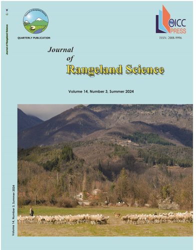

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The impact of human traffic on vegetation characteristics and species diversity in vicinity of the Almagol Wetland in Northern Iran

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Abstract:

Despite its ecological importance, the wetland edge vegetation could be strongly affected by human factors e.g., heavy traffic. In order to investigate the impact of human traffic on vegetation characteristics and plant diversity, a research was conducted at the edge of Almagol wetland in the northern Iran in 2021. The assessment was carried out through a reference area (affected by human traffic) and a control area (without human traffic). Sampling was done using a transect-plot method, and vegetation characteristics and diversity indicators were investigated. The results showed that the plant cover, and plant height had lower values in the reference area than to the control ($P < 0.01$). Excluding the freshness of perennial species, the factors of height, density and biomass of grass and non-grass species, annual and perennial species showed a significant difference compared to the control area. The average biomass production in the reference and control area was 98 and 264 kg/ha, respectively. Also, in the reference area, the diversity indices of Margalef and Shannon were 3.9 and 1.6, respectively while in the control area, the values were 4.9 and 2.45, respectively. In general, the long-term effects of human traffic in this area had significantly changed both the floristic characteristics and vegetation performance so that some plants have severely degraded.

Keywords: Floristic characteristics; Plant species; Diversity indices; Vegetation cover

1. Introduction

Wetlands are among the most biologically productive natural ecosystems that play a critical role in maintaining and improving water quality, reaching aquifers, and providing habitat for wildlife (Kaplan and Avdan, 2017; Pal and Talukdar, 2018; Singh and Sinha, 2022). Wetlands also control flood and play an important role in the land ecological condition e.g., soil, vegetation (Perennou et al., 2018; Rapinel et al., 2019; Xu et al., 2020).

Location and distribution of wetlands influence the landscape ecological functions and human wellbeing (Xu et al., 2020). However, the vegetation of the wetland edge could be strongly affected by human factors such as heavy traffic over time. In fact, as an important element, the vegetation around the wetlands play an important ecological role, i.e. food, shelter, which has changed and degradated under human factors. In recent years, due to the heavy traffic and human training, vegetation on edge of wetland in arid and semi arid areas severely changed (Gxokwe et al., 2020). Moreover, in many areas, human traffic or human footprints severely affected both soil and vegetation over time (Whitecotton et al., 2000; Jahantab et al., 2022).

Overall, monitoring wetland ecosystems are challenging due to their high spatial and temporal dynamics within a fine-grained pattern (Haidary et al., 2013; Rapinel et al., 2019), and human factors have threatened wetland ecosystems (Heintzman and McIntyre, 2019; Jamal and Ahmad, 2020; Rapinel et al., 2019). Therefore, knowledge about flora and vegetation is necessary for biological conservation, protection of rare/native plants, and vegetation management and land restoration in this areas (Hamedani et al., 2017; Jahantab et al., 2022).

In recent years, most studies, i.e. Baker et al. (2006), Kaplan and Avdan (2017), Pal and Talukdar (2018), Wang et al. (2018), and Singh and Sinha (2022) have been done on the effect of land use and land cover changes on the water quantity of wetlands. However, there is no detailed information about the human effect on vegetation in wetland edge. In recent years, the increase in human traffic in areas with natural attractions has led to further destruction of vegetation on the edge of water sources, especially wetlands.

In Iran, due to the geographical location and climatic conditions, wetlands have specific importance in landscape scale. Iran has more than 250 large and small wetlands, out of this number of wetlands, some such as Almagol (in Golestan province, Iran) have been registered in the Ramsar convention list as globally important wetlands (Qurbani et al., 2011; Hamedani et al., 2017). The Almagol international wetland is one of the inland wetlands and is one of the breeding centers of aquatic and waterside migratory birds. The edge of this wetland has significant vegetation due to its geographical location and climatic conditions, which has been affected due to military-tourist purposes, and there is no information about these changes (Hamedani et al., 2017).

According to the above mentioned and due to the geographical importance of Almagol international wetland, it is necessary to evaluate the vegetation characteristics of its edge under human traffic. Therefore, this study was carried out to find the effect of human traffic on the vegetation characteristics and diversity indicators in vicinity of Almagol wetland. The main objectives of this research were; 1) How do characteristics such as vegetation cover, density, height, biomass, and freshness of plants with different life forms change with distance from the edge of the wetland? 2) How have the diversity indices of Margalef and Shannon in this region changed over time under the influence of human traffic? Also, in this study, a control area (enclosed site without human traffic) was considered for comparison.

