Surveying riparian zone and water quality of Jajrud River

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Abstract

In this paper the riparian zones and water quality of Jajrud River were examined. Human and economic factors affecting the river ecosystem have been assessed for ten years. The evaluation results show that the total exploiters of agriculture, forestry and fisheries, 12.02%, the number of horticultural exploitation is 15.75%, the number of beekeeping exploitation is 18.01%, the number of active agricultural cooperatives 50%, the number of issued building permits has increased by 270.45%, the number of active service cooperatives covered by the General Directorate of Cooperatives has increased by 56.25%, the construction of freeways, highways and main roads has increased by 89.69%. Examination of qualitative parameters including nitrate, electrical conductivity, total dissolved solids, BOD_5, COD, pH, phosphate and ammonium shows that BOD_5, TDS and NH_4 exceeds 14 times, 16 times and 17 times more than allowable limits respectively.

Surveying riparian zones shows that a total of 168 ha of areas around the river need to be rehabilitated to restore vegetation that was effective in reducing and controlling non-point water pollution.

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Introduction

Riparian zones are habitats and plant communities around riverbeds and include hydrophilic plants. Around the rivers and lakes, the transition zone includes the biological community along the rivers and lakes. These communities are affected by their fresh water (Griggs, 2009; Chen *et al.*, 2019). They are usually narrow and fragmented and therefore vulnerable. In fact, they are part of the land that directly affects or is affected by rivers and streams. These areas include the immediate banks of rivers, including bed, margins and surrounding lands, and floodplains. The width of riparian zones depends on the type of river and its watershed. So the level that is affected and needs to be managed is different. The size of the riparian vegetation along the river

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changes over time. These ecosystems have a high biodiversity and are the source of many ecosystem services. These areas, with a sponge-like function, are effective in reducing water flow during flooding and absorbing water pollutants (Betz *et al.,* 2018). The management and restoration of riparian zones affect the aquatic animal health in two ways. First: Direct effect through physical protection of river canal and conservation of aquatic habitat. Second: Indirect effect through phytoremediation of pollutants from river water and increasing water quality. The health of aquatic animals depends on the quality of the water. Vegetation around the river or riparian zone plays an important role in the physical and chemical quality of water. Therefore, to maintain the ecological balance of the river, vegetation and animals are interdependent. Management and restoration of vegetation around the river preserves the geomorphological features and health of the river that directly affects the health of aquatic animals. Aquatic habitats for spawning and rearing larvae are protected. With the restoration of vegetation around the river and the physical protection of the canal and the riverbed and the preservation of habitats and water quality, the endangered aquatic animals' population will increase. In many parts of the country, these ecosystems need management so that their performance in water purification is not disrupted. One of the services of these ecosystems is the control of non-point and point pollution of rivers, which has become a major problem in many industrialized countries (Gunawardena *et al.,* 2018). Jajrud River is located in Shemiranat region in Tehran province. Shemiranat region has different uses that have compatible and adverse effects and consequences on the region's ecosystem. According to the latest statistics published by the National Statistics Center of Iran, the population of Shemiranat city has grown by 23.4% between 2007 and 2017. An examination of the situation in the region in terms of economic and human activities in the last ten years shows that the total number of farmers in the agricultural, forestry and fisheries sectors has increased by 12.02%. The number of horticultural exploitation is 15.75%, the number of beekeeping exploitation is 18.1%, the number of active agricultural cooperatives, 50%, the number of issued building permits, 270.45%, and the number of active service cooperatives under the coverage of the General Directorate of Cooperatives has increased by 56.25%. These exploits, if unsustainable and incompatible with the environment, affect the quality of river water as well as the surrounding vegetation. Construction of freeways, highways, main roads and side roads has increased by 89.69% (Statistical Yearbook of Iran 2019). An increase of almost 90% in the construction of all kinds of roads, in addition to the destruction of natural habitats, is accompanied by an increase in all kinds of pollution and waste. An increase of more than 270% in the issuance of building permits will affect the appearance and use of the area. At the same time, some human activities and various economic sectors have seen negative growth in the last ten years.

