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Flood-spreading effects on the chemical properties of the soil: a case study of the Tasuj station, Iran

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ABSTRACT

The objective of this paper is to determine whether the flood-spreading system at the Tasuj station in east Azerbaijan, Iran, has caused inappropriate chemical alterations to the properties of the soil. One question is whether the flood-spreading system was constructed at an inappropriate location leading to unintentional consequences. Composite soil samples were taken from three flooded areas, from three grids in each flooding area, and from two depths. Chemical characteristics of the soil including electrical conductivity, pH, concentrations of bicarbonate, chloride, sodium, calcium, and magnesium ions, and the sodium adsorption ratio in the flooded areas were measured. Because of calcareous, gypsum, shale, and marl formations in the first flooded area, dissolution of solutes of these formations increased the concentration of ions in the runoff (especially sodium and chlorine, to 19.50 and 21.90 mmol (charge) L^{-1}, respectively). These high ion concentrations caused the electrical conductivity of the runoff to increase significantly (up to 2.03 dS/m) compared to the other areas. High amounts of lime in the soil caused increasing buffering capacity of the area soil, as a consequence the flood-spreading did not cause significant changes to the soil pH and showed a difference of only 0.3–0.2 in the first flooded area compared to other areas.

Key words: circulatory system, geological formations, runoff, soil quality

HIGHLIGHTS

- Soil samples were extracted from grids in multiple flood areas and from multiple depths.
- Chemical characteristics in the flooded areas were measured.
- It is concluded that the flood-spreading system was constructed in an appropriate location.
- There is a minor problem associated with salts in the initial parts of flooded area.

1. INTRODUCTION

Agricultural sectors are highly dependent on water availability and can be severely affected by drought. Drought can impact other economic sectors also; for example, forestry and environmental sectors. The social sector is also affected in terms of changes to agricultural commodity prices, production structure, livestock production capacity, rural–urban migration flows, and other welfare measures. Poor management of water resources can exacerbate the effects of drought (Abraham *et al.* 2022; Faye 2022). Flood-spreading is a water management method that allows water to be used in various commercial, residential, or habitat improvement projects (Hudson 1987). Indeed, flood plains play an important role in global hydrological and biogeochemical cycles (Chomba *et al.* 2022). One problem with flood-spreading is the impact of the floods on the soil. This problem can determine success or failure of the flood-spreading system in a region. Due to presence of erosion-sensitive soils and formations and poor vegetation in arid and semi-arid watersheds, surface flows are often accompanied by soil erosion and sediment transport.

Large volumes of flood waters can contain salts and heavy suspended materials from various origins. These can cause infiltration of soluble materials and fine particles that change soil properties (Soleimani & Azami 2018; Slamian & Starkel 2022).

In some cases, flooding can cause unsuitable changes in the soil, can destroy vegetation, reduce permeability, and gradually change the salinity of the soil. On the other hand, by turning these soils into fertile lands, agricultural productivity can be enhanced.

The effects of flood-spreading on soil properties such as pH, electrical conductivity (EC), chloride, bicarbonate, sodium, calcium, and magnesium ions is not well characterized and depends on the nature and quantity of the floods (Salmasi & Salmasi 2007; Ghazavi *et al.* 2022). The quantity of flooding, in turn, depends on the intensity of rainfall, flood volume, and geological conditions of the watershed (Parissopoulos & Wheater 1992; Abraham *et al.* 2015; Cheng *et al.* 2020).

Dodcanloy (2017) showed an insignificant small decrease in soil pH in the flood-spreading area compared to the control in the Borjui watershed of Lordegan city, Iran. The authors attributed it to the lack of a significant change in the ratio of soluble cations due to high-quality water and the high concentration of calcium carbonate equivalent of the soil. Nosrati & Mohammadi (2014) found that the elevated amounts of activated lime in the soil and the presence of a sufficient concentration of sodium ion in the flood-spreading area of the Kermanshah plain could prevent a decrease in the soil pH. In this study, the EC of the soil in the spreading field, when compared to the control, showed an insignificant decrease. The amount of sodium in the surface depths of some parts of the field was significantly reduced compared to the control because most of the sodium salts were washed away by the flood.