2. Materials and methods

2.1 Study area

The Almagol international wetland is located in the Gorgan province (37.4305° N, 54.6451° E), in northern Iran (Figure 1). The wetland has the Mediterranean climatic conditions, where the region has a warm Mediterranean climate with hot and dry summers and mild winters. Annual rainfall varies between 250 to 300 mm and humidity varies between 26 and 100 percent. The annual evaporation rate is 1800-1900 mm. The minimum temperature is 5 °C and the maximum temperature is 42 °C (Hamedani et al., 2017).

The Almagol wetland with an area of 210 ha has a water volume of 5 Million Cubic Meters (MCM). The elevation of this wetland is 4 m a.s.l. and its average depth is 2 m and its maximum depth is 4 m. This wetland is rich in nutrients coupled with low salinity. The sources of water for this wetland are rainfall, surface water, and wastewater in the region (Hamedani et al., 2017). This area is a breeding ground for migratory waterfowl and waterside birds, and due to its geographical location close to Inche-Borun border market and access roads, it has many visitors. On the edge of the Almagol wetland, the recreation complex is located within 150 m of the wetland. Also, the Inche-Borun military area with an area of 4.18 ha is located in this area and has changed the area with high human traffic.

2.2 Data collection

The experiment was carried out through two reference and control sites at the edge of the wetland in 2021 (Figure 1). A site under the high-traffic and an enclosed site with no access road and no traffic (as control) were considered for sampling. Control area was selected in an adjacent area at a distance of 1 km with similar physiographic conditions under natural vegetation (Figures 1, 2).

Vegetation cover was performed based on a completely

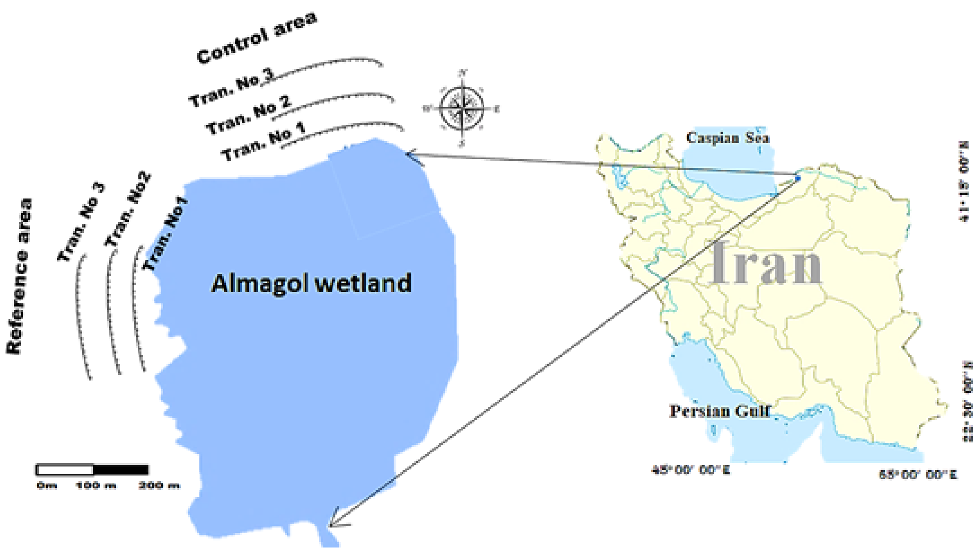

Figure 1. Geographical location of the Almagol wetland in northern Iran, and sampling points along the placed transects in edge of wetland.

Figure 2. General view of the Almagol wetland in reference and control areas.

randomized design in each site (Chambers, 1983). For this purposes an experimental analysis was done based on 1×2 m^2 plots placed along three 400 m transects at each site. Each transect was placed at a distance of 50 m from each other from the edge of the wetland to the outside edge, and 20 plots were placed along each transect and vegetation cover characteristics were investigated through the placed plots (Figure 1).

The most important characteristics of plants including cover, density, height, biomass and freshness were investigated and recorded based on plant life form (grass, non-grass, annual and perennial) in each plot. The freshness of the plants was calculated as a percentage based on weighing the harvested plants before and after drying to estimate the biomass. In the control area, the vegetation characteristic was also evaluated in the same way.

2.3 Data analysis

Species diversity was calculated in study plots. For this purpose, Shannon diversity index (Equation 1) and Margalef richness index (Equation 2) were calculated for both reference and control sites as follows (Margalef, 1958; Shannon, 1948):

$$E = (-\sum_{i=1}^{S} P_i \ln P_i)/\ln S \quad (P_i = N_i/N) \tag{1}$$

Where:
E = Shannon index,
Ni = the number of species i,
N = the total number of species,
S = the number of species present.

$$D = (S-1)/\ln N \tag{2}$$

Where:
D = Margalef diversity index,
S = Total number of species,
N = Total number of individuals.

