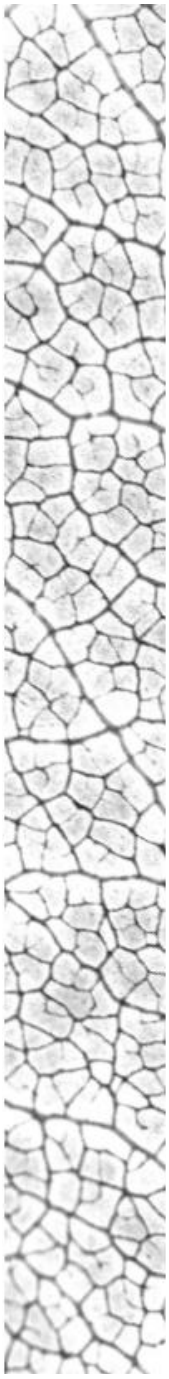

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Assessment of aquatic and semi-aquatic plants in arid regions: Testing factors affecting riparian plant distribution in the Draa Basin, Morocco

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Abstract
The main objective of this work was to study the richness and the effect of abiotic and anthropogenic factors on the distribution of riparian plant in Draa basin, which is part of the Oasis Biosphere Reserve located in South-East of Morocco. For this purpose, water quality parameters such as temperature, pH, salinity, electrical conductivity, Dissolved Oxygen, nitrate and phosphorus concentration, and riparian plants diversity were estimated at 12 stations along the Draa River and its tributaries using phytoecological surveys. The Canonical Correspondence Analysis (CCA) was performed to assess the relationship between environmental parameters, the distribution and abundance of riparian plants inventoried.
The results of the assessment of 12 phytoecological surveys revealed the existence of 86 species of aquatic and semi aquatic plants, divided into 76 genera and 30 botanical families, with 15.11% of the species are endemic and 9.30% as rare and threatened species. The Canonical Correspondence Analysis (CCA) results revealed that the salinity, the conductivity, degree of submersion and the nitrate concentration are the main factors affecting the composition and the distribution of the riparian plants in Draa basin.
Given the increasing human pressure on native riparian plant in the Mediterranean biodiversity hotspot region, including the climate change effects and habitat loss, urgent conservation measures are discussed for this and other riparian plant species.

Keywords: ecological factors, Draa basin, Morocco, floristic composition, phytoecological survey, riparian plant

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INTRODUCTION

The riparian plants that constitute the characteristic group of the riparian zones, they do not represent only reservoirs of biological diversity, but they also perform many functions, including hydrological functions (groundwater recharge, erosion protection, water purification, climate change mitigation), socio-economic functions (drinking water, agriculture, pastoralism, fishing and tourism) (Naiman et al. 2005).

However, like other African countries, riparian plants in Morocco suffer from various socio-economic threats, in particular overgrazing, overexploitation of natural resources, excessive pumping of water for agricultural

needs, pollution due to the discharge of solid and liquid waste, urban extensions, dam construction, and natural drought (Ennabili et al. 1996, Ennabili and Gharnit 2003, Ferchichi-Ben Jamaa et al. 2010). This has also been observed in the upper and middle Draa basins. These latters are part of the Oasis Biosphere Reserve located in South-East of Morocco (OBRSM) due to the originality of its habitats and the natural resources it contains. However, the upper and middle Draa basin is also characterized by a higher frequency of drought due to climate change and the effect of the anthropogenic activities, including the construction of Mansour Eddahbi dam, pasturage, pollution, pumping and drainage, this situation affects the composition, structure and distribution of riparian plants (Ennabili et

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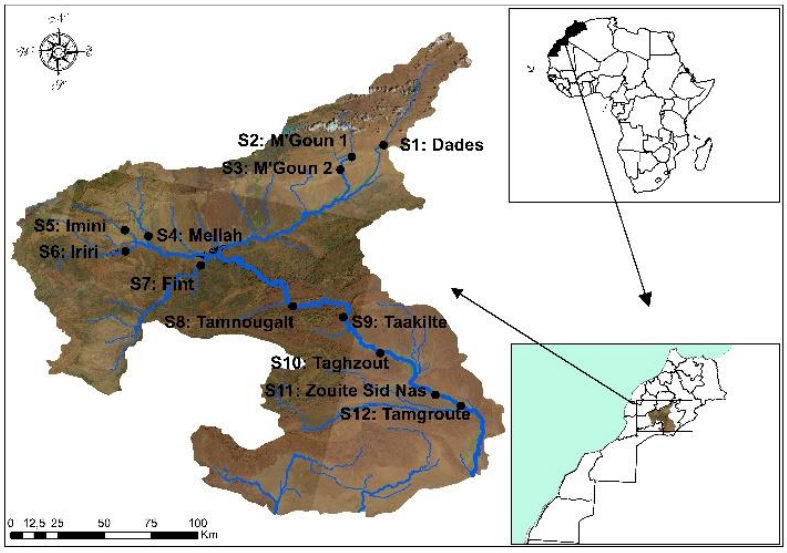