Household electricity subscribers decreased by 77.84% and the change in electricity sales per MWh unit was estimated at 85.98%. Industrial electricity subscribers have also experienced a growth of 12.5%. Water sales, number of fuel sales stations, light livestock breeding, heavy livestock breeding, poultry farming, number of greenhouse exploitation, number of agricultural exploitation operations, have had negative growth respectively, - 39.72%, - 23.80%, - 35.55%, - 76.02%, - 59.39%, - 31.57%, - 65.37%. Increasing and decreasing these human and economic uses, in addition to the consequences of climate change, has several effects on the region (Hashempour *et al.,* 2020). These activities have adverse effects on the riparian zones. Riparian zones play a significant role in purifying various water pollutants (Moogouei *et al.,* 2018; Moogouei and Chen 2020). The aim of this study was to investigate the area of polygons of riparian zone vegetation along the Jajrud River and areas without vegetation, from Sarband Sar to the entrance of Latian Dam using satellite images. Satellite images are a suitable tool for environmental and agricultural modeling (Liang *et al.,* 2018; Zhang *et al.,* 2020). In this study, Landsat / Copernicus satellite images measured the area of polygons without certain vegetation and the area of polygons that need of restoration. Also, the water quality of the river in terms of physical and chemical parameters between 1391 and 1398 in 5 sampling stations have been studied.

Material and Method

Jajrud water catchment with an area of 1892 Km^2 with coordinates of 35°:25" to 36° degrees northen latitude and 51°:23" to 52°: 6" eastern longitude located in the eastern part of Tehran (Behbahaninia and Salmasi 2019). The main tributary of this river originates from the Kharsang Mountain located in the northeast of Tehran and its length is 140 km. Then, after passing through Fasham village, and Oshan, it changes its direction to the southeast and enters Latian Lake after passing Rudak and Lashgarak. Then it flows towards Parchin and enters Varamin plain through Sharifabad canal. The branches of Jajrud River include Ahar, Afjeh, Omame, Oshan, Khairrudbar, Damavand, Rote, Shemshak, Keresht, Garmabdar, Lalon and Nasrabad. According to the statistics recorded in Shemiranat city in annual weather report in 2019, in 1396, the average air temperature has changed from 5.2°C to 28.1°C and monthly rainfall has changed from 0 to 109.5 mm. Relative humidity has changed from 9% to 70%.

Introducing marginal plant communities

The list of plants that live in or near the river is shown in the table 1.

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Table 1. List of plants in the Jajrud River for the riparian zone restoration program (Khorasani, 2001)

Scientific Name	Next to the water	Inside the water	Scientific Name	Next to the water	Inside the water
Nasturtium officinalis		*	Carex spp.	*	
Calamagrostis pseudoghragmites		*	*Sisymbrium irio*	*	
Mentha aquatica		*	*Crambe kotschyanus*	*	
Lythrum salicaria		*	*Holosteum umbellatum*	*	
Phragmites australis		*	*Chellidonium majus*	*	
Typha australis		*	*Rumex crispus*	*	
Catabrosa aquatica		*	*Mentha longifolia*	*	
Zanichelia palustris		*	*Agropyron repens*	*	
Callitriche palustris		*	*Anagalis coerulea*	*	
Juncus inflexous		*	*Arectium lappa*	*	
Malcolmia africana	*		*Xanthium spinosa*	*	
Conya canadensis	*		*Geranium spp*	*	
Erodium cicutatrium	*		*Epilobium hirsutum*	*	

Parameters studied in Jajrud River water

In this study, to evaluate water quality, nitrate, electrical conductivity, total dissolve solid, turbidity, BOD_5, COD, pH, phosphate and ammonium related to 6 sampling stations between 2012 and 2019 have been studied and compared. Sampling stations are Fasham, Jajrud, Meygoon, Oshan, Rudak and Latian Dam. Standard methods were used to measure the parameters measured. To measure turbidity, electrical conductivity, pH and TDS, turbometers, EC meters, pH meters and forums were used, respectively (Standard Methods for the Examination of Water and Wastewater 2020). These parameters have been compared with the water quality standard for environmental protection (aquatic ecosystems), Iran's environmental protection. Moreover, Jajrud water flows into the Latian Dam Lake, which is the source of drinking water supply in eastern parts of Tehran so, parameters have been compared with the water quality standard for drinking water also (Water and Soil Office of the Environmental Protection Agency 2016).

Cluster analysis of sampling stations

Cluster analysis was performed using SPSS software to check the similarity of water quality characteristics in different sampling stations. Mathematical and statistical calculations and cluster analysis were performed using 2016 Excel and SPSS 16 (Fan *et al.,* 2018).

Investigating the riparian zone along the Jajrud River using satellite imagery

In this study, vegetation around Jajrud River using Google Earth software (Emage Landsat/Copernicus, Emage @ 2020 Maxar Thechnologies) was investigated. Satellite images were taken between May and

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September 2017, and areas with dense vegetation and no vegetation were identified, and then polygons without vegetation were drawn and their area was calculated.

