Climate change and hydrological regime in arid lands: Impacts of dams on the plant diversity, vegetation structure and soil in Saudi Arabia

Bander M. Al-Munqethi *, Mohamed A. El-Sheikh, Ahmed H. Alfarhan, Abdullah M. Alkahtani, Ibrahim A. Arif, Rajakrishnan Rajagopal, Saud T. Alharthi

Department of Botany and Microbiology, College of Science, King Saud University, Riyadh 11451, Saudi Arabia

Abstract

As the direct effects of climate change on the hydrological regime, Saudi Arabia has constructed more than 522 dams of various capacities as part of economic and environmental development. The study aims to assess the impact of dams on plant diversity, vegetation structure and soil in Saudi Arabia. Thirty-five stands were selected from the dams of different sizes of Saudi Arabia. Vegetation samples were established before (upstream) and after (downstream) the dam, and at the undammed (unaffected by the dam) to compare species diversity in the dam sites and undammed sites and to document the potential effects of dams on vegetation structure. A total of 151 plant species belonging to 36 families have been recorded. The vegetation associations are essentially shrubby with widespread annuals. Six novel associations were identified with the application of TWINSPAN, DCA, and CCA programs. They were named after the characteristic species as follows: VG I: Acacia gerrardii-Caralluma retrospiciens; VGII: Acacia tortilis-Maerua oblongifolia; VGIII: Lycium shawii-Farsetia aegyptiaca; VG IV: Farsetia stylosa-Cornulaca monocantha; VG V: Suaeda aegyptiaca-Salsola imbricata-Prosopis farcta and VGVI: Xanthium strumarium-Ochradenus baccatus. These plant communities are evaluated and discussed according to their floristic structure, vegetation diversity and edaphic variables. The riparian or streamside zones upstream and downstream that are periodically flooded contain highly diverse plant communities that are structured by flooding, which creates disturbance and acts as a dispersal mechanism for plants than undammed sites.

1. Introduction

Climate change is an essential component for strategic water resource management in arid and semi-arid countries, including Saudi Arabia. It is a well-known fact that climate change could eventually deepen the water resource crisis in water-scarce regions (Abu-Allaban et al., 2015, Attenborough 2020, Šulyová et al., 2021). The Saudi authorities have implemented many strategies to safeguard water resources sustainability, including valuation of available water resources, new dams construction, desalination plants construction for domestic water supply, drafting of water conservation regulations, as well as the design and eventual enforcement of water-saving measures in agriculture (Darfaoui and Al Assiri 2010, MEWA 2019). But still, the higher temperature and inconsistent rainfall patterns in the hyper-arid areas e.g. Saudi Arabia is creating confusion in developing sustainable water resource management strategies (Tarawneh and Chowdhury 2018). Climatic variations will affect the hydrological regime, water availability, and quality by increasing the frequency and severity of droughts and floods, rainfall variability, and higher temperatures (Luhunga et al., 2017). Boulange et al., (2021) reported the role played by dams in minimizing flood risk in the future in the context of global climate change by using a hybrid model, integrating the universal hydrological model with a new generation of universal hydrodynamics model, which is very important in the sustainability and saving of freshwater. In Saudi Arabia, there are 522 dams across the country with a total storage capacity of 2.304.390.647 Billion cubic meters (MEWA 2020).
collect, store, recharge runoff and control flash floods. Dams are of great importance in development projects implemented by the MEWA (Ministry of Environment, Water and Agriculture, Saudi Arabia) to support water sources and develop these resources to provide drinking water and irrigation. It is reported that for a dam reservoir in the southwest region of Saudi Arabia, the loss through surface evaporation was in the range of 4.7–6.0 m per year (Missimer et al., 2012).

At the same time, dams also have various adverse effects on the environment and community, both during construction and afterward, but the most catastrophic effects occur during the operational phase, which can span thousands of years. The extent of impact is mainly related with the location of the dam, height of dam, size of reservoir and water residence time. Dams’ most prevalent effects are on water and air quality, aquatic ecology, land use, vegetation, and also on terrestrial animals (Alia and Liu 2021). The other major impacts include disturbance of wadi continuity, homogenization of habitats, downstream wadi bed incision, modification of wadi/groundwater exchange, downstream flow and water quality change, reduced water flow and silt deposition of wadi bed and the sediments carrying nutrients gets deposited in the reservoirs, the fertility of the land along the wadi gets reduced (Schmutz and Sendzimir 2018).

The vegetation is an important renewable natural resource on which the inhabitants of arid and semi-arid lands depend since ancient times. It meets most of the nutritional requirements of all living beings that live in their environment (Al-Nafi 2005). The vegetation is an important and diverse renewable resource on which the inhabitants of arid and semi-arid lands depend (Al-Nafi 2005). Ancient times. It meets most of the nutritional requirements of which the inhabitants of arid and semi-arid lands depend since ancient times. It meets most of the nutritional requirements of which the inhabitants of arid and semi-arid lands depend (Al-Nafi 2005).

A dam’s impact on biodiversity can be divided into upstream influences induced by confined water and downstream influences brought about by changes in stream flow and the quality water. According to some studies, dams generally reduce biodiversity because organisms, materials, and energy are hindered from crossing the dam, but the effects are greatly scale-dependent and will also reduce the complexity of types of vegetation as well as impact predominant vegetation in surroundings (Jansson 2006). Al-Sodany et al., (2015) on the other side, reported that the dams had no effect on plant diversity. In Saudi Arabia, investigations to examine the influence of dams on flora and vegetation are scarce. Sayed et al., (2020) studied the impact of the Wadi Jizan dam reservoir on its immediate ecosystems and local floristic diversity and deduced that the dam altered the sedimentation pattern, aided in the establishment of invasive aquatic plants, and caused changes in regional floristic diversity and distribution. As a result, the main goal of this study is to evaluate the influence of dams on the vegetation composition, species diversity and soil of dam sites in various regions of Saudi Arabia.

2. Materials and methods

2.1. Study location

Saudi Arabia has five distinct geological units. 1. The Arabian Shield, 2. The Arabian Platform, 3. The Tertiary and Quaternary harr-aat, 4. The Red Sea Coastal Plain and 5. The Major Sand Seas – Rub’ al Khali and Nafud. Landform regions of Arabia can be divided into coastal plains, salt flats, or sabkhas, wadis, deltas, desert islands, sand deserts, plateau, mountains, and scarp mountain regions (Fig. 1) (Edgell 2006).