All data were checked for the normality using the Kolmogorov-Smirnov test. ANOVA and unpaired T-test were then performed to compare data of reference and control areas using SPSS 17.1 statistical package software ($Sig. \leq 0.05$).

3. Results

The vegetation cover of the edge of this wetland consists of both perennial and annual species. There is a lot of grass around the wetland. There are also wild spinach (*Atrriplex sp.*) and other species that are grown in the edges of the wetland where grasses (e.g., *Avena fatua* L., *Alopecurus pratensis* L., *Lolium rigidum* Gaudin, *Cynodon dactylon* (L.) Pers.), and forbs (e.g., *Salsola dendroides* Pall., *Onopordum acanthium* L.) (annual/perennial species) grow in this area.

The measurement of the height of plant species in two selected areas showed significant differences (Figure 3). However, the most differences were related to the non-grass

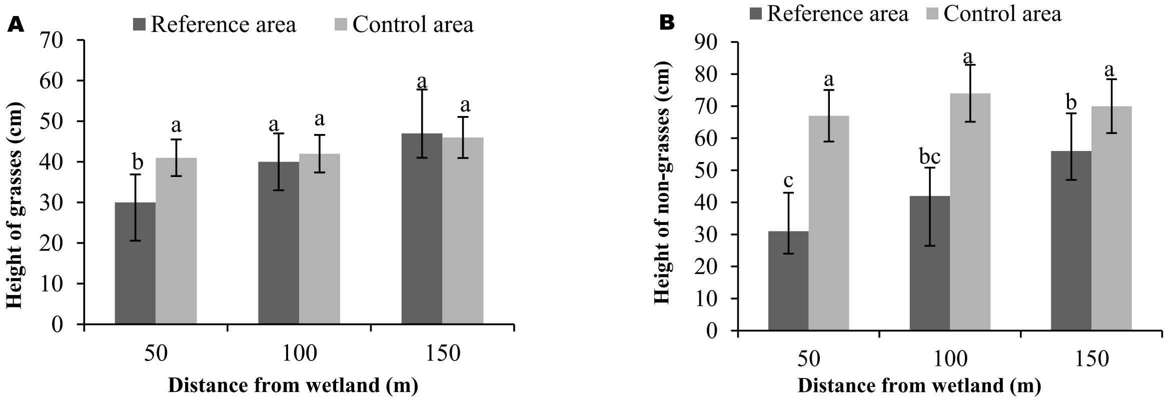

Figure 3. Height of Height of grass (A) and non-grass (B) species in reference and control area.

species so that the height of the grasses didn't show much difference between the reference and control areas, and also with the distance from the wetland except at 50 m from the wetland. The height of the perennial species was strongly influenced by the area where the values were much lower in the reference area than the control ($P < 0.01$). In general, under the influence of human traffic around the wetland, the changes in the height of non-grass species have been more than that of grasses. It seems that non-grasses have less resistance in dealing with environmental stresses such as human traffiking.

As one of the most important characteristics of plant communities, cover showed significant differences in this region. In general, firstly, a significant difference was observed between the reference and control areas in terms of vegetation cover changes ($P < 0.01$), where the average total cover was 13.7 and 35.3% in the reference and control areas, respectively. Also, the results showed that the amount of vegetation cover of perennial species (e.g., *Lepidium draba* L., *Taraxacum nevskii* Juz., *Onopordum acanthium* L., *Asparagus officinalis L.*) and annual species (e.g., *Silene apetala* Willd., *Raphanus raphanistrum* L., *Koelpinia linearis* Pall., *Crepis sancta* (L.) Bornm.) in the reference area increased with the distance from the wetland edge (Figure 4). Also, in the control area, the cover of perennial species close to the wetland had higher values, which probably happened under the influence of more moisture in the soil. Although these changes were different in relation to the reference area, they showed a significant reduction in general.

Figure 5 shows the density of plant species (annual, perennial, grasses and non-grasses) through the distance from the wetland in two reference and control areas. In general, the density of species of grasses and non-grasses has increased far away the wetland (Figure 5: A-B). On the other hand, there was a significant difference in the density of species between the control and reference areas. The low density of species (3 stands for non-grasses and 5 stands for grasses) was observed in points 50 m far from wetland in the reference area affected by human traffic. Similarly, the density of annual and perennial species in the reference and control areas has shown a significant difference ($P < 0.05$) (Figure 5: C-D).

