RESTORATION OF TAJAN RIVER THROUGH ECOLOGICAL DESIGN APPROACH

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ABSTRACT

Rivers are one of the main natural landscape element in urban areas. The ecosystem of the Riverfront is important as well as the ecosystem of the Rivers. However, research has shown that the current urban river development and riverfront maintenance projects has neglected regarding to the importance of organisms and urban ecosystem .Recent studies on the Tajar River in Iran are illustrated that ecological policies and strategies have not been succeeded in different aspects. Therefore, restoration of the Tajan River is not considered as a main issue for ecological design. The aim of this paper is identification of ecological issues of the Tajan River. Then, some ecological design approaches are presented and feasibility of the approaches are investigated in this paper. A qualitative method is proposed which includes interview and observation method. Based on above, ecological approaches and suggestions are recommended to habitation the health of river ecosystems. The results are indicated that application of the proposed approaches may effect on the ecosystem balance and ecological improvement of Tajan River.

Keywords: Tajan River, River Restoration, Urban River, Ecological Restoration

1. INTRODUCTION

As an essential environmental resource, the River is working as food and shelter source for a collection of flora and fauna, and is helping in the ecological shelter development and flood management [1]. However, irregular growth of population density, air pollution and acid rain, heavy metals, urban sewage disposal and their influences on natural waters are the major causes of environmental damage in urban areas. Additionally, a vast amount of agricultural industrial pollutants like pesticides and chemical fertilizers are contaminating the Rivers and drinking water sources in cities. [2].

Furthermore, many urban Rivers that they are placed very closely to residential and industrial buildings are destroyed by huge amounts of loads; for example, daily using of detergents and countless chemical products, dirty surface runoff of heavy rains and sewer overflow or improper disposal of wastewater [3]. Hence, the ecology and biodiversity condition of numerous urban Rivers are noticeably poor in comparison with natural freshwater figures [4,5,6]. River restoration as well as other ecological projects' design should maintain the ecosystem and operation processes. In order to preserve natural ecological system by means of green infrastructure following some principles such as provision the native plant is essential [7,8].

In this paper, current condition of Tajan River is investigated primarily. Then, an ecological framework is proposed for Riverfront design of Tajan River in Sari-Iran.

2. LITERATURE REVIEW

2.1 Background Study of Tajan River

Tajan River is one of the important Rivers of the Caspian Sea catchment area that emanates from several springs in the north of Iran. This River makes up part of the natural border between Iran and Turkmenistan. Tajan River economically has a significant role of people that inhabit in its shoreline. Accordingly, rich source of natural resources and raw materials, hosting a unique variety of living species and a developed natural economic system.

The River is the best place for the natural spawning of fishes of the Caspian Sea, such as Sturgeons and White fishes. This River's feed is rainfall, it reaches its water in the upper of the River, and flow to the Caspian Sea. The slope of the River in mountain area, special in south of the Sari is not very much. According to researchers' findings, the water of the River is not drinkable because of the excessive concentration of the ions in the River. However, the water is still consuming for the drinking and agricultural purposes [9,10,11].

Moreover, the Tajan's Riverfront is one of the Rivers is currently being neglected for the ecological studies. The study area of the Tajan River is consisted of two sides of the River from "Tajan Bridge" to the "Darab Bridge", around 1.5 Kilometres long (Figure1). Some of the main problems of Tajan River have mentioned in the following.

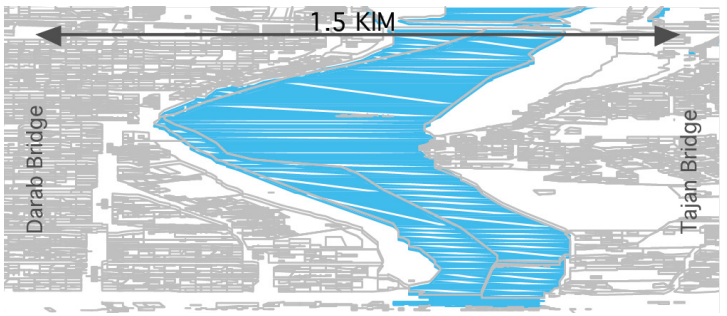

Figure 1: The study area,of Tajan River between "Darab Bridge" and "Tajan Bridge" around 1.5 KLM in Sari City. Scale: 1/30000

