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Develop an Integrated Conceptual Model to Determine Ecological Buffers in Urban Streams

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Abstract

For many years, buffers are playing an important role for protecting as well as exploiting urban streams environment. In 40s & early 50s Tehran with 5 urban streams which flow from northern mountains to southern deserts of the city had been created unique aesthetic nature. At that time no specific environmental regulatory implemented by the government but since lack of any disturbing population and any urban development, the urban nature was self protecting. But in recent decades a huge development occurs leading to impaired streams which no conventional buffers such as static quantitative buffer zone and qualitative buffer zone.

This paper is deeply investigating ecological restoration and promoting a new conceptual model as ecological buffer zone for Urban Streams. This buffer is agile, dynamic, and variable in both stream directions (longitudinal and latitudinal) consist of many layers such as biological (both fauna and flora), geotechnical, artificial infrastructure buffer, legal, historical, social, economical and etc Layers. If this model properly implemented longtermly will protect current urban nature and even enhance the environment eventually, partially, and gradually reverse to their historical natures. Ecological should be tailored for each individual river and stream based on few rules, tools and techniques.

The paper is based on three years extensive research study for all 5 major urban streams in Tehran and implementing on Farahzad upstream specifically. It elaborates how to define different above-mentioned layers and finally how to integrate all together. EB has been currently implemented in Tehran urban streams by the municipality.

Keywords: Quantitative Buffer, Qualitative Buffer, Ecological Buffer, Urban Stream, EB, Arc GIS.

1. Introduction

Urbanization affects streams by fundamentally altering longitudinal and lateral processes that in turn alter hydrology, habitat, and water chemistry; these effects create physical and chemical stressors that in turn affect the biota (Hughes et al., 2014). Urbanization leads to altering the morphology of urban streams by increasing storm water runoff, altering sediment regimes, and limiting space for channel change. Riding and configuring channel is the typical response to these issues (Vietz et al. 2016). Broadly speaking, it results in a phenomenon commonly known as the “urban stream syndrome,” whereby hydrographs become flashier (i.e., increased flow variability), water quality is degraded, channels are homogenized and incised, biological richness declines, and disturbance-tolerant and alien species increase in prevalence (Hughes et al., 2014). After a period it had been found that returning to the natural status of the streams will solve this problem; in other words, the stream and rivers should be restored. Honold et al., 2016 defined “restoration” as a process of renewal of intrapersonal resources that have diminished due to the adaptation to environmental demands such as stressors and challenging tasks. The objectives of stream restoration in urban areas are often presented as a return to a more natural condition, including improved water quality and biotic composition. Yet there is often tacit acceptance that many urban streams are so degraded that the probability of realizing such an objective is low (Carpenter et al. 2003).

Among the Tehran stream problems transferring rivers to concrete channel and narrowing their conducts, over contaminating by the entry of wastewaters, burying into covered channels and culverts, concreting bed, diverting flows from their main path and straitening meander are the most important. The initial assessment showed that infrastructure and high-rise building loading, population resides over land capacity, high-rise building in cones and obstacle rivers valleys, and destruction of rivers, destruction of the groves and woods of the north and east are among the source of threat to Tehran’s stream.

In addition to the problem related to the streams, air pollution is one of the major problems which Tehran is encountering. In recent years, inversion has caused several closures of schools and government centers during winters in city which lead to serious economic losses, environmental damages and mortality increase (Vafa-Arani et al, 2014). Dust storms forming in local and regional sources occasionally degrade the air quality of central Iran's cities like Tehran (Arhami et al., 2017).

The low height of the Planetary Boundary Layer (PBL) is one of the other issues of Tehran. PBL is the earth lowest atmosphere and defined by the exchange of heat, moisture, and momentum with the surface (Compton et al., 2013). Nabavia et al. (2019) showed that the height of the PBL in the Tehran city range from 18 to 4150 meter with a 1550 meter in different time of the year. It is conceivable that air pollution is especially hazardous when associated with shallow PBLs (Zilitinkevich, 2012).

The initiation of Tehran’s urban planning refers to the period before the Second World War, whereby at least three major efforts set the framework for the city’s growth and development: walling the city (1550s), expanding the walled city (1870s) and building a new urban infrastructure (1930s) (Madanipour, 2006). Over the last century, about 25 acts and plans were enacted to curb the physical development of Tehran city. Many of these acts and plans were just adopted but not seriously implemented as can be inferred from the expansion of city borders within 120 years ago [Figure 1].

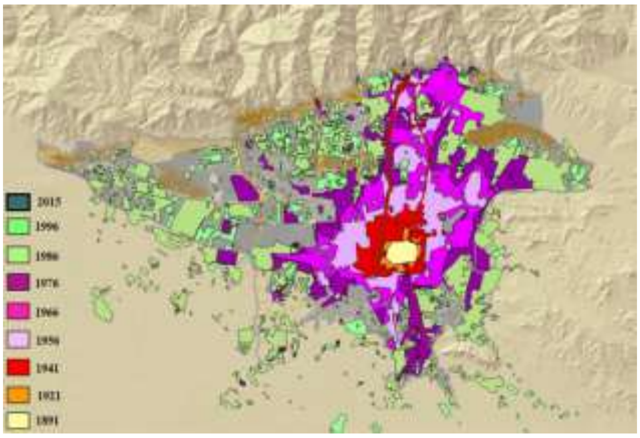


Figure 1 Tehran development during past 120 years

Urban Sprawl results in undesirable phenomena such as environmental destruction, city creeping, creation of rural-urban environments and so forth (Zali et al. 2016).

“Master Plan of Tehran River Improvement and Restoration” has been launched in April 2015 after a few years discussion between Tehran Municipality, Tehran City Council and Ministry of Energy of Iran. The overall project objective was to create and promote connectivity between, and attractiveness of, Tehran Rivers, City and Citizens on various scales ranging from local urban design to the city’s overall spatial development (Ahmadpour et al. 2017).

The 2030 Agenda established 17 Sustainable Development Goals (SDGs) and 169 global targets, relating to development outcomes and means of implementation for the period 2015–2030 (UN, 2018). Within the people-centered context of SDG 6 - Ensure availability and sustainable management of water and sanitation for all, target 6.6 among other eight targets in particular focus on protecting and restoring water-related ecosystems, so that they can continue to provide

sustainable water services to society (Dickens et al., 2017). Another important Goal related to water is SDG11 which addressing the life within an urban area: Make cities and human settlements inclusive, safe, resilient and sustainable.

In addition to approaching to SDGs missions, implementing above mentioned master plan, eliminating facilities and building in riverbed and floodplain to facilitate restoring these streams to such a level which people feel free to contact and enjoy spending time with, urban authorities in Tehran municipality decided to establish a guideline to define rules and requirement of an Ecological Buffer (EB) which in turn define the border of extents that restoration should be implemented in. This decision was made after starting the process of restoring Farahzad stream. Both Tehran Municipality and consultant firm which was studying and implementing restoration process, find some ambiguous on how to restore, up to which level restoration should be done, how to deal with acquired rights and other technical, socioeconomic and political hinders in Farahzad stream, specifically, and the rest of streams in the city generally.

In this Paper at the beginning of the methods section, all available river buffers and their differences with (EB) is defined. The layers that are used in defining the EB boundary and their importance for this buffer are presented, and at the last subsection, Farahzad stream is introduced as the case study. Results section consists of all generated buffer based on the fundaments and rules described in the method section. Criteria ranking based on the stockholders and experts as well as the integration of the layers is two other subsections. Conclusion and acknowledges are the last sections of this paper.

2. Methods

Many stream restoration projects had been done. Ritobäcken Brook in Finland, River Marden, and Mayes Brook in the UK are among small scale project that their main aim was restoring a natural river channel, River access in a local urban setting and climate adaption and social benefits respectively. In the medium scale, River Vida in Denmark and River Great Ouse in the UKhave the purpose were river continuity and connectivity with flood plains. In the large scale project Cheonggyecheon Stream in South Korea, Ciobarciu Wetland in Romania and River Isar in Germany are among the most known project have been done in the world (ECRR, 2013)

2.1 Ecological Buffer (EB)

The terms flood zone, floodplain, active floodplain, flood-prone area, riparian zone, and streamway or riparian setbacks are often used to describe land near the stream that is flooded(Ward et al. 2008).The evolution of the way of looking at the river buffer have been altered from a single task to multi-disciplinary perpous task. The primary functions of the buffer are considered to be sediment removal and erosion control, protection of water quality, moderation of shade and water temperature, maintenance of habitat structure diversity and ecological integrity, and improvement of landscape quality (Broadmeadow and Nisbet 2004). There are two main categories to define a buffer for streams: Fixed method which defines a constant distance from the river for all of the river length and variable distance method in which the setback will be varied based on the stream situation alongside river length. Wenger and Fowler (2000) assessment showed that most of the researches in defining stream setback have a minimum width of 50 to 100 meters. To include 90% of the streamside plant species minimum corridor widths ranged from 10 to 30 m above high water mark, depending on the stream. Minimum corridor widths of 75–175 meter were needed to include 90% of the bird species (Spackman & Hughes, 1995). Johnson and Buffler (2008) proposed 25 to 375 feet to control water quality. Fischer and Fischenich (2000) summarized minimum width recommendations for water quality considerations, Vegetation, Reptiles, Amphibians, Mammals, Fish, Invertebrates, and birds. They also proposed a general riparian buffer width guideline for five main functions:
1- Water quality protection: 5 to 30 meters, 2- riparian habitat: 30 to plus 500 meters, 3- stream stabilization: 10 to 20 meters, 4- flood attenuation 20 to 150 meters, and 5- detrital input: 3 to 10 meters.

During the discussion among experts who was involved in establishing the above mentioned Guideline, the EB was defined as a protective buffer that includes all biological units in an ecosystem. The main objective of the definition of EB was to separate two different categories of land use (urban and natural) in order to reduce the impact of urban development on the natural heritage and their function in protecting individuals and properties from natural hazards (flood, earthquakes, etc.), access control and Prevent occupation of neighboring natural ecosystems. Different approach to define a buffer for river and streams, the variable to define them, their aims, ease of implementation, dimensions which include and the suitable location are summarized as the Table 1.

Table 1 Historical evolution of urban stream Buffers

	Quantitative Buffers	Qualitative Buffers	Mix of Q-Q & few more Parameters	Comprehensive Ecological Buffers
Variable:	single	single	Multiple Variables	Bio Conservation/Protection
Aims:	Flood Protection	Pollution Control	Both Flood & Pollution Control	Multi-Disciplinary
Implementation:	Easy	Less easy	Complicate	More Complicated
Dimension:	1D	1D	2D	2D-3D only for Urban
Location:	Both for rural and urban	Both for rural and urban	More for Urban	urban

2.2 Layer used to generate EB

2.2.1 River Bed

There were three principal obligations which should be followed in order to manage activities surround the river in Iran. As Ministry of Energy is the central entity to manage and operate river in Iran this ministry established the regulation on behalf of the government. The first rule defines the river bed as a river, stream, creek bed which is determined by the Ministry of Energy or regional water companies in each location, according to hydrological and hydrologic statistics and maximum flooding with the return period of 25 years (MOE).

2.2.2 Quantitative Buffer

The second obligation is “Guidelines for determining the quantitative buffer” in which had been declared that the setback zone for rivers and streams, marshes and natural ponds for dredging and exploitation would be 1 to 20 meters from the bottom of the bed. Calculation of the river setback will be done by DLSRS method which uses Discharge of 25 years, Location, Stability Regime, and Social stress to define this setback.

2.2.3 Qualitative Buffer

The last rule which should be followed in order to define EB is ‘Guidelines for determining the qualitative buffer’. This guideline indicates that buffer for protecting quality of drinking water sources is exactly 150 meters (horizontal) and divided into three zones: the first zone A=20 meter, the second zone which is related to the river clasification or river order (n) and calculate from the following equation.

$$B = \frac{150-A}{n+1} \qquad \text{Eq. 1}$$

The third zone is defined based on the two other zone width as bellow.

$$C = 150 - (A + B) \qquad \text{Eq. 2}$$

The critical point in defining these triple zones is that each zone is allowed to have specific groups of land use (Table 2).