A decrease in the soil pH of up to ∼1 unit due to the increased organic matter and sodium salt leaching in Khajeh Sistan Mountain, Iran was reported by Dahmardeh Ghaleno *et al.* (2013). A significant increase in the soil pH (up to 0.7 units) was found at the Gorbayegan aquifer station. The presence of the Aghajari formation, which has a calcareous base, has increased the soil pH of this region.

The presence of saline marls in the uplands of the Poldasht flood-spreading system was a factor in increasing soil salinity and consequently increasing the soil pH in flood-spreading systems (Eisazade Razligi 2012; Ghazavi & Vali 2010). Based on research conducted on the Darab flood-spreading station, it was found that the EC of the soil was significantly reduced compared to the control soil because of high-quality floodwaters. The presence of shale and sandstone formations and non-solute formations was reported to be the cause of a 30% reduction in EC, chlorine, and sodium ions in the Kashmir flood-spreading compared to the control (Abotalebi 2015). The amount of bicarbonate was also decreased by 40%.

Ghaffari (1997) reported an increase in flood EC from 550 to 9,353 micro Siemens per centimeter of soil in the flood-spreading area compared to the control. The author attributed the increase to the Neogene marl formations north of the region. Derakhshi (2015) concluded that the existence of a large part of the Jahanabad watershed with calcareous-clay, gypsum, and salt formations as the reason for increasing EC and increasing the amount of sodium and sodium absorption ratio (SAR) in the flood-spreading system compared to the control. Flood leaching also caused salt to leach from the soil surface and accumulate at a depth of 10–20 cm and increase its salinity compared to the control area. Eisazade Razligi (2012) studied the effect of flood-spreading on soil properties and concluded that severe flooding caused the highest SAR because there was a significant increase in dissolved sodium. On the other hand, there was no significant increase in soluble calcium and magnesium.

Mironova *et al.* (2022) evaluated soil quality in urban ecosystems during the COVID-19 pandemic. Results showed that the greatest production levels of humus occured in recreational and floodplain areas, which was due to the measures taken to improve plant growth in these areas of the city.

Rangavar (2005) reported a significant increase in SAR in flood-spreading areas compared to the control. This change is due to sodium ions from marl formations in upland region of Jajarm area of Khorasan. Borabadi (2010) evaluated flood-spreading impacts on soil properties in the presence of evaporative formations, conglomerates, and sandstones – mainly salt-free formations. They concluded that EC at all depths decreased significantly. The values of EC at all depths were consistent with the amounts of sodium and chlorine in the soil, so the decrease in EC in the flood-spreading zone was due to the decrease in sodium chloride. Decreased soil pH was observed for all depths; however, it was significant only at the soil surface. At all depths, sodium and chlorine had a significant decrease compared to the control. Calcium and magnesium decreased in some samples compared to the control area and increased in others, and the changes were not significant.

The flood-spreading plain for the Tasuj aquifer in east Azerbaijan province, Iran has a history of more than 20 years of operation. This station has three flooding areas, namely Angoshtejan, Ahmadi, and Amestejan. Soil characteristics were monitored until 2006 (Khani 2010); since then, soils in the spreading area have not been monitored. As a result, there is a gap in knowledge for evaluating changes in the soil properties for nearly 15 years. In addition, the effect of flood-spreading on the characteristics of its three areas and a comparison among these three areas with no-flood or control area has not been studied. As knowledge about the effects of spreading of water on soils is important for water-land management, we study whether flood-spreading has any deleterious effects on soil chemistry. Is the flood-spreading system properly located and what are the effects that geological formations have on the chemical properties of the soils?

Soil samples were taken from two areas including three water-spreading systems and a control area. After analyzing the chemical properties of the soil, changes in the chemical properties between two areas were evaluated. Selection of the chemical properties of the soil has been carried out based on their impact on the soil salinity, sodium content, nutrient uptake by seedlings, bioavailability of elements, ionic competition, and biological activities.

2. MATERIALS AND METHODS

2.1. Description of the study site

The flood-spreading station is located north of the Tasuj town, in east Azerbaijan province, located in northwestern Iran (38° 02′N, 45° 03′W). The station has an area of nearly 560 km^2 and is at an altitude of 1,274 m. The area consists of 10 sub-basins that overlook the town of Tasuj and the villages of Amestjan and Angoshtjan. The Tasuj station is a flooding research area for agricultural and natural resources of east Azerbaijan and this was the reason for selecting this station for the study.

