a fourth document was drafted called “Development and Landscape Integration Guidelines for the Eastern Edge of Zaragoza”,[24] which represented some progress compared with the three previous proposals, as more attention was paid to the organization of non-urban space, with an intervention approach that could be exported to other market garden areas bordering the city. Emphasis was placed on managing agricultural space, preserving irrigation network and regulating transition spaces, this time defined around the La Olivera irrigation channel. It also contained a preview of the Special Protection Plan for Las Fuentes metropolitan orchards.[25] [Fig. 4].

The last development document worth mentioning corresponds to the District Plans for the City of Zaragoza, drafted in 2017–18 by the city council.[26] The “Summary of Las Fuentes District Plan”[27] contains 22 actions in a general comprehensive plan for the entire district and its surrounding area. The creation of the Special Plan for the Periurban Agricultural Park of Las Fuentes and the closing of the Green Ring of Zaragoza in the east are the two priority interventions. To a large extent, it contains the proposals established in the Master Plan for Green Infrastructure in Zaragoza, such as an ecological corridor over the road to Castellón and the rail line;[28] however, it does not adequately understand the irrigation system as an infrastructure network within the district and it does not address environmental and microclimate correction challenges in consolidated areas in the district.[29] [Fig. 5].

24 Written in 2011 within the framework of the collaboration agreement between the University of Zaragoza (Town Planning and Land Organization Area of the School of Engineering and Architecture) and the City Council of Zaragoza.

25 These guidelines establish an organization preview and draft intervention norms that could help to provide this space with a valid organization and management mechanism similar to those used for spaces such as South Milan Agricultural Park, the Baix Llobregat Agricultural Park and the Valencia metropolitan orchards Plan.

26 The city council initiated the drafting of three district plans for Zaragoza: Las Fuentes; San José in the east; and Delicias in the west.

27 Las Fuentes District Plan, drafted in July 2018 by the Planning and Urban Design Department of the City Council of Zaragoza with the technical coordination of Sergio Marta, architect (Ingennus Urban Consulting).

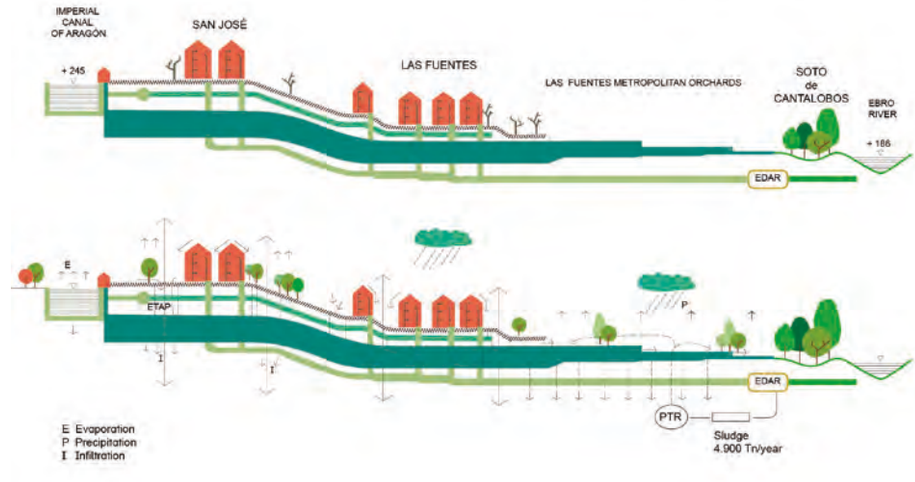
28 Action C.11.02, Green Infrastructure Master Plan of Zaragoza, 2016.

29 In Zaragoza, the average heat island is in the historic city centre and towards the east in Las Fuentes. Despite being close to a large extension of metropolitan orchards, several aspects combine to intensify the urban heat island, including its high building density, its location at the city’s lowest level and its unfavorable position for dominant winds. See Atlas Climático de Aragón. Department of the Environment. Government of Aragon. 2007.

[Fig. 4] General organization proposal. Development and Landscape Integration Guidelines for the Eastern Edge of Zaragoza. 2011. Source: Author's archive.