Table 2 Land use defined in Guidelines for determining the qualitative buffer

Buffer Zone	Allowable land use
1st zone: A	Non-Flooded Agriculture, Group 2 Infrastructure (Water, Electricity, Telecommunications, Bridges and Port Facilities) and Extensive Recreation (Without the Establishment of a Centralized Facility)
2nd zone: B	Non-Traditional Agriculture, Rural Residential, Industrial Group A And B, Infrastructure Group 1, Centralized Recreation, Fisheries and Livestock
3rd zone: C	Traditional Agriculture, Urban Residential And Commercial, Industrial Group C

In the new version of this guideline which is undergoing to be passed, allowable land uses and buffer zones width have been revised. It was declared that The width of the qualitative buffer is determined by the horizontal level from the bottom edge of the bed to the three zones of “protection (one)”, "supportive (two)" and "backup (three)", and the width of each area was determined as follows:

- Protection zone (zone one): The width of this area is equal to the width setback for surface waters, provided that it is not less than 7.5 meters and not more than 20 meters.
- Supportive zone (zone two): The width of the protection zone is three times more than the width of the protection zone. So this zone width is 22.5 to 60 meter.
- Backup zone (zone three): The width of this zone is equal to 150 meters of the minus width of the protection and support zones.

Protection zone is the most effective zone for protecting and controlling non-point and point sources pollution and for reducing their pollution levels by controlling unauthorized access, protecting water and water-dependent ecosystems and other practices mentioned for the zone.

2.2.4 Trench and the natural slope

There is several purpose intended for defining the buffer for trench and slope in stream corridors such as protecting natural slope, rise safety against natural hazards like sliding, falling and collapsing the slope, protecting the streaming landscape as natural heritage of the city, saving the habitat of flora. Assessing the stability of slope of the trench should be done using one of the slope stability analysis models such as Geo slope or Slide. Simulating the slope will lead to determining the critical surfaces’ Factor of Safety (FS) and the distance between the vertices of the slope and the farthest point where critical slip plates can be formed (b) [Figure 2].

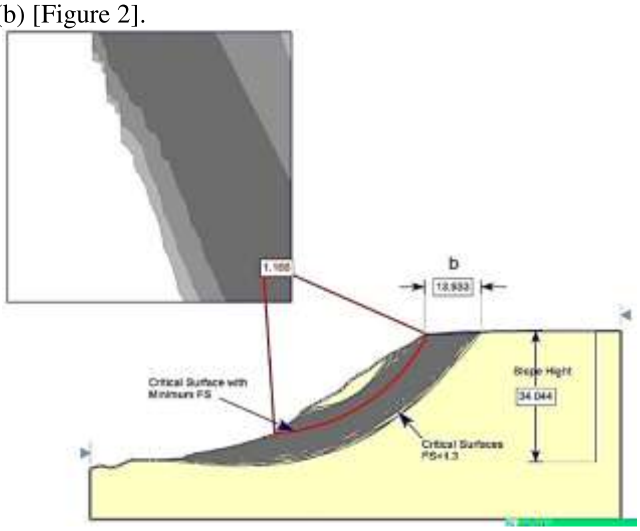


Figure 2 Slope characteristic in a stability analysis

All critical surface of rupture in which FS≤ 1.3 will be determined by model and their setback from the crown or slope buffer (SB) is equal to

$SB = C * b$ Eq. 3

based on the mechanical characteristics of soil C can be from 1.3 to 1.5. C for formation A is 1.3, for formation Bn the value of C is 1.4, and for other formation and made ground C is 1.5.

Based on the stability analysis if all critical surfaces have an FS from 1.3 to 1.5, the buffer will be five meters, and for FS≥1.5 there should be three meters distance from the vertices.

2.2.5 Valley boundary

Valley corridor should be defined as one of the criticallayers to define EB. This corridor should be defined based on old aerial images which indicate the undisrupted situation of the valley and complete by site investigation.

2.2.6 Flora

Defining a buffer for flora is one of the most crucial sections of an EB. In many sources, the flora buffer is called the riparian buffer. Different function cited for riparian buffers such as nitrogen (Mayer et al., 2007, Hefting et al.2005), phosphorous (Hoffman et al. 2009), sediment (Lee et al. 2000, Hook 2003), and erosion retention (Zaimes et al. 2004), preparing habitat (Barton et al. 1985, Marczak 2010), decreasing the temperature of soil (Chen et al. 1998) and water (Brown 1970, Tufekcioglu 2001) and preserving aquatic life (Teels et al. 2006), etc.

The best way to define the extent of riparian buffer in the urban environment is to derive its boundary from the areal image from the era which the corridor is not disrupted. In the situation that the areal image is not accessible the previous study related to define minimum riparian buffer would be useful. At least six stations should be used to investigate and analysis

species and define a buffer zone for them in which 90 percent of species covered. Spackman & Hughes (1995) urged that tree buffer will be defined through the site investigation and species richness should be determined from transformed species richness as

$$Richness = number\ of\ species\ /\ log10\ of\ the\ area\ sampled \qquad \text{Eq. 4}$$

Cumulative frequency of species (CFS) in each station calculated. Linear regression analysis between area and CFS are done. The defined buffer should cover more than 90 percent of species.

2.2.7 Fauna

The term fauna includes all animal living in a particular era or place. Defining a buffer for all living creature within or surround streams require considering buffer for aquatics creatures such as fishes and macro benthos, animals like mammals, reptiles, amphibians, and birds. Almost all scholar recommend sampling from undisturbed parts of streams to define appropriate buffers. Newbold et al. 1980 and Davies and Nelson 1994 recommendations could be used to define the buffer needs for aquatic creatures. To define the suitable buffer for reptiles and amphibian based on Rudolph and Dicks (1990) and Tassone (1981) recommendation could be used for birds. Spackman and Hughes 1994 could be used to define the mammal species exist in the buffer streams and determine their appropriate buffer.

2.2.8 Air corridor

In addition to dominant easterly wind Tehran which lay at the foot of mount Damavand, has mountainous local wind flow that flows from the northern mountain to the south of city through seven stream valley. One of the most critical issues which were considered in the EB is air corridor, a corridor which leads the flux of fresh airinter the city from the northern mountain. Modeling the mountainous flow in Tehranusing a CFD model help to comprehend the effects of EB and elevation order in improving weather condition and reducing the air pollution. Different scenarios could be definedforanalyzing in the CFD modeling process. The desired scenario for the EB is the buffer need to reduce an average 25% of carbon monoxideconcentration in 24 hours periods. It should be the noticed that the diminishing the polution concentrant are considerd based on local air flow not basd on the dominant wind flow. For this purpose, a 3D model of topography and building in the valley rendered and different formation to obtain desired reduction analysis and the final buffer for air corridor obtained. A hybrid model of Weather Research and Forecasting (WRF) (NCEP, 2019), Sparse Matrix Operator Kerner Emissions (SMOKE) (CEMPD, 2019) and Community Multiscale Air Quality(CMAQ) (EPA, 2019) have been used for modeling the impact of existance of structure and their order on the air quality. SMOKE model was used to prepare raw data for the diffusion of air pollution, WRF have been used to calculate meteorological and geographical parameters and eventually the output data of two other models intered to the CMAQ model to simulate the chemical processes, the transfering and settling of pollutants in the atmosphere, and determines the concentration of air pollutants in the city and the air corridor in specific.

2.3 Utility and infrastructure

All utility lines such aspower grids, water and wastewater network, natural gas pipeline, and telecommunication line should be called up and the required buffer for all of them must be observed. One of the most crucial points is the current subway path and their future development. Since the EB will be present to the city council to pass as a bill and apply on urban planning for new development all these buffers should be considered.

2.4 Fault line

After getting geology and fault line maps from official authorities such as Geological Survey & Mineral Explorations of Iran (GSI) or research from prominent scholar fault lines in the site will be defined. By surveying the site fault characteristics such as the precise location, slope and horizontal displacement of fault will be defined. The following equations will be used to calculate the safe distance from (buffer of) slide of different kind of fault lines.

- Safe distance of construction on hanging wall of normal, reverse and trust faults

$$S_1 = AZ_1 + 2B + U * (2D + H)/(\tan\theta) \qquad \text{Eq. 5}$$

- Safe distance of construction on Footwall of normal, reverse and trust faults

$$S\_2 = AZ\_2 + 2B + (U * 2D) \qquad \text{Eq. 6}$$

- Safe distance of construction on two sides of strike-slip faults

$$S\_1{,}2 = AZ\_1{,}2 + 2B + 1.5 * (U * 2D) \qquad \text{Eq. 7}$$

In the above equations AZ is the variable crushed zone which is determined through geophysics or typical trunking techniques.$AZ_1$and AZ_2 are width of the crush of the d zone around fault a in hanging wall and footwall of dip-slip faults and their aggregate is AZ, in strike-slip faults these two values are equal. D is the vertical displacement, θ is the angular of fault slope which is determined through geophysics or typical trunking techniques, U is risk factor which is defined based on

International building cod (IBC), B is the width of strip foundation or dimension of circular footing and individual footing, and H is the summation of the depth of penetration of stress and depth of structure foundation.

2.5 Tailoring layers

According to the topography, climate, and socioeconomic issues which would exist in a different area, additional criteria could be introduced to define the EB. For instance, streams and rivers located in a cold climate will be frozen periodically in the year, or the sea water would intrude the river and cause retreating the river water and raise the water elevation in specific period of year in the coastal area. The technical team should consider the local issues like situation mentioned above, in defining additional layers to have a comprehensive and tailored EB for all urban streams.

2.6 The importance of criteria

Yu et al. (2005) simply defined value as the ratio of perceived benefit to perceived cost. The systematic process of Value Management (VM) which is a team base and collaborative approach can be simply divided into three main phases, Value Planning (VP), value engineering (VE) and value analysis (VA) (Karunasena et al., 2016). Client's briefing, brainstorming, evaluation, weighted value criteria, and preferred scheme are steps of the value planning process (ICE, 1996). Value planning has been used to define the main criteria for determining EB based on experts and stakeholders point of views.

The Analytic Hierarchy Process (AHP) and raster calculation in GIS medium have been used in the value planning process for defining the importance of criteria. AHP is a theory of relative measurement of intangible criteria. With this approach to relative measurement, a scale of priorities is derived from pair wise comparison measurements only after the elements to be measured are known. In this method, paired comparisons are made with judgments using numerical values taken from the AHP absolute fundamental scale of 1 to 9. A scale of relative values is derived from all these paired comparisons, and it also belongs to an absolute scale that represents how much more one element dominates another concerning a given attribute (Saaty, Thomas L. 2005, Saaty, Thomas L. 2008).

The each generated layer are transported to specific raster which the layer raster value is the weight obtained from the AHP process, and their boundaries are defined from the different approach used by the related team. The final boundary will be calculated from the equation below in which L is the distance from the river line to the externalboundary of EB from the beginning of the river to the end of it. In this equation i is the number of layers, w_i is weighedof i^{th} layer, and T_i is i^{th} buffer width.

$$L = \sum_{i=1}^{i=10} w_i T_i \qquad \text{Eq. 8}$$

3. Case study

Iran capital city, Tehran is located at 35°412 463 N, 51°252 233 E and have 1200 meter average elevation. The difference of elevation height among the lowest and the highest point of the city is near 700 meter (Habibi et al., 2017). There are six major valleys in Tehran in which water flows. By moving from the right side of Tehran to the left one Darabad, Darband, Darakeh, Farahzad, Kan and VardAvard are located. Valleys are V-shape in the north part of the city and almost covered by concrete channel in the middle part of the city because of the antiquity of urban pattern and the low depth of rivers. Farahzad River is originated from the Alborz Mountains in the north and passes a valley, directed to a concrete canal and finally meets main west floodway of Tehran (Andik and Sarang, 2017). A segment of 3.2 Km length of Farahzad stream [Figure 3] has been select to apply the guideline on to assess its function. From the upstream of the Farahzad stream to the downstream of it there can be all available criteria for determining EB exist but fault line.