2.2. Climate

The dominant air mass incursion over this region during winter is Polar Continental air which develops as an intense anticyclone over central Asia. High-pressure conditions give rise to dry stable air (Fig. 2) (Alrashed and Asif 2015). In summer, the high temperatures over the Peninsula lead to the development of Tropical Continental air which forms part of the Monsoon low circulation centered over north-west India. The air is very dry and the intense convection raises vast quantities of dust into the lower atmosphere and gives rise to poor visibility and generally hazy conditions. The summer heat over the Peninsula also draws in unstable Tropical Maritime Monsoon air from the Arabian Sea and the two tropical air masses merge at the Intertropical Convergence Zone (ITCZ).

In winter, Polar Maritime air sometimes invades the Kingdom from the Mediterranean. Depressions embedded in this air mass often track across the desert plains of northern Saudi Arabia and give rise to much-needed rainfall. Four seasons are generally recognized in the Kingdom, although their distinctiveness varies from region to region. This is particularly true when comparing coastal locations such as Jeddah or Jizan with more continental locations such as Riyadh at 591 m a.s.l.

2.3. Sampled stands

Five different dam sites were carried out located at the dams constructed in the wadis in the central (Riyadh and Al-Qassim), Western south (Bisha and Jizan) and northern regions (Hail) in Saudi Arabia (Fig. 1a). Vegetation samples were established before (upstream) and after (downstream) the dam, and at the undammed (unaffected by the dam) to compare species diversity in the dam sites and undammed sites and to document the potential effects of dams on vegetation structure (Fig. 1b). Thirty-five stands were selected from these five sample dam sites, during the spring season of 2018. Each stand was approximately 50 × 50 m, covering most of the plant species inside it (Table 1).

2.4. Floristic analysis

All the plants from the sampled stands were listed. Identification of the species and their chorotypes was carried out based on (Collenette 1998) and (Chaudhary 1999, 2000, 2001). The life forms of the collected species were determined (Rauklaender 1934). The percentage of vegetation coverage for each plant species studied in each study site was estimated by following the abundance cover method, where it was estimated as a percentage (Kent 2011).

2.5. Soil analysis

Thirty five soil sample were collected from each stand at a depth of 0–30 cm and air dried and sieved into 2 mm. Soil organic matter was estimated by the soil ignition method (Dean 1974). Soil texture was determined by the hydrometer method (Bouyoucos 1962). Soil water extract was prepared (1:5), by dissolving 100 g air dried soil in 500 ml distilled water for estimation of pH and electrical conductivity (EC) as mS/cm using pH and Conductivity Meter (McLean 1983). Elemental analysis was performed to determine the concentrations of K, Ca, Mg, Na, Fe, Mn, and P through the Inductively Coupled Plasma Mass Spectrometry instrument (NEXION 300D ICP-MS). The total nitrogen content in the samples was determined using the Micro-Kjeldahl method (AOAC 1980; Allen et al., 1974).
2.6. Vegetation data analysis

The calculated plant coverage values for all plant species in all sites studied were subjected to multivariate analysis using the TWINSPLAN program and the DECORANA ordination program, according to the methods mentioned by (Hill 1979a, Hill 1979b) to highlight the key plant communities in the area of research. The CANOCO software was then used to identify the most relevant environmental factors that influence the distribution of plant populations in the research region based on the plant species cover, diversity indices, and soil parameters (Ter Braak and Smilauer 2002). Species richness (α-diversity) was calculated as the average number of species/stands. Species relative evenness was calculated by Shannon-Wiener index $H' = -\sum_{i=1}^{s} p_i \log p_i$, and the relative concentration of dominance was expressed by Simpson index $C = \sum_{i=1}^{s} p_i^2$ where (s) is the number of species and ($p_i$) is the relative cover value of the i-th species (Pielou 1975, Magurran 1988, 2004).

2.7. Statistical analysis

The Pearson’s correlation coefficient (r) was used to examine the relationship between coordination axes on the one hand and soil variables and plant communities on the other. The difference in plant diversity, site characteristics and soil variables of plant populations was also evaluated by analyzing one-way ANOVA, then applying correlation and analyzing the variations in the plant communities and prevailing environmental variables by the SPSS Program.

3. Results

3.1. Floristic composition, life forms spectra, and biogeographic affinities

The surveyed sites yielded a total of 151 plant species from 117 genera and 36 families (Table 2). The highest number of plant spe-
cies were represented in the pre-dam site (upstream) with 108 species (71.5%), followed by the post-dam site (downstream) with 107 species (70.8%), and the lowest number was in the unaffected site (undammed) with 36 species (23.8%). Among the 36 represented families, Poaceae was the most dominant with 23 species (15.2%) followed by Asteraceae (12.5%), Fabaceae (10%), Chenopodiaceae (8%), Brassicaceae (6.6%) and Boraginaceae (5.2%). Annuals (39.74%) represented the main floristic group followed by perennial herbs (18.54%), shrubs (15.23%), sub-shrubs (8.61%), annual and perennial grasses (7.28% each) and trees (3.31%). Chorological analysis of the species in the study area revealed that monoregional elements have dominant representation with 87 species (57.62%) belonging to (SA), followed by biregionals with 24 species (27.81%), having representatives of SA-IT and SA-SM elements, while the pluriregional elements have the lowest number with only 22 species (14.57%) of which SA-IT-Med were dominated.

3.2. Plant associations

TWINSPLAN was applied to divide and determine the composition of the plant communities based on the coverage of 151 plant species from 35 sites. The plant communities were separated at the fourth level of the TWINSPLAN Program (Fig. 3a; Table 3; Table 4). Six plant communities i.e. associations were obtained and were named according to the dominant plants with the highest value for presence and coverage as follows: VGI: *Acacia gerrardii-Caralluma retrospiciens*; VG II: *Acacia tortilis-Maerua oblongifolia*; VG III: *Lycium shawii-Farsetia aegyptiaca*; VG IV: *Farsetia stylosa-Cornulaca monocantha*; VG V: *Suaeda aegyptiaca-Salsola imbricata-Prosopis farcta* and VG VI: *Xanthium strumarium-Ochradenius baccatus*.

The application of DCA confirmed the separation among these communities. A Detrended Correspondence Analysis (DCA) also confirmed the separation of the same six vegetation groups, by placing them along two primary axes AX1 and AX2 (Fig. 3b).