Results

Quality parameters of Jajrud River water

The water quality of the river in terms of non-point source pollution has been studied between 2012 and 2019. (Fig 1-9). For each parameter, the average data presented in multiple sampling stations is determined. According to the water quality standard for environmental protection (aquatic ecosystems), the allowable pH for rivers of group 1 is between 6 and 9. Water quality standard for drinking use, for group 2 (for water that after normal physical treatment, chemical treatment and disinfection such as pre-chlorination, coagulation and clotting, settling, filtration and disinfection can be drunk), is between 5 to 5.9. In this research according to standard the amount of pH is within the allowable limit (Figure 1).

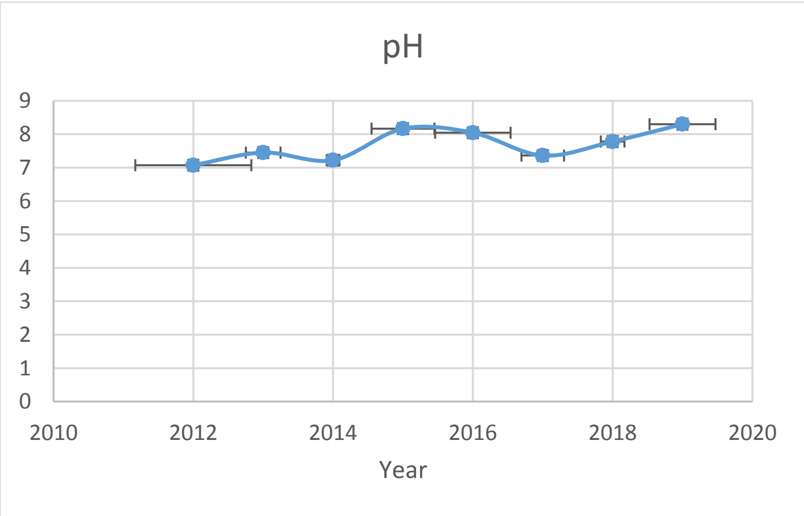

Figure 1. Changes in the pH of Jajrud River water between 2012 and 2019. All the data are the average of three replicates ± SD.

In the standard of the Environmental Protection Organization of Iran, the allowable amount of COD has not been determined for the two mentioned uses. COD values are presented in figure 2.

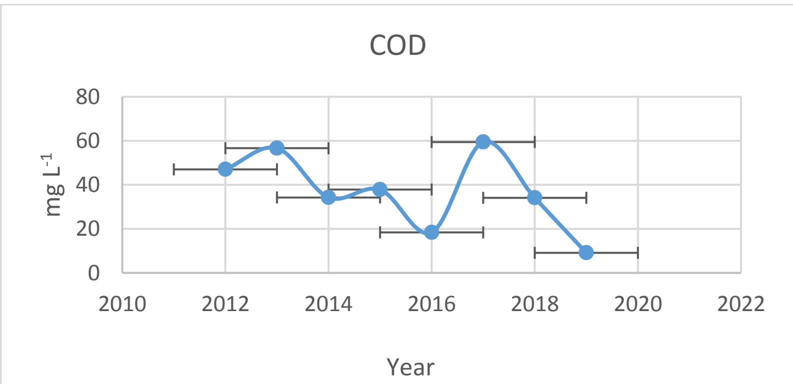

Figure 2. COD changes of Jajrud River water between 2012 to 2019. All the data are the average of three replicates ± SD.

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According to the water quality standard for environmental protection (aquatic ecosystems), the amount of BOD_5 allowed for group 1 rivers is less than 3. Comparing to the standard of water source for drinking use (less than 5 mg per liter) BOD_5 values in this research is much more than allowed level (Figure 3).