Fig. 1. Geographical location of prospected stations in the upper and middle Draa basin

al. 1996, Hammada, 2007, Fawad et al. 2013). In this sense, understanding and quantifying the environmental and anthropogenic factors that influence the distribution patterns of riparian plants is crucial for integrated management practices of this ecosystem.

Unfortunately, there are almost no studies dedicated to the effect of ecological and anthropogenic factors on the zonation of riparian plants in the Draa basin. Previous studies describe in particular the hydrological, morphological and biological parameters of the basin (de Jong et al. 2008, Heidecke and Heckelei 2010, Warner et al. 2013).

The aims of this work are: (i) the elaboration of an inventory of the riparian vegetation of the rivers of the upper and middle Draa basin, (ii) the characterization of the plant groups in the study area, and (iii) the identification of the ecological and anthropogenic factors determining the zonation of the identified plant groups.

MATERIALS AND METHODS

Study area

Given that the lower part of the Draa basin is completely dry, this study has been carried out in the upper and middle sections of Draa basin. The area is located in South-East of Morocco between latitudes 32.001 N and 29.651 N and between longitudes -7.753 W and -5.391 W, has a total surface area of 31.010 km² and constituted the upstream part of the great Draa basin, which contains about 7% of Morocco's groundwater resources (Agoussine and Bouchaou 2004).

From a geological point of view, the study area is characterized by a diversified geological substrate dominated by ancient Paleozoic rocks concentrated in the Zagora basin (Middle Draa) on which a film of recent sediments rests in discordance. This type of formation consists mainly of schist, sandstone and quartzite. Whereas the upper Draa, around the Ouarzazate basin, it is essentially constituted by neogen-quaternary sediments (Agoussine and Bouchaou 2004).

The study area **(Fig. 1)** is characterized by a weakly dense hydrographic network with two main rivers Dades River and Draa River which receive on their banks the flows of several tributaries among which, we can quote the Mellah, Imini, Iriri, Ouarzazate, Douchene and Fint Rivers. The climate of the basin area is Mediterranean, ranging from subhumid in high altitude areas to sub-saharan climate in low altitude areas (Zagora area) (Agoussine and Bouchaou 2004). Precipitation and temperatures show a great inter and intra-annual irregularity with a succession of dry years over several successive years. The average annual rainfall is around 300 mm in the High Atlas Mountains, 120 mm on the Ouarzazate plateau, and 60 mm in Zagora area (Agoussine and Bouchaou 2004).

Sampling

The approach followed is based on the requirements of the European standard for the study of aquatic plants in rivers (Känel *et al*. 2017). We inventoried 12 stations distributed along the Draa River and its tributaries during the period from March 2018 to July 2019; each station is divided into two parts (right and left bank). The twelve study stations are spaced from each other from 500 m to 1 km from the north to the south of the study area. Six stations were inventoried in the upper Draa (S1: Dades, S2: M'Goun 1, S3: M'Goun 2, S4: Mellah, S5: Imini and S6: Iriri) and the 6 others stations were located in the middle Draa (S7: Fint, S8: Tamnougalt, S9: Taakilte, S10: Taghzout, S11: Zouite Sid Nas and S12: Tamgroute) **(Fig. 1)**.

The choice of the stations was based on ecological and anthropogenic factors that influenced the

morphological, physicochemical and ecological quality of the rivers.

The collections of aquatic plants were mainly carried out during the spring and summer of 2018: this can be justified by the presence and development of the reproductive organs of each species collected such as flowers and fruits in order to better identify it later.

The collected data in the field has been grouped within several parameters: Topographic parameters (geographic coordinates, bank slope, slope exposure, stream flow velocity); Soil parameters (substrate and soil type); The physicochemical parameters of water (maximum water depth, conductivity, salinity, concentration in dissolved oxygen water, pH, nitrate concentration); Anthropogenic parameters (focused in particular on water quality, habitat quality and use of adjacent plots); Biological variables (type of formation and floristic list) with abundance-dominance coefficients for each species estimated by using the (1-5) Braun-Blanquet scale (1932).

