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Original Article

Drought and flood footprint: An environmental analysis of plant biodiversity changes in Al-Hawizeh Marsh, Iraq

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Abstract: This study aimed to assess environmental changes and degradation in Al-Hawizeh Marsh-Umm al-Naaj Pond, southern Iraq, from 2017 to 2023, focusing on plant diversity and its response to variations in rainfall, flooding, and water quality. It compared the wet season (2018/2019) with the severe drought season (2022/2023). Field surveys and data on the region's rainfall patterns showed a sharp annual variation. The 2018/2019 season recorded 413.6 mm of annual rainfall, resulting in complete flooding of the marsh (100% in the spring). In contrast, the drought seasons (2020/2021) saw rainfall of no more than 31.2 mm. The drought became more severe in the 2022/2023 season, as the AL-Hawizeh Marshes in Misan were flooded by only 5% of the area that could be flooded. The reduced freshwater releases associated with the drought led to a significant deterioration in water quality. In 2023, chloride (Cl) ion concentrations nearly doubled, and TDS and EC values increased significantly compared to 2018. The most severe impact of drought was on vegetation cover, where a radical ecological shift occurred between 2018 and 2023. In 2018, aquatic plants dominated (70%) of plant diversity. By 2023, this ratio had reversed, with terrestrial plants comprising (73%) of plant diversity, and 16 terrestrial plant species of Iraqi flora were recorded for the first time in the marshlands. The study confirms that climatic fluctuations, represented by the annual variation in rainfall, are the main determining factor for water levels in the marshes, and that periods of severe drought led to widespread structural deterioration in the region's ecosystem, increased salinity, water pollution, and a complete shift in plant biodiversity towards terrestrial and halophyte species.

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Introduction

Wetlands are among the most productive ecosystems on earth and provide the biosphere with about 20% of the planet's total biodiversity (Gopal, 1995). Wetlands cover $8.6x10^6$ km^2, representing approximately 6.4% of the land surface (Mitsch and Gosselink, 1993). Marshes are generally wetlands inundated by continual water, characterized by prominent vegetation cover, mostly emergent herbs, and which adapts to water-logged soil conditions that stay at or over the water level permanently or temporarily (Myers and Ewel, 1992). One of the largest Iraqi wetlands is Al-Hawizeh Marsh, which lies on the east bank of the Tigris River in the southern Iraqi provinces of Misan and Basra and covers an average area of approximately 3500 km^2. This marsh is typical of Mesopotamian marshes in terms of its vegetation, hydrology, and biodiversity (Douabul et al., 2005).

The study of the diversity and distribution of aquatic macrophytes is a critical component of understanding aquatic biological systems, given the crucial ecological role of aquatic vegetation and the plants' capacity to characterize water quality. Al-Hassany (2010) studied epiphytic algae on aquatic plants in Al-Hawizeh Marsh and highlighted their relationship with aquatic plants and their crucial role in the food chain of the Al-Hawizeh ecosystem,

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supporting the availability and spread of invertebrates and fish. Al-Hilli et al. (2009) presented a streamlined classification framework for marsh vegetation that includes six categories based on the development of prevailing species and their areas relative to the normal seasonal water depth. This system showed that tall, herbaceous plants constituted the majority of vegetation species in most marshes. Al-Abbawy and Al-Mayah (2010) recorded 35 aquatic plant species in Al-Hawizeh marsh, the highest number, compared with 27 and 24 species in Al-Chebaish and Al-Hammar marshes, respectively. A study of ecological habitats in Al-Hawizeh Marsh, conducted by Nature Iraq (2010), found 25 aquatic and semi-aquatic plant species, including established submerged plants, rooted floating plants, and free-floating plants dominated by *Hydrilla verticillata*. In 2017, a new species, *Azolla filiculoides* Lam., was recorded in Al-Hawizeh Marsh by Al Tameemi and Al-Kanani (2020).