The soils of Tasuj aquifer area have relatively well-to-moderate drainage, sandy loam texture with high rubble, high permeability, and are in the Entisol category. The climate is semi-arid and cold. In the eastern region (Angoshtjan area), there is a surface texture which is a consequence of the presence of marl formations and surface sediments. This surface layer is not deep. The western and central part of the region (Ahmadi, and Amestajan areas) is very large and full of gravel and rubble (Jalali 2012; Habibzade 2020). Flood-spreading is accomplished by a circulatory method and there are three flooded areas that were selected: Angoshtjan, east Anghoshtjan or Ahmadi, and Amestajan (Figure 1). Also, a control area was selected: the adjacent lands had similar management, homogeneity in terms of soil type and geology.

In Figure 1(b), there are five valves that receive irrigation water from an upstream canal. Active valves have been shown with blue circulatory canals and inactive valves (two cases) are shown in red. The width of the upstream canal is 0.5 m and carries water with a volumetric flow rate of about 0.08 m^3/s. The width of circulatory canals is about 0.2 m with a length of 200 m.

2.2. Soil sampling

Soil sampling was performed in the three flooded areas and in one control area (Figure 1(b)). Three active valve distributions of water in each flooded area were selected. If each grid is divided into three zones, namely beginning (initial), middle, and end, there is a higher probability of deposited sediments in the initial zone of each grid. Consequently, these areas (initial zones of each grid) were selected for soil sampling. One composite soil sample (from three points at random) was taken in the initial zone of each grid (with three grids for three flooded areas, there were nine samples). Two depths of soil (0–20 and 20–60 cm) were selected from each grid (18 samples for flooded areas). Also, one composite soil sample was taken from the control area (a total of 20 soil samples). Samples were taken after flooding in May 2020.

2.3. Soil preparation and analyses

After air drying, the samples were passed through a 2-mm sieve to facilitate measurement of the basic properties of the soil. In the laboratory, soil pH (Thomas 1996), EC (Rhoads 1996), organic matter (Nelson & Sommers 1996), calcium carbonate (Suarez 1996), bicarbonate (Frakerberger 1996), and chlorine (Frakerberger 1996) were determined.

Carbonate ion with a pH of less than 9 was present in very small amounts in the soil solution, and in this study, pH values of the soil samples were less than 8 (Table 1); therefore, this ion is not measured. The SAR was calculated using the following formula:

$$\mathrm{SAR} = \frac{[\mathrm{Na}]}{\sqrt{[\mathrm{Ca} + \mathrm{Mg}]}} \quad (1)$$

where the brackets indicate the concentration of ions per millimole (+) per liter.

2.4. Data analysis

A data normality test was performed using the Kolmogorov–Smirnov method. The *t*-test was used to compare the mean scores. The software used for statistical analysis was SPSS version 25.