2.1.1 Water pollution

The water of the Tajan River is used for industries, irrigation of agricultural fields and animal farming. Moreover, the water of the river is providing an aquatic environment for river biota such as invertebrates and many kinds of fishes [11]. The River is surrounded by rice fields and agricultural farms. Hence, agricultural wastes and human disposals are contaminating the riverfront of the Tajan [12]. Farmers are consuming the huge amount of fertilizers and pesticides that are permeating the water resources. The mentioned issue made an adverse effect of the water resources. The statistics demonstrated that 30,000 tons of pesticides were consumed in the arable land in 2006 [11]. The nine OP and organochlorine pesticide were identified as the main water pollutants of the Tajan River [9,13,14].

2.1.2 Encroaching on the Riverside of Tajan River

The Tajan River originates from the forested mountain and cross the city nearby the residential and industrial constructions in Sari. Eventually, the river flows to the Caspian Sea. The investigations are shown that there is not a comprehensive supervision on constructing the buildings in the riverfront.

Therefore, many parts of riverfront lost their green area and superseded with construction and building materials and rubbishes. Living in this area is pretty dangerous and have made many problems for residents during the flood time [15,11].

2.1.3 Illegal Fishing and Decreasing the Population of the Fish

Chemical pollutants have been found at greater levels in several ecological sections like Tajan River, Riverine runoff [9], sediments [14], birds [12], and fish [13,16]. Diazinon is one of the most frequently used organophosphate pesticides and is identified often in the Tajan River water [9] are extensive in the surroundings of the basin and can certainly increase adverse effects to aquatic environmental health. Caspian Sea produces 90 percent of the world's caviar [16]. One of the main central breeding homes for sturgeon types and it offers spawning grounds for them is Tajan River. Diazinon pesticide is a risk to the Tajan River environment. Furthermore, the Diazinon pollutes the fishery products that are consuming by the people [11]. In recent decades, one of the major problems for surface water resources is biochemical pollution [17]. Therefore, these types of pollution are reduced quantity of the fishes in the river during the last few years [13].

2.2 Principles of Riverfront Design

In order to identify the ecological issues in this research, three river restoration projects were chosen based on the similar features with Tajan River. Additionally, the main reason for selection of these projects relied on urban context and issues of the rivers.

The projects are: Yongning River Park of Taizhou city, China, Cheong Gye Cheon River in Seoul, South Korea and Los Angeles River in California, United States (Table 1).

3. METHODOLOGY

The methodology of the research is divided to observation and interview with experts. The observation was done based on the self-observation method. Some of the prevalent tools like maps, camera and available photos were utilized to analyse the Tajan river site.

The interview done in the second semester of 2012. Three experts were chosen for the interview that they were familiar with the site. The interview was conducted based on the open-ended questions and three experts who were selected based on a set of criteria that are; one architect (Expert 1) and one landscape architect (Expert 2) who have been professionally involved in landscape architectural design with theoretical and practical background and one ecologist (Expert 3) who has experience for the River design and ecological design especial focus on the north of the Iran.

Therefore, appropriate data were collected by means of personal observation and then validated by the experts. The outputs of validation by the experts were considered as the results of the research.

4. RESULTS AND DISCUSSION

Tajan is the river which is located in northern part of Iran and facing with various types of pollution like water pollution, environmental pollution and so on. Moreover, developing the unplanned constructions and encroached building on the riverfront, are destroyed the riverfront greenery. Therefore, this research is investigated the mentioned issues as a main topic. The ecological issues of the Tajan River are identified from the literature, observation and interview with the experts. Then, identified issues are validated by the experts and potential solutions are recommended for improving the circumstances of the river. A comprehensive guideline is proposed based on the observation and interview with experts. The guideline consists of the common principles and approaches that may be useful for the ecological restoration of the river.