3.3. The relationship between the distribution of the designated sites and soil characteristics

There was a definite relation between sites distribution and environmental variables along the AX1 axis (Fig. 4, Table 5), where

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Table 1
The distribution of study samples and their locations.

| No. | Dam Site | GPS Location | Stand no. |
|-----|----------|--------------|-----------|
| 1   | Riyadh   | 24°46′29.2″N 46°31′52.7″E | 1,2,3,4,5,6,7 |
| 2   | Hail     | 26°49′19.2″N 41°36′08.5″E | 22,23,24,25,26,27,28 |
| 3   | Bisha    | 19°41′46.2″N 42°29′14.4″E | 8,9,10,11,12,13,14,15,16,17,18,19,20,21 |
| 4   | Jizan    | 17°02′56.5″N 42°57′27.5″E | 29,30,31,32,33,34,35 |
| 5   | AlQassim | 26°11′57.2″N 44°01′24.4″E | 24,25,26,27,28,29,30,31,32,33,34,35 |

Table 2
Composition of plant species and families, genera, life forms and biogeographic affinities in the dam locations.

| Floristic variables | Upstream site | downstream site | Undammed site | Total |
|---------------------|---------------|-----------------|---------------|-------|
|                     | No. | %  | No. | %  | No. | %  | No. | %  |
| **Floristic Diversity** |     |     |     |     |     |     |     |     |
| Species number | 108.0 | 71.5 | 107.0 | 70.8 | 36.0 | 23.8 | 151.0 | 100.0 |
| Family number | 33.0 | 91.6 | 28.0 | 73.5 | 18.0 | 27.3 | 68.0 | 39.74 |
| Genera number | 90.0 | 76.9 | 86.0 | 73.5 | 32.0 | 27.3 | 117.0 | 100.0 |
| Life form | 47.0 | 76.3 | 44.0 | 73.3 | 13.0 | 21.6 | 60.0 | 39.74 |
| Annual herb | 8.0 | 72.7 | 10.0 | 90.9 | 1.0 | 9.09 | 11.0 | 7.28 |
| Perennial grass | 7.0 | 63.6 | 7.0 | 63.6 | 1.0 | 9.09 | 11.0 | 7.28 |
| Perennial herb | 17.0 | 60.71 | 17.0 | 60.71 | 8.0 | 28.5 | 28.0 | 18.54 |
| Shrub | 14.0 | 60.86 | 15.0 | 65.21 | 9.0 | 39.13 | 23.0 | 15.23 |
| Sub-shrub | 11.0 | 84.61 | 10.0 | 76.9 | 1.0 | 7.69 | 13.0 | 8.61 |
| Tree | 4.0 | 80.0 | 4.0 | 80.0 | 3.0 | 60.0 | 5.0 | 3.31 |
| **Chorological distribution** |     |     |     |     |     |     |     |     |
| Monoregional elements | 33.0 | 30.56 | 30.0 | 28.84 | 13.0 | 36.11 | 24.0 | 27.81 |
| Biregional elements | 17.0 | 15.74 | 16.0 | 14.95 | 4.0 | 11.11 | 22.0 | 14.57 |

Fig. 2. The climatic zones in Saudi Arabia after (Alrashed and Asif 2015).
the values of sand, EC, Ca, Fe and species richness were positively correlated by \(r = 0.50, 0.62, 0.81, 0.75, 0.50\), respectively. While the silt ratio was negatively correlated with the AX1 axis by \(r = -0.54\). Na \(r = 0.43\) was correlated positively with the AX2 axis while Shannon \(r = -0.42\) was correlated negatively with that axis.

### 3.4. The relationship of plant distribution correlation with soil variables

The woody plants in the upper negative left side of the axis AX1 were associated with values of clay, Silt, O.M., and Simpson, and these plants include Acacia gerrardii, Heliotropium curassavicum, Lawsonia inermis and Acacia oerfota (Fig. 5). Xerophytes plant at the upper positive right-hand side of the axis AX1 were associated with K, Na, Ca, Fe, Mg and EC, and among these plants were Echinops spinosissimus, Lepidium aucheri and Sperratedia diandra. Psammophytes located in the lower negative right of the axis AX2 were also associated with sand, soil pH, Shannon and species richness and the number of Total plant species such as Rumex vesicarius, Aizoon canariense, Lycium shawii, Zilla spinosa, and Emex spinosa. While, the ruderal plants located at the negative left side of the axis AX2 were associated with N, P species evenness, and total cover (e.g. Xanthium strumarium subsp. brasilicum, Haloxylon salicornic, Citrullus colocynthis, Teucrium polium, and Aristida adscensionis).

### 3.5. The relationship of the diversity indices with soil factors

A correlation analysis matrix confirms the relationships between diversity indices and edaphic factors (Table 6). It was found that the total species number was correlated positively with pH \(r = 0.436\), and the total plant cover was negatively correlated with clay \(r = 0.362\). While the species richness was positively cor-
Table 3
Synoptic table of plant species in six vegetation clusters after the application of TWINSPAN. The six vegetation groups are: VGI: *Acacia tortilis*-Maerua oblongifolia; VG II: *Acacia tortilis*-Maerua oblongifolia; VG III: Lycium shawii-Farsetia aegyptiaca; VG IV: *Farsetia stylosa-Cornulaca monocantha*; VG V: *Suaeda aegyptiaca-Salvadora imbricata-Prosopis farcta* and VG VI: *Xanthium strumarium-Ochradenus baccatus*.

