

LANDSCAPE DESIGN FOR SUSTAINABILITY AND ECOSYSTEM SERVICES IN AN URBAN ENVIRONMENT: CASE STUDY OF TEHRAN AND HIS KAN RIVER

Ilda Vagge¹ 
Gioia Maddalena Gibelli²
Alessio Gosetti Poli³

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Abstract: *The authors, with the awareness that climate change affects and changes the landscape, wanted to investigate how these changes are occurring within the metropolitan area of Tehran. Trying to keep a holistic method that embraces different disciplines, reasoning from large scale to small scale, the authors tried to study the main problems related to water scarcity and loss of green spaces. Subsequently they dedicated themselves to the identification of the present and missing ecosystem services, so that they could be used in the best possible way as tools for subsequent design choices. From the analysis obtained, the authors have created a masterplan with the desire to ensure a specific natural capital, the welfare of ecosystem services, and at the same time suggest good water management practices. It becomes essential to add an ecological accounting to the economic accounting, giving dignity to the natural system and the ecosystem services that derive from it.*

Keywords: *Green infrastructure, Natural capital, Ecological network, Landscape ecology.*

1. INTRODUCTION

Nowadays it is important to try to design new green spaces that are linked to the concept of sustainability and that try to solve efficiently problems that in certain areas of the world are new, but that in other places, such as Iran, are historical problems. One of the main problems that urgently needs to be addressed is water scarcity or drought (Nasrabadi & Abbasi Maedeh, 2014, Anker *et al.*, 2019), mainly due to climate change but also due to incorrect water management and practices that lead to the not valorization of water resources; but it is also due to the strong uncontrolled growth of the population that consequently leads to an increase in water demand and uncontrolled exploitation of water resources (Pari Var *et al.*, 2008; Faryad, & Taheri, 2009). Ensuring this natural capital, the wealth of ecosystem services and biodiversity, means providing greater community welfare and development opportunities, as well as reduced vulnerability. It becomes essential to begin to add to economic accounting also an ecological accounting, in which to assign a qualitative and quantitative value to resources, natural systems and their services (Smaniotto Costa *et al.*, 2008; Haq, 2011; Shahani, 2012; Dinavardi *et al.*, 2014; Green *et al.*, 2016; Pulighe *et al.*, 2016; Jennings *et al.*, 2019).

The purpose of the project was to visualize a green public system that could help to improve social-ecological aspects, life quality and rediscover the natural capital that is present in the West part of Tehran, passing through the basin of Kan river (Figure 1). The research tried also to

¹ University of Milan, Department of Agricultural and Environmental Sciences, Via Celoria 2, 20133 Milan, Italy

² Studio Gioia Gibelli, Via Senato 45, 20121, Milano, Italy

³ Polytechnic University of Milan, Via Bonardi, 3 20133, Milan, Italy

understand the impact that urban greening can have on a city like Tehran, that in the last twenty years has experienced strong urbanization at the expense of the present green.

By analysing the current situation of Tehran, we have faced the lack of public green, poor pedestrian infrastructures, a discontinuity of the green due to the urbanisation the city is living. Moreover, Tehran is confronting the important problem of scarcity of water, which implies different and connected dynamics. Our vision to give a solution to these problems is to propose some guidelines that can be used to create a green network.

The strategies in the work was trying to keep social, ecological and economic levels united, taking into account the human and cultural heritage of the place (Masnavi *et al.*, 2016), including the natural ones. The ecological network become a green infrastructure connecting the different areas of the city, each one with similar aspects but also with its own uniqueness. That's why it became essential to give guidelines, tools that can be adapted to each situation and problem. The design was focused on supporting and preserving the cultural heritage, without altering the present situation, but rather trying to value what we have recognized as potential.

