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SMALL RIVERS AND LANDSCAPE

NBS to mitigate flood risk

Abstract
The aim of this paper is to mitigate hydrogeological risk, closely bound to climate change, through the forecast of green and blue infrastructures, basing the solutions mainly on nature-based solutions (NBS). A further aim is to restore the ecosystems of the landscapes and to allow the provision of various benefits to societies.
The novelty of the paper is the application of a method that measures improvements from the point of view of flood mitigations by means of devices that, at the same time, decrease the hydraulic hazard and increase the urban endowments of settlements.
Indeed, there is a new way of avoiding flooding involving nature as part of the solution as well as allowing for the provision of benefits to societies.
A methodological analysis of the cases studied was carried out in order to achieve an actual diagnosis regarding the flooding risk of these landscapes so as to identify possible areas of intervention.
The case-studies in Argentina and Italy are two small settlements that, although located in such distant and diverse places, have similarities in flood phenomena and in the relationship between urban fabric and waterway.
In order to mitigate hydrogeological risk, through the provision of green and blue infrastructures, mainly through NBSs, a methodological tool to identify a range of possible interventions capable of mitigating the risk through territorial and urban planning of suitable "green and blue infrastructures" (GBIs) applying different NBSs has been developed.

Keywords: urban planning resilience, urban nature-based solution, linear combination indices, ecosystems services, green infrastructure.

Introduction
Climate change is defined as "a climate change that is directly or indirectly attributable to human activities, which alter the composition of the planetary atmosphere and which add to the natural climatic variability observed on similar time intervals" [1]. Although to a lesser extent, climate change, or even just an increase in climate variability, which can cause a hydraulic risk, indirectly and synergistically influences the resilience to other factors, generating stress factors on the environment and on the production and social system that modify the vulnerability and exposure of ecosystems.
A disaster resilient community is one that can face an extreme event with a tolerable level of losses, both in terms of human lives and damage, and is able to put in place risk mitigation actions to reach a level of sufficient protection. The implementation of Nature-Based Solutions (NBSs) is a practical option that is evident in the processes of mitigation and adaptation to climate change and in disaster risk reduction.
A *Green Infrastructure* (GI) consists of a network of natural and semi-natural areas strategically planned with other environmental features, designed and administered to provide a wide range of *Ecosystem Services* (ESs) [2] delivering a set of environmental benefits while maintaining and improving the ecological functions [3]. GIs can mitigate the effects of climate change and the extreme events that they pose, managing, for example, the devastating power of floods or landslides by re-establishing spaces and functions [4, 5, 6]. In general, the main elements of a GI include parks, private gardens, agricultural fields, hedges, trees, woodland, green roofs, green walls, rivers and ponds [7]. The theme of GIs is closely related to ESs as a set of functions naturally provided by ecosystems [8, 9, 10], and which are fundamental to maintaining the resilience of a territory. In this framework, the *nature-based solutions* (NBSs) [11, 12] are natural devices that aim to protect, manage and restore natural or modified ecosystems in a sustainable way. They improve the resilience of urban infrastructure, increase urban biodiversity, as this in turn improves rich biotopes and landscape connectivity, they protect aquatic ecosystems, and create biodiversity-rich areas to support flora and fauna. Green and blue infrastructures (GBIs) have enormous potential to modulate the urban climate by reducing the effects of the urban heat island, balancing daytime fluctuation temperature and supporting natural air ventilation. The implementation of NBSs in the GBIs is a practical option in the processes of mitigation and adaptation to climate change and in disaster risk reduction. They have to be integrated into the urban planning of cities to be effective, which means a change of mentality for all the agents involved: public administrations, companies and citizens. NBSs can address connections with other sustainable urban development goals, as the resilience of the city and the promotion of the health and wealth of urban residents. Instead, GBIs reinforce the infrastructure of urban ecosystems combining the demands of sustainable water and stormwater management with the demands of urban planning and life.