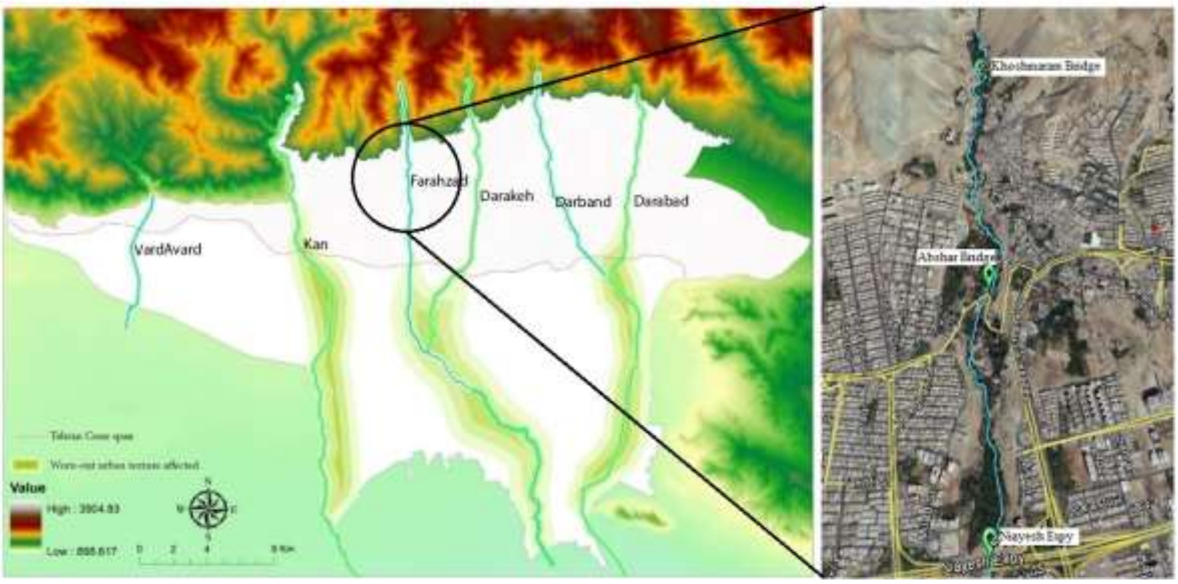


Figure 3 Farahzad stream location in Tehran

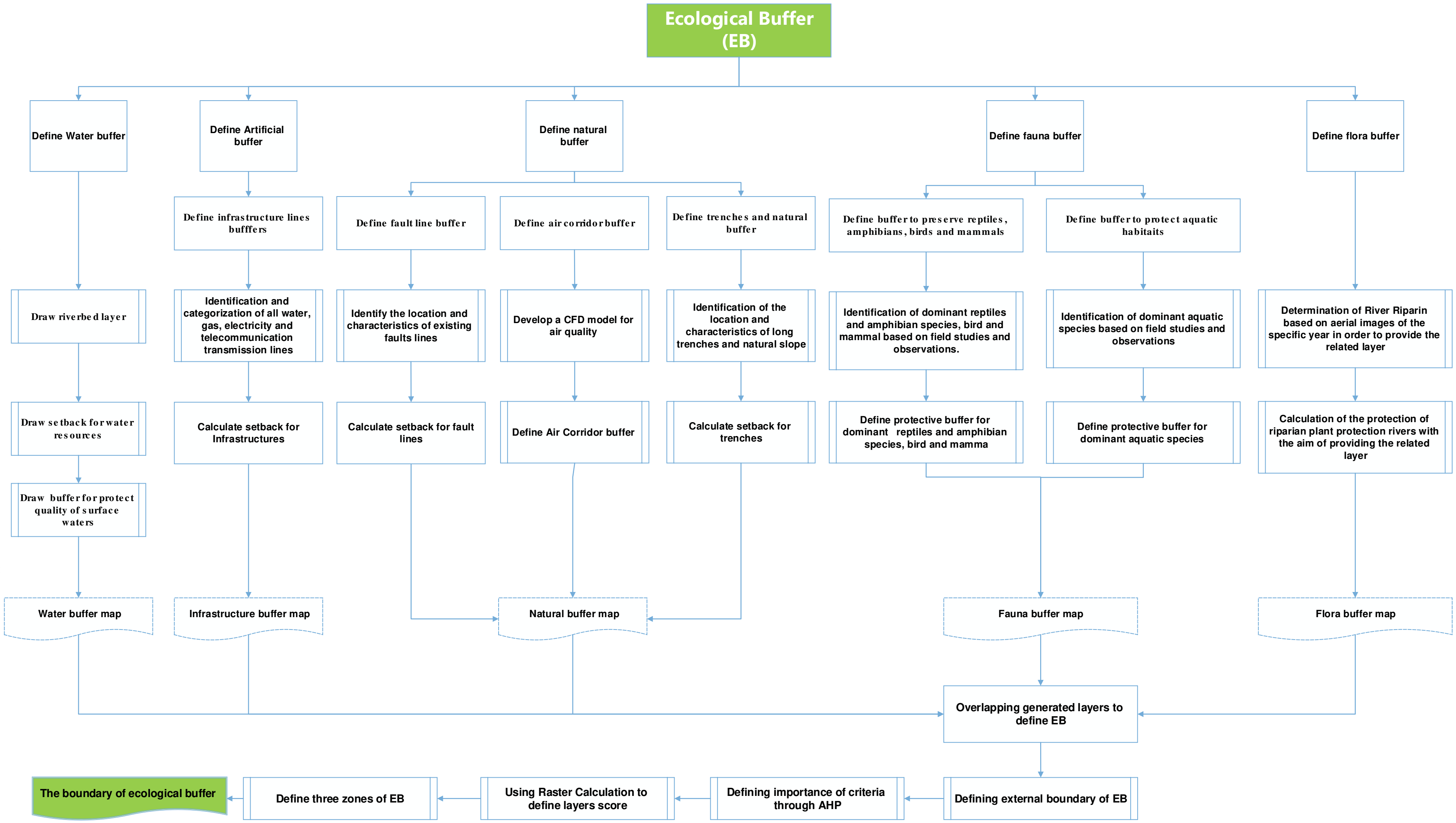


Figure 4 Proposed methodology to define EB

4. Results

4.1 Buffer layers

4.1.1 River bed, Quantitative buffer and Qualitative buffer

River bed buffer is defined by running a hydraulic model such as Hec-Ras for a 25 years returning period discharge and generated Dem by omitting all man-made structure such as bridge, canal, building, etc. The quantitative buffer and three zones of qualitative buffer are calculated based on the stream information and draw using GIS software like Arc GIS. All these layers are depicted in [Figure 11].

4.1.2 Trench and the natural slope

Trenches and natural slope surround the stream are among aspects of natural heritage and should be considered in defining EB. Limit analysis and Slide 6.0.2 software have been used to analyze the stability of the slope of the site based on Simplified Bishop, Corrected Junbou, and Simplified Junbou methods. Ten cross-sections have been selected, and critical surfaces with FS≤1.3 determined [Figure 5]. The buffers for each section have been defined as

Table *3*, and final buffer showed in Figure 11.

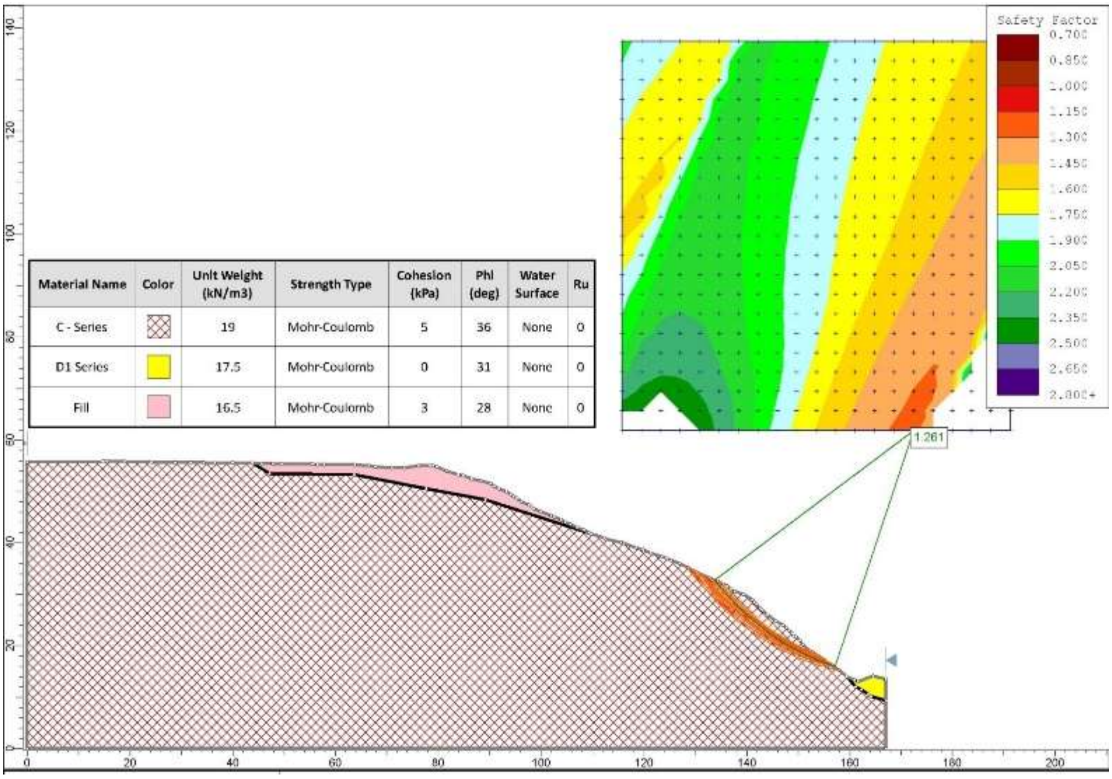


Figure 5 Slope Stability Analysis for one of the selected sections of Farahzad stream

Table 3 Defined stability buffer (SB) for ten section of Farahzad stream corridor

No.	Section	Side	Min FS	B (meter)	Formation	SB (meter)
1	1+500	East	1.1	13.08	Fill on Bn	13.08×1.5 = 19.62
2	1+500	West	1.30	0	C	5
3	1+900	East	1.06	13.72	Fill on Bn	13.72×1.5 = 20.58
4	1+900	West	1.26	0	C	5
5	2+100	East	>1.3	0	C	3
6	2+100	West	1.01	17.83	Fill on Bn	17.83×1.5 = 26.75
7	2+600	East	1.16	5.27	Fill on C	5.27×1.5 = 7.91
8	2+800	East	1.21	0	Fill on C	5
9	3+000	West	1.29	3.09	C	3.09×1.4 = 4.32
10	3+300	West	>1.3	0	C	3

4.1.3 Valley boundary

The valley boundary is defined based on the old map that existed from past studies of Farahzad.

4.1.4 Fauna

Five stations from the downstream of Farahzad to the highest elevation of the nearby mountain has been selected and assessed of which two stations were nearly undisrupted both for fauna and flora. Three categories have been defined to be determined under the fauna groups: reptiles and amphibians, birds, and mammals. After site surveying and analyzing existing documents on reptiles and amphibians Ophisops elegans, and Natrix tessellate species have been found in the intended site. Based on the observed species and previous recommendation, the minimum buffer width to protect reptiles and amphibians in Tehran is assumed to be 30 meters from the end of the river bed. In the surveyed site passer domesticus, Pica Pica, Corvus corone, Pycnonotus leucotis, and Tit species have been observed. Based on the observed birds species, buffer designated to them is 60 meters. According to the sensitivity of bird species to regenerate, any land use and facilitate in this buffer zone should be prohibited. In terms of mammals Mus Musculus, Schreibersii Miniopterus, and Vulpes Corsac species have been found. 100 meters width buffer has been designated to mammal based on suggestions. All three buffer layers for fauna are presented in [Figure 11].

4.1.5 Flora

Cumulative frequency of flour per station has been determined and results [Figure 7] indicate that more distance from the urban environment, more species were observed. Site investigations shows that the species are reducing by taking distance from the stream sides in all five stations somehow that the number declined from average eight species in a distance of ten meters from the stream edge to 1 species at a distance of 70 meters and the distance of 80 meters there were no species found in site investigation. Figure 6 depicted the number of species of each station. Species like Cercis Siliquastrum, Robinia Pseudoacacia, Juglans Regia, Ficus Carica, Fraxinus Excelsior, Platanus Orientalis, Populus Alba, Salix Acmophylla and Ailanthus Altissima observed as the tree. Eupatorium Cannabinum, Gundelia Tournefortii, Capparis Foliolosa, Capparis Spinose, Acanthophyllum Pachycephallum, Datisca Cannabis, Astragalus Vereskiensis, Calamagrostis Psuedophragmites, Rubus Anatolicumare found among shrub species. There were also other different herb species.