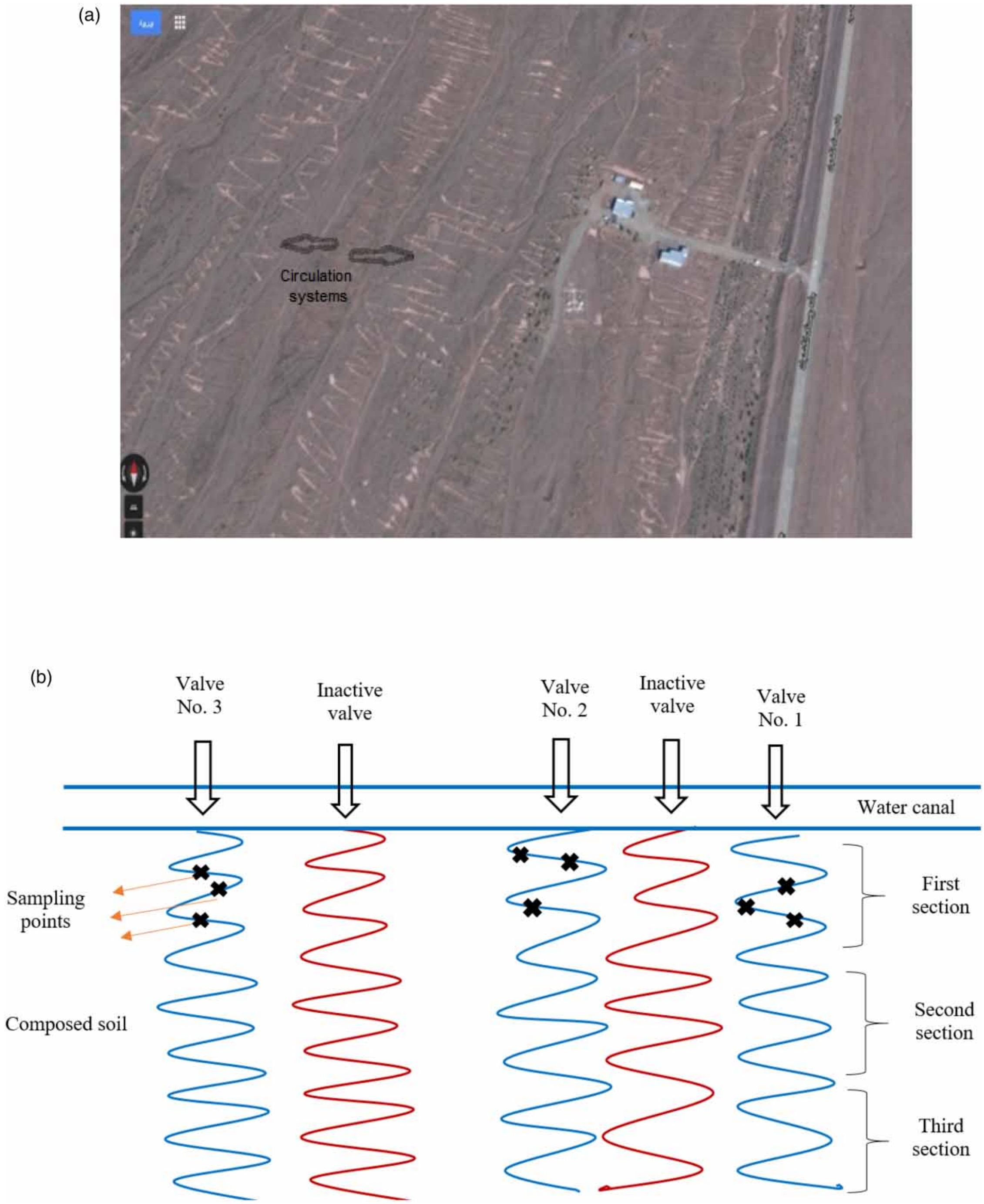

Figure 1 | Google Earth view, schematic picture, photographs, and geographic location of the studied area. (a) Google Earth view; (b) schematic picture of the studied area; (c) photographs of the studied area; and (d) location of the Tasuj Station, Iran. (*continued*.)

3. RESULTS AND DISCUSSION

Based on the testing results using the Kolmogorov–Smirnov method, all the chemical properties of the soil had a normal distribution (Table 1), hence the comparison was performed using a *t*-test. Table 1 shows the statistics of chemical properties of field soils. To analyze the effect of flood-spreading on soil chemical properties, the general characteristics of field soils will be discussed first.