Methodology
This study, starting from a methodology which has already been developed and applied to a different context [13], adapts it and applies it to the two case studies presented here.
We have developed two previously studied methods: after quantifying each service and obtaining the synthetic index of reduction of the hydrogeological risk (IsrRI) of the projects developed, we will obtain a number, which in itself will have no value, but acquires a relative value, and when compared with the different project states of the case studied, to the base state and the trend project status (project solution to the minimum of the regulations), we can identify if the precise interventions are more or less effective than the current state of the project. The main reason for the selection of the objects of study are the urban problems they present, in relation to the hydrogeological risk. The hydraulic risk mitigation interventions are selected and these differ between structural and non-structural.
Structural interventions are, for example, extensive structural interventions (hydraulic-forestry arrangements, hydraulic-agricultural arrangements) and intensive structural interventions, such as: rolling tanks, embankments, spillways and diversions, bank defenses, bridles, thresholds, riverbed ducts, river rectifications, ditches, storage squares.
Non-structural interventions are relocation, change of intended use and regulatory requirements regarding the works and functions permitted in hazardous areas.
Specifically, the aim of structural interventions is to reduce the danger: they generally involve the construction of high cost works whereas non-structural interventions are aimed at preventing and mitigating potential damage and are typical of planning (evacuations, emergency plans, territorial monitoring, warning and alarm systems, restrictions on use, territorial controls, etc.)in fact, they have greater flexibility and relatively reduced costs.
Specifically, non-structural interventions are aimed at preventing and mitigating damage and are typical of planning.

For the construction of the IsrRi, in considering structural interventions, the selected indicators are:

- Exposed Area to danger:

$$Ap = St\ [m^2] \quad (1)$$

- Permeability ratio:

$$Rp = Sp / St\ [m^2/m^2] \quad (2)$$

For what protects non-structural interventions, the indicators developed to measure impacts were selected:

- User index:

$$Iu = Ci(Slp) / St\ [m^2/m^2] \quad (3)$$

where:
St = Territorial surface [m^2]
Sp = Permeable surface, that is, deep draining [m^2]
Ci(Slp) = Gross usable surface [m^2]

- Function index:

$$If = f(Zto) \quad (4)$$

At this point it is possible to build two synthetic indexes:

- Synthetic Hazard Reduction Index (IsrP):

$$IsrP_i = x_1Ap_I + x_2Rp_i \quad (5)$$

The parameter "p_i" is a combination coefficient that can depend on the need. It is measured by the variation in the value of the indices between the base scenario and the project scenario (reduction of the area to hazard Ap and increase of the permeability ratio Rp), while assuming $x_1 + x_2 = 1$.

- Synthetic damage reduction index (IsrD):

$$IsrD_i = y_1Iu_i + y_2If_i \quad (6)$$

It measures the variation of the indices between the base scenario and the project scenario (variation, the objective is to reduce Iu and If), and it is assumed that:

$$y_1 + y_2 = 1 \quad (7)$$

Once $IsrP_i$ and $IsrD_i$ are identified, the IsrRI is calculated as a linear combination of these indices, assuming that the sum of the coefficients p_1 and p_2 is 1:

$$IsrRI_i = p_1IsrP_i + p_2IsrD_i \quad (8)$$

The parameter *i* is to define the generic area where we have to apply the Index.
IsrPi is assessed as a linear combination of the variation of hazardous areas, as a result of structural interventions, and the increase in the permeability induced by the plan relative to the time interval, considering a certain time interval, and assuming the sum of the coefficients x_1 and x_2 and the coefficients y_1 and y_2 as unitary. In a similar way, $IsrD_i$ was built, but referred to the variation of Iu and If, assuming the sum of the unit coefficients.
Once IsrP and IsrD have been identified, it is possible to identify IsrRI, as a linear combination of these indices, assuming the sum of the p_1 and p_2 unit coefficients.
The weights x, y and p derive from experts' opinions and they can be calibrated to make the indexes be as reliable as possible. Experts can be defined as hydraulic works experts, environmentalists and urban planners to name but a few. The two indices implemented within the proposed calculation model are then compared to the scale of performance that gives each index a score scale that varies between 0-30, which are in turn divided into 4 performance classes.
The different values found in the literature, [14, 15] for each ecosystem service according to the type of land cover were homogenized, by performing an arithmetic mean operation, in a single table that follows the same type of evaluation as the more complex approaches. They are based on the capacity of different types of land cover to provide an individual service:
0 = no capacity;
1 = low capacity;
2 = significant capacity;
3 = medium capacity;
4= high capacity;
5 = very high capacity.
A methodological analysis of the cases studied was then carried out in both the Argentinian and Italian cases in order to achieve an actual diagnosis about the flooding risk of these towns, so as to identify possible intervention areas.
In both cases, the proposed interventions are based on specialistic studies. In particular, in the case of Ariano, a hamlet of Olevano sul Tusciano (Italy), various technical documents were made available (land use, hazard and risk maps, etc.) to support the urban planning process to renew the urban plan for the entire municipal area. This is not the case of Idiazabal (Argentina), where an additional investigation was requested to supplement the available documentation.

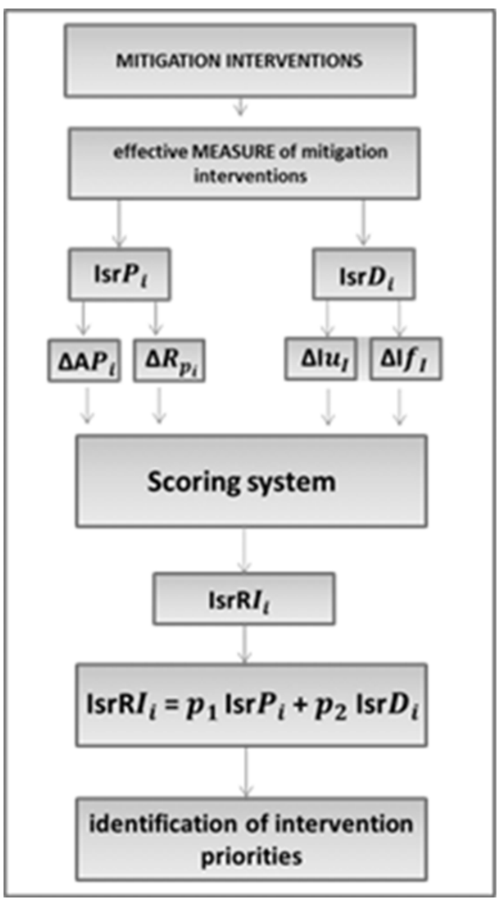

Fig. 1. Scheme of Synthetic Index of reduction of hydrogeological risk [13].