2. TWO IMPORTANT PROBLEMS

2.1. Water scarcity

More than 50% of population lives in the west and north, while about 70% of water resources is located in these areas (Bitaraf, 2000). Construction and performance of hydraulic structures such as dams, Qanats, and conveyance channels for reservoirs, transmission and distribution systems have been experience by Iranian people for 3000 years ago. Three decades ago, before 1970, because of low population, agricultural nature and low rate of urban population, water supply was not considered as a critical problem of the country. During the last three decades, large dams have been built around the big cities such as Tehran, Isfahan, Ahvaz, in order to supply water for urban, industrial and agricultural consumption. Where surface water has not been available, ground water has also been used as water resources for supply. Since 1980, a rapid population growth as well as rapid economic change has led to significant agricultural and industrial development and consequently increasing urban population (Manouchehri, 2000). Consequently, dramatic changes have been encountered in water demand. Since 1990 water supply has appeared as a critical national problem. There are mainly four reasons for which water crisis occurs (Manouchehri, 2000):

1. Rapid population growth which is disproportional to the environmental capacity,
2. Development of different parts of the agriculture, industry and urbanization,
3. A decrease in the number of appropriate structures to store, distribute and convey water; due to the lack of financial sources, which has led to the less investments,
4. Worldwide occurrence of drought.

Recent studies show that water demands have increased at a rate of about 5 to 6 percent annually. During recent years water consumption has risen above 350 liters/person/ day. If the population continues to rise at the same rate (about 2 percent annually) as it did from 1995 to 2000 the volume of water consumption in Tehran is projected to reach 1300 Mcm in 2030. Most of the water is expected to be supplied by groundwater pumping and the transmission of water from further reservoirs (National Research Council, 2005).