The Tigris River is the primary determinant of hydrological conditions in the Al-Hawizeh Marsh. The water system exhibits distinct seasonal variations; the river reaches its highest levels in April and May, and its lowest in September and October. Furthermore, the region experiences a rainy season from November to April, with annual rainfall of no more than 136 mm (Al-Mayah et al., 2014). Seasonal and annual variation in the amount of water entering the marsh is natural and part of the marsh's unique dynamics. However, the frequency and severity of drought have increased in many regions in recent centuries due to climate change (Arnell, 2008; Cook, 2018). Climate change affects vegetation phenology in both terrestrial (Badeck et al., 2004; Richardson et al., 2013; Cong et al., 2017; Shen et al., 2018a) and freshwater ecosystems (Shen et al., 2018b, 2019). Therefore, this study was conducted to assess the effects of the drought that occurred in Al-Hawizeh Marsh during 2022-2023, following an unprecedented and heavy rainfall season in 2019-2020, and its impact on the diversity of aquatic and semi-aquatic plants in the region. The plant diversity of the spring 2017/2028 season was compared with that of the same area in spring 2022/2023.

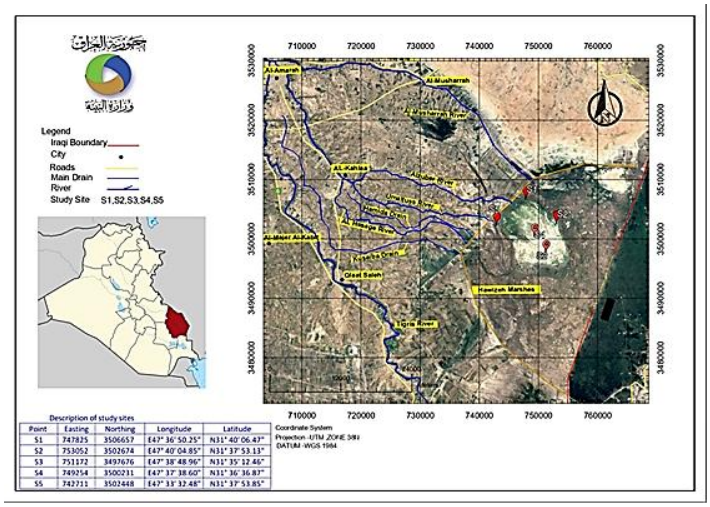

Figure 1. Map of the study area (Al-Hawizeh Marsh) and study sites.

Materials and Methods

Study area: The study included a survey of aquatic and semi-aquatic plants in the Al-Hawizeh Marsh, Umm al-Naaj Pond. Five sites were selected to conduct the survey and collect plant samples in the spring season of 2018 and 2023 (Fig. 1).

Vegetative cover survey: Plant samples were collected manually monthly in March, April, May, and June 2018, and in the same months in 2023, as spring is the flood season in the marshes of southern Iraq, where the plant sampling sites can be reached by boat. The samples were washed with marsh water and stored in plastic bags until they reached the laboratory, where they were identified at the Plant Laboratory, College of Agriculture, University of Misan. References used to identify aquatic plant species included Townsend and Guest (1985), Al-Miyah and Al-Hamim (1991), and Al-Miyah et al. (2014). The presence or absence of plant species at each marsh station was recorded monthly.

Water releases and inundation rates: Data on water releases to Al-Hawizeh Marsh and monthly inundation rates for the study years were obtained from the Misan Environment Directorate and the Marshlands Restoration Center (CRIMW) in Misan. Rainfall rates for the study years were also obtained from the Iraqi Agrometeorological Center, Ministry of Agriculture, to enhance our understanding of the water

Table 1. Rainfall (mm) in Al-Hawizeh Marsh 2017-2023.

Rainy Season	Rainfall Amount (mm)
October 2017 to June 2018	64.3
October 2018 to June 2019	413.6
October 2019 to June 2020	109.1
October 2020 to June 2021	31.2
October 2021 to June 2022	69.5
October 2022 to June 2023	203.9

Table 2. Inundation area percentage of Al-Hawizeh Marsh 2018-2023.