Idiazábal is crossed by the El Chato stream and is a town located in the Union department, Ballesteros district, province of Córdoba, Argentina and is located 250 km from the city of Córdoba, 151.85 meters above sea level. It is located in the Pampas Plain where the relief is very flat with little slope. Hydrographically, Idiazabal belongs to the Plata Basin. This region has an average annual availability of 22,000 m^3/s, (the "average annual availability" refers to the river's water flow) mostly provided by the Bermejo, Paraguay, Uruguay and Paraná rivers. It also has the highest concentration of population and productive activity. The area is exposed to natural hazards such as floods, droughts and hail, which spoil crops and is exposed to winds called Pampero and Sudestada. The extension of the pampas and the absence of natural barriers allow winds to reach high speeds, which cause soil erosion, especially in the driest periods.
The sustainable model proposed for the area is based on the direct survey of the shortcomings, which provide a basis to the particular objectives set out for the development of the new plan. The increase in green spaces, capable of reducing flood levels and increasing regulation services, are reflected in the increase in the synthetic danger index (synthetic danger index as a weighted average of the dimensional scores, assigned to the various sub-areas of intervention, on the basis of the respective area surfaces), and therefore the risk reduction. However, even more noticeable are the non-structural measures, which express the high-risk reduction by increasing the damage rate.
It is assumed, then, that not only the implementation of structural measures directly helps to mitigate flooding, but also complementing these with non-structural measures determines the guidelines of a sustainable construction of the city.
An expeditious method for the quantitative assessment of flood risks in terms of exposure is proposed from the urban point of view. To this aim, a methodology for the territorialization of hydraulic risk using and evaluating the non-structural interventions and the structural interventions, has been identified and a process for assessing the effectiveness of the actions of the mitigation plan has been identified.
After carrying out an analysis of the current state of the Town, and obtaining the numerical assessment of the different indicators, different deficiencies or problems in the sector have been detected, which afflict the current population. On each of these problems, we will work with an intervention proposal that attempts to address these flaws:

- Lack of interventions in the basin of the stream to prevent flooding- Non-structural interventions
- Lack of public green spaces. - Structural intervention
- Waterproofing. - Non-structural interventions
- Land uses - Non-structural interventions
- Lack of social cohesion - Non-structural interventions

Each of the problems mentioned above is described below, with the corresponding proposals for action.

INDEX VALUES	MAX CLASSES THRESHOLD	CLASS
INDEX > 25	30	1
15<INDEX <= 25	25	2
5<INDEX <= 15	15	3
INDEX < 5	5	4

Fig. 2. Synthetic Index of reduction of hydrogeological risk [16].

Lack of interventions in the basin

This problem is of highest priority due to the proximity of the area to the river system, representing the greatest inconvenience when there are heavy rains. A further problem is that the poor state of the basins which does not allow society to take advantage of the benefits it can bring. Pollution resulting from society using it as a garbage dump, and poor maintenance, also make the stream an unattainable site.

With the aim of eliminating floods due to the mishandling of the works and promoting the use of this as an urban space, the following interventions emerged:

Firstly, the installation of 4 retention tanks that, thanks to their ability to retain large water covers, make it possible to reach the control point that previously collapsed with a much smaller cover and thus avoid flooding downstream. These tanks are of very simple construction and only involve the excavation of the area and the creation of a dike with green gabions. The outflow of the planned retention tanks is managed in part through the drainage of water and in part return the flow to the river after some time. In this way, the use of naturalistic engineering allows for a better adaptation and operating under sustainability standards and we return to the land what long ago was lost with the abuse of deforestation in the desire to gain more arable land.

Secondly, the creation of a flood park, with the reconstruction of the riverbanks thanks to the use of naturalistic engineering, avoiding their continuous collapse and loss of land. This park will have a pedestrian path and a bike path that will link this with the previous ecological corridor project and will be made with blocks that allow high permeability and will have urban equipment capable of withstanding the great efforts produced by large water currents. In addition, it will have flexible equipment supported on piles that allow the normal development of activities in case of complete flooding. In this way it allows society to repeatedly use these facilities at any time of the year.

Lack of public green spaces

The flood park project, although wide and largely captures and changes the shortcomings of existing public spaces, it is not enough to satisfy the total population.Therefore, the new park next to the restructuring of the train station park, re-functionalization of the space left by the former club and the reforestation of the streets will not only help mitigate flooding thanks to the increase in permeable area and improve air quality but will also contribute to new social spaces for meeting.

Waterproofing

The project includes the completion of the drainage networks with a separate system, thus achieving a lower impact and the reduction of runoff due to waterproofing.

In addition, the reuse of rainwater and gray water is indirectly promoted through different devices in order to reduce direct runoff over the project area. The planned separated drainage system is a traditional device but the way in which it is integrated in a larger system of interventions aimed at improving the resilience of the towns is new.