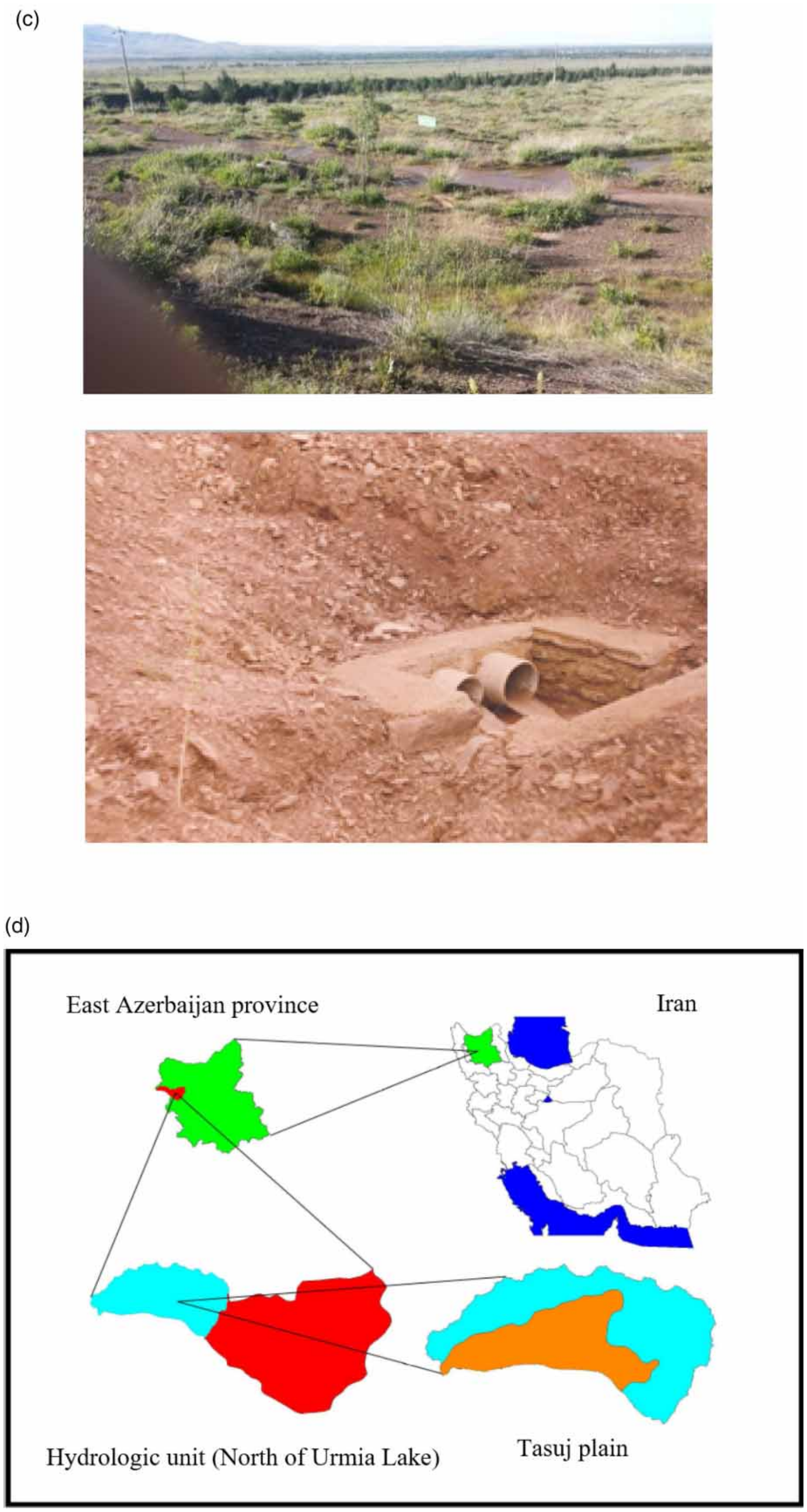

Figure 1 | Continued.

Various factors such as evaporation from the soil surface and soil drainage (which depend on the chemical, physical, and biological properties of the soil) can affect chemical properties of the soil for both flooded and control areas. Since three studied areas have the same soil type and similar levels of vegetation, slope (about 5%), and texture (sandy loam), it is

Table 1 | Statistics of various chemical properties of tested soils

Property	Depth (cm)	Minimum	Maximum	Mean	Standard deviation	Probability level[a]
pH	0–20	7.36	7.69	7.52	0.73	0.226
	20–60	7.31	7.75	7.60	0.81	0.193
EC ($dS.m^{-1}$)	0–20	0.93	2.03	1.60	1.22	0.432
	20–60	0.64	1.67	1.07	0.24	0.387
Na^+ ($mmol_cL^{-1}$)	0–20	13.25	19.50	15.61	3.28	0.832
	20–60	13.80	17.60	15.50	3.22	0.683
Ca^{2+} ($mmol_cL^{-1}$)	0–20	6.50	8.50	7.17	1.31	0.235
	20–60	6.30	8.90	7.38	1.21	0.294
Mg^{2+} ($mmol_cL^{-1}$)	0–20	2.20	3.10	2.82	0.91	0.185
	20–60	2.11	3.15	2.81	1.01	0.195
Cl^- ($mmol_cL^{-1}$)	0–20	14.10	20.50	17.20	3.31	0.315
	20–60	14.20	21.90	17.68	3.34	0.390
HCO_3^- ($mmol_cL^{-1}$)	0–20	0.60	0.88	0.79	0.21	0.071
	20–60	0.78	1.00	0.88	0.11	0.094
SAR ($mmol\ L^{-1})^{0.5}$	0–20	5.34	9.65	7.81	1.31	0.215
	20–60	5.40	9.30	7.68	1.21	0.190

[a]The probability value is related to the results of the Kolmogorov–Smirnov test.

expected that evaporation and drainage will be similar. The main factor that changes the chemical properties of the soils will be the nature of floods and this factor is affected by the intensity of rainfall and the type of land formations of the upland basin (Parissopoulos & Wheater 1992).