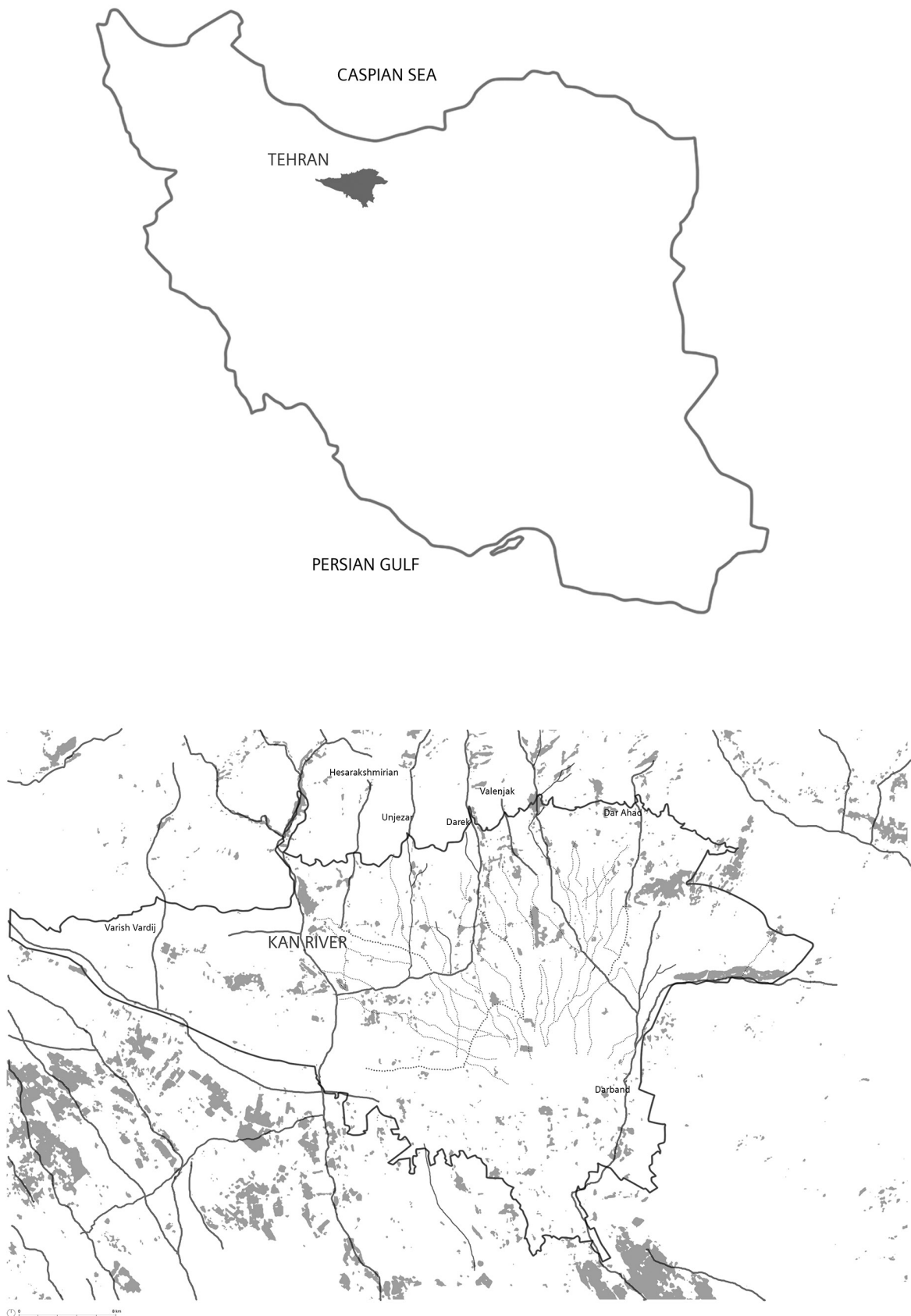


Figure 1. Study area: Kan basin and green areas
Source: Elaboration made by authors

2.2. Loss of green

Today in many cities there is an evident imbalance between nature and city due to the lack of a coherent green network and to an unsustainable urban development that creates a fragmentation and a loss of the natural infrastructure. Therefore, the intent to realize ecological network nowadays is a big challenge, need and solution for other important problems. A green system, thanks to its intrinsic connectivity features, allows a sense of cohesion of the cities, creation and improvement of ecosystem in urban environments, improvement of bioclimatic conditions, and a general improvement of life quality (Saboonchi *et al.*, 2018).

In the metropolitan area of Tehran, it's easy to notice how the natural ecological features and the built don't have a dialogue and a complementary interaction, due to the uncontrolled sprawl that the city is living. This continuous expansion of the city has changed a lot the ratio between impervious land, vegetation land and open land, leading at the phenomena of fragmentation (Figure 2). All the four periods show that the increase of impervious land is gradual and its percentage of increase is constant throughout the time. Meanwhile for the open land the main changes occurred during the first period (1988-1998) and the second one (1998-2008). The biggest loss of the vegetation was during the third period (2008-2018) when it was almost about the 50%. In 1988 the open land was the main subject of the city, more than twice than the impervious land, but during the years it left a big amount of its coverage to the impervious land, with a decreasing around the 68% from 1998 to 2018. More or less the same thing happened to the vegetation land that lost his 69% of coverage (Rousta *et al.*, 2018).



Figure 2. Fragmentation of green

Source: Landsat Image Gallery – Elaboration made by authors

Preservation, restoration of the remnant natural patches and corridors became a good way to continue the natural flows, offer the possibilities to have benefits in several respect, and solve other problems that afflict the city, with the opportunity to create a sustainable and resilient city. The possibility of preserving all this means being able to maintain the ecosystem services that

are offered to us by nature, and therefore to reconsider the importance of the value of natural capital. Starting to give value to nature means realizing that many resources on earth cannot be replaced and therefore we must begin to review our way of living, of consuming and heading towards new economies, capable of indicating its sustainability performance or the different environmental impact of certain choices, actions, products.

3. MATERIALS AND METHODS

For the collection of materials, we made use of the bibliography available from the Tehran University database, while for the various maps, we used specific sites such as Landsat Science and Google Earth. Instead, for the processing of the collected data, we used programs such as *Gis* (Geographic information system, QGIS software) and *Cad* (Computer-Aided Drafting). For the calculation and evaluation of ecosystem services, we instead referred to Burkhard & Maes (2017).

We used a holistic method, trying to reach the general aim from different parallel layers. Even if the projects are restricted to specific areas, they try to deal with all the problems that have been analysed and addressed. Our purpose was to give a contribution for a different vision of the areas taken into consideration, hypothesizing how the city changes in the moment in which the revitalization of some areas is realized. We have tried to set ourselves neutral in front of all the issues that have emerged, so that we would reach more specifically the goal of inspiring in some way the citizens of Tehran. For our work we tried to follow a subdivision guided by the scale, starting from the largest XL to the little XS. In this way the reader could have an easy comprehension and control of every single aspect characterizing the site, and at the same time could approach gradually to the final proposal. The idea was to create a sort of journey, beginning with a general knowledge of the city of Tehran and its problems, then exploring the selected areas, and their issues on a large scale; and finally dealing with the site where the project has been developed.