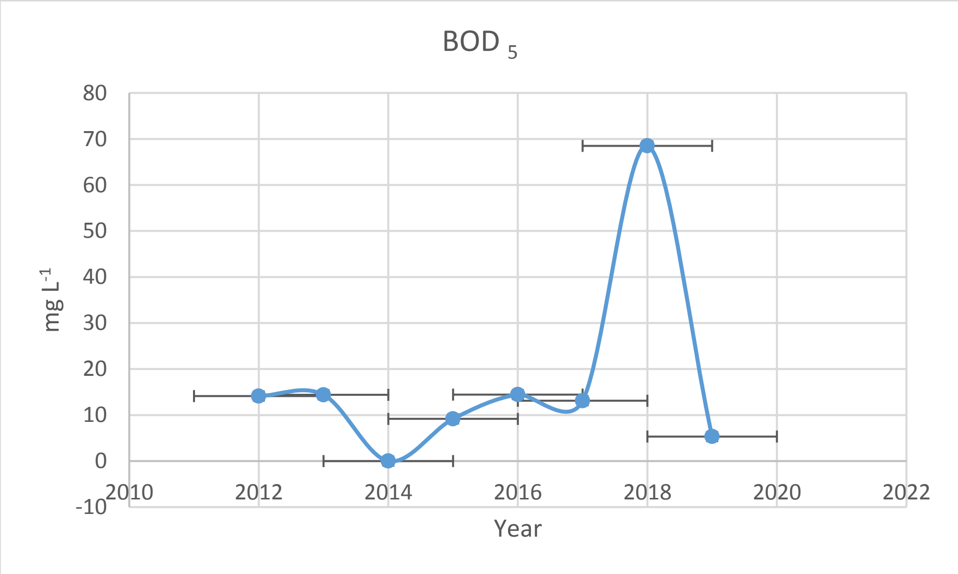

Figure 3. BOD_5 changes in Jajrud River water between 2012 and 2019. All the data are the average of three replicates ± SD.

Sometimes it has reached 14 times the allowable limit. According to the water quality standard for environmental protection (aquatic ecosystems), the amount of TDS allowed for Group 1 rivers is not mentioned. TDS values are presented in figure 4.

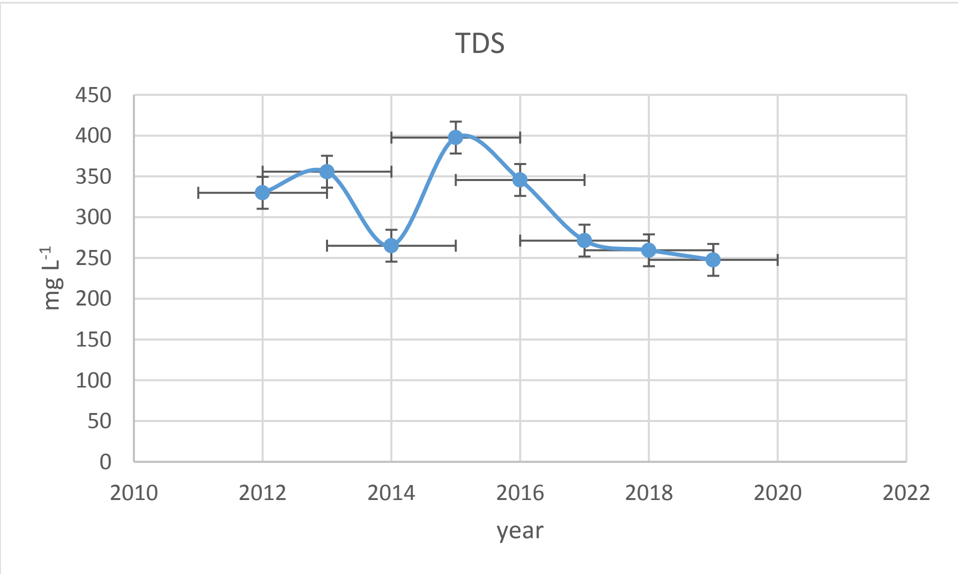

Figure 4. TDS changes in Jajrud River water between 2012 and 2019. All the data are the average of three replicates ± SD.

According to the water quality standard for environmental protection (aquatic ecosystems), the amount of EC allowed for Group 2 rivers is not recommended. The allowable level for EC in water quality standard for drinking use is 2000. In this research all measured EC values are above 2000 (Figure 5).

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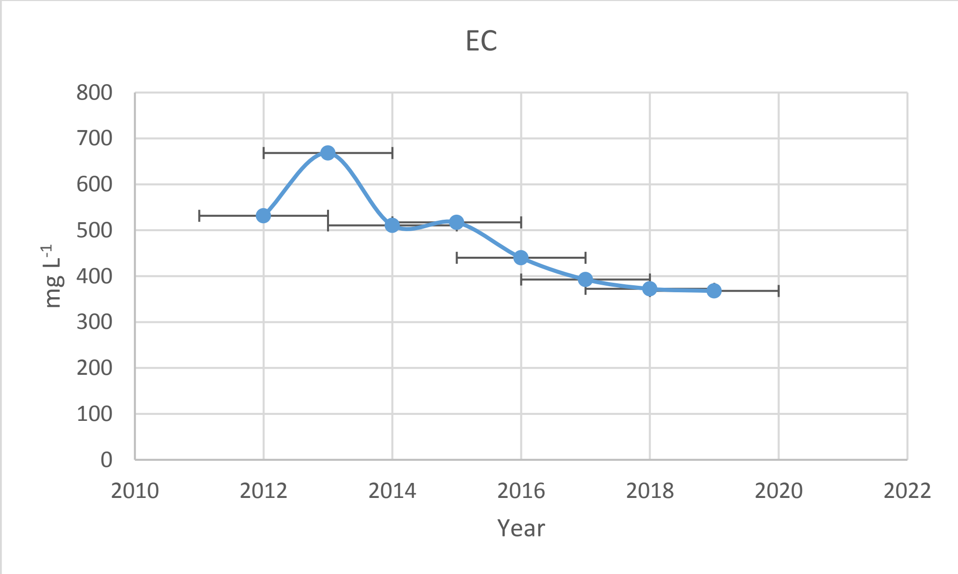