| Group No. | No. of relevés | Family | Life form | Chorotype | 1 | 2 | 3 | 4 | 5 | 6 |
|-----------|----------------|--------|-----------|-----------|---|---|---|---|---|---|
| Acacia gerrardii | Fabaceae | SA | Shrub | – | 82.2 | – | – | – | – | – |
| Caralluma retroversa | Asclepiadaceae | SA + SZ | Perennial herb | 72.5 | – | – | – | – | – | – |
| Dactylolostemon scindicum | Poaceae | TR | Perennial grass | 72.5 | – | – | – | – | – | – |
| Setaria verticillata | Poaceae | TR | Annual grass | 72.5 | – | – | – | – | – | – |
| Blepharis ciliaris | Acanthaceae | SA-IT | Perennial herb | 62 | – | – | – | – | – | – |
| Cenchrus ciliaris | Poaceae | SA | Perennial grass | 62 | – | – | – | – | – | – |
| Aerva lanata | Amaranthaceae | SA-SI-SZ | Annual herb | 62 | – | – | – | – | – | – |
| Trianthemum triquetra | Aizoaceae | Med-SA-IT | Annual herb | 62 | – | – | – | – | – | – |
| Senia alexandrina | Poaceae | SM | Shrub | 50 | – | – | – | – | – | – |
| Ochthochloa compressa | Poaceae | SM | Perennial grass | 50 | – | – | – | – | – | – |
| Stipagrostis uniplumis | Poaceae | SA | Perennial grass | 50 | – | – | – | – | – | – |
| Elyanina indica | Poaceae | TR | Annual herb | 50 | – | – | – | – | – | – |
| Salvadora persica | Salvadoraaceae | SM | Shrub | 50 | – | – | – | – | – | – |
| Chloris barbata | Poaceae | AM | Shrub | 50 | – | – | – | – | – | – |
| Prosopis julifora | Fabaceae | AM | Shrub | 50 | – | – | – | – | – | – |
| Sporobolus prolificus | Poaceae | SA-IT-EA | Perennial grass | 34.9 | – | – | – | – | – | – |
| Indigofera spinosa | Fabaceae | SA | Shrub | 34.9 | – | – | – | – | – | – |
| Seuverum portulosum | Aizoaceae | TR | Perennial herb | 34.9 | – | – | – | – | – | – |
| Cissus rotundifolius | Vitaceae | TR-AF | Perennial herb | 34.9 | – | – | – | – | – | – |
| Indigofera semintiuida | Fabaceae | SM | Perennial grass | 34.9 | – | – | – | – | – | – |
| Acacia oeifula | Fabaceae | SA-IT | Shrub | 34.9 | – | – | – | – | – | – |
| Scoparia dulcis | Scrophulariaceae | TR | Perennial herb | 34.9 | – | – | – | – | – | – |
| Zahraa pentandra | Aizoaceae | SM | Perennial grass | 34.9 | – | – | – | – | – | – |
| Dactylolostemon aegyptium | Poaceae | TR | Perennial grass | 34.9 | – | – | – | – | – | – |
| Abutilon bidentatum | Malvaceae | SA | Subshrub | 34.9 | – | – | – | – | – | – |
| Lawsonia inermis | Lythraceae | SU-ZA | Tree | 34.9 | – | – | – | – | – | – |
| Tephrosia nubic | Fabaceae | TR-AF | Perennial herb | 7.3 | – | – | – | – | – | – |
| Tribulus pentacentus | Zygophyllaceae | SM | Annual herb | 91.3 | – | – | – | – | – | – |
| Calotropis procera | Asclepiadaceae | SM | Shrub | 70 | – | – | – | – | – | – |
| Conyza bonariensis | Asteraceae | TR-AM | Annual herb | 62 | – | – | – | – | – | – |
| Lotus arabicus | Fabaceae | SA-SI-SU-ZA | Annual herb | 62 | – | – | – | – | – | – |
| Acacia tortilis | Fabaceae | SA | Shrub | 62 | – | – | – | – | – | – |
| Chloris virgata | Poaceae | TR | Annual grass | 50 | – | – | – | – | – | – |
| Maerua oblongifolia | Poaceae | SM | Shrub | 50 | – | – | – | – | – | – |
| Ricinus communis | Euphorbiaceae | SA-SM | Shrub | 50 | – | – | – | – | – | – |
| Retama raetam | Fabaceae | SA | Shrub | 50 | – | – | – | – | – | – |
| Amaranthus albus | Aizoaceae | AM | Annual herb | 50 | – | – | – | – | – | – |
| Verbescina encleoides | Poaceae | AM | Annual herb | 50 | – | – | – | – | – | – |
| Xanthium brasiliicum | Asteraceae | EU-Med | Annual herb | 50 | – | – | – | – | – | – |
| Heliotropium curassavicum | Boraginaceae | AM | Perennial herb | 34.9 | – | – | – | – | – | – |
| Anticharis linearis | Scoripthraliaceae | SA-IT | Annual herb | 34.9 | – | – | – | – | – | – |
| Portulaaca oleracea | Portulaeaceae | COSM | Annual herb | 34.9 | – | – | – | – | – | – |
| Indigofera oblongifolia | Fabaceae | SM | Shrub | 34.9 | – | – | – | – | – | – |
| Molikiosis ciliata | Boraginaceae | SM | Shrub | 34.9 | – | – | – | – | – | – |
| Gypsophila capillaris | Caryophyllaceae | SA | Annual herb | 34.9 | – | – | – | – | – | – |
| Cleome amphylocarpia | Cleomeaceae | SA | Perennial herb | 34.9 | – | – | – | – | – | – |
| Rumex dentatus | Polygonaceae | Med-IT-ES | Annual herb | 34.9 | – | – | – | – | – | – |
| Typha domingensis | Typhaceae | Med-IT-SA | Perennial Shrub | 34.9 | – | – | – | – | – | – |
| Echinops spinosissimus | Asteraceae | SA | Perennial herb | 34.9 | – | – | – | – | – | – |
| Pluchea dioecoridis | Asteraceae | SA-SI-SZ | Shrub | 34.9 | – | – | – | – | – | – |
| Datura stramonium | Solanaceae | AM | Annual herb | 34.9 | – | – | – | – | – | – |
| Digitaria ciliaris | Poaceae | TR | Annual grass | 34.9 | – | – | – | – | – | – |
| Heliotropium longiflorum | Boraginaceae | SM | Perennial herb | 34.9 | – | – | – | – | – | – |
| Echinochloa colona | Poaceae | TR | Annual grass | 34.9 | – | – | – | – | – | – |
| Zilla spinosa | Brassicaceae | EU-Med-IT | Shrub | 81.6 | – | – | – | – | – | – |
| Picris babylonica | Asteraceae | SA | Annual herb | 82.2 | – | – | – | – | – | – |
| Diplotaxis acris | Brassicaceae | Med-IT-TR | Annual herb | 82.2 | – | – | – | – | – | – |
| Scroceopulus arabicus | Caryophyllaceae | SA-IT | Annual herb | 82.2 | – | – | – | – | – | – |
| Asphodelus fistulosus | Asphodelaceae | Med | Perennial herb | 82.2 | – | – | – | – | – | – |
| Spargula falax | Caryophyllaceae | SA | Annual herb | 82.2 | – | – | – | – | – | – |
| Isatis lusitanica | Brassicaceae | Med-IT | Annual herb | 72.5 | – | – | – | – | – | – |
| Calandula arvensis | Asphodelaceae | Med-IT | Annual herb | 62 | – | – | – | – | – | – |
| Centaurea pseudosinica | Asteraceae | SA | Annual herb | 62 | – | – | – | – | – | – |
| Echinops glabertius | Asteraceae | SA | Perennial herb | 50 | – | – | – | – | – | – |
| Rostaria pumila | Poaceae | Med-SA-SI | Annual grass | 50 | – | – | – | – | – | – |
| Emex spinosa | Polygonaceae | IT | Annual herb | 50 | – | – | – | – | – | – |
| Echium rauwolfia | Boraginaceae | SZ | Annual herb | 50 | – | – | – | – | – | – |
| Chenopodium mural | Chenopodiaceae | SA-IT | Annual herb | 50 | – | – | – | – | – | – |
| Paronychia arabica | Poaceae | TR-AF | Annual herb | 50 | – | – | – | – | – | – |
| Trichodesma Africana | Boraginaceae | SA | Shrub | 50 | – | – | – | – | – | – |
| Notocerus bicorne | Brassicaceae | SA | Annual herb | 50 | – | – | – | – | – | – |