4. ANALYSIS AND RESULTS

The starting point of the analyses, following the methodology reported in the previous paragraph, was the geolocation of the area of the Kan river, seeking from a wide territorial scale to fix it in space and to see at first map reading what its relationship was with the whole system, natural capital. Subsequently, our study concentrated on the Kan River basin scale analyzing the dynamics that interest it. We therefore started to analyze the Kan river as a focal element, as it influences all the other dynamics. We analyzed its relationship with the city, using typological sections as a tool to understand how it is seen and experienced by the inhabitants. Subsequently, we focused on understanding how over the years it has changed in its morphology and how these changes have influenced the surrounding vegetation, and the daily activities that depended on the river. Finally, we concentrated on understanding the risks of vulnerability that the Kan River causes in the section of city of Tehran that it passes through. The analyses then focused on ecosystem services, working both at the Kan basin scale level and at the neighborhood scale level. On both scales, therefore, we have identified the ecosystem services present at the moment, and then try to identify which ecosystem services were absent and which ones among those present to be improved (Figure 3). It was also fundamental to recognize each of them their importance, weight starting from the needs that had been stated by the inhabitants of the western part of Tehran.

The analyses we carried out allowed us first of all to understand what the dynamics involved in the study site were, then to understand the major problems that the site presented and then to

understand what was the value and potential of the natural capital present. From the analysis, in particular from the summary map that we have realized (Figure 4), we can see that the main problems of subsidence and flooding concern the whole basin, from north to upwards, hitting large areas of the city that presents different addresses: residential and north and south, sports and industrial in the central part. It is also noted that there has been a great loss of greenery over the last forty years, and this loss has encouraged certain problems, as can be seen in the northern part, where the greenery that once served as protection against flooding is now one of the most vulnerable. The map also shows how it is necessary to try to reinsert that lost green along the river along its entire stretch, trying to re-naturalize its margins, and go to build new green areas in the areas most prone to flooding, which can increase natural capital presents, which in recent years has been impoverished, leading to a decrease in the presence and efficiency of ecosystem services. This last consideration stems precisely from the analyses we have made regarding ecosystem services. By comparing those present and those necessary for an improvement in the quality of life, we have been able to give a qualitative and quantitative value to the landscape, both at present and in the concept state. The ecosystem services of the analyses have become project tools and founding elements of the following project guidelines. In fact, the subsequent design choices were all aimed at thinking about a green infrastructure that was able to emit the necessary ecosystems, and that every single part of it could eliminate in its entirety, or at least in large part, the problems that we had identified.

5. MASTERPLAN DESIGN

The vision for Kan rivers was to make it an ecological corridor that can start from the foot of the mountain to the city limits, creating and restoring relations with the urban fabric it meets, and leading to a general improvement in the quality of life of this part of the city of Tehran, offering for those cities accessible, safe and sustainable green areas. The aim was reached thanks general strategies that foresee the protection the existing open space, the realization of new open space as green area or parks where to practice cultural and recreational activities; to involve the community in the organization of the activities that have to result integrated each other; to supply access to local biodiversity; to implement the sense of security, accessibility and attraction of the spaces; and to think new policies for a good practice related to the management and maintenance of this new area (Payami Azad & Laghai, 2013). For the Kan basin it was also important suggest different tools, measure that allows to reduce the hazard of flood. To achieve this result, become fundamental think of good watershed management practices in order to reduce the flood at upstream, use vegetation to obstacle entry of sediment and erosion, create along the river buffer zone. Also, the city can have an important role, by reducing the impervious surfaces, and becoming the area where to host detention ponds, bioretention ponds, swales, cisterns and so on (Andik & Sarang, 2017).