As the intensity of precipitation is similar for the whole area, it will be formation differences that cause changes in the chemical properties of the soil. Upland of the first flooded area are marl and shale formations. During floods, their runoff is harvested. Because the uplands of the Amestejan and Ahmadi flooded areas are composed of conglomerate and sandstone formations, their runoff will have low salt content. The high permeability of the soil can cause the transfer of solutes to lower soil depths, which results in increased EC and concentration of soil ions in lower depths. During each flood, some salts are easily washed from the soil surface. Table 2 provides the comparison of the mean of the basic chemical properties of the soils of the Tasuj floodplain in the three regions (Amestejan, Ahmadi, and Angoshtejan). Each property (such as pH) is obtained by measurement of the property in one composite soil sample (three soil subsamples from three points for each sample).

3.1. pH values

Since runoff of non-saline formations upland of most parts of the flooded and control areas had good quality, the pH of the soil will be reduced by freshening. However, the decrease was small (0.2–0.3 units) and insignificant. In the initial parts (the first grid) of Angoshtejan flooded area, the presence of high solute concentrations from the upstream marl formations could lead to a change in soil pH; however, no change was observed. This outcome is due to the flood-spreading system being located on an alluvial fan consisting of quaternary alluvium, which has increased the lime in the soils. The presence of lime increases the buffering capacity of soils and resistance to fluctuations in the soil pH (Strawn *et al.* 2020).

The findings of the present study are consistent with those of Dodcanloy (2017) and Nosrati & Mohammadi (2014). On the other hand, significant increase in soil pH in the study of Dahmardeh Ghaleno *et al.* (2013) despite the calcareous nature of the soil may be due to the large size of the lime particles and the inactivity of the lime. The presence of plentiful lime leads to low reactivity with soil particles. Indeed, this is a rule in chemical reactions. The dolomitic nature of lime can also make the soil less able to react. Because dolomite is a mixture of calcium carbonate and magnesium carbonate, and the latter has less solubility, the solubility of dolomite is less than lime (calcium carbonate). Significant decreases in soil pH in Borabadi (2010), despite non-calcareous and non-saline soils, may be related to carbon dioxide gas retention and thus increase the concentration of carbonic acid. This negligible buffering capacity together with carbonic acid production causes significant decreases in soil pH in his study.