According to data observed and the calculation is done for them it had been obtained that if a 50 meters buffer has been considered for riparian zone more than 90 percent of flora species which observed in the undisrupted station will be preserved.

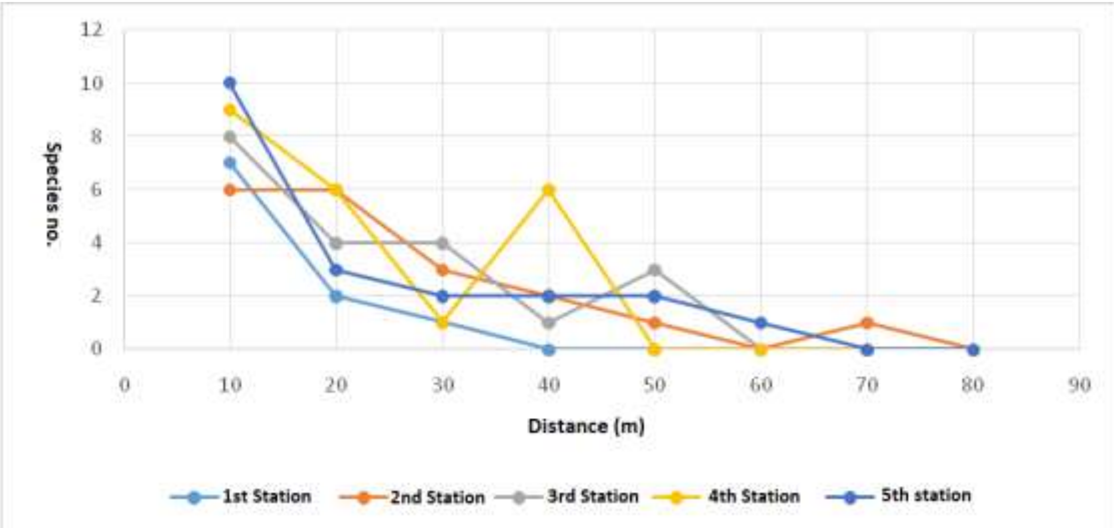


Figure 6 Number of Species found in 5 different stations in respect to the station distance from the stream bed

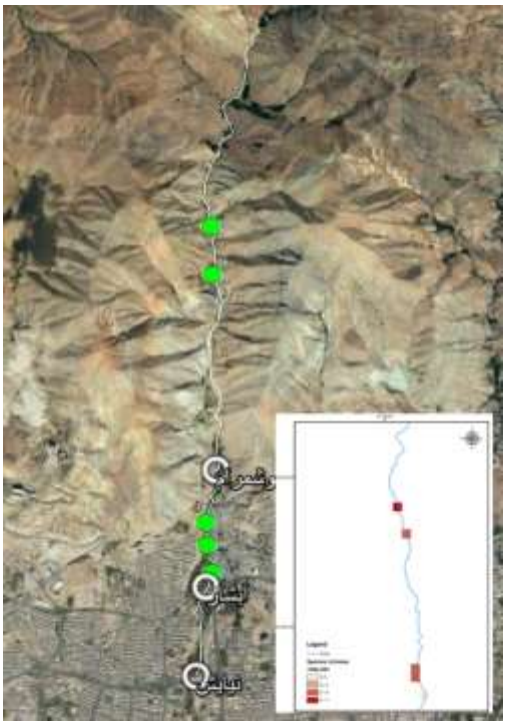


Figure 7 Selected stations to investigate species in Farahzad stream corridor

4.1.6 Air Corridor

In WRF model temperature and wind speed at the height of 10 meters above the surface are simulated and calibrated by observed data from terrestrial stations. The model depicted that PBL in winter and fall of Tehran can be a closest to surface as depicted in Figure 8. SMOKE model provide the concentration of carbon monoxide for hourly frame of modeling period. It was observed that concentration in the central region of city have a higher values.

Figure 8 Predicted Planetary Boundary Layer Height (PBLH) in winter and fall by WRF model

Using Hybrid model of WRF, SMOKE and CMAQ models in Farahzad stream showed that following the rules related to elevation of building in stream valley will cause to 12% reduction in air pollution in a 1 km buffer width and 25% reduction in 500 meters buffer width [Figure 9]. The rule indicates that the first front of the building should have one floor, the next one hastwo floors and so on.

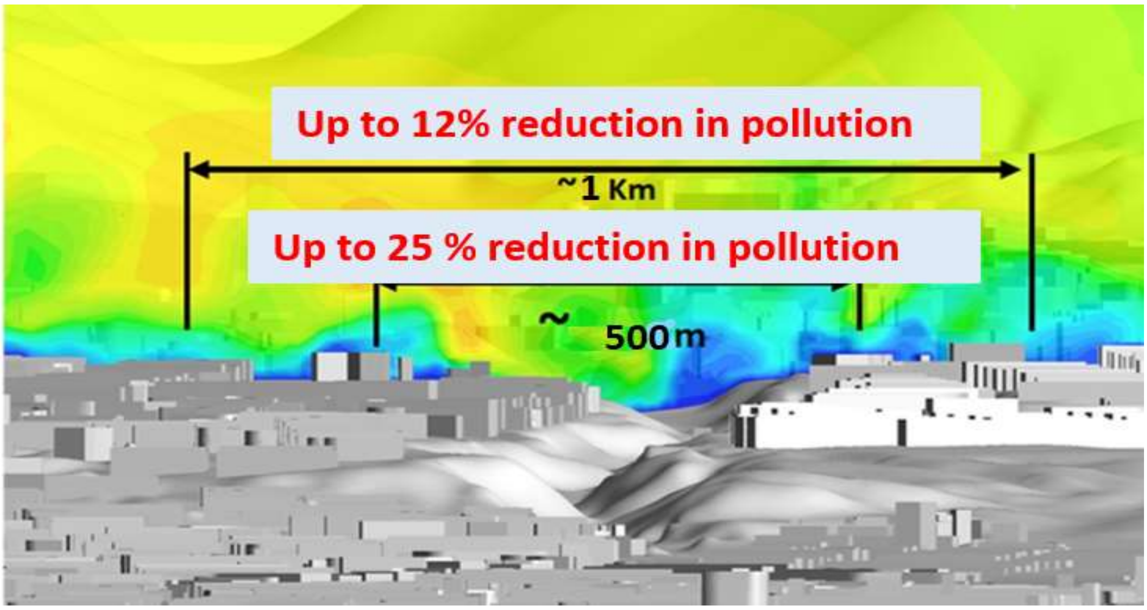


Figure 9 Effects of stream buffer on the reductions of air pollution

Changing attitude about Tehran main corridor for development from crossover highwaies to develop based on the stream corideor and develop city to be adjasted with this corridors can be one of the key point in deminishing air pollution.

4.2 Utility and infrastructure

All utility and infrastructure inquired and their buffer determined based on national legal obligations.

4.3 Fault line

There was no fault line in the site were study had been done.

4.4 The importance of criteria

More than 40 stockholders and experts in the field of water resources, hydraulic and sediment, Geo techniques, urban planning, geology, law, animal and plant ecology, economy, and environment had participated in value planning workshops which were held for more than 50 hours. Based on the participant point of view, environment and its sub criteria like water and sediment quality and quantity, soil, and air quality, fauna and flora biodiversity, etc. have the most important to define the EB with 24 percent of the overall score. Legislative requirements received 22 percent of scores. Technical aspects, social and cultural aspects and economic received the rest of score with 19, 18 and 17 percent, respectively.

Above mentioned experts also decided on the layer which should be take part in defining the EB. They filled up the AHP forms to clarify the value of each layer in EB. Nine generated layers in GIS environments had been selected as the buffer for ecological units: river bed, a quantitative buffer, qualitative buffer, high rise trench, valley boundary as river container, Fauna, flora, air corridor, and fault line. The last layer is defined as a restriction for construction and as there is not any fault line located in Farahzad valley this layer have been declined. Both quantitative buffer and qualitative buffer are binding to implement since they are legalacts. Each of these layers has one or more of the above functions which are presented in the Table 4.

Table 4 Defined function for each layer

Layer\function	Edges and access to water	Vegetation	Removing nutrients	Sediment control	Flood control	Habitat	Water temperature control	Air flow	Earthquake management	Natural heritage
River bed	✓				✓	✓				✓
Quantitative buffer	✓		✓		✓	✓				
Qualitative buffer			✓	✓	✓	✓				
Trench						✓				✓
Valley boundary						✓				✓
Fauna						✓				✓
Flora	✓	✓	✓	✓	✓	✓				✓
Air corridor							✓	✓		
Fault line									✓	✓

Experts have defined the importance of each layer for each function through a pair wise comparison. The final result presented in the Table 5 indicated that the fault line layer only actslike an earthquake management function, air corridor layer just provide air flow function. Other layers have different impacts on functions.

Table 5 average importance of each layer based on its function from experts' point of view

Layer\function	Edges and access to water	Vegetation	Removing nutrients	Sediment control	Flood control	Habitat	Water temperature control	Airflow	Earthquake management	Natural heritage
River bed	50	20	10	20	30	30	10	0	0	20
Quantitative buffer	50	20	10	20	100	30	10	0	0	20
Qualitative buffer	30	20	100	100	100	80	10	0	0	20
Trench	100	0	0	0	100	50	0	0	100	100
Valley boundary	100	0	0	0	100	50	0	0	100	100
Fauna	100	100	100	100	0	100	100	100	0	100
Flora	0	0	0	0	0	100	0	0	0	100
Air corridor	0	0	0	0	0	0	0	100	0	0
Fault line	0	0	0	0	0	0	0	0	100	0

Combining Table 4 and Table 5 lead to the weight of each layer's importance. The average importance which experts defined for each layer will give the final results [Figure 10]. From the expert's point of view preparing a corridor for fauna is the most important criteria to be imbedded in EB with a score of 0.187. Qualitative buffer is the next criteria with a score of 0.149. Flora, valley boundary, trench and natural slope, and river bed are the less critical criteria to define EB. The experts declared that a buffer for fault line has the least important to define an EB in an urban environment, this criteria received 0.031 scores among others. Since watching birds, mammals and other animals in the urban environment is a rare event in Tehran because of the urbanization pressure on stream corridors. It would be logic that participants have the most tendencies to creating a buffer for movement and habitat for fauna. Consisting all rule and regulation about protecting water in stream and rivers and the reputation of the related guideline may lead the selection of these criteria as the second important criteria to define the EB. It seems that the absence of a fault line in Farahzad valley leads to ignore this criterion in determining EB and receive the least score in the AHP process.