The project wants to be a model where it is possible to co-centre two essential strategies: the human connection and the connection of the green, where the river becomes the starting element and on which lay the main bases. The project master plan (Figure 5) was the result of the different considerations that have been made previously. Four fundamental principles can be recognized: the naturalisation of the river, the expansion of the corridor also in the directions transversal to the river, the reforestation of the area and the creation of phyto-purification systems. In addition to proposing a consistent realization of green areas, it was essential to identify equipped areas that can be used as a meeting place by the community: it was therefore tried to redevelop some previous buildings of the quarry, reassigning to them new functions such as

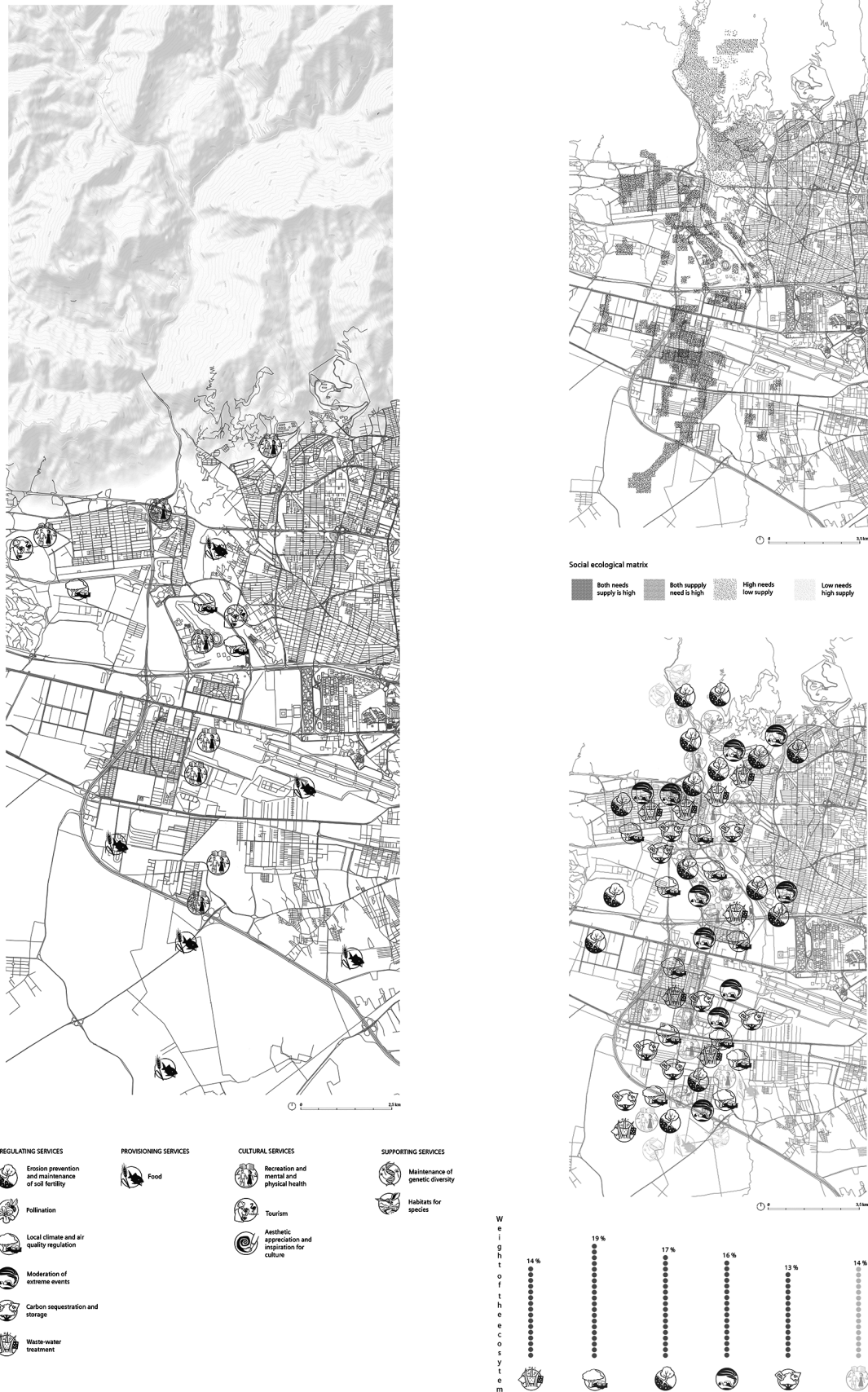


Figure 3. The ecosystem services distribution
Source: Base Open Street Map – Elaboration made by authors



Figure 4. Risks within Kan basin
Source: Base Open Street Map – Elaboration made by authors

museums, art galleries and cultural centers. At the same time, equipped areas and squares have been created that can become a place for outdoor activities such as sports, concerts and cultural events organized by the community.