Month	Year	Area suitable for flooding (km2)	The area actually submerged (km2)	Submergence percentage %
March	2018	1055	403	38
	2019		1055	100
	2020		981	93
	2021		939	89
	2022		422	40
	2023		591	56
April	2018	1055	465	44.1
	2019		1055	100
	2020		1002	95
	2021		939	89
	2022		432	41
	2023		556	53
May	2018	1055	454	43
	2019		1055	100
	2020		950	90
	2021		928	88
	2022		432	41
	2023		656	62
Jun	2018	1055	411	39
	2019		939	89
	2020		918	87
	2021		823	78
	2022		53	5
	2023		436	41

situation in the Al-Hawizeh Marsh during the study period.

Water quality measurements: During sampling and visits to the designated sites, key water characteristics were measured, revealing seasonal variations in the marsh's water quality. The laboratories of the Environment Directorate in Misan were used to measure the following characteristics: pH, EC (mS/mC), TDS (mg/L), NO_3 (mg/L), PO_4 (mg/L), Ca (mg/L), and Cl (mg/L).

Results and Discussions

Rainfall: Table 1 shows annual rainfall variation in the Al-Hawizeh Marsh (Iraqi Agrometeorological Center (IAC), 2024). The 2018/2019 season was among the most remarkable rainy seasons, with annual rainfall exceeding 413.6 mm in the study area. In contrast, the 2020/2021 season saw severe drought (Fig. 2), with annual rainfall in the marshes not exceeding 31.2 mm.

Water inundation percentage: Table 2 shows the flood rates of Al-Hawizeh Marsh during the spring season, which is the main flood season. This rise in water levels is due to two main factors: increased rainfall during late winter and early spring in the areas upstream of the Tigris and Euphrates rivers and their basins, which increases the water flow in these rivers. Additionally, higher temperatures in early spring in the upstream highlands increase winter snowmelt, causing periodic flooding in the river system. These floods are a major factor in the environment of the Tigris-Euphrates river system, particularly in the

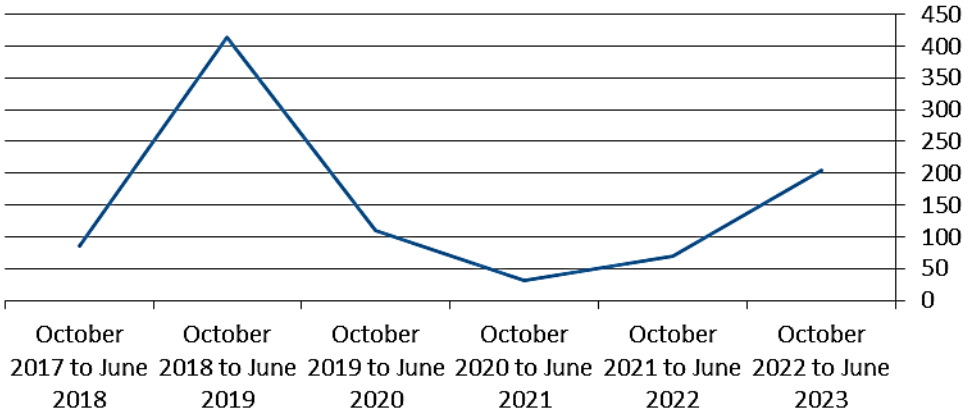

Figure 2. Rainfall amount (mm) in Al-Hawizeh Marsh 2017-2023

deltaic floodplains of lower Mesopotamia (UNEP, 2001).

The data show that Al-Hawizeh Marsh experienced a significant deterioration in their waterlogged areas during 2022 and 2023 (Figs. 3, 4). In June 2022, the flooded area did not exceed 53 km², which is only 5% of the total floodable area estimated at 1055 km². The NDVI technique, as reported by Ali et al. (2024), showed that Al-Hawizeh Marsh, whose water surface was assessed using Landsat 8 imagery, experienced significant changes in area from 2016 to 2023. This deterioration peaked in 2022 and 2023, with the marsh almost drying up. Their study also showed that seasonal variation in climate factors is the main driver of marsh water levels in southern Iraq.