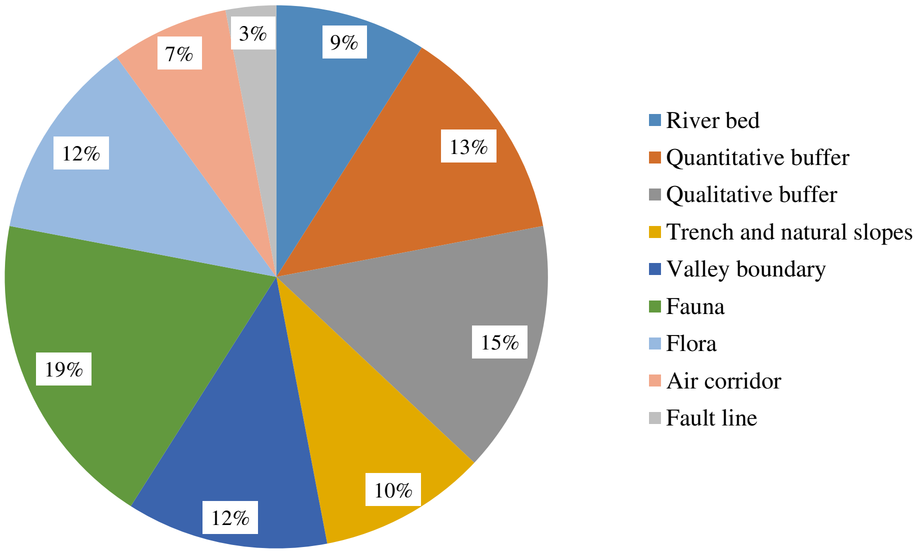
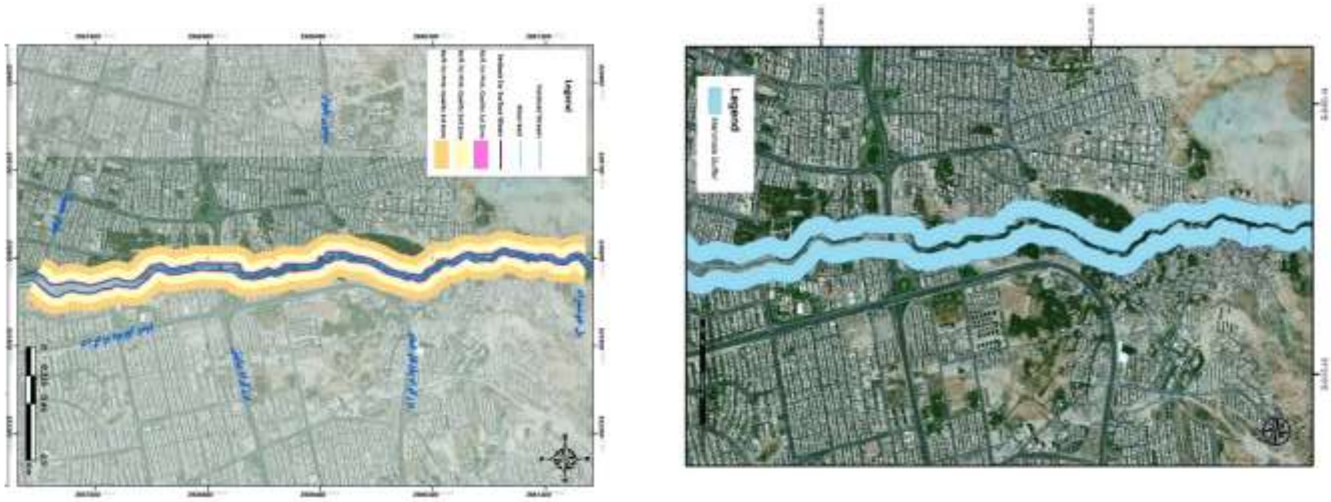


Figure 10 Importance of each layer to define ecological buffer zone for Tehran Urban Stream (EB)



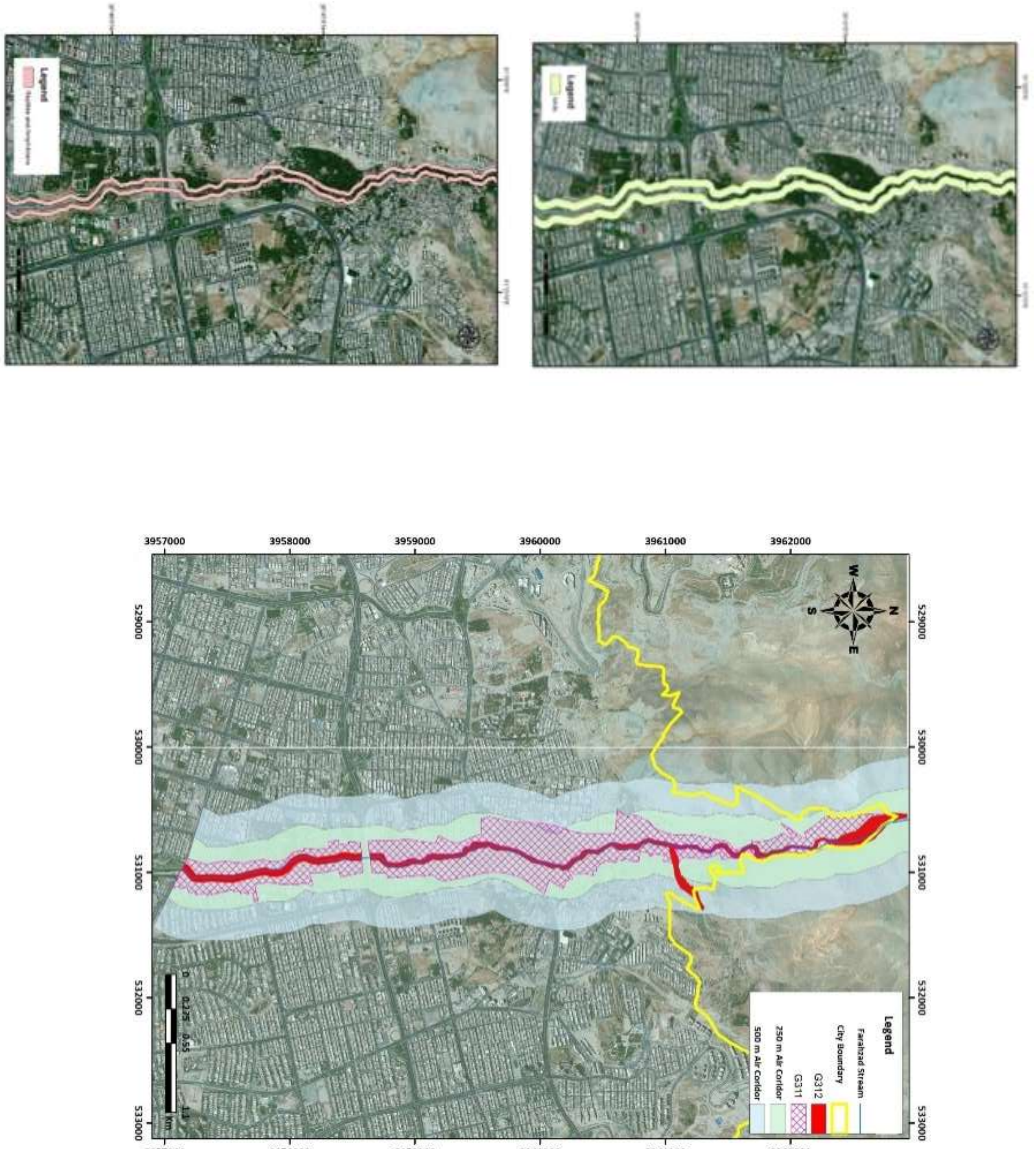


Figure 11 Generated layer by each field experts for their related buffer

4.5 Layers integration

Since the Government rules like ‘Guidelines for determining the Qualitative buffer’ used a three-zone buffer to apply different land use in each zone, EB also used the same pattern. All layers score will be assessed, and three zones will be defined from discretizing the scores range to three categories: from 76 to 374 will be defined as protection zone, from 375 to 671 will be defined as supportive zone and eventually from 672 to 969 will be assigned to the backup zone. The result showed

[Figure 12] that the protection zone that is depicted by blue color has an average width of 150 meters and is equal to 23 hectares. The supportive zone depicted by green color. This buffer's width is near 40 meters and has 9-hectare area. Eventually, the backup zone which is depicted by yellow color has an average width of 220 meters and 65 hectares of the overall 97 hectares. Since a considerable part of the EB cover existing private property and to simplify the implementation of buffer, the final boundary adjusted with the existing developments in a way that a block either placed in the buffer or not. Authors had been proposed that the city authorities and city council acquire the properties located within the buffer and look at acquiring rights as a part of the restoration process.

5. Conclusion

The obstacle to define a suitable width for restoring Tehran streams lead city authorities to look forward to a corridor in which restoration implemented. The EB is a buffer zone which including all biological units in existing ecosystem to be protected. It is multi-disciplinary and needs sustainability approach thus range of legal Act and fundamental criteria engaged in defining it. River bed as the width of river through which a 25 years flood pass, quantitative buffer indicate that at the end of the river bed from 1 to 20 meters setback should be defined for banning the activities surround the rivers and streams, and eventually qualitative buffer are among these mandatory obligations. Since the restoration process requires considering the natural situation of the stream before disturbing, other natural element should be embedded in the process of determining EB thus a range of criteria like buffers for trench and natural slope, fauna and flora, air corridor, and fault lines added to the EB. The buffer of all utility and infrastructure in the present and future also considered. Since the local winds in stream corridors cause the attenuation of pollution concentration, air corridor makes a key role in defining EB.

All buffers defined by experts of each field in a GIS layer in a way that for each criterion the boundary of setbacks draws as two lines along with the streamline weather with a fix or variable width trough through value planning. A team of stakeholders and expert from different fields decided about the importance of each buffer in determining final EB through an AHP pair wise comparison. Fauna, protecting the water quality, Flora, valley boundary, trench and slope, river bed and fault line received the highest to lowest score in defining EB, respectively. Each layer for related criteria transferred to the raster environment with a raster number of the score received from the experts' opinion and final buffer determined using Raster Calculator in Arc-GIS model. All pixels in the EB received a raster number from 76 to 374 and eventually this interval separated to three equal subintervals as the three zones of EB: Protective, supportive, and backup zones.

This buffer should be tailored for each streams and based on the local situation, new layers would be take part in defining the boundary of the EB. It is variable and in case of Iran it is more than is more than an integrated buffers obtained from legal obligations.

Since defining a triple zone buffer solely does not cover all intended functions of EB, the allowable land use in each zone is underway to be defined based on sustainable development criteria and the existing obligation. Team is also seeking to 1- provide an integrated model for aggregating and integrating multiple ecological layers, 2- provide a synergistic model for stakeholder management in determining EB 3- develop environmental flow needs model for urban rivers based on ecological needs as their upcoming researches.

Figure 12 Three-zone Ecological Buffer for Farahzad stream

6. Author Declarations

Data transparency (Availability of data and material): We make sure that all data and materials support our published claims and comply with field standards and provided tables and figures are not scanned copy.

Ethics approval and consent to participate: Yes

Consent for publication: Yes

Conflicts of interest/Competing interests: Not applicable

Funding: Not applicable

Code availability: Not applicable

Authors contributions:
Amin Sarang: 55%
Behnam Andik: 15%
Mojtaba Ardestani: 15%
Farnoosh Moradizadeh Kermani: 15%

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Figures

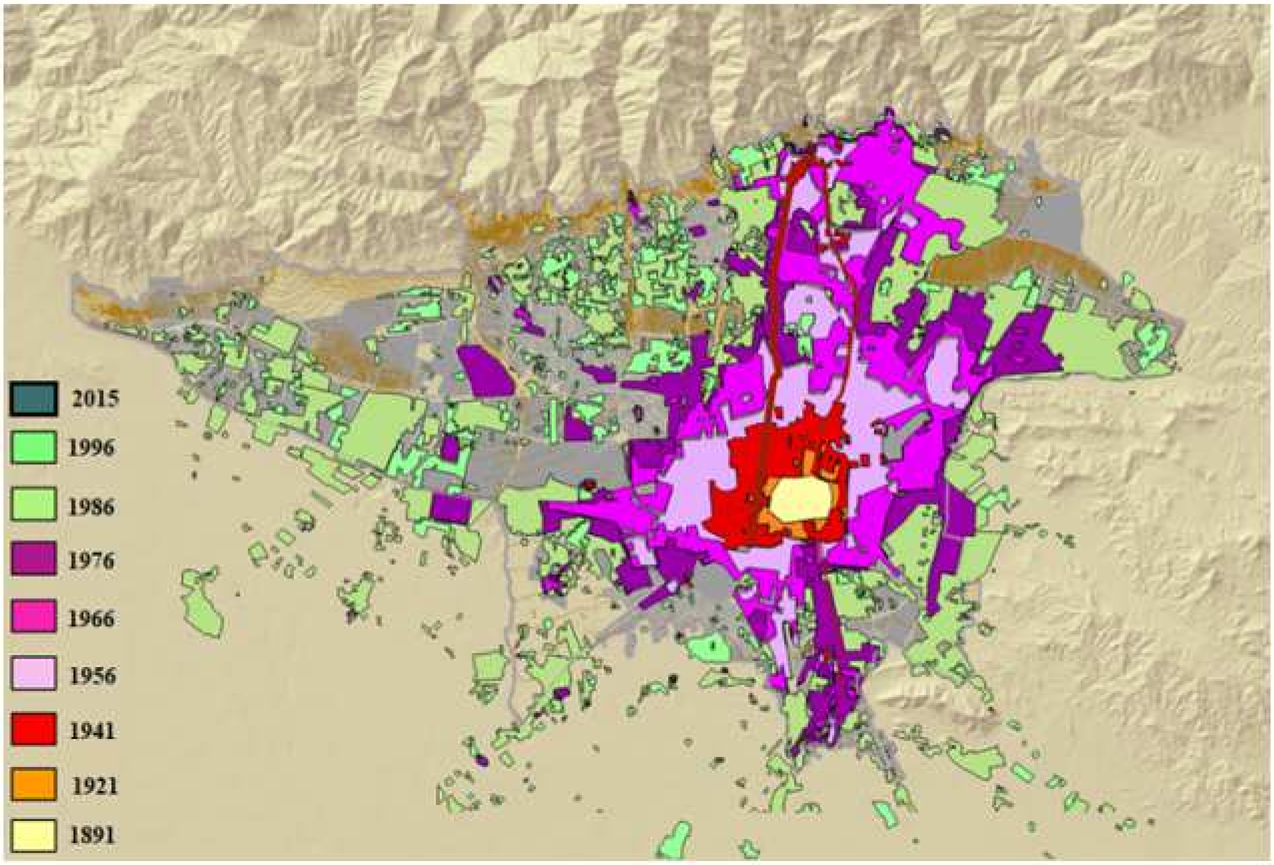

Figure 1

Tehran development during past 120 years Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