Figure 5. EC changes in Jajrud River water between 2012 and 2019. All the data are the average of three replicates ± SD.

Nitrate is one of the major non-point source pollutants in most aquatic ecosystems. The allowable limit for this parameter is not set in the standard of water ecosystems, but for drinking water use is 50 mg L^{-1}. In this research nitrate concentrations are in acceptable level comparing to standard (Figure 6).

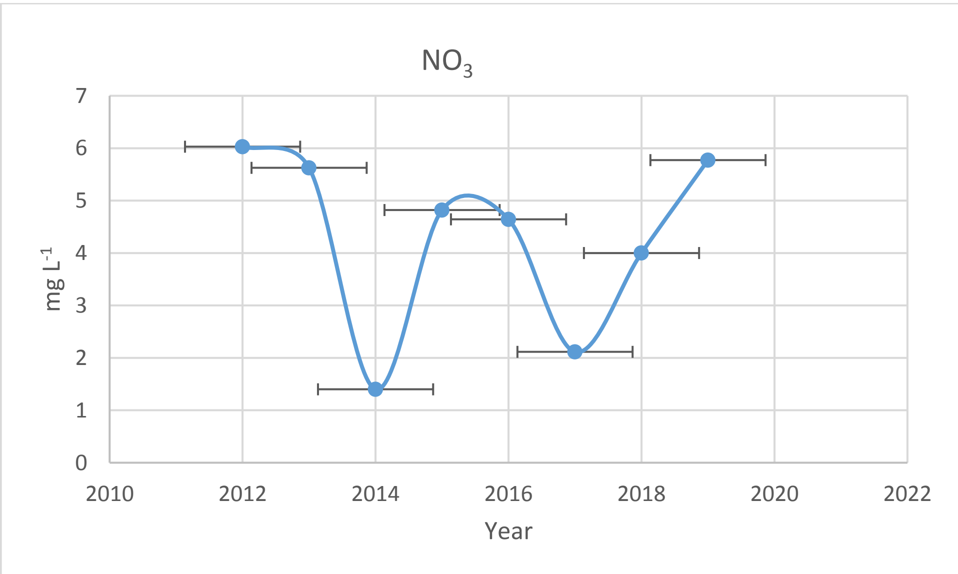

Figure 6. Changes in NO_3 water of Jajrud River between 2012 and 2019. All the data are the average of three replicates ± SD.

The permissible concentration of ammonium in aquatic ecosystems is less than or equal to 1 mg L^{-1} and for drinking water use is less than 1.5 mg L^{-1}. In this research in some cases, ammonium concentration have been reported up to 17 times higher than allowed level (Figure 7).

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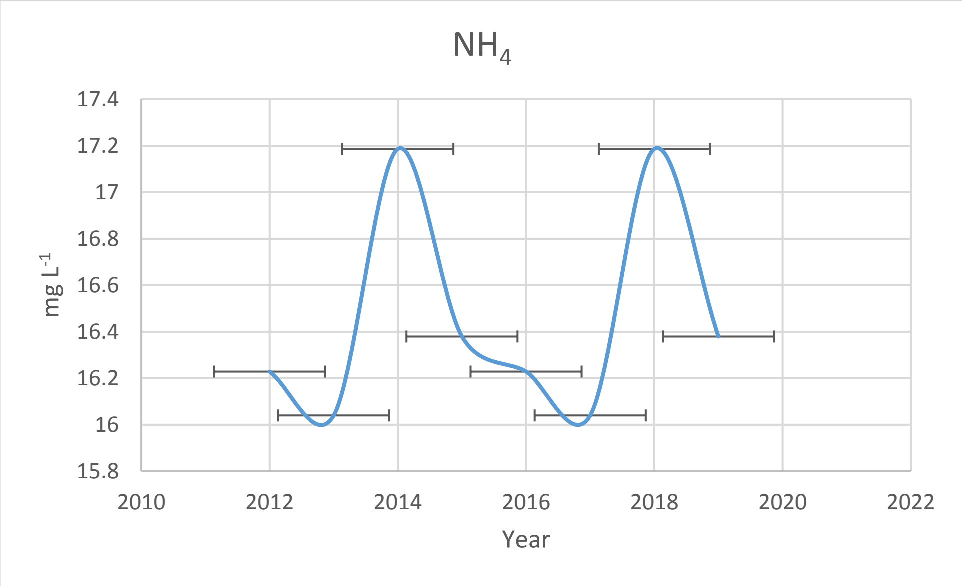

Figure 7. NH_4 changes in Jajrud River water between 2012 and 2019. All the data are the average of three replicates ± SD.