Table 1 shows the changes in biomass of the plant species in plots in relation to distance from wetland. Generally, control area showed the higher biomass production than reference area (Sig.<0.01). Moreover, the most inter changes in biomass was related to the reference area ($Sig. < 0.01$) where each distance far from the wetland showed different biomass productions. The average biomass production in the reference and control areas was 98 and 264 kg/ha, respectively. Control area didn't show a significant difference through three distances from wetland (Table 1). In general, in both the reference and control areas, with distance from the wetland, the vegetation cover for all the evaluated life forms has shown a relative increase. Moreover, although there is a difference between three distances from wetland in the control area, the difference was not significant (Table 2).

Unlike characteristics of height, cover and biomass, plant freshness showed differences in the region at the late growing season. In general, the freshness of the plants in the control area was lower than the reference area. Also, in both reference and control areas, the freshness of plants showed a relative decrease with distance from the wetland. Probably, this factor is directly affected by soil moisture or the volume of plant biomass under human traffic (Figure 6). The evaluation of the changes in the edge of the wetlands has strongly caused changes in the diversity indices ($P < 0.05$). The lowest value of diversity indices was observed in the reference area and in 50 m far from wetland. By moving away from the wetland, the diversity showed a relative increase. In general, the diversity indices in the reference area showed a significant decrease compared to the control area so that the average values of Margalef and Shannon indices in the reference area were 3.9 and 1.6, respectively while they were 4.9 and 2.45, respectively, in the control area (Figure 7). On the other hand, close to the wetland, due to the unfavorable conditions of soil ventilation and excessive moisture in the soil, it causes the natural selection of plant species, which causes the dominance of some species in this area. Therefore, in the control area, a relative increase in diversity indicators was seen with a distance from the wetland.

4. Discussion

Preliminary results of this study showed that drastic changes have been taken place in vegetation at the edge of the Almagol wetland under human traffic over time. Based on

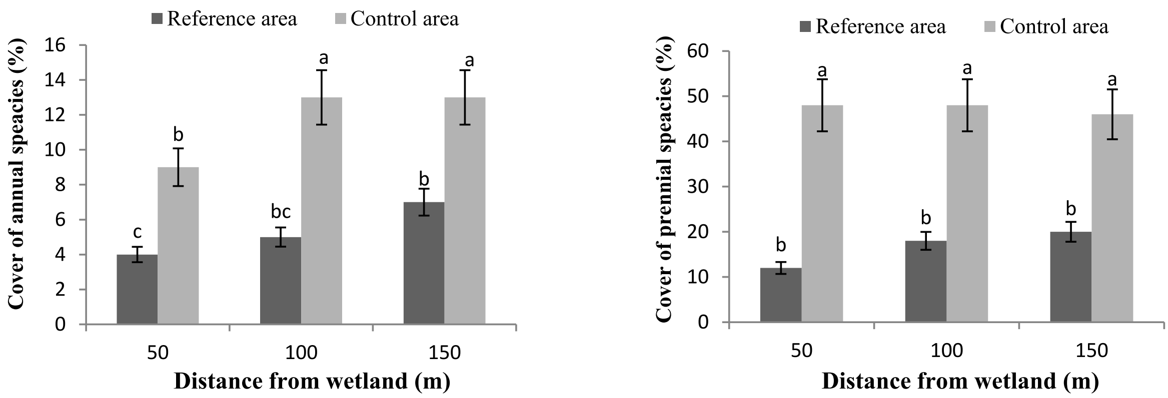

Figure 4. Cover of perennial and annual plant species in two study sites.