In order to address the problem of water scarcity, the project has decided to propose three natural purification areas that can clean the water coming from the sewage system and put it back into circulation, in particular pouring it into the river from which it can then draw as a resource to irrigate the fields. These waste water management systems also provide incentives to improve water quality. Water purification takes place in two different stages: the first stage is characterised by phytoremediation, one of the five phytoremediation techniques; the second stage is phytodepuration. The first step takes place in the areas where the new agricultural fields designed specifically to carry out this function have been created. In phytoremediation the roots of plants absorb those organic compounds present in the water, such as chromium, mercury and cadmium. Here we have chosen to use plants such as *Helianthus annuus* L., *Brassica juncea* (L.) Czern., *Zea mays* L. and *Medicago sativa* L.. The water that has undergone this first treatment is then channeled towards the two wetlands, which are composed of three different basins arranged in terraces. Here the water undergoes another purification treatment before being channeled directly into the river. The plants that have been identified are all hydrophytes such as: *Phragmites australis* (Cav.) Trin. ex Steud., *Iris pseudacorus* L. and *Typha latifolia* L.

6. FUTURE DEVELOPMENT

The main intent therefore was to provide guidelines, which can be used as tool to be repeated in the design of new green areas in order to create a sustainable city. We ourselves have tried to make a reflection on these guidelines that we have assumed in order to make a configuration of a green network to be implemented in Tehran. Our vision is to try to develop other continuous bands along the borders of the metropolis of Tehran, assuming the value of buffer zones and transit zones with the others reality outside the city; and at the same time play a leading role in controlling urbanization that is living, the other perspective is to see the rivers not only as a starting point for incentive a realization of a green corridors according to their vertical development, but also suggest green areas with horizontal development that can be interpreted or as important patches to be placed in urban voids or as corridors that connect to other vertical ones. All this vision that we have is part of a wider vision: the possibility of rebalancing the urban ecosystem. Rebalancing the urban ecosystem means trying to reduce the gap between the three components that make up the ecosystem: producer, consumer and decomposers. Internally, the urban ecosystem is made up of consumers represented by man and decomposers represented by purifiers; producers are not present, since most of the resources come from outside. If it is possible to increase the city's ability to produce the resources necessary for its operation; to reduce man's unscrupulous use of the resources present and to make the best use of decomposers, the ecosystem approaches a situation of entropy, general equilibrium. To achieve this goal for us the solution is to try to protect and rebuild the natural capital, and trying to develop new economic models that allow the enhancement and conservation of ecosystem services allowing them to guarantee the services they can offer us. This commitment therefore involves various actors in the territory, as well as national, regional and municipal institutions. The concept of „transdisciplinarity” becomes fundamental: to create working groups where figures from different sectors such as economics, environment, landscape, architecture, ecology, agronomy, etc. are present; and who make their knowledge available to the will to create landscapes, territories that are protected and more resilient than human stress, and at the same time start thinking about a market that looks more and more interested in sustainability.