No values are specified in the standard for phosphate concentration. Phosphate and turbidity measured values are presented in figures 8 and 9. Phosphate is also a major source of non-point source pollution. The total phosphorus standard for environmental protection is less than 0.065 mg L^{-1}. This parameter also has a significant destructive effect on aquatic ecosystems, especially the Latyan dam lake.

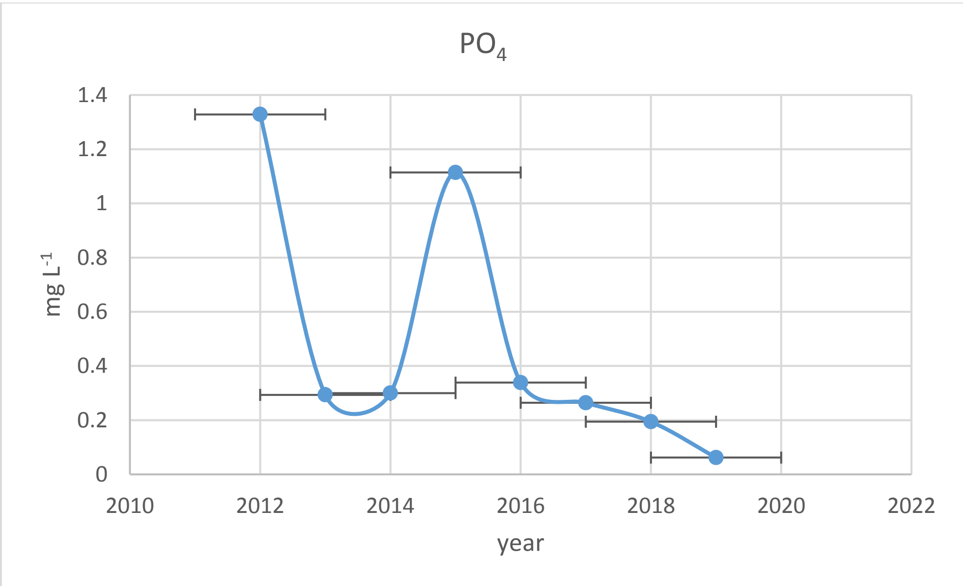

Figure 8. PO_4 changes in Jajrud River water between 2012 and 2019. All the data are the average of three replicates ± SD.

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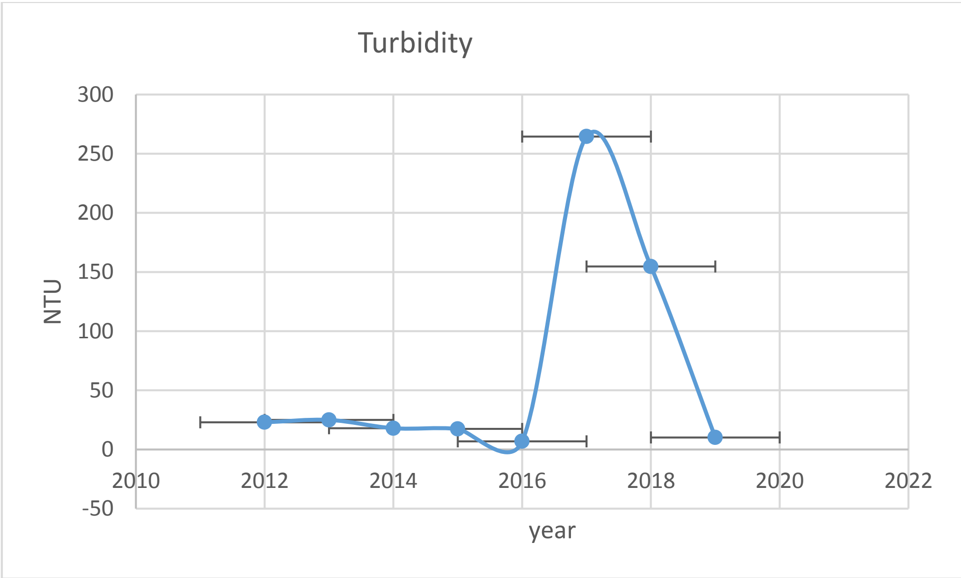

Figure 9. Changes in the turbidity of the Jajrud River between 2012 and 2019. All the data are the average of three replicates ± SD.