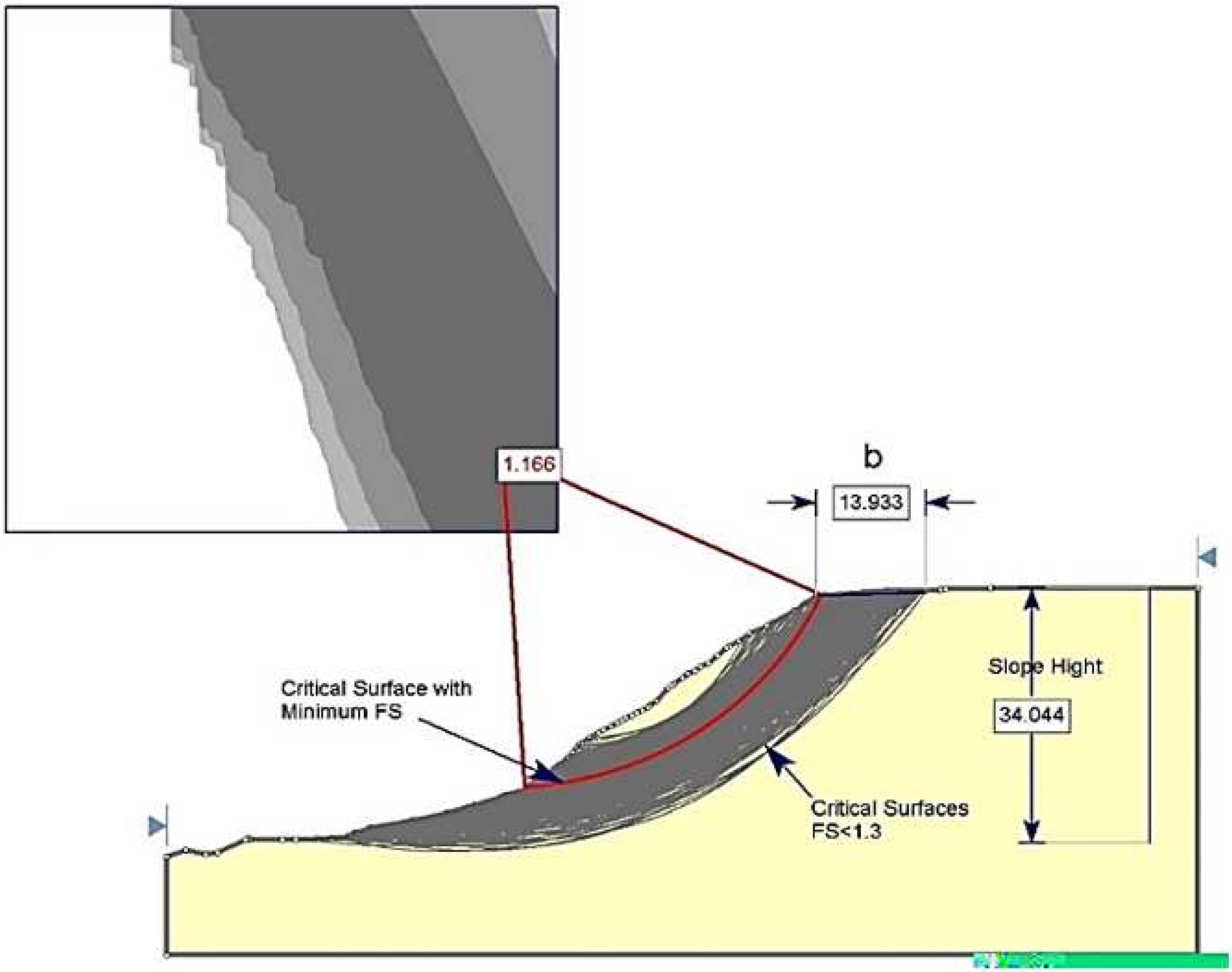

Figure 2

Slope characteristic in a stability analysis

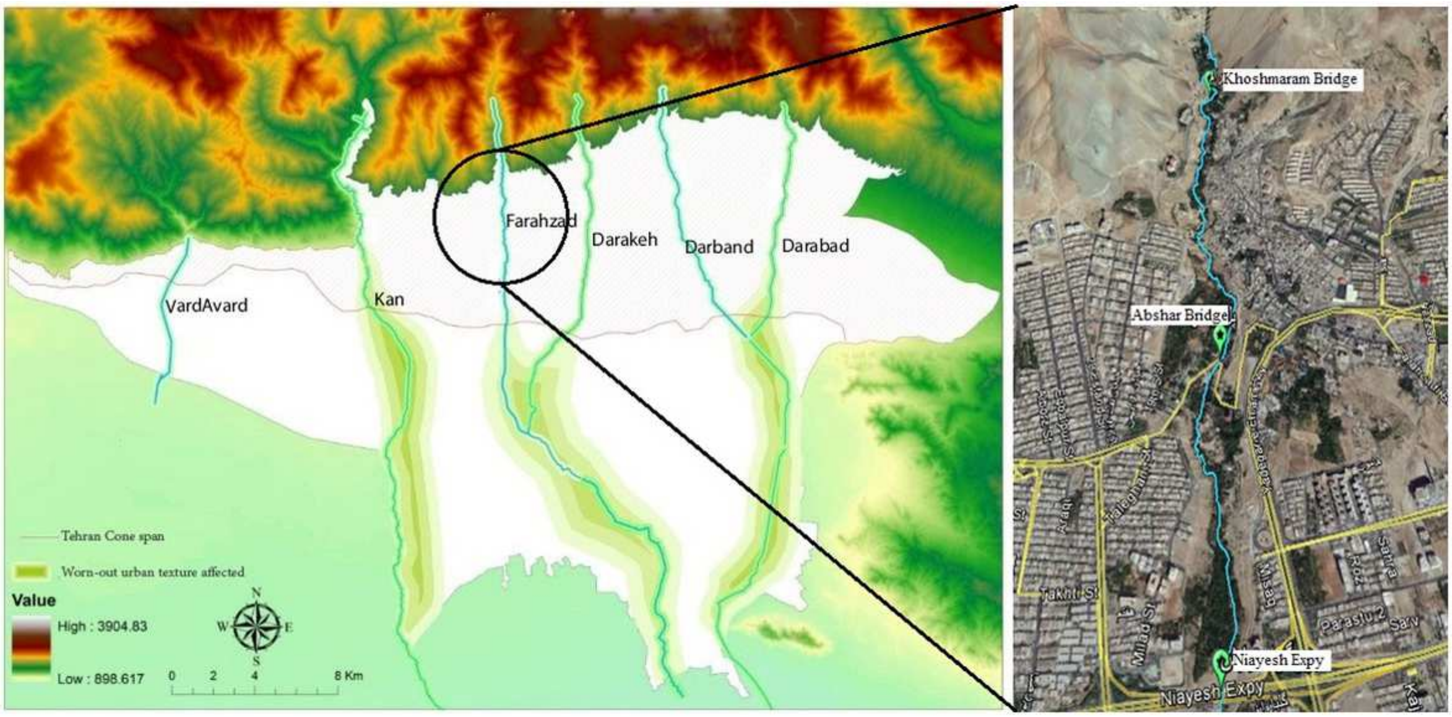

Figure 3

Farahzad stream location in Tehran Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