Table 1: Ecological Principles and Approaches in Riverfront Design

Principle	Approach	Proposed by
Reduce hardscape with removing engineering works.	1. The concrete was demolished and replaced with a gradual slope.	[18,19]
	2. The River was brought back to surface by demolishing a highway, which was used to cover the ugly and smelly River.	[20,21]
Provide several landforms and channel sections for the slope of the bank	1. Change repetitive embankment slope with dams and mounds.	[20,22]
	2. Compound channels are used instead of seasonal flu	[23,24]
Use materials that are permeable	Areas that accessible for water at the bank are paved	[21]
To reduce water speed use the produce gentle slope	1. The road on top of the bank beside the River was pressed back.	[20,21]
	2. The steep embankment was reformed into a composed slope.	[23]
	3. For recreational and mixed areas use gradual slope.	[24]
Maintenance the bank with plants	1. On the embankment walls were used ground cover and planting.	[18,20]
	2. Applied to the sloped embankment planting zone and planting box with native type.	[21]
Provide conditions for vegetation sequence	1. Sloped bank covered with native vegetation such as trees, shrubs, and grasses.	[20,21,22]
Create or defend meadow, grasslands and wetlands	The wetland was protected and creates for bird, fish, and amphibian to generate.	[18,19,20]
For local wetland mitigation banks, provide places	To reduce the top flow of storage, flood outdoor the channel, should classify the parts.	[18,19,25]
Provide wide and long buffer, particularly in sensitive natural zones	1. The constant practical riparian corridor was planned in long-term vision.	[21,23]
	2. A River buffer that meets the necessities of riparian environment was planned.	[19]
	3. Wetland with plants on the urban crossings of the River performance as a huge buffer.	[18,20]
	4. A dense vegetation belt is connected at the boundary between wetland park and urban surroundings.	[26,27]
Support animal migration	1. Wetland provides migration resources such as water, food, and shelter	[25,26]
	2. Constant riparian corridor provides habitats for birds, amphibians, mammals, reptiles, fish and invertebrates.	[23,27]
	3. For bird migration installed the islands.	[27]
For habitats of wildlife should provide condition	1. Established the wetland as habitats or shelters in flood seasons for fish and other aquatic life.	[18,26]
	2. In long-term vision, fish passages, ladders and glance pools are planned.	[27]
	3. For sheltering and generating fishes, was provided the fish ladders	[20,21]
	4. Bio-engineering was proposed throughout the upper reaches for wildlife territories.	[28]
Protect and enhance for water quality and quantity for water pollution	1. To treat surface overflow Install "water quality treatment terraces" in the channel or adjacent to the channel Create "green strips" on top of the banks	[28]
	2. To treat storm water runoff schoolyard and Pocket parks for make liner parkland sideways of the streets should be linked to good water quality.	[27]
	3. To avoid water pollution was recognized, limited water resources should provide an individual sewage system that is used to maintain water quality.	[25,28]
Provide temporary storm water storage on site with alternative structures	1. Existing a wetland park as a seasonal flooding stowage and a water quality improvement facility.	[23,26]
	2. For irrigation or infiltration is proposed off-channel storages	[19,29]
To deposit sediments and reduce pollutants with adopted structures	For reducing the pollutants flow into the River with overflow use on-site treatment structures.	[20,22]
Chose native plants	Native plants are used in making more natural look in area of poorer residence mixed with retails.	[29]
Water infiltration with Plant vegetation	1. Accept the function of infiltration with plants in wetland parks.	[18,26]
	2. Can be used for pretty water quality via infiltration within green strips.	[20,30]
Connection the isolated spots in the city	Riparian corridor and also immigration routes need to be linked together and lastly is into the mountain	[23,26]
Recognize potential spaces for corridor expansion	Places as "existing rights-of-way, power line easements, rail easements, and brown field can be restored for open spaces.	[21,24]

4.1 Result of Site-Observation

Site observation was analysed collected information by means of prevalent tools like camera, photos and maps. The duration of observation was 1 month in the summer of 2012. All the processes of the observation was reported. 1.5 kilometre distance of riverfront of Tajan River were investigated in detail. Moreover, general status of the organic pollutants is reported in following sections for better clarifications.

4.1.1 Water Pollution

The results of the observation indicate that east coast of the river is constructed by residential and industrial constructions. There is not any control for the sewage of these constructions along the river. Therefore, the sewage of mentioned constructions is contaminating the river.

The other source of pollution of the River is agricultural fertilizers from rice fields in the west part of the river specifically. Thus, the observation shows that the both sides of the river are polluted by various types of pollutants (Figure 2).

Figure 2: current condition of water pollution of Tajan River.

4.1.2 Environmental Pollution

The observation is indicated human wastes are the main reason for the environmental pollution along the river. There are no appropriate actions for the regeneration of the riverfront. Besides, abandoned space along the river became a place for the landfill of the disposals (Figure 3).