Cluster Analysis

Euclidean distance function has been used to adjust the method of measuring the distance between the water parameters of Jajrud River in water quality measurement stations. The results of cluster analysis of sampling stations are shown in Figure 10.

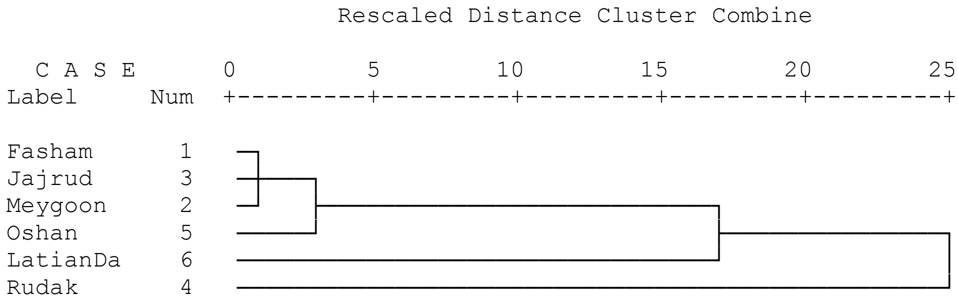

Figure 10. Cluster analysis of similarity of measured parameters in Jajrud River water at stations 1- Fasham, 2- Meygoon, 3- Jajrud, 4-Rudak, 5-Oshan, 6-behind Latian dam.

Investigation of riparian zones with satellite images

To check the satellite images, first the shape file of Jajrud region in GIS software has been converted and retrieved in Google Maps software and then analyzed. In areas where the Jajrud River canal has been destroyed and vegetation in the riparian areas has been destroyed, polygons have been mapped and measured in proportion to the degraded appearance of the land. Satellite images show the vegetation of the area. According to the photos as well as maps related to topography, soil type, rainfall, temperature and speed and wind direction, sunny hours and also considering the ecological needs of native plants in this area, vegetation can be reconstructed in designated polygons. One hundred and sixty eight ha of land around the Jajrud River need to restoration (Table 2).

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Table 2. Polygons in need of restoration in the riparian areas of the Jajrud River

Polygon No.	Unit	Total area
1-57	(m^2)	1680200

Discussion

In developing countries, industrialization and the lack of water treatment infrastructure have created point and non-point pollution (Gunawardena *et al.,* 2018). Non-point source pollution is difficult to quantify and control compared to point source pollution caused by industrial activities (Asadi, 2005). One of the most effective ways to control this pollution is to use vegetating to uptake different types of water pollutants. Plants have an important role in remediation of various types of environmental pollution through the process of phytoremediation (Moogouei *et al.,* 2018; Moogouei and Chen 2019). According to studies conducted by Hashemipour et al. In 2020 on the effects of climate change on the watershed of Jajrud region, Tehran Pars Water treatment Program (TWTP) will not guarantee the water quality of water according to standard in Jajrud catchment area. Therefore, it is necessary to increase control measures related to non-point source pollution and monitoring of water quality parameters. Analysis of the water quality parameters of the Jajrud River shows that these parameters are similar in the cities of Fasham, Jiroud and Meygoon. In other words, in terms of the similarity of the changes, these three cities classify in one cluster. The situation is different behind the Latian Dam, and the station is located separately in a cluster. The city of Rudak is in a different situation from the above 4 cases and is in a separate category. Satellite images can also be used to examine vegetation changes and zoning for restoration program (Sadr and Rodier 2012; Liang *et al.,* 2018; Xie *et al.,* 2019). Using this technique, the percentage of vegetation changes can be examined. The loss of vegetation around the river, shown in Figure 11, is one of the main causes of sediment transfer to the river during rainfall, resulting in increased water-suspended solids.

Figure 11. Polygons without vegetation around the river (Dimension 1116x632, Width 1116 pixels, height 632 pixel, Resolution 96 dpi; Imagery Date: 09/19/2019; 35° 49' 20.19" N 51° 34' 35.32" E elev 5595 ft eye alt 6730 ft).

In some areas, construction has been carried out on the riverbed (Figure 12), which makes it very difficult to restoration. In different polygons, for example, in an area of 7766 m^2 in the figure 13, the possibility of restoration is zero. A survey of the riparian zone showed that in many parts of the river canal, the river canal has been destroyed.