The rainfall data (Table 1) are consistent with the variation in the volume of water that flooded the Al-Hawizeh Marsh during the same period (Table 2). The dry season of 2022/2023 negatively impacted the amount of water released into Al-Hawizeh Marsh. This contrasts with the 2018/2019 rainy season, in which rainfall reached 413.6 mm, resulting in the Al-Hawizeh Marsh being 100% flooded during the spring season (March, April, and May 2019) (Table 2).

Water quality: The results of calcium ions (Ca), chloride ions (Cl), total dissolved solids (TDS), and electrical conductivity (EC) (Table 3) indicate elevated salinity levels in the waters of the Al-Hawizeh Marsh during the study period. The significant increase in Ca concentrations from April 2018 (150 mg/L) to May 2018 (358 mg/L) is attributed to natural evaporation and the low water levels at the

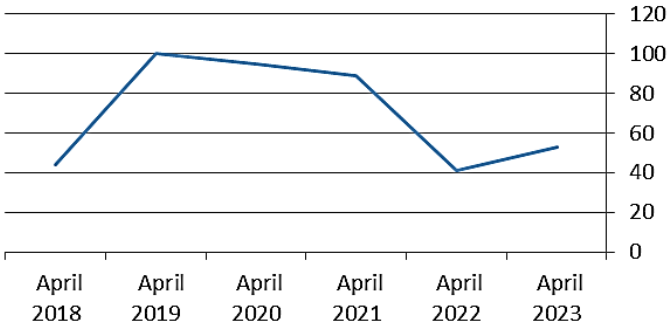

Figure 3. Submergence percentage (%) of Al-Hawizeh Marsh in April 2018-2023.

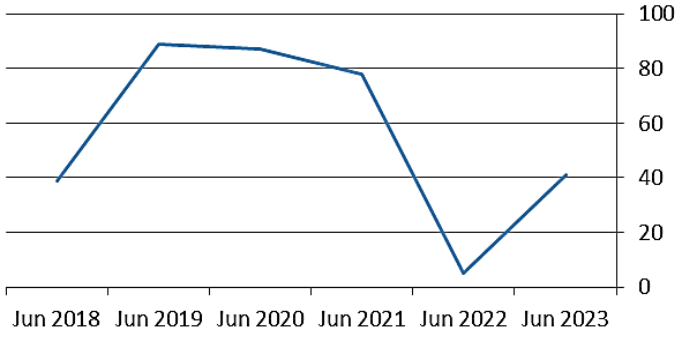

Figure 4. Submergence percentage (%) of Al-Hawizeh Marsh in June 2018-2023.

end of the flood season. In 2023, Ca concentrations were lower than in May 2018, but increased between April (175 mg/L) and May (250 mg/L) for the same seasonal reason (evaporation).

Chloride (Cl) increased significantly in 2023 compared to 2018, reaching 895 mg/L in April 2023 versus 410 mg/L in April 2018. This sharp increase in Cl indicates a strong decrease in freshwater releases (water scarcity) and a possible increase in the influence of other salinity sources, resulting in much

Table 3. Some physical and chemical properties of water during april & may of 2018-2023 in study area.

Month	Water Quality						
	pH	EC (ms/mc)	TDS (mg/L)	NO3 (mg/L)	PO4 (mg/L)	Ca (mg/L)	Cl (mg/L)
April 2018	7.5	2733	1728	5.31	0.168	150	410
April 2023	7.5	3979	2478	17.93	0.761	175	895
May 2018	8.3	3110	1553	8.31	0.531	358	600
May 2023	8.2	4250	2556	15.72	0.766	250	850