Table 2 | Properties of soils in the grids in three regions in the floodplain

	Amestejan region			Ahmadi region			Angoshtejan region				
Control	The third grid	The second grid	The first grid	The third grid	The second grid	The first grid	The third Grid	The second grid	The first grid	Depth (cm)	Property
7.37	7.49	7.45	7.47	7.38	7.40	7.36	7.59	7.61	7.69^{a}	0–20	pH
7.35	7.51	7.41	7.39	7.37	7.36	7.31	7.68	7.70	7.75	20–60	
1.33^{b}	1.13^{a}	0.93^{a}	1.36^{b}	1.36^{b}	1.26^{ab}	1.33^{b}	1.73^{bc}	1.56^{b}	2.35^{c}	0–20	EC (dsm^{-1})
1.19^{ab}	1.06^{ab}	0.90^{a}	0.96^{a}	1.38^{b}	1.26^{ab}	1.13^{ab}	1.56^{bc}	1.73^{c}	1.50^{bc}	20–60	
13.25^{ab}	15.20^{b}	14.00^{ab}	14.64^{ab}	15.50^{b}	15.70^{b}	15.00^{b}	19.50^{c}	16.20^{bc}	16.33^{bc}	0–20	Na^{+} ($mmol_cL^{-1}$)
15.15^{b}	14.35^{ab}	14.85^{a}	14.00^{ab}	13.93^{a}	13.83^{a}	13.80^{a}	16.60^{c}	17.05^{c}	16.00^{c}	20–60	
6.15^{a}	7.80^{ab}	7.50^{ab}	8.50^{b}	8.10^{b}	8.00^{b}	8.50^{b}	7.90^{b}	7.50^{ab}	8.18^{b}	0–20	Ca^{2+} ($mmol_cL^{-1}$)
6.30^{a}	8.00^{b}	8.25^{b}	8.90^{b}	8.90^{b}	8.15^{b}	8.60^{b}	8.00^{b}	7.80^{ab}	8.20^{b}	20–60	
2.27^{a}	3.10^{b}	2.20^{a}	3.00^{b}	2.40^{a}	2.35^{a}	2.20^{a}	2.85^{ab}	2.85^{ab}	3.15^{b}	0–20	Mg^{2+} ($mmol_cL^{-1}$)
2.35^{a}	3.00^{b}	2.11^{a}	2.30^{a}	2.75^{a}	2.30^{a}	2.45^{a}	3.10^{b}	2.50^{a}	2.85^{a}	20–60	
14.80^{a}	14.10^{a}	15.00^{ab}	16.10^{b}	16.90^{b}	17.00^{b}	17.10^{b}	20.50^{c}	20.30^{c}	19.75^{c}	0–20	Cl^{-}($mmol_cL^{-1}$)
14.20^{a}	14.35^{a}	16.0^{b}	16.65^{b}	17.60^{b}	15.10^{ab}	15.10^{ab}	21.90^{c}	20.10^{c}	20.30^{c}	20–60	
0.60^{a}	0.63^{a}	0.65^{ab}	0.70^{ab}	0.79^{ab}	0.88^{ab}	0.80^{ab}	0.70^{ab}	0.70^{ab}	0.75^{ab}	0–20	HCO_3^{-} ($mmol_cL^{-1}$)
0.78^{a}	0.78^{a}	0.85^{ab}	0.85^{ab}	0.85^{ab}	0.84^{ab}	0.85^{a}	0.85^{ab}	1.00^{b}	0.88^{ab}	20–60	
5.65^{a}	5.90^{a}	5.90^{a}	5.70^{a}	5.70^{a}	5.34^{a}	5.55^{a}	8.70^{b}	9.65^{b}	8.70^{ab}	0–20	SAR ($mmol\ L^{-1})^{0.5}$
5.64^{a}	6.40^{a}	6.00^{a}	5.40^{a}	5.55^{a}	5.75^{a}	5.75^{a}	8.65^{b}	9.30^{b}	8.00^{a}	20–60	

Note: In each row, values with at least one common letter have a significant difference.

3.2. EC values

Comparison of the EC of the soils showed a variety of formations and runoff over the years. High-dissolution formations (calcareous marl formations, gypsum marl, and shale formations) upland of the first flooded area (Angoshtejan), especially the initial part (the first grid) of this area, leads to an increase in concentrations of solutes of the runoff, which resulted in an increase in the EC of the soil of this area and a significant difference between grids in this area compared to the other flooded and control areas. On the other hand, the existence of low solute formations (sandstone and conglomerate) upland of the Ahmadi and Amestejan areas reduced the EC of the soil in these areas. Ghazavi & Vali (2010), Abotalebi (2015) and Ghaffari (1997) made similar findings in their research.

Due to the soil coarse texture, leaching of solutes was predicted to increase EC at low depths. However, with the exception of a single grid in the first flooded area (Angoshtejan), such a result was not obtained. Sampling depths were 0–20 and 20–60 cm. However, if sampling was performed using smaller depth-intervals of soil, such as 0–5, 5–10 or 0–10 and 10–20 cm, it may be possible to see an increase in EC with increasing depth; similar to what Borabadi (2010) reported in the soil samples of the study area.

3.3. Sodium ion content

The greater extent of the marl and shale formations upland of the first flooded area (Angoshtejan) compared to other flood areas caused the resulting flood to have a high concentration of sodium ions. This is because the prevalent ion in these formations is sodium. The concentration was higher in this area compared to the Ahmadi, Amestajan, and the control areas. The difference between the flooded areas and the control at both depths was significant. Higher EC values and sodium content in the first flooded area (Angoshtejan) than other areas including the control showed that this ion has a greater effect on EC than other ions. The cationic nature of sodium ions leads to its adsorption by negatively charged soil particles and causes this ion to modestly leach into the soil with water movement (Ponammpereno 1972; Bleam 2017). This causes sodium concentrations in the second depth of some grids to be higher than the first depth. It may be due to coarser texture in these grids than other grids and control: coarse soil texture causes more water movement than does fine texture.

Sodium has more weakly bonds than calcium and magnesium ions. Thus, the leaching of sodium ions exceeds that of calcium and magnesium ions.