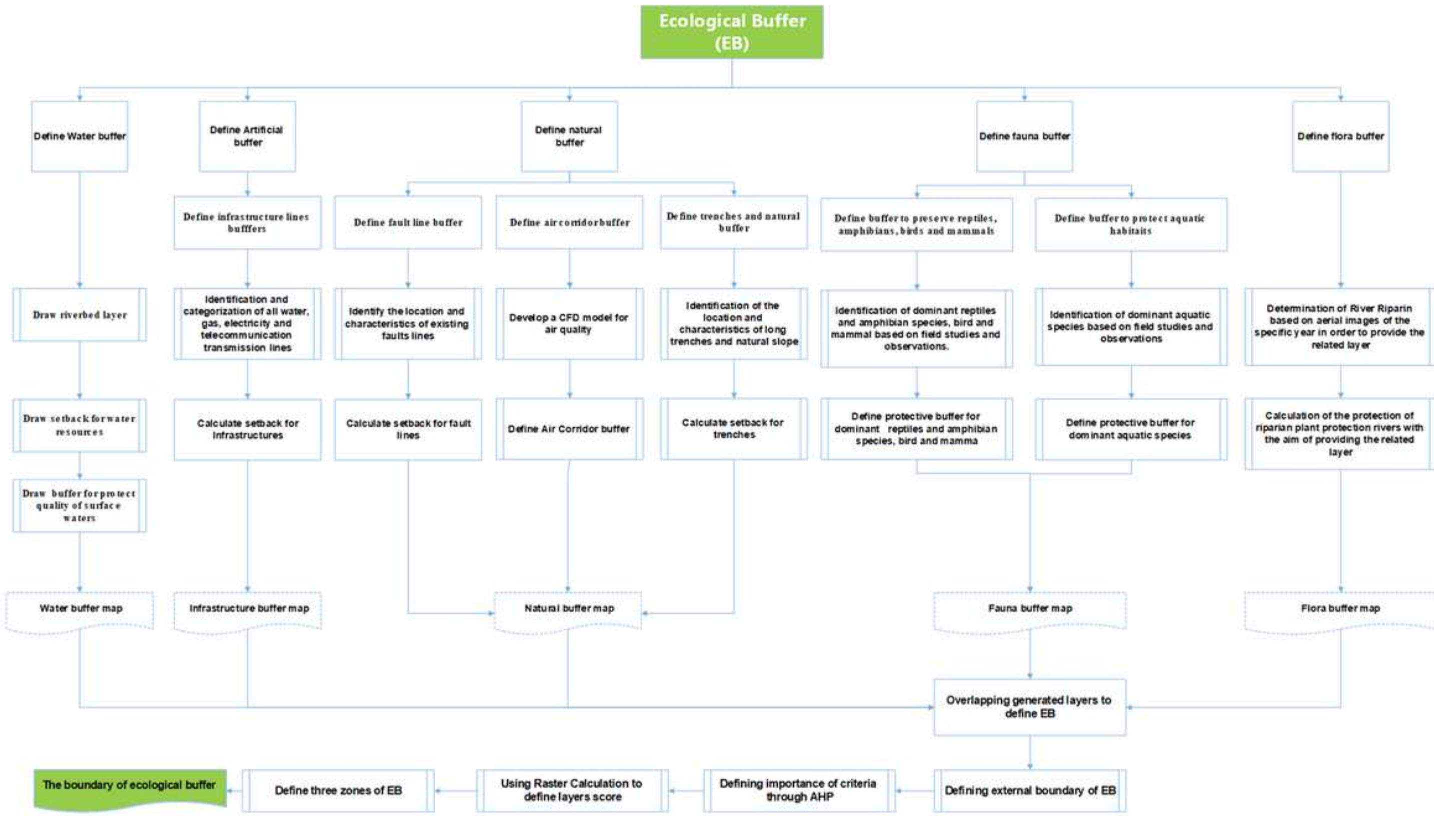

Figure 4

Proposed methodology to define EB

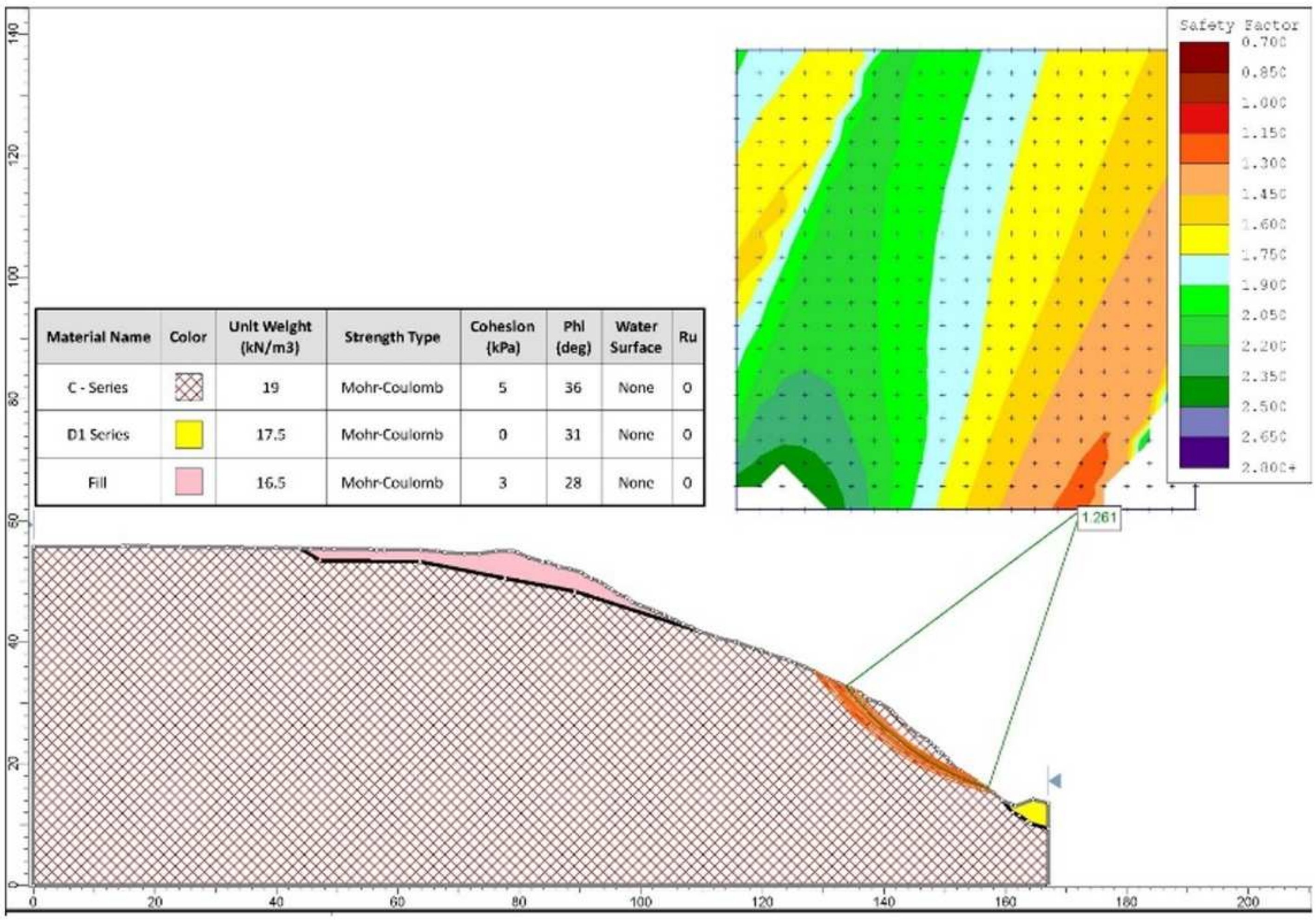

Figure 5

Slope Stability Analysis for one of the selected sections of Farahzad stream

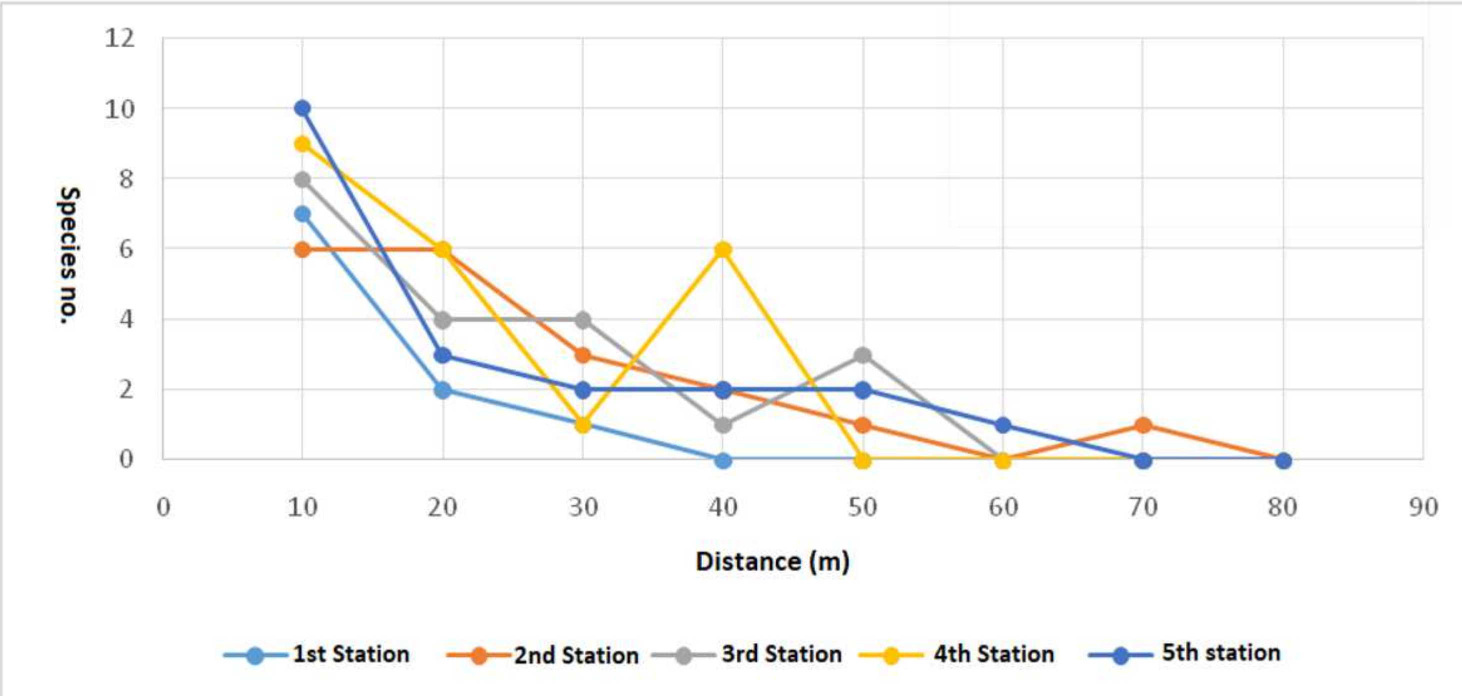

Figure 6

Number of Species found in 5 different stations in respect to the station distance from the stream bed

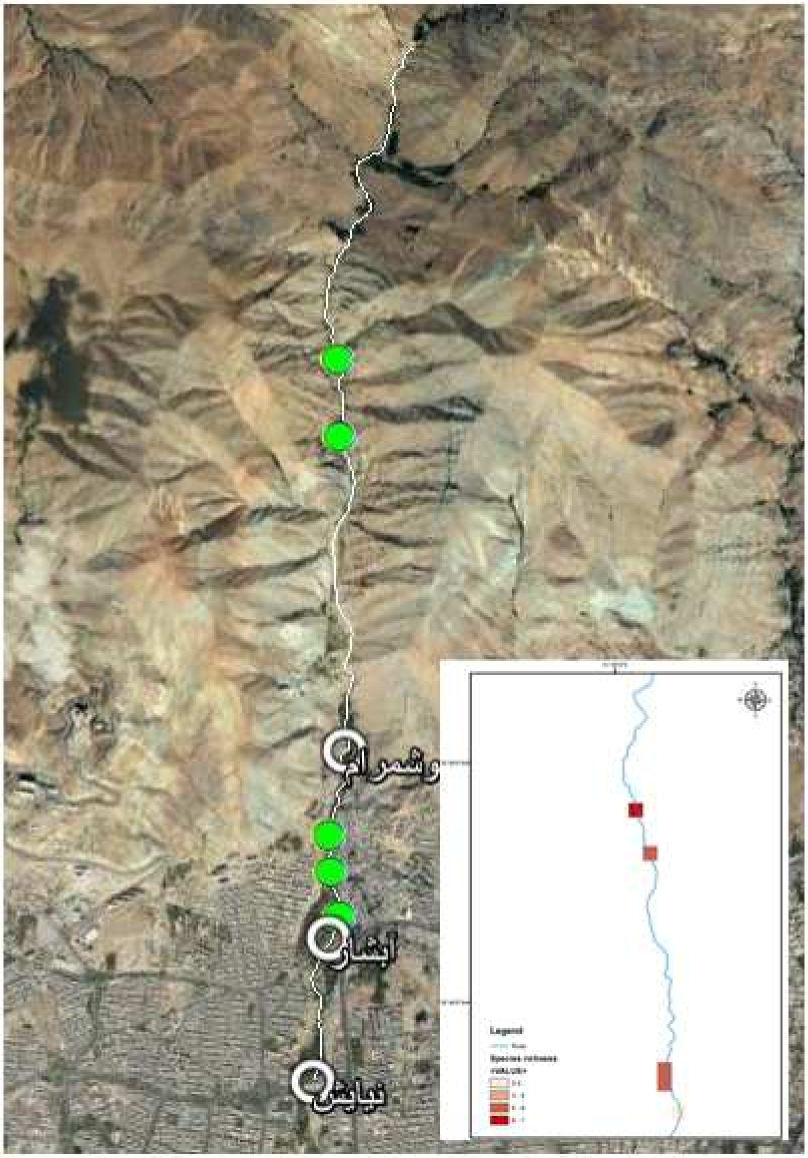

Figure 7

Selected stations to investigate species in Farahzad stream corridor Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