[Fig. 5] Las Fuentes District Plan. 2018. Priority action strategies. Source: City Council of Zaragoza Town Planning Department.

Las Fuentes District Plan is primarily the result of considering several municipal technical services and it presents an integrated vision; however, it does not include other stakeholders with direct responsibility for the management of natural



[Fig. 6] Diagram explaining water flows in the eastern edge of Zaragoza, from the Imperial Canal of Aragon to the River Ebro. Current scenario (top image) and proposed hybrid scenario between urban an agricultural strata (bottom image). Source: Author.

watercourses (Confederación Hidrográfica del Ebro – Water Authority of the River Ebro) or irrigation (Miraflores Irrigation Community). It is worth considering whether the flow in the main irrigation canals—11,000 M m^3/year, which is 20 times more than the flow in the water supply system—would be a sound starting point for a comprehensive overhaul of the water cycle in the eastern part of Zaragoza based on a stance capable of including traditional water supply, sewer and irrigation systems as an integrated network instead of three separate networks.[30]

The irrigation network and the urban water networks currently operate in two spheres with completely independent physical locations and responsibility. The city sphere is managed by the City Council of Zaragoza, includes a domestic consumption network and a sewer system, whose wastewater is collected and taken to La Cartuja Baja wastewater treatment plant. The irrigation system sphere comprises in its urban section an underground network crossing the districts of San José and Las Fuentes and supplies water to the adjoining “huerta”. It has drainage canals leading to the River Ebro and is managed by the Miraflores Irrigation Community.

Reviewing this current status and opting for a hybrid system with more water flow interrelation by rediscovering the main irrigation canals and secondary watercourses would also enable the “agricultural stratum”, in other words, the fertile soil of the metropolitan orchards, to “emerge”. This would lead to trees being planted along its banks, thus contributing to improving the district’s natural infiltration indices and to increasing evapotranspiration. [Fig. 6]

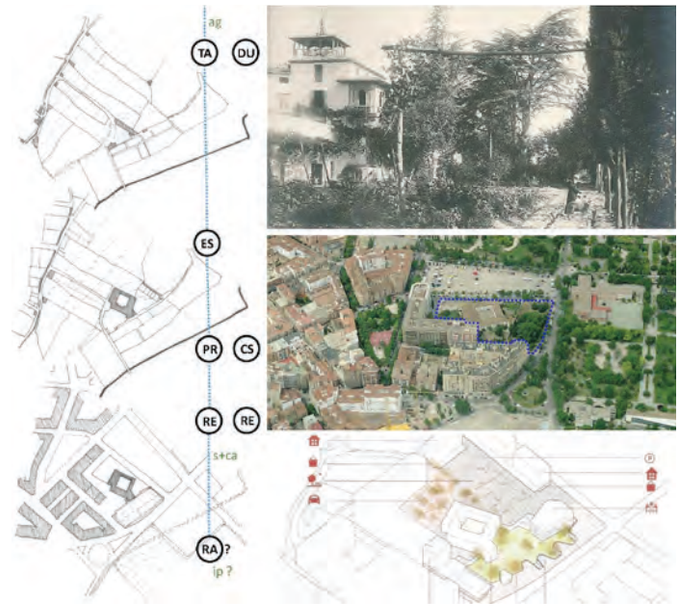
The Mayor “acequia” or irrigation canal of Las Fuentes, fed by the Adulas irrigation canal from Parque Grande Park and by the Ontonar irrigation canal from high San José, could become a driving factor of interior transformation projects. The La Filla drainage canal from Torre Ramona Park could structure the expansion of the park and its link to the Veterinary Medicine Campus until it reaches Las Fuentes Park. The transition and connection areas with Las Fuentes metropolitan orchards should be coordinated with the La Raya and La Olivera irrigation ditches.

Besides playing an active role in public spaces, these open watercourses could collect surface runoff in public green areas and also rainwater from the roofs of buildings. The route of irrigation waterways could be designed as “storage spaces” for this excess water and they would be permanent sheets of water inside the city. These flows could be used during droughts to irrigate urban green areas, or to feed the copses of the Ebro riverbank.