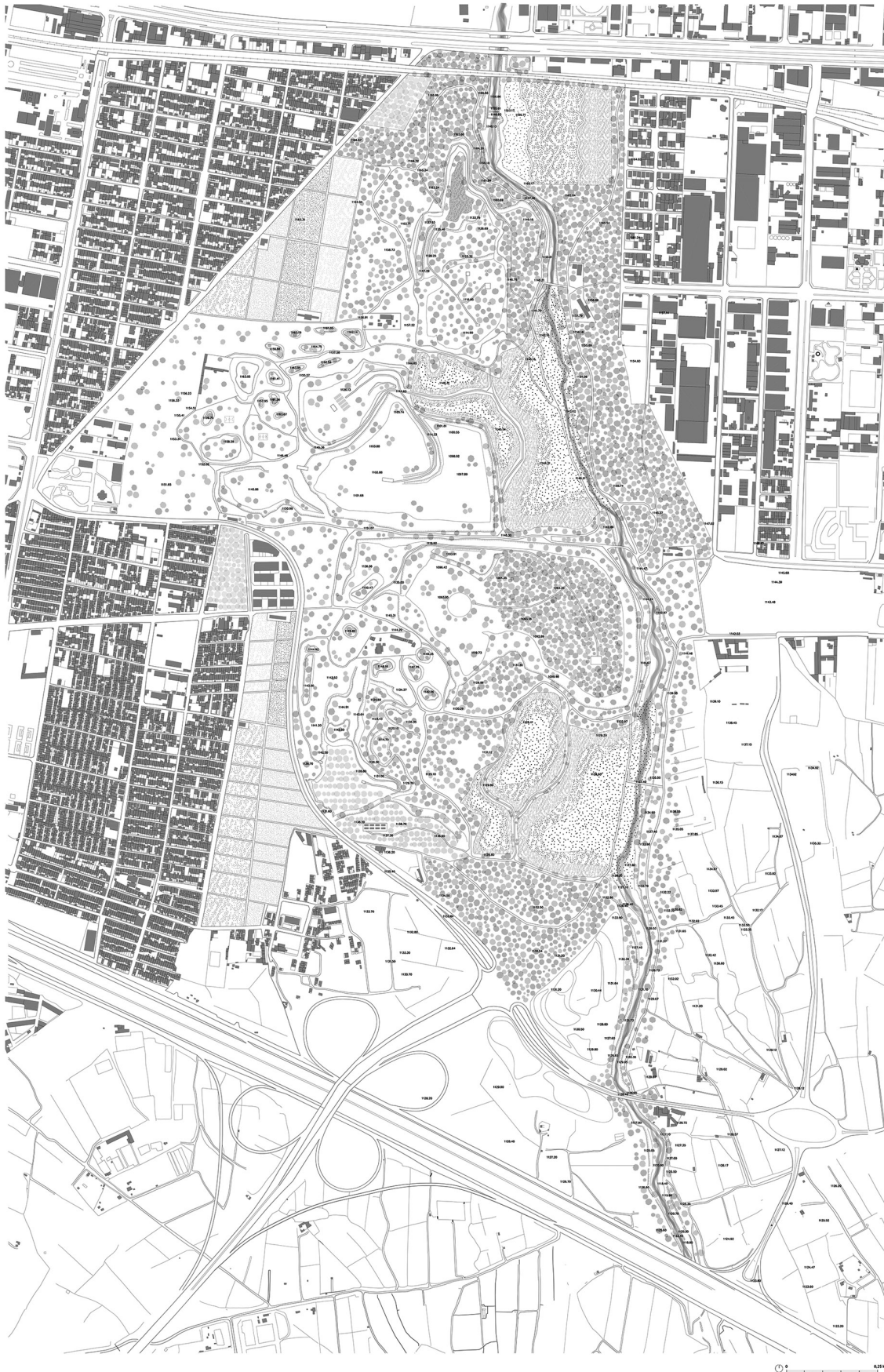


Figure 5. The future vision

Source: Base from Cad materials – Elaboration made by authors

7. CONCLUSION

It was important for us to provide us with tools and multidisciplinary approaches so as to be able to better understand the dynamics that involve this fragile area. Our visions of greens have tried to understand what the problems were and what their potential, allowing us then to orient the city towards the direction that for us seemed more appropriate. The starting point of the project was to investigate the relationships between human dynamics and the emergence of the problem of drought. Our intent was to provide guidelines that could be a tool to be used in order to manage the problem of water in a new way and at the same time try to take the city to a city sustainable, thanks to the creation of green connections and patches. Working on different scales, and integrating the whole project as a journey, gave us the possibility of being able to be always aware of our choices and to remember ourselves as the project area, which belongs to the small scale, be it always influenced by the dynamics concerning the larger scales.

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