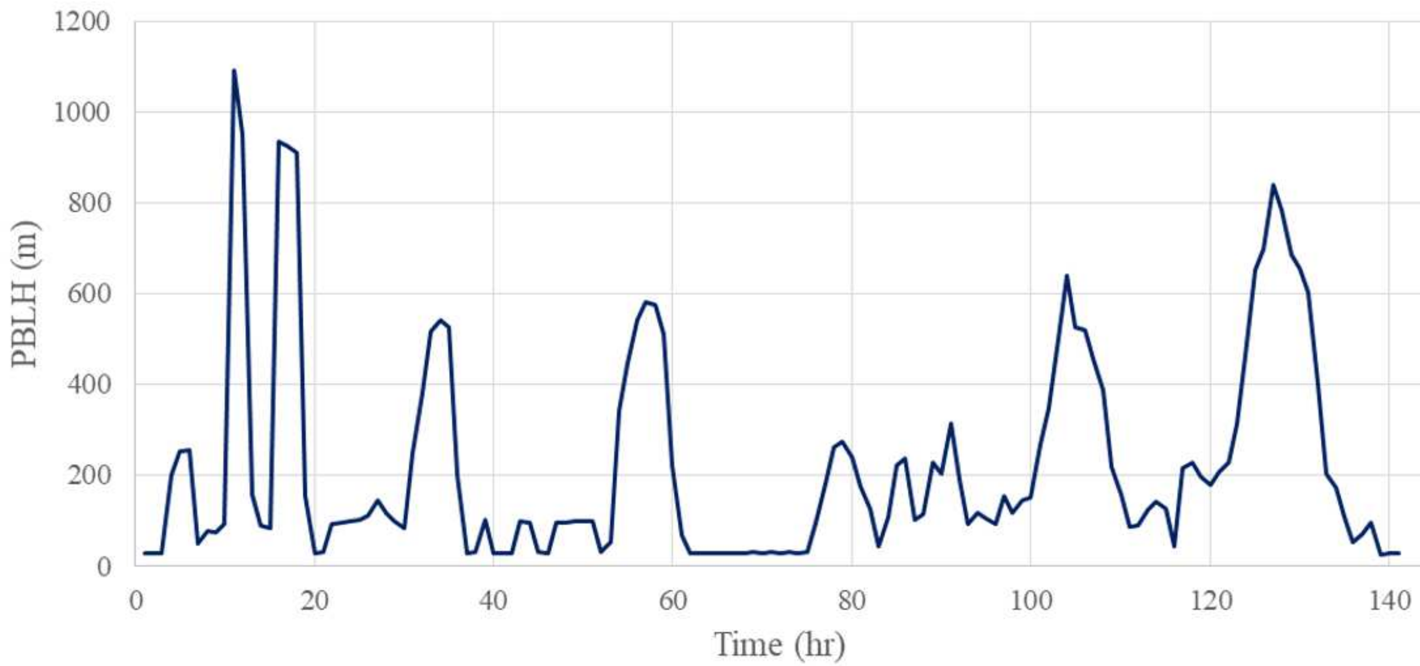

Figure 8

Predicted Planetary Boundary Layer Height (PBLH) in winter and fall by WRF model

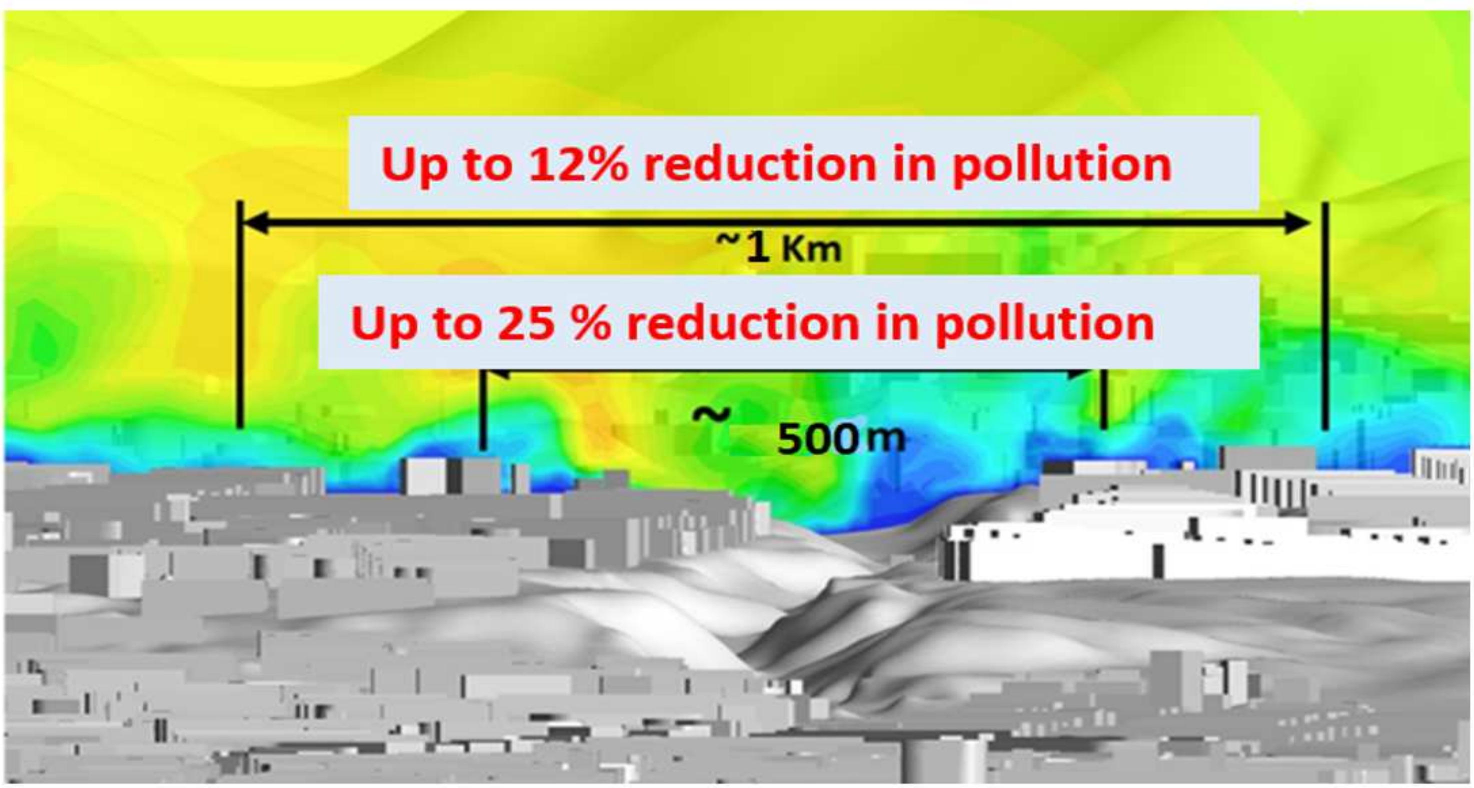

Figure 9

Effects of stream buffer on the reductions of air pollution

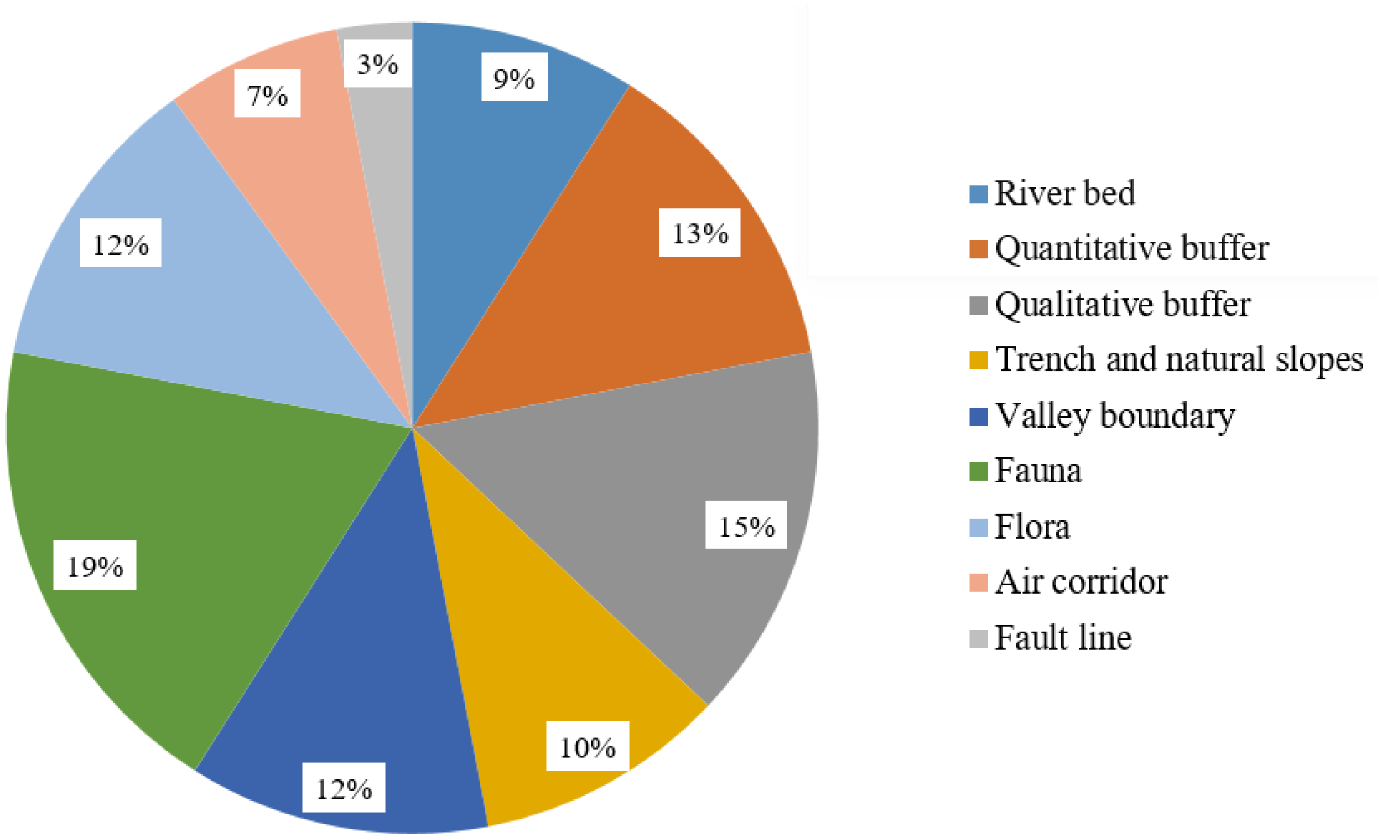

Figure 10

Importance of each layer to define ecological buffer zone for Tehran Urban Stream (EB)

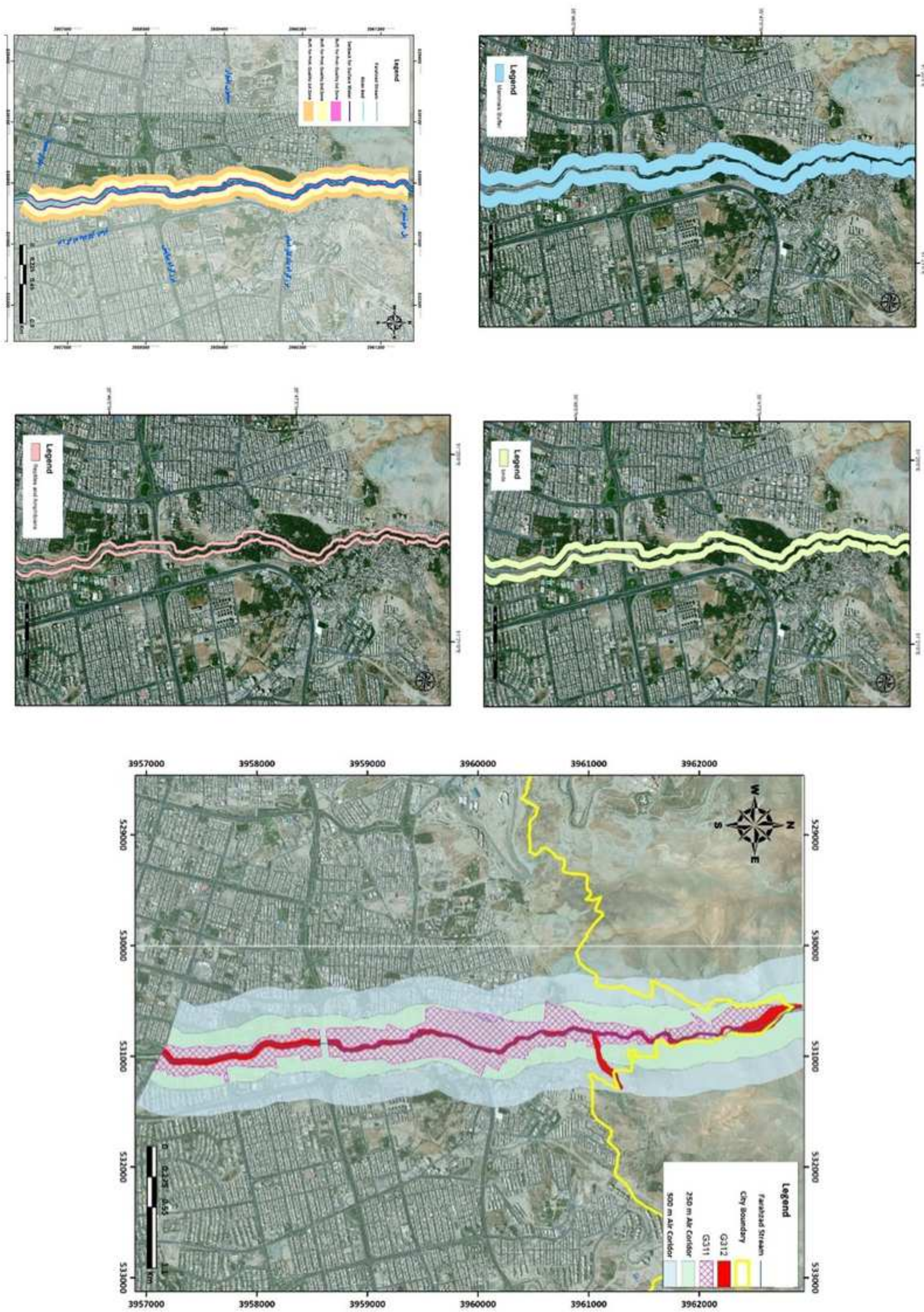

Figure 11

Generated layer by each field experts for their related buffer Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 12

Three-zone Ecological Buffer for Farahzad stream Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.