Soil uses

Another non-structural measure is the creation of policies that benefit crop diversity. Over time, due to the lack of regulation, their homogeneity and non-rotation were promoted, strongly affecting the behavior of the soils and their impact on floods. With the new policies the soil will acquire the ability to irrigate the rainwater below, generating large permeable areas.

Lack of social cohesion

This project, in addition to the completion of the fabric, promotes the creation of equipment that allows for the normal development of society and unifies the entire town.

To a large extent the flood park will acquire the role of connector thus benefiting not only the landscape but also the sustainability of the project.

Total area concerned [ha]		Hazard class areas ante operam		
110		P1	P2	P3
Post operam	P1	10	15	70
	P2			15
	P3			

Total area concerned [ha]		Damage class areas ante operam			
23,2		D1	D2	D3	D4
Post operam	D1			23	80
	D2				7
	D3				
	D4				

ISRP calculated		Hazard class areas ante operam		
23,2		P1	P2	P3
Post operam	P1	0,0	2,7	19,1
	P2	0,0	0,0	1,4
	P3	0,0	0,0	0,0

ISRD calculated		Risk class areas ante operam			
26,6		D1	D2	D3	D4
Post operam	D1	0,0	0,0	4,2	21,8
	D2	0,0	0,0	0,0	0,4
	D3	0,0	0,0	0,0	0,0
	D4	0,0	0,0	0,0	0,0

$$IsrRI_i = p1 \cdot IsrP_i + p2 \cdot IsrD_i = 24,56$$

Classification index		
Value of IsrRI	Class	Effectiveness of intervention
IsrRI > 25	1	Remarkable
15 < IsrRI ≤ 25	2	Average
5 < IsrRI ≤ 15	3	Slight
IsrRI ≤ 5	4	None

Fig. 3. Hazard Index, Damage Index and related classification of the Hydrogeological Risk Reduction Index for Idiazabal [16].

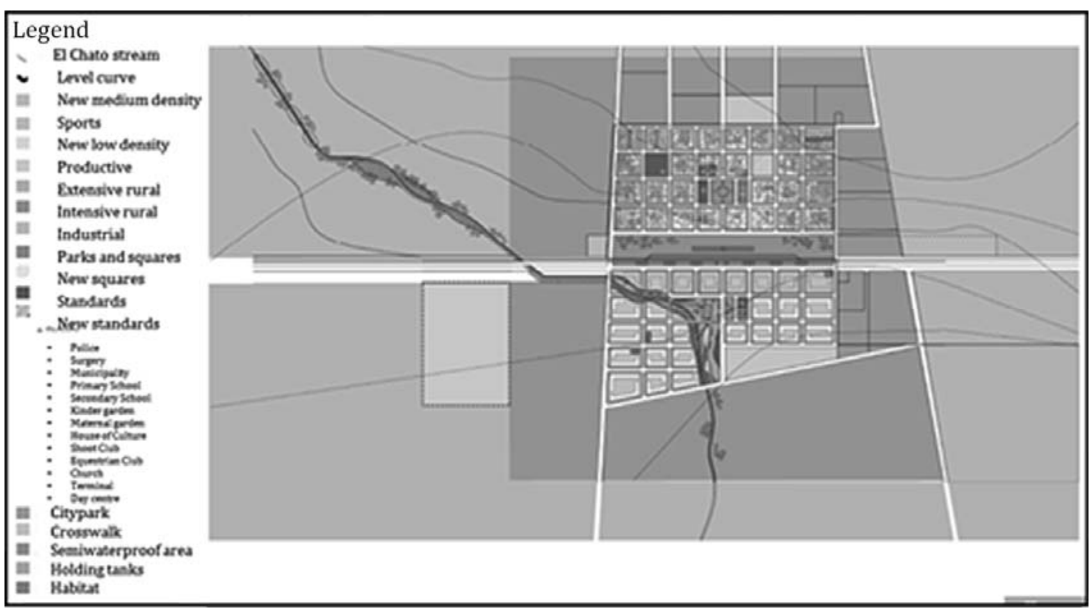

Fig. 4. Project proposal for sustainable development for Idiazaba [16].