Figure 3: Current Condition of Environmental Pollution of Tajan River.

4.1.3 Encroaching on the Riverside of Tajan River

The job opportunities in the Sari which is the centre of province lead to immigration of people from the rural. Therefore, residential projects are increased dramatically.

Observations are showed that mass development in residential area is the major problem in riverfront of Tajan River. Therefore, riparian area along the river is substituted by the residential constructions.

According to the interview with people that living in that area, the price of the land in that area is increasing incredibly. People are changed green area to the high residential buildings to utilize the view of the river. Thus, the large area around the river has low-density of plants (Figure 4).

Figure 4: current condition of residential area around the Riverside.

4.1.4 Low Percentage of Green Space

The observation is shown that the user density at green spaces throughout the river is low. There is a lack of plant diversity in riparian area. Furthermore, construction development of the riparian zone is effecting on the ecology of the river. The presence of the native trees is protecting the soil against the erosion. However, the population of the native trees has been decreased because of the human inferences (Figure 5).

4.1.5 Lack of Function of the Greenery

The study of the site is demonstrated that some important features along the river is dramatically is weak. These factors could be categorized into the shade and shadow, shelters, and beauty of plantation. Generally, the status of the plantation in the Tajan riverfront is moderate and there are no maintenance activities for the existed plants (Figure 6).

Figure 6: current condition of Riverfront of Tajan River.

4.2 Result of Interview with Experts

The results of the interview with experts are presented in the (Table 2). The identified issues for the Tajan River are certified by the experts. However, one of the experts believed that the population of the wildlife is decreased in the Tajan River and its riverfront. Principles and approaches for restoration of the Tajan River landscape are recommended by the experts in the Table 2. These approaches may improve the Tajan River ecological landscape.

Figure 5: current condition of a bounded space near the Tajan Riverside.

Table 2: table of ecological principle and approach in Tajan River according to expert's recommendations.

Principle	Approach	Expert
Sewage treatment	Minimize alteration of River flow	Expert 3
Management of the uneven and limited distribution of riparian zone	1. Enhancement of River margins	Expert 2
	2. Restoration of riparian habitats	Expert 2 Expert 3
Link isolated patches in the Riverbank	1. Provide street trees to link River corridor with city green spaces.	Expert 1 Expert 2
Proposed aquatic garden along the ecological park for the purpose of greening the waterways besides providing aesthetic and educational value to the Tajan River corridor	1. Construction of boardwalk shall not bring pollute the water and damage the existing vegetation.	Expert 2 Expert 3
	2. A weekly cleaning is subjected to remove the invasive aquatic species to control their spread.	Expert 3
	3. The water quality is subjected to monthly monitoring to investigate the effectiveness of aquatic planting treating the water and prepare a remedial plan.	Expert 2 Expert 3
Storm water management	1.protect natural system reduces runoff and peak flow	Expert 2
Management of encroachment of development	1. Retention and replanting with non-invasive species	Expert 2 Expert 3
	2. The nature of existing development	Expert 1 Expert 2
Use planting that increasing the habitat of wildlife that traces pollution (biodiversity).	1. The use of floating vegetation islands/mats to treat the water: to prevent these floaters from being invaded and spread uncontrollably, floating booms are used to contain them within a designated area	Expert 2 Expert 3
	2. Selection of water cleansing plants with phytoremediation abilities, floating booms shall be used to contain the invasive aquatic to prevent from spreading uncontrollably.	Expert 2 Expert 3
Floating island	1. Floating island provides des habitat for aquatic and contributes to the water remediation.	Expert 2
	2. Water control plants naturally develop a biofilm of bacteria and facilitation the water cleansing.	Expert 3
	3. This zone also creates a sub aquatic feeding and spawning habitat for fish and other anchor prevents the floating from drifting away.	Expert 2 Expert 2
Support of the migration animal around the buffers along River	1. To support migration animal is kept buffers along River.	Expert 2
	2. Retain some relatively inaccessible area of the Riverbank to provide a refuge for wildlife within the urban framework.	Expert 1 Expert 3
Rain garden	An infiltration rain garden is a form of the bio retention facility designed to have aesthetic appeal as well as a storm water function. Rain gardens are commonly a concave landscape area where runoff from roofs or paving infiltrates into deep constructed soils and subsoil below. On subsoils with low infiltration rates, rain gardens often have a drain rock reservoir and the perforated drain system to convey away excess water.	Expert 1 Expert 2 Expert 3
Concept of "low maintenance", high performance"	1. To be implemented by selecting the suitable waterway plants.	Expert 1 Expert 2
	2. Different species of wetland plants are selected and designed for purification purpose to absorb different pollutants from the River water.	Expert 2
	3. Selection of flowering and fruitful trees as component along the River to add interest to the users.	Expert 1
	4. Sufficient amount of canopy to provide shade and enhance feelings of calmness for doing activities.	Expert 1 Expert 2