(continued on next page)
| Group No. | Family                  | Life form | Chorotype | 1 | 2 | 3 | 4 | 5 | 6 |
|----------|-------------------------|-----------|-----------|---|---|---|---|---|---|
| Tribulus terrestris | Zygophyllaceae | SA-SM | Annual herb | – | – | 34.9 | 1 | – | – |
| Teucrium polium | Lamiaeceae | SA | Subshrub | – | – | 50 | – | – | – |
| Plantago clitoria | Plantaginaceae | SA | Annual herb | – | – | 34.9 | – | – | – |
| Aizozone canariense | Aizoaceae | SM | Annual herb | – | – | 34.9 | – | – | – |
| Paritaria alsinifolia | Urticaceae | Med | Annual herb | – | – | 34.9 | – | – | – |
| Lycium shawii | Solanaceae | SA | Shrub | – | – | 34.9 | – | – | – |
| Plantago ovata | Plantaginaceae | SA-IT | Annual herb | – | – | 34.9 | – | – | – |
| Aristida adscensionis | Poaceae | Med-IT-SA | Perennial grass | – | – | 34.9 | – | – | – |
| Avnilla ginricia | Asteraceae | SA | Subshrub | – | – | 34.9 | – | – | – |
| Acacia ehrenbergiana | Fabaceae | SM | Shrub | – | – | 34.9 | – | – | – |
| Salvia deserti | Lamiaeceae | SA | Subshrub | – | – | 34.9 | – | – | – |
| Farsetia stylosa | Brassicaceae | SA | Perennial herb | – | – | 100 | – | – | – |
| Launaea nudicaulis | Asteraceae | SA-SI-TR | Annual herb | – | – | – | 100 | – | – |
| Plantago boissieri | Plantaginaceae | SA-SM | Annual herb | – | – | 100 | – | – | – |
| Cornusca monacantha | Chenopodiaceae | SA-SI | Shrub | – | – | 100 | – | – | – |
| Polycarpae repens | Caryophyllaceae | SH-SM | Perennial herb | – | – | 100 | – | – | – |
| Eragrostis barbieri | Poaceae | SM | Perennial grass | – | – | 80 | – | – | – |
| Sueda aegyptica | Chenopodiaceae | SA | Annual herb | – | – | – | – | 89.8 | – |
| Salsoa imbricata | Chenopodiaceae | SA | Subshrub | – | – | – | – | 89.8 | – |
| Chenopodium album | Chenopodiaceae | TR | Annual herb | – | – | 89.8 | – | – | – |
| Spergularia diandra | Caryophyllaceae | Med-IT-Eu | Annual herb | – | – | 79.1 | – | – | – |
| Cressa cretica | Convolvolaceae | PAL | Annual herb | – | – | 79.1 | – | – | – |
| Chenopodium glaucum | Chenopodiaceae | Med | Annual herb | – | – | 79.1 | – | – | – |
| Bascia erophora | Chenopodiaceae | SA-SM | Annual herb | – | – | 79.1 | – | – | – |
| Tetraena simplex | Zygophyllaceae | SM | Annual herb | 1 | – | – | 69.6 | – | – |
| Polyggon monospermiensis | Poaceae | Med-IT-SA | Annual grass | – | 1 | – | 69.6 | – | – |
| Fumaria servilia | Asteraceae | Med-IT | Subshrub | – | – | 67.4 | – | – | – |
| Oligomeris linifolia | Resedaceae | Med-SA-SZ | Annual herb | – | – | 67.4 | – | – | – |
| Senecio flavus | Asteraceae | SA-IT | Annual herb | – | – | – | 67.4 | – | – |
| Prosopis farcta | Fabaceae | SS-TT | Shrub | – | – | 54.2 | – | – | – |
| Mesembryanthemum nodiflorum | Aizoaceae | Med-SA-Eu | Annual herb | – | – | 54.2 | – | – | – |
| Lolium rigidum | Poaceae | Med-IT | Annual grass | – | – | 54.2 | – | – | – |
| Phragmites australis | Poaceae | Med-IT-SA-SM | Perennial grass | – | – | – | 54.2 | – | – |
| Diplotaxis hatra | Brassicaceae | SA | Annual herb | – | – | 37.8 | – | – | – |
| Sueda vermiculata | Chenopodiaceae | SA | Perennial herb | – | – | 37.8 | – | – | – |
| Lepidium acheri | Brassicaceae | IR-TR | Annual herb | – | – | 37.8 | – | – | – |
| Fumaria parviflora | Papaveraceae | Med | Annual herb | – | – | 37.8 | – | 37.8 | – |
| Heliotropium aegyptiacum | Boraginaceae | SA | Subshrub | – | – | 37.8 | – | – | – |
| Conza stricta | Asteraceae | SA-TR-IT | Perennial herb | – | – | 37.8 | – | – | – |
| Trigonella anguina | Fabaceae | SA | Annual herb | – | – | 37.8 | – | – | – |
| Frankenia pulverulenta | Frankeniaceae | ES-Med-IT | Annual herb | – | – | 37.8 | – | – | – |
| Asphodelus tenuifolius | Asphodelaceae | SA-SM | Annual herb | – | – | 37.8 | – | – | – |
| Asphodelaceae | Boraginaceae | SA-IT | Annual herb | – | – | 37.8 | – | – | – |
| Xanthium strumarium | Asteraceae | EU-Med | Annual herb | – | – | – | – | – | 81.3 |
| Ochradenus baccatus | Resedaceae | SA-SM | Shrub | – | – | – | – | 79.1 | – |
| Salsola cyclophylla | Chenopodiaceae | SA | Shrub | – | – | 54.2 | – | – | – |
| Atriplex halimus | Chenopodiaceae | Med-SA-SI-TR | Shrub | – | – | 54.2 | – | – | – |
| Panicum maximum | Poaceae | TR-EA | Perennial grass | – | – | – | 54.2 | – | – |
| Carthamus oxyantha | Asteraceae | SA | Subshrub | – | – | – | 37.8 | – | – |
| Tribulus macropterus | Zygophyllaceae | TR AF | Subshrub | – | – | – | 37.8 | – | – |
| Avena fatua | Poaceae | Med | Annual grass | – | – | – | 37.8 | – | – |
| Casca campestris | Cuscutaceae | AM | Annual herb | – | – | – | 37.8 | – | – |
| Echinops ericanus | Asteraceae | IT | Perennial herb | – | – | – | 37.8 | – | – |
| Zygophyllum coccineum | Zygophyllaceae | SA | Perennial herb | – | – | – | 37.8 | – | – |
| Catapodium rigidum | Poaceae | Med | Annual grass | – | – | – | 37.8 | – | – |
| Heliotropium baciferum | Boraginaceae | SA | Subshrub | – | – | 33.8 | – | – | – |
| Cynodon dactylon | Poaceae | SA-IT | Perennial grass | 18.5 | – | – | 23.3 | – | – |
| Fagonia indica | Zygophyllaceae | SA | Perennial herb | – | – | 34.5 | – | – | 53.4 |
| Acacia etbaica | Fabaceae | SM | Tree | 1 | – | – | – | – | 69.6 |
| Capparis spinosa | Capparaceae | SA-IT | Shrub | – | – | 20 | 60 | – | – |
| Pulicaria incisa | Asteraceae | SA-SZ | Perennial herb | – | – | 56.8 | – | – | – |
| Tamaria rotata | Tamaricaceae | SA | Shrub | 5.2 | – | – | 56.8 | – | – |
| Citrullus colocynthis | Cucurbitaceae | SA | Perennial herb | 16.9 | 16.9 | 2 | – | – | – |
| Anaisociodan lanatam | Apiaceae | SA | Annual herb | – | – | 35.6 | – | 15.5 | – |
| Polygonum argyroceleon | Polygonaceae | IR-TR | Annual herb | – | – | 2.0 | 16.7 | 2.0 | 0.17 |
| Forskailles tenaximisa | Urticaceae | SA-SM | Perennial herb | – | – | 50 | – | 50 | – |
| Malva parviflora | Malvaceae | SA-SM | Annual herb | – | – | 54.2 | 23.9 | – | – |
| Cylindria hexagona | Resedaceae | SH-SM | Shrub | – | – | 20 | – | – | – |
| Solanum nigrum | Solanaceae | SM | Annual herb | – | – | 23.3 | – | – | – |
| Basma muricata | Chenopodiaceae | SA | Annual herb | – | – | 42 | – | – | – |
| Anastasia hierochuntica | Brassicaceae | SA | Annual herb | – | – | 2.5 | – | – | – |
| Rumes vescarius | Polygonaceae | SA | Annual herb | – | – | 37.5 | – | – | – |
| Sisymbrium irio | Brassicaceae | Med-SA | Annual herb | – | – | 50.9 | – | – | – |
| Stipa capensis | Poaceae | SA-SM | Annual grass | – | – | 50 | – | – | – |
| Fagonia brugueri | Zygophyllaceae | SM | Perennial herb | 4.6 | 34.4 | 19.5 | – | – | – |
related with sand, pH, and Fe (r = 0.336, 0.668, 0.385), respectively, and a negative correlation was observed with silt (r = –0.377). The species evenness has a negative correlation with P (r = 0.430). The Shannon index has shown a positive correlation with pH (0.477), while the Simpson index was associated negatively with pH (r = –0.420) and Fe (r = –0.35) content.