Olevano sul Tusciano is located in the foothills of the Picentini Mountains. The municipal area includes the middle stretch of the Tusciano river valley, it borders Acerno to the north, Montecorvino Rovella to the westwith the mountain range comprising Costa Calda Mountain, Molaro Mountain and Raione Mountain to the east

The total extension of the municipal territory is about 26 km² with a population of around 6.993 inhabitants and an average population density of about 268,96 inhab. per km², it has an average altitude of 22 m asl, and it is completely crossed by the Tusciano river which cuts through its valley from the Quaternary.

After analyzing the current state of the town, a series of modifications are considered in defined areas that help improve the sustainability index. Lack of interventions in the brook basin are listed as follows:

1) The degradation of the borders of the brook means that areas near the basin suffer from floods even in periods of low returns. For this purpose, the cleaning of the affected area was developed as a first step and then the edges were built with the use of naturalistic engineering which mitigated the impact of floods.
2) The use of sloping edges in the upper sector to create spaces for different activities such as natural amphitheaters, which in times of floods function as retention tanks and resist flood impacts.

It is evident that in territories with a small space which are already consolidated, it is difficult to implement public infrastructure that helps to mitigate the impact of floods. This is why the project defines non-structural solutions such as the incentive to use green terraces in public buildings or promote the use of water collection and treatment systems in residential buildings and thus avoiding runoff due to the low permeable area that characterizes Italian settlements.

The basin today is an element of transversal discontinuity of the city and the development of activities on the basin could represent an integration in the social sphere. The creation of the linear park is an opportunity to promote the longitudinal connection of a potential urban ecological network, which uses parks, native vegetation, streets, green areas, lagoons and the stream as a biodiversity support. In addition, it will promote integration in society promoting exchange and reunion in various activities.

With this premise, it was decided to promote the completion of the residential area, excluding the historic center and moving the cultivation areas to the outskirts of the municipal limit, complemented by public facilities and commercial use. In addition, in the new residential area those that were formerly cultivated areas were transformed into small urban parks that promote the sustainable development of the town and improving the ability to dispense ecosystem services.

Total area concerned [ha]		Hazard class areas ante operam		
110		P1	P2	P3
Post operam	P1		6	
	P2			8
	P3			6

Total area concerned [ha]		Damage class areas ante operam			
25		D1	D2	D3	D4
Post operam	D1		4	7	14
	D2				0
	D3				
	D4				

ISRP calculated		Hazard class areas ante operam		
10,0		P1	P2	P3
Post operam	P1	0,0	6,0	0,0
	P2	0,0	0,0	4,0
	P3	0,0	0,0	0,0

ISRD calculated		Risk class areas ante operam			
22,0		D1	D2	D3	D4
Post operam	D1	0,0	0,0	6,0	0,0
	D2	0,0	0,0	0,0	4,0
	D3	0,0	0,0	0,0	0,0
	D4	0,0	0,0	0,0	0,0

$$IsrRI_i = p1 \cdot IsrP_i + p2 \cdot IsrD_i = 18,4$$

Classification index		
Value of IsrRI	Class	Effectiveness of intervention
IsrRI > 25	1	Remarkable
15 < IsrRI ≤ 25	2	Average
5 < IsrRI ≤ 15	3	Slight
IsrRI ≤ 5	4	None

Fig. 5. Hazard Index, Damage Index and related classification of the Hydrogeological Risk Reduction Index for Olevano sul Tisciano [16].