At the same time, uncovering the irrigation canals would make it possible to restore certain mediating relationships between lost agricultural roots associated with

30 Miraflores Irrigation Community has a concession from the Imperial Canal of Aragon of 1,980 l/s “from sunrise to sunset”. The most important flows in the urban area correspond to the following “acequias” (irrigation canals): Adulas (15 l/s), Monares (350 l/s), Plano (800 l/s), Ontonar (250 l/s) and Miraflores (40 l/s).

[Fig. 7] Sequence of urban processes in the Memoria Garden “mediating site” in high San José. Source: Author.



[Fig. 8] Sequence of urban processes in the old Torre Ramona farmhouse “mediating site” in Las Fuentes. Source: Author.

heritage places and with forming new public spaces or spatial nodes that are part of a system structuring the district and the city. These interventions establish a connection between natural, market garden and urban strata at the same place. Good examples of this type of “mediating sites”: evolved through history are Memoria Garden, a project completed in the early 1990s in high San José, and the old Torre Ramona farmhouse and its historic garden, in Las Fuentes, which is due comprehensive renewal.[31] [Fig. 7] [Fig. 8]

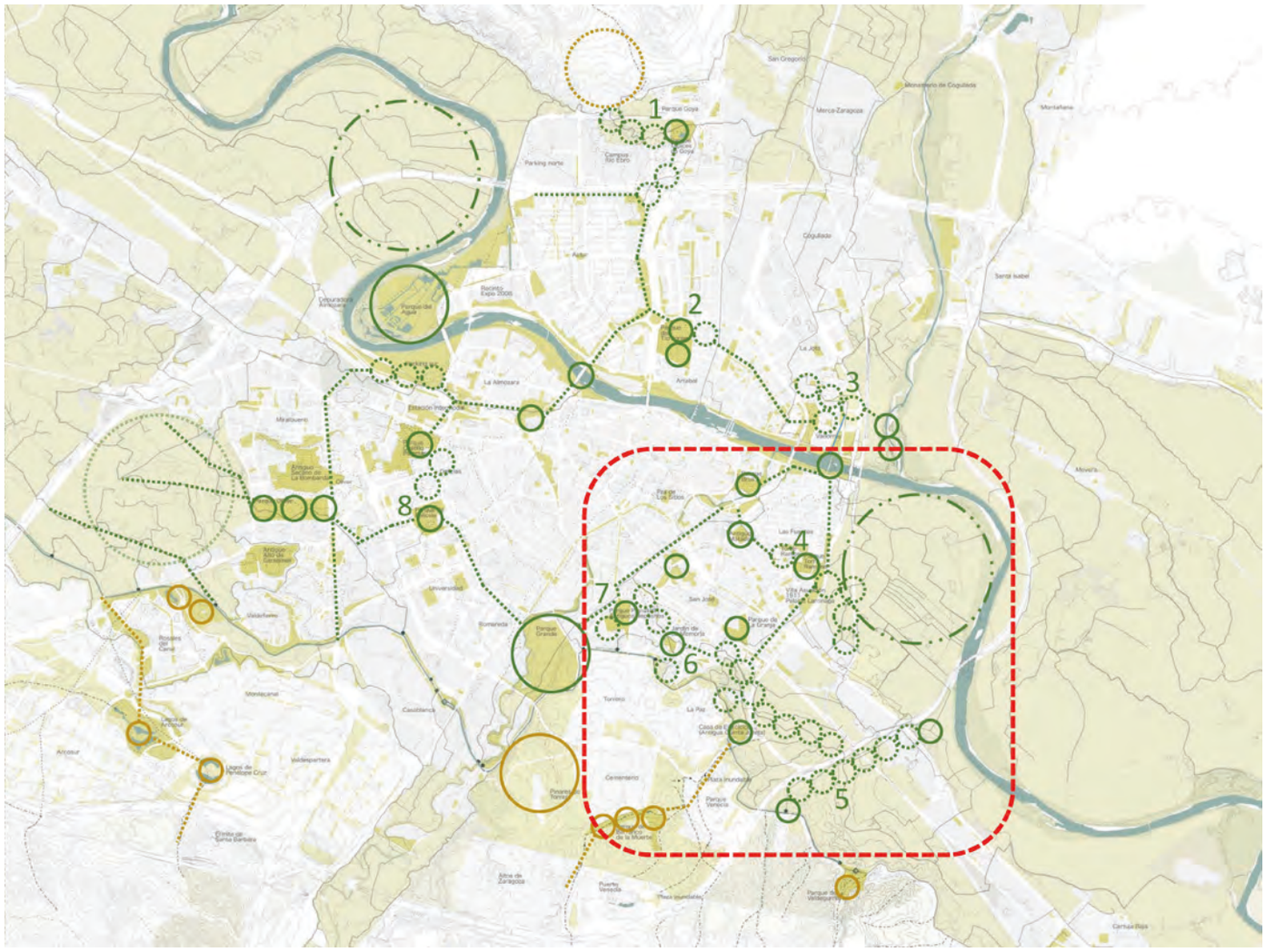
In line with studies conducted on international reference works in “urban hybridization” researches, these proposals would achieve an effective “environmental and spatial hybridization”, making visible all the spatial elements forming part of the city’s water system and water transfer mechanisms, and a water infrastructure linking the city’s singular places, external agricultural spaces and copses along the Ebro riverbank. [Fig. 9]