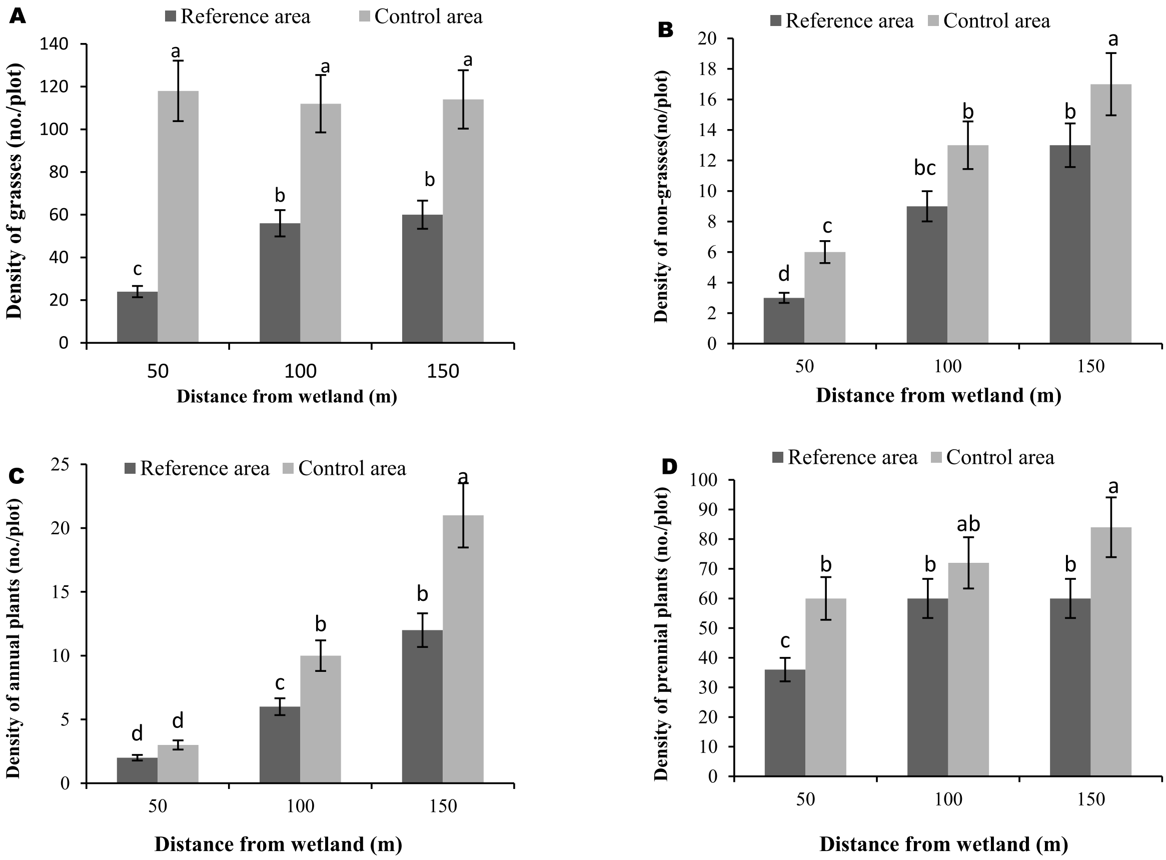

Figure 5. Density of grasses (A), non-grasses (B), annual (C), and perennial (D) species in relation to distance from wetland in two study sites.

Table 1. Mean value (±SD) of biomass of perennial and annual species (kg/ha) between three distance from wetland in two study sites.

Distance from wetland (m)	Perennial species (kg/ha)		Annual species (kg/ha)	
	Reference area	Control area	Reference area	Control area
50 m	107 ± 23^{B}	414 ± 74^{A}	42 ± 10^{B}	84 ± 75^{B}
100 m	149 ± 35^{AB}	398 ± 10.2^{A}	62 ± 20^{AB}	155 ± 25^{AB}
150 m	151 ± 30^{A}	380 ± 93^{A}	70 ± 20^{A}	156 ± 38^{A}

Means of column followed by the same letter are not differ by the Tukey test ($P < 0.05$).

Table 2. Mean value (±SD) of biomass between refrence data and control for each plant life form.

Life form	Site	Distance from wetland			Mean (kg/ha)
		50 m	100 m	150 m	
Perennial species	Reference area	107 ± 23^{b}	149 ± 35^{b}	151 ± 30^{b}	135.7^{B}
	Control area	414 ± 74^{a}	398 ± 102^{a}	380 ± 93^{a}	397.3^{A}
		0.01	0.01	0.01	0.01
Annual species	Reference area	42 ± 10^{b}	62 ± 20^{b}	70 ± 20^{b}	58.0^{B}
	Control area	84 ± 75^{a}	155 ± 25^{a}	156 ± 38^{a}	131.7^{A}
		0.01	0.01	0.01	0.01

Means of column for each plant life form followed by the same letter are not differ by the Tukey test ($P < 0.01$). Uppercase letters show the comparison between the transects in each region, and lowercase letters show the comparison between the two studied regions.

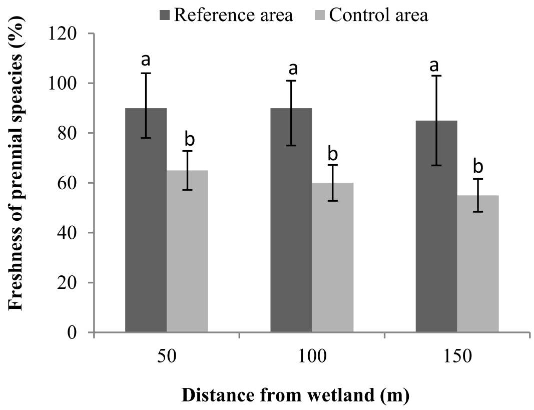

Figure 6. Percent of freshness of perennial species in relation to distance from wetland in two study sites.