3.4. Calcium and magnesium ion contents

As calcium and magnesium elements appear together in most geological formations, these elements are studied together. The presence of veins of lime, dolomite, and gypsum in the uplands of Ahmadi increased the concentration of calcium and magnesium ions in the resulting runoff as a result of dissolution of calcium and magnesium salts. However, the concentration of these ions in the soil samples of the Ahmadi area did not show a significant difference compared with other areas. One of the reasons could be the slight dissolution of the minerals containing these two ions due to the insufficient soil pH and the lack of fine mineral particles: for high dissolution of Ca and Mg salts, acidic pH is necessary. Whereas, soil samples with low alkaline pH are not conducive to the dissolution. Fine particles have more reactivity than coarse particles. Because fine particles of Ca and Mg salts are uncommon in the region, the salt reaction with water will be slow.

The dolomitic origin of the minerals contain Ca and Mg ions and this fact that dolomite has a low solubility relative to lime, could be another reason for no significant difference in these ion contents between Ahmadi and other areas. The concentrations of these two ions in the three flooded areas were higher than the control area. Due to their cationic nature and stronger bonding with soil particles, they had less leaching than sodium ions to lower soil depths. Eisazade Razligi (2012) studied the effect of flood-spreading on soil properties and did not observe high soluble Ca and Mg in grids with high flood regions.

3.5. Chloride content

The relatively high concentration of chloride in the first flooded area is due to the presence of saline marl formations in the uplands which enters the runoff due to the dissolution of this ion and increases its concentration in this area. There are significant differences between the grids of this area and most grids of other flooded areas and the control. The chloride concentration did not match the sodium ion concentration. This is because chloride can bind to other cations such as calcium, magnesium (Hawlin *et al.* 2017). The anionic nature of chloride causes these ions to move to lower soil depths through repulsion by soil particles. In spite of the fact that chloride has one negative charge, in most soil samples the amount of this ion in the second depth of the soil is greater than in the first depth.

3.6. Bicarbonate content

The presence of veins of calcareous formations upland of the second flooded area (Ahmadi region) caused a slight increase in the bicarbonate concentration in the soils of this area. However, the differences with other flooded and control areas were not significant. Like chloride, the bicarbonate in most grids in the second depth of the soil was higher than at the surface.

3.7. SAR values

The SAR is affected by sodium (Na), calcium (Ca), and magnesium (Mg) ions in the soil; changes to these ions will change the amount of this ratio in the soil. The presence of soluble formations causes an increase in the salt concentrations of these ions in the runoff from the first flooded area. This leads to an increase in the SAR in this area. Hence, except for one grid, a significant difference was obtained between grids of Angoshtejan and those of other locations. In the Ahmadi area, due to the presence of gypsum and calcareous veins, the concentration of Ca^{++} and Ma^{++} in runoff from these formations increased, which resulted in a decrease in the SAR. However, there was no significant difference between this area and others. Eisazade Razligi (2012) found that grids with greatest flooding had the highest SAR and the highest amount of soluble Na.

4. CONCLUSIONS

The findings of this study on the Tasuj flood-spreading (in Iran) areas that do not have erosion-sensitive, saline, gypsum and calcareous formations in their upland (Amestejan and Ahmadi) areas are as follows. They experience no decrease in the chemical properties of the soil as a consequence of flood-spreading operations. Moreover, lower surface temperature (LST) in agricultural fields and forests as compared to human-induced built-up areas (Kumar *et al.* 2022) causes slow reaction in the soil solution. However, the presence of erosion-sensitive, saline, gypsum, calcareous, and shale formations in the uplands of the first flooded area (Angoshtejan area) has led to a slight change to the chemistry of the soils. In the Tasuj floodplain, the flood-spreading has no deleterious effect on the chemical properties of the soil and has played a beneficial role in the region. In other words, the flood-spreading system has been constructed at an appropriate location and the geological formations of the area do not have a detrimental effect on the chemical properties of the soils. A small problem is the increase in sodium ions and the SAR has affected the first grids of the flooded area. Efforts could be made to reduce this issue through appropriate amendments.

Precise sampling and measurement of the chemical properties of the soil are the strengths of this study. However, for better evaluation of flood-spreading system it is recommended that physical and biological properties should be determined and future research efforts should be directed in that area.

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ETHICAL APPROVAL

This article does not contain any studies with human participants or animals performed by any of the authors.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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