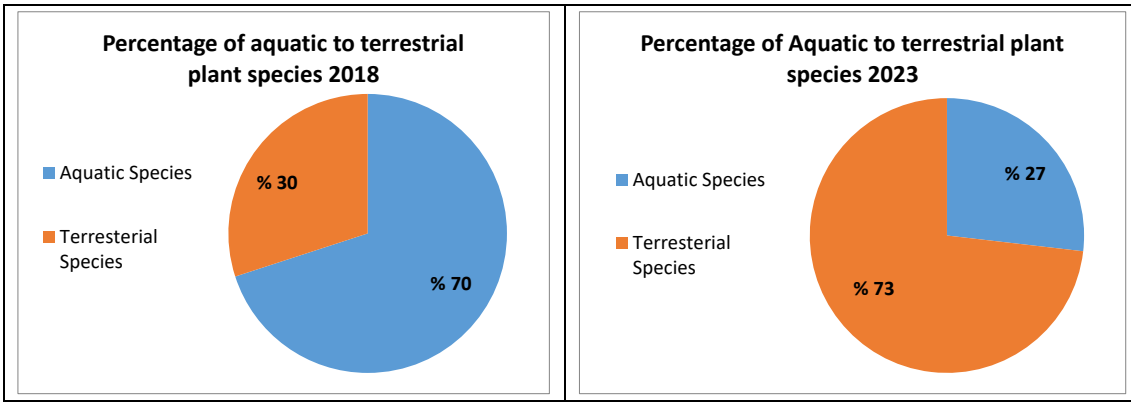

Figure 5. Percentage of Aquatic to Terrestrial Plant Species in Al-Hawizeh Marsh in Spring 2018 and 2023.

higher concentrations of soluble salts. Furthermore, the TDS and EC follow the same pattern as Cl, with their values being much higher in 2023, reaching (2556 mg/L) TDS and (4250 µS/cm) EC in May 2023, compared to (1553 mg/L) TDS and (3110 µS/cm) EC in May 2018. This is clear evidence that water quality deteriorated significantly in 2023 due to the drought, as salinity and salt concentration increased as the amount of fresh water flowing decreased.

Nitrates (NO_3) and phosphates (PO_4) results indicate elevated nutrient contamination from agricultural or sewage runoff (AlMaarofi et al., 2014). In 2023, nitrate concentrations increased significantly, reaching 17.93 mg/L in April 2023, compared to 5.31 mg/L in April 2018 (approximately 3.4 times higher). This sharp increase suggests a substantial rise in contamination from sewage and/or agricultural fertilizers. The reduced water releases in 2023 meant that existing contamination was being diluted by less freshwater. PO_4 concentrations also increased in 2023 (April 2023: 0.761 mg/L compared to April 2018: 0.168 mg/L), although the increases were less dramatic than those for nitrates. The results show a high variation in water quality between a good water season (2018) and a dry season (2023). In 2023, the decrease in freshwater releases led to a sharp rise in salinity (Cl, TDS, and EC) and a high increase in the concentrations of polluting nutrients, NO3 and PO_4.

Vegetative cover: The study area's vegetation cover showed marked variation in plant species distribution between 2018 and 2023. During the severe water shortages of the two drought seasons (2022 and 2023), many aquatic plants disappeared, while many terrestrial species not previously recorded in the marsh environment and its banks appeared. Simultaneously, the spread of halophyte plants (*Suaeda aegyptiaca, Seidlitzia rosmarinus,* and *Cressa cretica*) was observed due to increased salinity from low water levels.

In total, 30 plant species were recorded in 2018, and this number increased to 41 species in 2023 (Table 4). Within the vegetation cover recorded in 2018, aquatic plants were the dominant category, with 21 species, accounting for 70% of plant diversity, while only 9 terrestrial plant species were recorded. In contrast, the results of plant surveys conducted after the 2022 and 2023 droughts showed a marked change in the region's plant composition. The number of

Table 4. List of Plant Species Recorded in Al-Hawizeh Marsh in Spring 2018 & 2023.