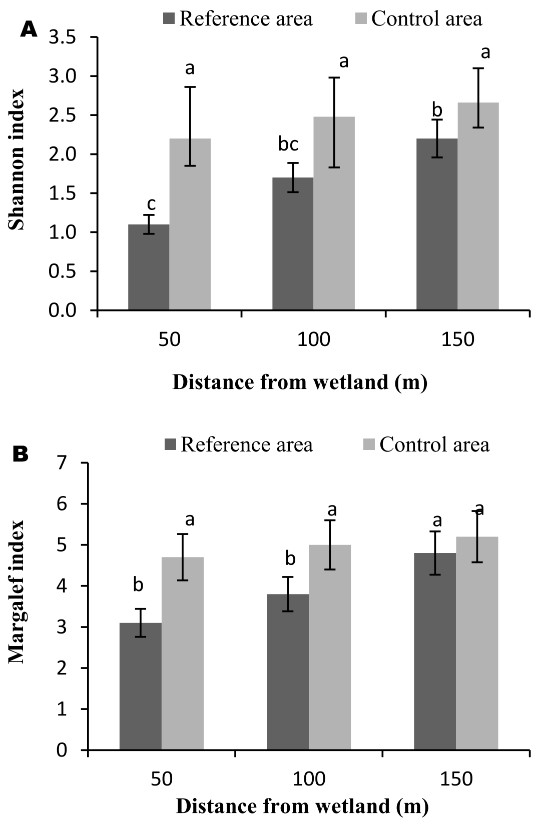

Figure 7. Species diversity/richness indices for study sites in edge of the Almagol wetlands.

the results, the most change was related to cover, biomass, height and diversity indices. The results revealed that there were also differences in vegetation in relation to distance from the wetland under human traffic. In general, in the wetlands of dry and semi-arid regions, the distribution of plants is more limited and the changes of plant species are in the gradient from the wetland to the dry side (Sefidian et al., 2015). Therefore, the changes in different life forms were noticeable in which perennial specie showed more changes than annual species. In fact, different life forms react differently to human traffic and trampling; for example, the more resistant woody speacies have less recovery abilities because of their woody nature while annual species will have a higher recovery ability in the short term (Piscová et al., 2015).

In this area, the density of annual plants (i.e. *Silene apetala* Willd.) was severely influenced by human traffic. In annual species, plant production by seeds is an important mechanism for recovery of plant communities (Larreguy et al., 2014) which may be severely influenced by soil destruction and compaction (K\uurová, 2016; Lei and Middleton, 2018). This phenomena is more important in arid and semi-arid areas due to stressful environmental conditions (Sanou et al., 2018). In addition, sometimes, under the deep penetration of seeds in the soil due to heavy traffic, the axial hypocotyl must elongate further in order for the cotyledon to reach the soil surface (Jahantab et al., 2022). Therefore, it seems that annual species in the soil have been severely affected in the high traffic areas, which has caused a reduction in growth and biomass production. Furthermore, seed production can be severely affected by human traffic over time, which reduces plant reproduction, especially in annual species.

The evaluation of the vegetation cover and plant production in the reference area affected by human traffic showed lower amounts compared to the control area. In general, traffic on the soil causes the decline in soil structure and increase soil compaction, which in turn changes the rhizosphere around the roots of plants, which will result in a decrease in plant performance (Saravi et al., 2015). In the same way, these changes were more noticeable closer to the wetland, which probably happened due to more moisture in the soil and more compaction of the soil. In general, humidity improves soil conditions, and better transport of materials in the soil, and causes better plant growth and increased production (Tavili et al., 2019). However, the reduced leaf area and lower leaf dry matter content under human traffic and trampling may further affect goods and services provided by ecosystem (Li et al., 2021).

Moreover, the freshness of perennial species in the reference area was higher than control area. Probably due to the lower growth of plant species in this area, the humidity of plant organs has also been higher. It seems that in this warm region, with the increase in the amount of biomass, the amount of consumption or the removal of moisture in the organs of plants increases. Similarly in previous study, changes in characteristics such as yield and freshness of plants have been directly affected by soil compaction (Dias et al., 2021).