3.6. Soil properties of plant associations

The plant community of VGI: *Acacia gerrardii- Caralluma retrospiciens* community characterized by the high percentage of silt (32.84%) and Simpson index (0.22), while the low values were K, Mn, species richness and Shannon index values (3.58, 0.002, 2.08, 0.002) respectively (Table 7). The *Acacia tortilis-Maerua oblongifolia* community VG II had the high values of species cover (208.57 m/100 m), while the low value was recorded with clay (8.34%) and pH (7.29).

*Farsetia aegyptiaca* VG III had the high values of pH, total plant species, the species richness, species evenness and Shannon index (8.37, 17.75, 4.00, 0.91, 1.11), respectively, while the EC, Ca, Mg, and Simpson index had the lowest values of (0.12, 9.58, 2.06, 0.08), respectively. The plant community of *Farsetia stylosa-Cornulaca monocantha* VG IV had the high values in the sand, EC, Na, Ca, K, Mg, N and P (82.40, 1.92, 74.82, 247.92, 57.72, 30.39, 10.30, 2.93) respectively, while the O.M., silt and species evenness (1.72, 5.15, 0.77), respectively. Finally, the community dominated by *Xanthium strumarium-Ochradenus baccatus* VG VI had high contents of O.M. (3.36%), and clay (19.41%), while sand, Na, Fe, P, and the total number of species had the lowest values (54.72, 6.68, 0.40, 0.04, and 9.33), respectively.

4. Discussion

Climate change, population growth, and other anthropogenic factors have increased global demand for water, particularly in arid zones. Dam construction is one of the main strategies for storing and protecting runoff water for consumption and agricultural needs. Despite these socioeconomic roles, desert reservoirs fell into controversy because of their complex impact on desert ecosystems such as their influence over climate, ability to modify sedimenta-
Table 5
The Person simple correlation coefficient (r) between environmental variables and DCA axes. The significant values are in bold, * p ≤ 0.05, ** p ≤ 0.01, *** p ≤ 0.001.