5. RECOMMENDED GUIDELINE

The results and finding of the research could offer a comprehensive guideline for development of Tajan River restoration. Table 3 is proposed a guideline for restoration of ecological approach of the Tajan River. The results of the Table 1, Table 2 and observation are combined and validated by the experts. Then, validated outputs are created the guideline of the research.

Table 3, ecological approaches and design recommendations of Riverfront design of Tajan River

Principle	Design Recommendations
	A. Water pollution
Protect and enhance for water quality and quantity for water pollution	1. To treat surface overflow Install "water quality treatment terraces" in the channel or adjacent to the channel Create "green strips" on top of the banks
To deposit sediments and reduce pollutants with adopted structures	1. For reducing the pollutants flow into the River with overflow use on-site treatment structures.
Use planting that increasing the habitat of wildlife that traces pollution (biodiversity).	1. The use of floating vegetation islands/mats to treat the water: to prevent these floaters from being invaded and spread uncontrollably, floating booms are used to contain them within a designated area 2. Selection of water cleansing plants with phytoremediation abilities, floating booms shall be used to contain the invasive aquatic to prevent from spreading uncontrollably.
Sewage treatment	1. To avoid water pollution recognized, limited water resources should provide an individual sewage system that is used to maintain water quality. 2. Minimize alteration of River flow
Storm water management	1.protect natural system reduces runoff and peak flow
	B. Environmental pollution
Create or defend meadow, grasslands and wetlands	1. The wetland was protected and create for bird, fish, and amphibian to generate 2. Restore degraded riparian habitats 3. Impediments and eyesore along the River such as rubbish and trash must be removed. 4. Introducing River edge beautification and landscaping measures buffer treatment. 5. Providing vegetated aquatic ledges along the River. 6. Existing waterside habitats and features of value for wildlife such as mangrove ecosystem should be maintained and protected. The existing area of the soft vegetated bank at areas adjacent to the engineered bank to be retained.
Use materials that are permeable	1. Areas that accessible for water at the bank are paved 2. Use permeable pavement. 3. For embankment engineer work can be used natural materials such as grass and rocks. 4. Offer constant trail with permeable pavement on sloped floodplain.
Use local materials	- Wood to be chosen as the material for the construction of floating deck, boardwalk and gazebo provide a sense of naturalness.
Rain garden	An infiltration rain garden is a form of the bio retention facility designed to have aesthetic appeal as well as a storm water function. Rain gardens are commonly a concave landscape area where runoff from roofs or paving infiltrates into deep constructed soils and subsoil below. On subsoils with low infiltration rates, rain gardens often have a drain rock reservoir and the perforated drain system to convey away excess water.
	C. Low Percentage of Green Space
Provide conditions for vegetation sequence	1. Sloped bank covered with native vegetation such as trees, shrubs, and grasses. 2. Provide green wall edges along commercial and residential area
Chose native plants	1. Native plants are used in making more natural look in area of poorer residence mixed with retails. 2. Advise massive lawn with bunched or dense native plants. 3. Afford programs to study native species for public spaces. 4. Green field as a storm water management alternative in flood season can be used.
Eco-garden	1. Create interactive activities for children connect with nature. 2. Educate people about pollution in interactive ways. 3. Planting the trees monthly
River forest approach	1. Proposing riparian zone as the main element to develop Tajan River landscape. 2. Implementation of suitable forest plant for the site. 3. Riparian zones, vegetation should be referred as a guide to design this site
	D. Encroaching on the Riverside of Tajan River
Reduce hardscape with removing engineering works.	1. The concrete was demolished and replaced with a gradual slope. 2. Use of the root word is the root mass or root ball of a tree, including a portion of the trunk for armour a stream bank by deflecting stream flows away from the bank.
Management of encroachment of development	1. Retention and replanting with non-invasive species 2. The nature of existing development
Management of the uneven and limited distribution of riparian zone	1. Enhancement of River margins 2. Restoration of riparian habitats
Maintenance the bank with plants	1. On the embankment walls were used ground cover and planting. 2. Applied to the sloped embankment planting zone and planting box with native type. 3. Use plants to make large floodplain and gentle bank. 4. To cross at narrow, shallow places fix stepping stones and rocks in the River. 5. Accept vertical planting on steep bank slopes. 6. Propose native plants for bank stabilization and water infiltration. 7. Provide buffer zone to divide train trail and green link area.