Figure 12. Construction on the riverbed (Dimension 1116X632, Width 1116 pixels, height 632 pixel, Resolution 96 dpi; Imagery Date: 06/30/2019; 35° 50' 38.93" N 51° 33' 34.83" E elev 5684 ft eye alt 6218 ft).

Figure 13. Areas without the possibility of restoration from the river bank.

Research on the Qarachai River in Markazi Province has shown morphological changes and lateral erosion along the river. Sand harvesting, agricultural runoff, flood irrigation of marginal lands, soil saturation, margin vegetation fires, cutting of vegetation in marginal lands, geological and lithological structure of river banks, human factors, water diversion, agricultural drainage are important factors in changing the stability and destruction of the sides (Agharazi *et al.,* 2018). One of the methods of protecting the river wall is biological protection. The vegetation on the river walls strengthens the soil if properly managed. Tree roots strengthen the soil and improve soil structure and increase soil and wall strength. The root increases soil resistance and therefore the soil tolerates flood stress. Types of tamarisk and willow, which are native to this region, have a dense root system and can play an important role in bed stability and erosion control. In a study of rivers in northern China, non-point source pollution was significantly remediated through the restoration of riparian zones (Mi *et al.,* 2015). In this study, after restoration of riparian zones, the rate of reduction of NH_3-N has increased from -14.29% to 66.29%. BOD_5 has risen from - 0.5% to 7.25%. Ecological engineering will significantly reduce non-point source pollution, increase water quality, increase biodiversity, and bring economic benefits (Ameri Siahouei *et al.,* 2019). In a study conducted in 2010 on the Jajrud River (Behbahaninia and Salmasi, 2019). The average nitrate was 3.3 and 8 mg L^{-1}, respectively. In the present study, the range has changed from 1.2 to 6. So managing the riparian zone around the Jajrud River help restoration of the ecosystem. Therefore, in order to manage non-point source pollution, it is necessary to replant the riparian zones according to the table 3.

Table 3. Executive plan and practical objectives of management and restoration of riparian zones in order to control non-point source pollution

Practical objectives	Executive plan
Prepare a list of plants in riparian areas	Determining plant health
Development of riparian areas with native species	Cultivation of plants up to 30 meters wide, which can be done by attracting public participation
Announcement of protection area	Concluding a protection agreement between potential owners and conservation organizations
Field training of target groups	Education
Attract participation, local communities, reconstruction projects and create recreational opportunities	Attracting the participation of local communities in the planning process of the meeting
Phone protection and recovery	Prepare a list of the phone

The range of parameters is important in terms of vegetation river resilience. Comparing the measured parameters with the environmental protection standard, and identifying the parameters within the unauthorized range, shows at what thresholds these measures have exceeded the tolerance level of riparian communities. Therefore, it is necessary to examine the ability of each native plant species to remediate the predominant pollutions of this river, which are mainly BOD_5 and ammonium. Replanting of vegetation should be with a focus on native plant species with high remediation and bioaccumulation potential especially for those mentioned parameters. Replanting must be implemented in damaged areas without vegetation. Moreover improving water quality increases the

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possibility of developing aquaculture. In the last ten years, agricultural, forestry and fisheries activities have increased by 12.02 percent. Development of rainbow trout farms in Jajrud River can help vegetation density in addition to protein production. Nitrogen and phosphorus in fish feces are nutrients for the plant. On the other hand, the establishment of Rainbow trout facilities on the Jajrud River will emit wastewater to the environment. Use of phytoremediation technique for aquaculture wastewater treatment and choose of hyper accumulator plants reduce adverse environmental impacts of aquaculture. Simultaneously aquaculture wastewater can be accounted as nutrients for plants in vegetation restoration projects. The best exposure level of pH for rainbow trout is between 6.5 to 8.5 (Moogouei *et al.,* 2010). This level for DO is between 7 to 13 mg L^{-1}. The acceptable continuous exposure level of TDS for rainbow trout is less than 400 mg L^{-1} (Moogouei *et al.,* 2010). The best exposure level of nitrate is less than 0.55 mg L^{-1} and the acceptable continuous exposure level of nitrate is less than 50 mg L^{-1}. The acceptable continuous exposure level of turbidity is less than 25 (NTU). Our findings in 2019 shows that, the average of these parameters in this study is 8.3, 8.61 mg L^{-1}, 247.62 mg L^{-1}, 5.77 mg L^{-1}, 10.2 NTU respectively. Therefore, after the EIA procedure, rainbow trout farms can be established there.

Conflicts of interest

None of the authors has any conflicts of interest to declare.

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