| NAME                          | AX1  | AX2  | AX3  | AX4  |
|-------------------------------|------|------|------|------|
| O.M. %                        | −0.3771 | 0.3403 | 0.2128 | 0.0396 |
| Silt %                        | −0.5486** | 0.4987* | −0.0697 | −0.0321 |
| Sand %                        | 0.0014 | 0.3603 | 0.5733 | 0.4568 |
| E.C. mS/cm                    | 0.6284** | 0.5062** | −0.1037 | −0.1672 |
| pH                            | 0.4956** | −0.2562 | 0.2891 | −0.3763 |
| Na mg/L                       | 0.1302 | 0.4329* | 0.2062 | −0.2641 |
| Ca mg/L                       | 0.8106** | 0.3096 | −0.1477 | 0.0564 |
| K mg/L                        | 0.3881 | 0.0593 | 0.1323 | −0.1878 |
| Mg mg/L                       | 0.4130** | 0.4096** | −0.0561 | 0.0321 |
| Fe mg/L                       | 0.0025 | −0.3164 | 0.4068 | −0.285 |
| Mn mg/L                       | −0.2172 | −0.2869 | 0.0994 | −0.0257 |
| N mg/L                        | 0.0736 | −0.2497 | 0.2549 | −0.2856 |
| Total no. of species.         | 0.4289** | −0.4453* | 0.2083 | −0.2577 |
| Total cover %                 | −0.0687 | −0.3805 | −0.6517 | 0.0464 |
| Sp. Richness                  | 0.5042** | 0.3263 | 0.5097 | −0.1706 |
| Sp. Evenness                  | −0.2183 | −0.1505 | 0.3026 | −0.0404 |
| Shannon-H                     | 0.1711 | −0.4236* | 0.2395 | −0.21 |
| Simpson-(C)                   | −0.0766 | 0.2676 | −0.1862 | 0.1244 |

Fig. 5. The relationship of plant species distribution to soil factors that have a significant effect of the direct coordination axes (CCA ordination). For complete species name see Table 2.

Table 6
Correlation between diversity indices and soil factors. The significant values are in bold, * p ≤ 0.05, ** p ≤ 0.01, *** p ≤ 0.001.

| Name                        | O.M. (%) | Silt (%) | Sand (%) | Clay (%) | E.C. mS/cm | pH | Na (mg/L) | Ca (mg/L) | K (mg/L) | Fe (mg/L) | Mg (mg/L) | Mn (mg/L) | N (mg/L) | P (mg/L) |
|-----------------------------|----------|----------|----------|----------|------------|----|-----------|-----------|----------|-----------|-----------|-----------|-----------|----------|
| Total no. of species.       | −0.226   | −0.302   | 0.327    | −0.248   | 0.083      | 0.436** | −0.024    | 0.193     | 0.059    | 0.175     | 0.070     | 0.032     | −0.054    | −0.044   |
| Total. Cover (m/100 m)      | −0.219   | 0.028    | 0.089    | −0.362*  | −0.071     | −0.251  | 0.024     | −0.034    | −0.149   | −0.140    | −0.048    | −0.179    | −0.056    | −0.066   |
| Sp. richness                | −0.154   | 0.385    | 0.336*   | −0.075   | 0.146      | 0.668** | −0.017    | 0.293     | 0.134    | 0.385*    | 0.115     | 0.213     | 0.002     | −0.065   |
| Shannon H                   | 0.176    | 0.038    | −0.045   | 0.044    | −0.040     | 0.310   | 0.019     | 0.072     | −0.294   | 0.252     | 0.077     | 0.238     | −0.080    | −0.43    |
| Simpson-(C)                 | −0.088   | 0.224    | 0.236    | −0.162   | 0.064      | 0.477*  | 0.021     | 0.194     | −0.072   | 0.278     | 0.045     | 0.156     | −0.061    | −0.228   |
|                            | −0.037   | 0.106    | −0.114   | 0.082    | −0.089     | −0.42*  | −0.075    | −0.195    | 0.138    | −0.35*    | −0.063    | −0.237    | 0.047     | 0.298    |
Table 7
Mean and ± standard deviation results of one-way ANOVA summarizing the attributes of each of the six vegetation types according to various environmental and edaphic variables.

| Factor         | VG1            | VG2            | VG3            | VG4            | VG5            | VG6            | Total Mean | F- value |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|------------|----------|
| O. M. (%)      | 3.15 ± 1.67    | 1.94 ± 0.91    | 1.82 ± 1.00    | 1.72 ± 0.58    | 2.18 ± 1.79    | 3.36 ± 1.92    | 2.43 ± 1.50 | 1.337    |
| Silt (%)       | **32.84 ± 17.29** | 17.75 ± 13.37 | 9.53 ± 6.58    | 5.15 ± 5.76    | 6.38 ± 3.17    | 25.87 ± 17.58  | 17.85 ± 15.63 | 4.339** |
| Sand (%)       | 54.86 ± 17.44  | 73.91 ± 14.62  | 79.28 ± 7.67   | **82.40 ± 11.31** | 81.28 ± 4.83   | 54.72 ± 27.16  | 69.63 ± 18.86 | 3.793** |
| Clay (%)       | 12.30 ± 3.61   | **8.34 ± 1.53** | 11.19 ± 1.00   | 12.45 ± 5.56   | 12.34 ± 2.81   | **41.90 ± 17.10** | 12.52 ± 5.84  | 3.287** |
| EC (mS/cm)     | 0.93 ± 0.84    | 0.36 ± 0.24    | **0.12 ± 0.04** | 1.92 ± 1.44    | 8.04 ± 0.13    | 0.35 ± 0.22    | 0.72 ± 0.86  | 4.875** |
| pH             | 7.32 ± 0.19    | **7.20 ± 0.14** | 7.93 ± 10.72   | 7.48 ± 33.66   | 39.58 ± 39.30  | 27.73 ± 31.73  | 7.32 ± 0.13  | 36.23*** |
| Na (mg/L)      | 49.16 ± 32.65  | 20.52 ± 25.61  | 7.93 ± 10.72   | 231.41 ± 184.44 | 73.64 ± 128.23 | 6.68 ± 4.40    | 22.60 ± 13.49 | 6.592*** |
| Ca (mg/L)      | 33.73 ± 25.38  | 36.36 ± 54.72  | **9.58 ± 3.56** | 247.92 ± 301.32 | 27.39 ± 23.25  | 7.29 ± 1.33    | 11.95 ± 18.20 | 9.247*** |
| K (mg/L)       | **3.58 ± 1.35** | 4.51 ± 1.29    | 5.63 ± 2.05    | 30.39 ± 13.72  | 0.01 ± 0.01    | **0.40 ± 0.22** | 0.21 ± 1.44  | 6.705*** |
| Mg (mg/L)      | 5.13 ± 3.64    | 0.54 ± 0.63    | 1.16 ± 1.05    | **30.39 ± 13.72** | 0.01 ± 0.01    | 0.00 ± 0.00    | 0.01 ± 0.02  | 1.527    |
| Mn (mg/L)      | 11.83 ± 9.45   | 5.79 ± 4.17    | **2.06 ± 0.66** | **0.39 ± 0.00** | 0.02 ± 0.00    | 0.02 ± 0.00    | 0.32 ± 2.41  | 4.792** |
| N (mg/L)       | 2.67 ± 1.64    | 3.56 ± 2.70    | 3.24 ± 2.33    | **10.30 ± 3.11** | 0.03 ± 0.01    | 0.00 ± 0.00    | 0.34 ± 2.76  | 4.792** |
| P (mg/L)       | 0.06 ± 0.05    | 0.05 ± 0.03    | 0.35 ± 0.17    | **2.93 ± 4.11** | 0.09 ± 0.15    | 0.04 ± 0.03    | 0.28 ± 0.98  | 5.175** |
| Total species  | 3.71 ± 3.55    | 12.00 ± 4.86   | **17.97 ± 6.35** | 37.00 ± 29.70  | 75.67 ± 81.15  | **9.33 ± 2.34** | 12.77 ± 5.21  | 3.673*** |
| Total Cover    | 80.29 ± 47.14  | 208.57 ± 133.03 | 78.86 ± 70.40  | **3.51 ± 1.67** | 3.80 ± 0.51    | **34.00 ± 12.60** | 94.46 ± 95.30 | 9.340*** |
| Sp. Richness   | 2.98 ± 0.05    | 2.13 ± 0.55    | 4.00 ± 0.97    | **0.77 ± 0.29** | 0.85 ± 0.11    | 2.43 ± 0.77    | 2.89 ± 1.09  | 8.114*** |
| Sp. Evenness   | 0.80 ± 0.09    | 0.82 ± 0.08    | **0.91 ± 0.04** | 0.82 ± 0.09    | 1.00 ± 0.10    | 0.81 ± 0.17    | 0.90 ± 0.21  | 3.436** |
| Shannon H'     | **0.00 ± 0.00** | 0.20 ± 0.19    | **1.11 ± 0.14** | 0.20 ± 0.25    | 0.11 ± 0.07    | 0.19 ± 0.10    | 0.16 ± 0.11  | 2.079    |
| Simpson C      | **0.22 ± 0.13** | 0.18 ± 0.09    | 0.08 ± 0.03    | 0.20 ± 0.25    | 0.11 ± 0.07    | 0.19 ± 0.10    | 0.16 ± 0.11  | 2.079    |