Principle	Design Recommendations
	A. Illegal fishing and decreasing the population of the fishes
For habitats of fishes should Provide condition	1. Established the wetland as habitats or shelters in flood seasons for fish and other aquatic life. 2. In long-term vision, fish passages, ladders and glance pools are planned. 3. For sheltering and generating fishes, was provided the fish ladders 4. For fishing or aquatic organism observing offer physical access to the lesser level of multiple channels. 5. Support the stream bank structurally, provide habitat for fish and other aquatic animals and supply food for aquatic insects with root wads.
Floating island	1. Floating island provides des habitat for aquatic and contributes to the water remediation. 2. Water control plants naturally develop a biofilm of bacteria and facilitation the water cleansing. 3. This zone also creates a sub aquatic feeding and spawning habitat for fish and other anchor prevents the floating from drifting away.
	B. Decreasing the population of the wildlife
Support animal migration	1. Wetland provides migration resources such as water, food, and shelter 2. Constant riparian corridor provides habitats for birds, amphibians, mammals, reptiles, fish and invertebrates. 3. For bird migration installed the islands. 4. Bio-engineering was proposed throughout the upper reaches for wildlife territories. 5. To support migration animal is kept buffers along River. 6. Retain some relatively inaccessible area of the River bank to provide a refuge for wildlife within the urban framework.
	C. lack of function of the greenery
Offer visual, vistas and overlooks access	1.provided open and semi-open spaces with various plant combinations 2. Improving and protecting spots of dangerous view corridors. 3. Using an classifiable plant palette in the streets as a mark of the optional view 4. Provide shade tree to get shading in the Riverside area. 5.use colourful plants to separate between spaces
Concept of "low maintenance", high performance"	1. To be implemented by selecting the suitable waterway plants. 2. Different species of wetland plants are selected and designed for purification purpose to absorb different pollutants from the River water. 3. Selection of flowering and fruitful trees as component along the River to add interest to the users. 4. Sufficient amount of canopy to provide shade and enhance feelings of calmness for doing activities.

One of the main problems of Tajan River is water pollution. According to the results; several solutions are recommended for protecting of the water against the pollution. These solutions could be categorized into quality and treatment of the water. Another main problem is environment pollution in this area is including the waste from industrial and residential area around the site. This issue with the water pollution makes the many problems for the fishes, aquatic and birds. With create the clean spaces for example grassland and meadow; we let the fishes to have generated. Using the local and permeable material is one way to provide a sense of naturalness with the cleaner environment.

Moreover, encroaching on the riverside of Tajan River is one of the issue which has mentioned in the literature review and interview with experts repeatedly. Reduce hardscape with removing engineering works is a main approach to against the encroaching on the riverfront. Also, decreasing the population of the fishes has the direct relationship with the water pollution. The expert result told provides the floating island can be useful for increasing the population of the fishes and aquatics.

6. CONCLUSION

Riverfronts may help increase types of variation, decrease water pollution, and adequate climatic changes in their close spaces [30]. Therefore, many of these opportunities, which are gradually connected to preserve an improved quality of life, have been linked with an urban improvement, drainage mechanism, and stress on flood control [31].

The Tajan River project, will be a long-term work to decrease the negative effects on pollution around the riverside. Various strategies has been advanced to recover the quality of the river and riverside ecology that might be utilise in the future. Finally, the study demonstrates the development of a systematic solution that should be integrated with the knowledge of urban planning, landscape ecology, environmental science, and hydrology together.

This research was only absorbed on ecological development and improvement on the riverfronts of Tajan River. Future research focus might be on the linkage between the improving sustainable riverfront environments with economic or social-cultural principles, but not just in the study area. The mentioned guideline could be valuable for the improvement of similar rivers in northern part of Iran.

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