Also, plant diversity indices under human traffic were significantly reduced compared to the control area. In general, stress-causing factors such as their excessive movement in the soil cause the destruction of species sensitive to stress, and this will benefit some other species, but in this area, human traffic during the year reduces plant diversity. In fact, plant diversity is directly affected by compacted soil characteristics (Yazdanshenas et al., 2013; Jahantab et al., 2022). Therefore, control area had higher values of diversity indices. On the other hand, the dominance and excess of some plant species cause the destruction and the decline of some other species, which causes a decrease in species diversity. Whitecotton et al. (2000) showed that how military training influences soil and vegetation properties after 2 years of intensive training in the USA were first of all, human traffic changed the characteristics of the soil and then, the characteristics of plants caused the loss of vegetation.Piscová et al. (2021) and Li et al. (2021) also reported that with the proximity to trampling intensity under human traffic, there was a significant decrease in plant cover, abundance and species diversity and richness in Alpine plant communities. Based on the obtained results in this area, almost all the vegetation characteristics, i.e. covere, density, freshness, species diversity have hanged under the influence of human traffic. Therefore, increasing human populations and traffic in proximity to wetlands are important factors of wetland degradation (Geijzendorffer et al., 2019) and human activities severly can influence wetland resources and vegetation (Zhang and Yu, 2021) and its monitoring is essential to improve the wetland environmental conditions (Karimi Sangchini et al., 2020).

5. Conclusion

Vegetation at the edge of Almagol wetland showed significant changes under the influence of long-term human traffic. Due to soil compaction, in this area, the vegetation changes were different depending on the vegetative life form (annual and perennial) and their biological form (grass and non-grass). The cover, height and biomass showed the highest values near the wetland. The freshness of perennial plants in the reference area had higher values than the control area. Also, plant diversity in the reference area showed a significant decrease compared to the control area. Overall, the results highlighted the importance of well-managed wetland edge for vegetation conservation. However, it is suggested to investigate the effects of human traffic on the change of physical and chemical properties of soil in the wetland edge in future studies. And in the same way, the relationship between the changes in soil and vegetation characteristics in the vicinity of wetlands that are affected by heavy human traffic should be evaluated. This can be done in the form of a monitoring program through permanent plots (inserting geographic coordinates) to evaluate the long-term effects of human traffic on the health of wetland ecosystems and to protect and continue the ecological functions of theses valuable ecosystems. Also, if it is not possible to carry out protective measures such as enclosure in some touristic areas on the edge of the wetland, identifying species resistant to human traffic for cultivation in these areas can be considered in future research.

Authors Contributions
All authors have contributed equally to prepare the paper.

Availability of Data and Materials
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Baker C., Lawrence R., Montagne C., Patten D. (2006) Mapping wetlands and riparian areas using Landsat ETM+ imagery and decision-tree-based models. *Wetlands* 26:465–474.

Chambers J.C. (1983) Methods for vegetation sampling and analysis on revegetated mined lands. *US Department of Agriculture, Forest Service, Intermountain Forest and Range Experimental Station,* 151.

Dias S.M., França A.C., Silva R.S. da, Carvalho R. de C.R., Aguiar F.R. de (2021) Interaction soil compaction and soil moisture in physiological responses of freshly planted coffee. *Journal of Environmental Analysis and Progress* 6:370–378.

Geijzendorffer I.R., Beltrame C., Chazee L., Gaget E., Galewski T., Guelmami A., Perennou C., Popoff N., Guerra C.A., Leberger R. (2019) A more effective Ramsar Convention for the conservation of Mediterranean wetlands. *Frontiers in Ecology and Evolution* 7:1–8.

Gxokwe S., Dube T., Mazvimavi D. (2020) Multispectral remote sensing of wetlands in semi-arid and arid areas: a review on applications, challenges and possible future research directions. *Remote Sensing* 12 (24): 4190.

Haidary A., Amiri B.J., Adamowski J., Fohrer N., Nakane K. (2013) Assessing the impacts of four land use types on the water quality of wetlands in Japan. *Water Resources Management* 27:2217–2229.

Hamedani H., Naqinezhad A., Fadaie F. (2017) Ramsar international wetlands of Alagol, Almagol and Ajigol in eastern parts of the Caspian Sea: a floristic and habitat survey. *Caspian Journal of Environmental Sciences* 15:357–372.

Heintzman L.J., McIntyre N.E. (2019) Quantifying the effects of projected urban growth on connectivity among wetlands in the Great Plains (USA). *Landscape and Urban Planning* 186:1–12.

Jahantab E., Yazdanshenas H., Saray A.A., Matinkhah S., Khazaei M. (2022) Seed burial depth, seedling emergence, and height as affected by animal trampling in marl soils. *Plant Ecology* 223:493–506.

Jamal S., Ahmad W.S. (2020) Assessing land use land cover dynamics of wetland ecosystems using Landsat satellite data. *SN Applied Sciences* 2:1–24.

Kaplan G., Avdan U. (2017) Mapping and monitoring wetlands using sentinel-2 satellite imagery. *ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences* 4:271–277.

Karimi Sangchini E., Ownegh M., Sadoddin A., Yousefi Mobarhan E. (2020) Predicting the Impacts of Land Cover Management Scenarios on the Run-off Volume and River Pollutants Using the L-THIA Model for the Hablehrud basin. *Watershed Management Researches Journal* 33:36–52.