The six vegetation groups are: VG I: Acacia gerrardii; Caralluma reticulata; VG II: Acacia tortilis - Maerua oblongifolia; VG III: Lycium shawii-Farsetia aegyptiaca; VG IV: Farsetia stylosa-Coralluma monochana; VG V: Suaeda aegyptiaca-Salsola imbricata-Prospis fascia and VG VI: Xanthium strumarium-Ochodraeus baccatus. Significant level *P ≤ 0.05, **P ≤ 0.01, ***P ≤ 0.001.
number of therophytes and perennial herbs. This may be due to the ability of this plant community to cope with harsh environmental conditions, as they have a great competitive ability to adapt to this habitat. Additionally, small dams yield relatively small reservoirs, and their leakage may be greater than those of larger dams (Principe 2010). VG IV, Farsetia stylosa - Cornulaca monacantha, which inhabits the small arid dam of Al-Qassim area were characterized with high content of sand, minerals and low organic matter. This community had the lowest species diversity due to the aridity as well as less water availability and represented a xerophytic habitat with adaptive and limited plant species distribution (Alatar et al., 2012, Al-Gifri et al., 2018).

The associations, VG V- Suaeda aegyptiaca-Salsola imbricata-Prospis farcta, and VG VI-Xanthium strumarium-Ochradenus baccatus inhabits the upper and lower zones of the small dams in Al-Qassim and Al-Riyadh respectively, dominated by a high content of clay and organic matter due to high water permeability along with low rainfall, contributed to lower species diversity (Principe 2010). Further, dams potentially change the flood disturbance regime and block the downstream dispersal of plant propagules such as seeds, which will affect the diversity of many wild plants. They may also drown the riparian zone within their impoundments and cause the riparian ecosystem to become fragmented.

From (Fig. 6a and b) it is clear that the species diversity (total species number, species richness and total cover) of the upstream, downstream and riparian habitat zones were higher than that of undammed habitat. As a consequence, vegetation adaptations will be diversified and evolving over time, resulting in a significantly riparian zone and different landscape within the dam reservoir. These modifications will occur as a result of the loss of prior vegetation, possible invasion by exotics and native plants, and major changes in hydrological regimes, as well as erosion and sedimentation events impacting and forming novel plant communities (New and Xie 2008).

Moreover, the average length of time that water remains within the boundaries of an aquatic system is one of the key parameters.
controlling the system’s biogeochemical behavior. This time scale, known as the water residence period, is critical for various and complicated activities in reservoirs (Rueda et al., 2006). There are also reports on the major consequences of reservoirs, which can be characterized as river continuity interruption, silting of wadi bed, homogeneity of ecosystems, downstream wadi bed incision, adjustment of wadi-groundwater exchange and downstream circulation, and water quality modification (Schmutz and Sendzimir 2018). Moreover, the results of the present study showed that the prevailing soil texture in the dam area was loamy soil other than the undammed sites, and this is considered as a good texture for the growth of woody plants and their spread because it helps in deepening the roots to great distances to absorb water from great depths and in drainage quality (Al-Nafi 2005).

5. Conclusion

The construction of a dam or water conductor system creates certain physical, ecological and social changes. In the present study, six plant associations were identified with high floristic diversity and species richness, which inhabited a modified loamy soil in the riparian zones other than undammed zones. Since, dams potentially change the flood disturbance regime and block the downstream dispersal of plant propagules (i.e., seeds), which may cause a downstream change in native and exotic plant species diversity. Dams also drown the riparian zone within their impoundments and cause the riparian ecosystem to become fragmented. The critical thing is to explore and anticipate all environmental and social impacts early in the planning process so that appropriate steps can be taken to avoid, mitigate, or compensate for such impacts.

Data availability

The authors confirm that the data supporting the findings of this study are available within the article.

CRediT authorship contribution statement

Bander M. Al-Munqedhi: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft. Mohamed A. El-Sheikh: Conceptualization, Formal analysis, Funding acquisition, Investigation, Supervision, Writing – original draft, Writing – review & editing. Ahmed H. Alfarhan: Conceptualization, Formal analysis, Funding acquisition, Supervision, Writing – review & editing. Abdullah M. Alkahtani: Investigation. Ibrahim A. Arif: Rajakrshnan Rajagopal: Writing – review & editing. Saud T. Alharthi: Validation.

Declaration of Competing Interest

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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