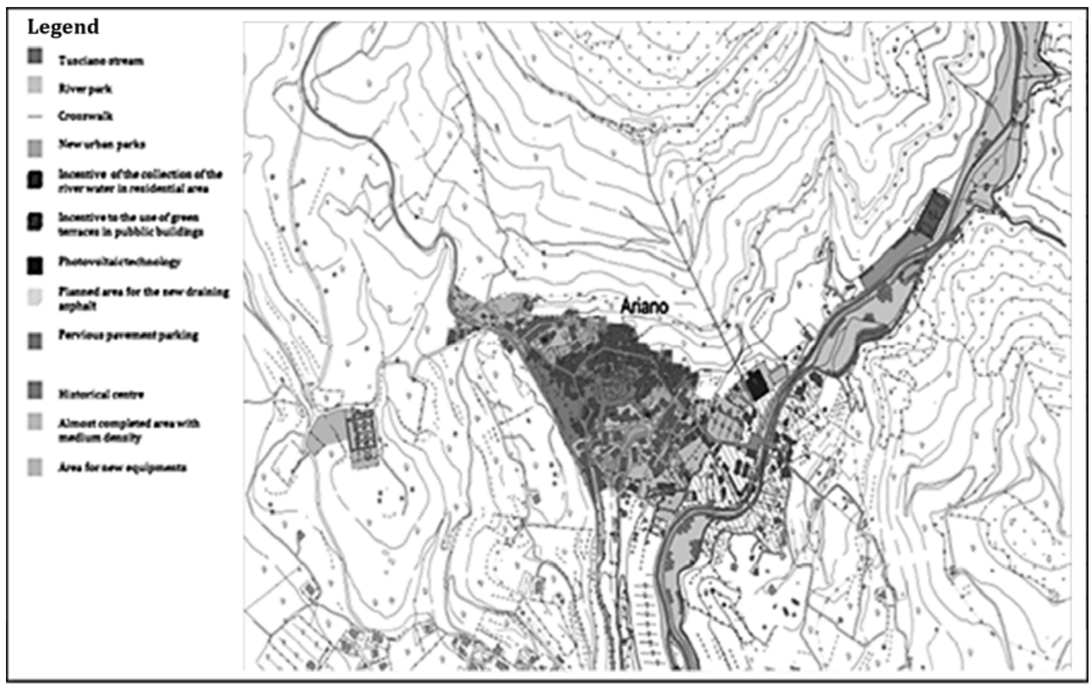

Fig. 6. Project proposal for sustainable development for Olevano sul Tusciano [16].

Results and Discussion

The structural measures did not make it possible for the danger to be completely eliminated but when compared with the project, the correct use of the flood park in these dangerous areas is evident. The increase in green spaces is reflected in a decrease in the synthetic danger index, and this leads to risk reduction. However, even more noticeable are the non-structural measures, which express the high-risk reduction by decreasing the damage rate.

It is assumed, therefore, that not only the implementation of structural measures directly helps to mitigate flooding, but that these complement non-structural measures determining the guidelines for sustainable urban construction. The change in land use in areas with greater exposure directly modifies the function indices and those related to the green system, which help to mitigate the hydrogeological risk.

Conclusive remarks

From the results obtained, it is evident that the current development of the city does not take into account a projection that makes it possible to build a flood-resistant urban environment, stripped of sustainable characteristics but it responds to current solicitations regardless of the impact of these in the not so distant future.

In the urban-sustainable proposals that were developed, mainly those indexes of greater significance were taken into account, which substantially modify the degree of

sustainability of the settlements, such as the presence of nature and the importance of ecosystem services. The proposal attempts to correct these characteristics, firstly by proposing the creation of spaces or tanks conducive to appeasing flooding and reforestation of watersheds unlike a landscape with sparse coverage. Secondly, the creation of green spaces of different scales is proposed, improving the environment and promoting the return of the services that the ecosystem offers us.
The ultimate goal of this study is to pursue, through sustainable urban planning, even greater levels of settlements efficiency [17] as well as safety and quality of life.

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