No.	Family	Scientific name	Life Form*	2018	2023
1	Amaranthaceae	*Chenopodiastrum murale*	SA/T	-	+
2	Amaranthaceae	*Suaeda aegyptiaca*	SA/T	-	+
3	Amaranthaceae	*Amaranthus albus*	SA/T	-	+
4	Amaranthaceae	*Seidlitzia rosmarinus*	SA/T	-	+
5	Amaranthaceae	*Chenopodium album*	SA/T	-	+
6	Amaranthaceae	*Alternanthera sessilis*	A	+	-
7	Apocynaceae	*Cynanchum acutum*	SA/T	+	+
8	Apocynaceae	*Apocynum venetum*	SA/T	+	+
9	Araceae	*Lemna minor*	A	+	+
10	Asteraceae	*Eclipta alba*	A	+	+
11	Asteraceae	*Xanthium strumarium*	SA/T	-	+
12	Asteraceae	*launaea mucronata*	SA/T	-	+
13	Asteraceae	*Sonchus asper*	SA/T	-	+
14	Asteraceae	*Sonchus maritimus*	SA/T	+	-
15	Asteraceae	*Conyza dioscridis*	SA/T	+	+
16	Boraginaceae	*Heliotropium curassavicum*	SA/T	-	+
17	Capparaceae	*Capparis spinosa*	SA/T	+	+
18	Ceratophyllaceae	*Ceratophyllum demersum*	A	+	+
19	Convolvulaceae	*Cressa cretica*	SA/T	-	+
20	Cyperaceae	*Cladium mariscus*	A	+	-
21	Cyperaceae	*Torulinium odoratum*	SA/T	+	+
22	Elatinaceae	*Bergia capensis*	A	+	+
23	Fabaceae	*Alhagi graecorum*	SA/T	-	+
24	Faboideae	*Melilotus indica*	SA/T	-	+
25	Hydrocharitaceae	*Najas armata*	A	+	-
26	Hydrocharitaceae	*Hydrilla verticillata*	A	+	-
27	Juncaceae	*Juncus articulatus*	SA/T	-	+
28	Lamiaceae	*Lycopus europaeus*	A	+	-
29	Molluginaceae	*Glinus lotoides*	SA/T	-	+
30	Onagraceae	*Jussiaea repens*	A	+	-
31	Plantaginaceae	*Bacopa monnieri*	A	+	+
32	Poaceae	*Sorghum halepense*	SA/T	+	+
33	Poaceae	*Aeluropus lagopoides*	SA/T	-	+
34	Poaceae	*Polypogon monspeliensis*	SA/T	-	+
35	Poaceae	*Phragmites australis*	A	+	+
36	Poaceae	*Paspalum distichum non / Paspalum*	SA/T	+	+
37	Polygonaceae	*Rumex crispus*	SA/T	-	+
38	Polygonaceae	*Polygonum argyrocoleum*	SA/T	-	+
39	Polygonaceae	*Persicaria salicifolia*	A	+	-
40	Polygonaceae	*Persicaria lapathifolia*	A	+	-
41	Polygonaceae	*Rumex dentatus*		-	+
42	Potamogetonaceae	*Potamogeton crispus*	A	+	+
43	Primulaceae	*Samolus maleraudi samolus valerandi*	A	+	+
44	Ranunculaceae	*Ceratocephala falcata*	SA/T	-	+
45	Ruppiaceae	*Ruppia maritima*	A	+	-
46	Salviniaceae	*Azolla filiculoides*	A	+	+
47	Salviniaceae	*Salvinia natans*	A	+	-
48	Solanaceae	*Solanum nigrum*	SA/T	+	+
49	Tamaricaceae	*Tamarix brachystachys*	SA/T	-	+
50	Tamaricaceae	*Tamarix aucheriana*	SA/T	-	+
51	Typhaceae	*Typha australis*	A	+	+
52	Verbenaceae	*Phyla nodiflora*	A	+	+

aquatic plants decreased to 11 out of 41 recorded species (27%), while terrestrial plants increased to 73% of the vegetation cover, representing 30 species. This dramatic reversal (Fig. 5) in the dominance of aquatic versus terrestrial plants between 2018 and 2023 indicates the severe impact of drought in the

Table 5. List of plant species recorded for the first time in Hawizeh Marsh 2023.

No.	Family	Scientific Name
1	Amaranthaceae	*Amaranthus albus*
2	Amaranthaceae	*Chenopodiastrum murale*
3	Amaranthaceae	*Chenopodium album*
4	Amaranthaceae	*Seidlitzia rosmarinus*
5	Asteraceae	*launaea mucronata*
6	Asteraceae	*Xanthium strumarium*
7	Boraginaceae	*Heliotropium curassavicum*
8	Convolvulaceae	*Cressa cretica*
9	Fabaceae	*Alhagi graecorum*
10	Faboideae	*Melilotus indica*
11	Molluginaceae	*Glinus lotoides*
12	Poaceae	*Aeluropus lagopoides*
13	Poaceae	*Polypogon monspeliensis*
14	Polygonaceae	*Rumex crispus*
15	Polygonaceae	*Rumex dentatus*
16	Ranunculaceae	*Ceratocephala falcata*

region, which has led to a clear change in vegetation cover and plant diversity.