Conclusions

Analyzing the eastern edge of Zaragoza has highlighted the potential of the functioning irrigation networks hidden underneath San José and Las Fuentes districts. The condition of these districts—dense, highly developed and with very low rainfall, but with a substantial irrigation network with quite considerable flows—corresponds to the features of cities identified as “irrigated cities”.

The interesting sequence of proposals and urban renewal plans drafted in recent years has enabled the analysis of several proposals to link urban areas of these districts with their adjoining metropolitan orchards. Although the circumstances that could set the proposed actions in motion still need to arise, these documents do not fully address the water network as a system structuring the space and as infrastructure capable of ensuring the whole is internally cohesive, yet also integrated in the rest of the city. The hidden irrigation network under the streets of Las Fuentes and San José is a clear opportunity to achieve these objectives. However, they cannot be attained without directly involving the stakeholders responsible for managing the irrigation infrastructures, eradicating management based on blinkered views of strict sectoral responsibility,[32] and evolving towards a comprehensive review of the water cycle in the city.

31 An interesting project could be undertaken to restore the former garden—located alongside the old La Filla irrigation canal at a lower level than the rest of the district—and the still standing publicly owned old Torre Ramona farmhouse it surrounds.



[Fig. 9] Intervention proposal to uncover mediating sites between natural, agricultural and urban areas as green infrastructure in the consolidated city. The proposals for Las Fuentes and San José districts are in the main box: 4. Torre Ramona, La Filla drainage canal, and connection with the Agricultural Park of Las Fuentes metropolitan orchards. / 5. Imperial Canal of Aragon–Ebro connection system through the San Antonio and the Media Legua drainage waterways. / 6. Hillside of San José district. / 7. Old water tanks next to Pignatelli Park. Source: Author.

In the case of the eastern edge of Zaragoza, and in other "irrigated cities", the general objectives of "environmental and spatial hybridization" between artificial and natural systems are shared with international experiences that have implemented urban strategies to combat climate change by focusing heavily on issues such as the storage capacity of rainwater and its urban reuse. However, actions in "irrigated cities" with an arid climate and a strong agricultural bias will mainly stem from operations to make the city's agricultural structure more visible, to create ecological corridors inside the city and to correct the urban microclimate in highly dense areas with significant levels of compactness.

Acknowledgements

Javier Millán Soler, Technical and Administration Manager of the Miraflores Irrigation Community in Zaragoza, with thanks for his kind explanations and the data provided to write this article.

32 To give just one example, in the Municipal Ordinance for Ecoefficiency and Comprehensive Water Management Quality (City Council of Zaragoza, 2011), a document over 27,000 words long, the term "acequia" (irrigation canal) is only mentioned twice to explain that it is considered a public watercourse and discharges into it are prohibited.

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