K\uurová J. (2016) The impact of soil properties and forest stand age on the soil seed bank. *Folia Geobotanica* 51:27–37.

Larreguy C., Carrera A.L., Bertiller M.B. (2014) Effects of long-term grazing disturbance on the belowground storage of organic carbon in the patagonian monte, argentina. *Journal of Environmental Management* 134:47–55.

Lei T., Middleton B.A. (2018) Repeated drought alters resistance of seed bank regeneration in baldcypress swamps of North America. *Ecosystems* 21:190–201.

Li W., He S., Cheng X., Zhang M. (2021) Functional diversity outperforms taxonomic diversity in revealing short-term trampling effects. *Scientific Reports* 11 (1): 18889.

Margalef R. (1958) Information theory in ecology. *General Systems* 3:36–71.

Pal S., Talukdar S. (2018) Application of frequency ratio and logistic regression models for assessing physical wetland vulnerability in Punarbhaba river basin of Indo-Bangladesh. *Human and Ecological Risk Assessment* 24 (5): 1291–1311.

Perennou C., Guelmami A., Paganini M., Philipson P., Poulin B., Strauch A., Tottrup C., Truckenbrodt J., Geijzendorffer I.R. (2018) Mapping Mediterranean wetlands with remote sensing: a good-looking map is not always a good map. *Advances in ecological research* 58:243–277.

Piscová V., Sevcík M., Hresko J., Petrovic F. (2021) Effects of a Short-Term Trampling Experiment on Alpine Vegetation in the Tatras, Slovakia. *Sustainability* 13 (5): 2750.

Qurbani M., Taghipour A.A., Mahmoudzadeh H. (2011) Survey and analysis of land use changes in the international wetlands of Alagol, Almagol and Ajigol of the Turkmen Sahara using multi-temporal satellite images. *Geography and environmental planning* 48 (4): 167–184.

Rapinel S., Fabre E., Dufour S., Arvor D., Mony C., Hubert-Moy L. (2019) Mapping potential, existing and efficient wetlands using free remote sensing data. *Journal of environmental management* 247:829–839.

Sanou L., Zida D., Savadogo P., Thiombiano A. (2018) Comparison of aboveground vegetation and soil seed bank composition at sites of different grazing intensity around a savanna- woodland watering point in West Africa. *Journal of Plant Research* 131 (5): 773–788.

Saravi M.M., Chaichi M.R., Attaeian B. (2015) Effects of soil compaction by animal trampling on growth characteristics of Agropyrum repens (Case Study: Lar Rangeland, Iran). *International Journal of Agriculture & Biology* 7:909–914.

Sefidian S., Salman Mahini A.R., Mirkarimi H., Hassan Abbasi N.A. (2015) Vegetation classification based on wetland index with the help of remote sensing and ground sampling (Case study: Algal International Wetland). *The scientific research quarterly of wetland ecobiology - Islamic Azad University, Ahvaz branch* 24:5–32.

Shannon C.E. (1948) A mathematical theory of communication. *The Bell system technical journal* 27:379–423.

Singh M., Sinha R. (2022) A basin-scale inventory and hydrodynamics of floodplain wetlands based on time-series of remote sensing data. *Remote Sensing Letters* 13 (1): 1–13.

Tavili A., Bashari H., Yazdanshenas H., Jafari M., Arzani H., Azarnivand H. (2019) Morphophysiological changes of wild Stachys multicaulis species under physical conditions during the cultivation process. *Heliyon* 5 (7): e02093.

Wang B., Waters C., Orgill S., Gray J., Cowie A., Clark A., Li Liu D. (2018) High resolution mapping of soil organic carbon stocks using remote sensing variables in the semi-arid rangelands of eastern Australia. *Science of The Total Environment* 630:367–378.

Whitecotton R.C.A., David M.B., Darmody R.G., Price D.L. (2000) Impact of foot traffic from military training on soil and vegetation properties. *Environmental Management* 26:697–706.

Xu X., Chen M., Yang G., Jiang B., Zhang J. (2020) Wetland ecosystem services research: A critical review. *Global Ecology and Conservation* 22:e01027.

Yazdanshenas H., Jafari M., Azarnivand H., Arzani H., Nasiri M. (2013) Investigating the Effects of Soil Factors on Biodiversity in Plant Communities of Karvan Rangeland (Case Study: Isfahan Province, Iran). *Journal of Rangeland Science* 4:34–42.

Zhang J., Yu X. (2021) Analysis of land use change and its influence on runoff in the Puhe River Basin. *Environmental Science and Pollution Research* 28 (30): 40116–40125.