In the post-drought vegetation cover of the study area (2023), 22 new plant species were documented that were not recorded in the 2018 surveys. All 22 species are classified as terrestrial plants. These new species were divided as follows: 6 species were previously recorded in the marshes and wetlands of Iraq in earlier reference studies (Alwan, 2007; Al-Mayah et al., 2012). The remaining 16 species (Table 5) were terrestrial plant species already recorded in the Iraqi flora and were documented for the first time within the Iraqi Marshes environment (Fig. 6). The reversal of the aquatic-to-terrestrial plant dominance ratio and the emergence of 22 new terrestrial plant species after the severe drought that hit the area in 2023 are conclusive evidence of the structural change and profound ecological transformation drought has brought about in the marshes' plant diversity.

Conclusion

The results analysed showed large annual variation in the Al-Hawizeh Marsh between seasons of heavy rainfall and severe drought, with profound effects on water cover, water quality, and plant biodiversity. Drought has had a profound and structural impact on plant diversity. In 2018, aquatic plants were dominant, accounting for 70% of recorded species. However, surveys conducted in 2023, following periods of drought, revealed a dramatic reversal of dominance, with terrestrial plants (73%) replacing aquatic plants (27%). Furthermore, 16 new terrestrial plant species, previously unrecorded in the Al-Hawizeh Marshes, were documented, providing compelling evidence of a profound ecological shift and actual desertification of large parts of the marshes.

References

Al-Abbawy D.A.H., AI-Mayah A.A. (2010). Ecological survey of aquatic macrophytes in restored marshes of southern Iraq during 2006 and 2007. Marsh Bulletin, 5: 177-196.

Al-Hassany J.S. (2010). A study of the ecology and diversity of epiphytic algae on some aquatic plants in Al-Hawizeh Marshes, southern Iraq. Ph.D. Thesis, College of Science for Women University of Baghdad. 178 p.

Al-Hilli M.R.A., Warner B.G., Asada T., Douabul A. (2009). An assessment of vegetation and environmental controls in the 1970s of the Mesopotamian wetlands of southern Iraq. Wetlands Ecology and Management 17(3): 207-223.

Figure 5. Photos of Terrestrial plants recorded for the first time in Al-Hawizeh Marsh 2023. (A) Amaranthus albus, (B) Chenopodiastrum murale, (C) Chenopodium album, (D) Seidlitzia rosmarinus, (E) Launaea mucronata, (F) Xanthium strumarium, (G) Heliotropium curassavicum, (H) Cressa cretica, (I) Alhagi graecorum, (J) Melilotus indica, (K) Glinus lotoides, (L) Aeluropus lagopoides, (M) Polypogon monspeliensis, (N) Rumex crispus, (O) Rumex dentatus, (Q) Ceratocephala falcate.


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Ali Z.A., Alawadi W.A., Al-Rekabi W.S. (2024). Evaluation of different water indices for extraction surface water of AL-Hawizeh Marsh from landsat 8 imagery. TWIST, 19(3): 77-88.

AlMaarofi S., Douabul A.Z., Warner B.G., Taylor W.D. (2014). Phosphorus and nitrogen budgets of the Al-Hawizeh marshland after re-flooding. Hydrobiologia, 721: 155-164.

Al-Mayaha A.A. Al-Abbawya D.A.H., Al-Assadia W.M.T., Al-Saadia S.A.A., Al-Edanyb T.Y. (2012). Status of aquatic macrophytes in Saffia Nature Reserve, South of Huwaiza Marsh, Iraq. Marsh Bulletin, 7(1): 1-16.

Al-Mayah A.R., Al-Hemeim F.I. (1991). Aquatic plants and algae (Part 1 and 2). Dar Al-Hekma, University of Basrah. 736 p. (In Arabic)

Al-Mayah A.A., Al-Hilli, M.R., Hassan F.M. (2014). Marsh Flora of Southern Iraq Before Desiccation. Al-Basaer Company S.A.R.I. pp: 8-9.

Alwan A.R.A. (2006). Past and present status of the aquatic plants of the marshlands of Iraq. Marsh Bulletin, 2: 160-172.

Al Tameemi K.A.K., Al-Kanani K.A. (2020). An ecological study of Azolla filiculoides Lam. Newly recorded in Misan water bodies, Iraq. Plant Archives, 20(Supplement 1): 309-318.

Arnell N.W. (2008). Climate Change and Drought. Options Mediterraneennes, Series A, No. 80.

Badeck F.W., Bondeau A., Böttcher K., Doktor D., Lucht W., Schaber J., Sitch S. (2004). Responses of spring phenology to climate change. New Phytologist, 162: 295-309.

Cong N., Shen M., Yang W., Yang Z., Zhang G., Piao S. (2017). Varying responses of vegetation activity to climate changes on the Tibetan Plateau grassland. International Journal of Biometeorology, 61: 1433-1444.

Cook B.I., Mankin J.S. Anchukaitis K.J. (2018). Climate Change and Drought: From Past to Future. In Topical Collection on Climate Change and Drought, Cook, B. I. Current Climate Change Reports.

CRIMW (2025). Center for the restoration of marshes and wetlands, Ministry of Water Resources, Republic of Iraq, Unpublished Data.

Douabul A.A.Z., Warner B., Asada T., Abaychi J.K., Alwash A.J. (2005). Restoration processes in Abu Zirig-Central Marsh: A case study. Special Session 9: Restoration of Mesopotamian Marshes of Iraq. The Ecological Society of America (ESA), August 2005 Annual Meeting, Montréal, Canada.

Gopal B. (1995). Wetland and biodiversity: How to kill two birds with one stone? In: W. Giesen (Ed.). Wetlands biodiversity and development. Proceeding of Workshop of the Int. Conf. on Wetlands and Development held in Kuala Lumpur Malaysia Wetlands International Kuala Lumpur, 1997. pp: 18-28.

IAC. (2024). Iraqi agrometeorological center, Ministry of Agriculture, Republic of Iraq, Unpublished Data.

Mitsch W.J., Gosselink J. (1993) Wetlands. 2nd edition, Van Nostrand Reinhold, New York. 722 p.

Myers R.L., Ewel J.J. (1992). Ecosystems of Florida. University of Central Florida Press. 765 p.

Nature of Iraq (2010). Surveyed in winter and summer 2005-2010 for Al-Hawizeh Marsh southern Iraq. Draft a Report Prepared for the Iraq National Marshes and Wetlands Committee. 7 p.

Richardson A.D., Keenan T.F., Migliavacca M., Ryu Y., Sonnentag O., Toomey M. (2013). Climate change, phenology, and phenological control of vegetation feedbacks to the climate system. Agricultural and Forest Meteorology, 169: 156-173.

Shen X., Liu B., Henderson M., Wang L., Wu Z., Wu H., Lu X. (2018a). Asymmetric effects of daytime and nighttime warming on spring phenology in the temperate grasslands of China. Agricultural and Forest Meteorology, 259: 240-249.

Shen X., Liu B., Xue Z., Jiang M., Lu X., Zhang Q. (2019). Spatiotemporal variation in vegetation spring phenology and its response to climate change in freshwater marshes of Northeast China. Science of the Total Environment, 666: 1169-1177.

Shen X., Xue Z., Jiang M., Lu X. (2018b). Spatiotemporal change of vegetation coverage and its relationship with climate change in freshwater marshes of Northeast China. Wetlands, 1: 11.

Townsend C.C., Guest E., Omar S.A. (1985). Flora of Iraq. Ministry of the Agriculture Republic of Iraq University Press of Glasgow Monocotyledons. 587 p.

UNEP (2001). The Mesopotamian Marshlands: Demise of an ecosystem division of early warning and assessment, United Nations Environment Programme, Nairobi, Kenya.