Systematic identification of plants was performed by using the available flora literature (Negre 1961, Quezel et Santa 1962-1963, Fennane *et al*. 1999, 2007, 2014). While the determination of the conservation status of the taxa studied was based on the catalogue of vascular plants of Morocco (rare, threatened or endemic) (Fennane and Ibn Tattou 1998). The collected plants were properly dried, pressed and well conserved in the herbarium of the Museum of Natural History of Marrakech.

Data analysis

A canonical correspondence analysis (CCA) was carried out using *Past software* version 3.23 (Hammer et al. 2001) to assess a linear combination of environmental variables (Altitude, type of substratum, depth of water, salinity, conductivity, nitrate, oxygen dissolved) that best explained the distribution of species. The 'Species' matrix contained the maximum abundance (five classes: 1- cover < 5%: 2- 5-25%: 3- 25-50%: 4- 50-75%: 5- >75%) of each station (12) and 'station' matrix contained for each station the variables for the environnemental factors.

RESULTS

Floristic composition

The processing of 12 phytoecological surveys carried out in the Draa River and its tributaries shows an estimated specific richness of 86 aquatic and semi aquatic species, divided between 76 genera and 30 families. The Asteraceae, Poaceae, Brassicaceae, Chenopodiaceae and Zygophyllaceae represent 51.16% of the total specific **(Fig.2 A)**. The highest stationary specific richness is observed in the upstream part of the basin, in particular Dades, M'Goun 1 and M'Goun 2, Iriri and Fint with (n >=17 species).

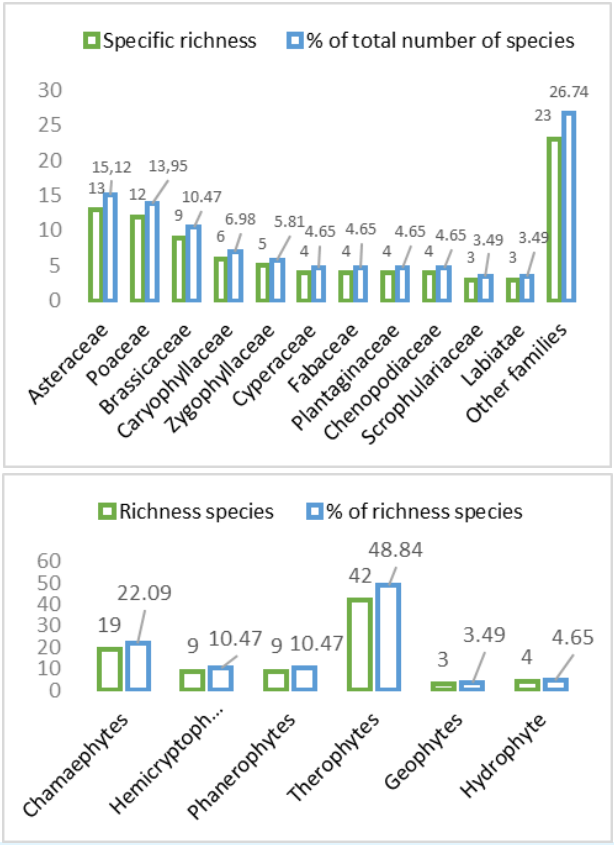

Fig. 2. A) Specific richness and proportion relative of first eleven families of the riparian plants of upper and middle Draa basin. **B)** Biological spectrum and proportion relative of inventoried riparian plants of the upper and middle Draa basin

The determination of the biological types adopted by Raunkiaer (1934) makes it possible to organize the plants according to the positioning of their survival organs and thus of their meristems of growth during the unfavorable period which can be either the hot season, or the cold season.

The 86 species listed belong to 6 biological types **(Fig. 2 B)**. This floristic list is dominated by therophytes (annual) with 42 species (48.84% of the total number), followed by chamaephytes with 20 species (23.26% of the total number), then hemicryptophytes with ten species (11.63%), phanerophytes with nine species (10.47%), hydrophytes with four species (4.65%) and geophytes with only one species (1.16%). Referring to the catalogue of rare, threatened or endemic vascular plants of Morocco (Fennane M and Ibn Tatou M 1998), The rare and threatened species inventoried in Draa River and its tributaries were represented by 8 taxa, whereas 13 species are reported as endemic.

According to the list of halophilic species treated by Hammada *et al*. (2004), Draa River and its tributaries present 11 halophilic species belonging to six different families. Depending on the degree of salinity, we have identified species that are strict halophytes (*Frankenia*

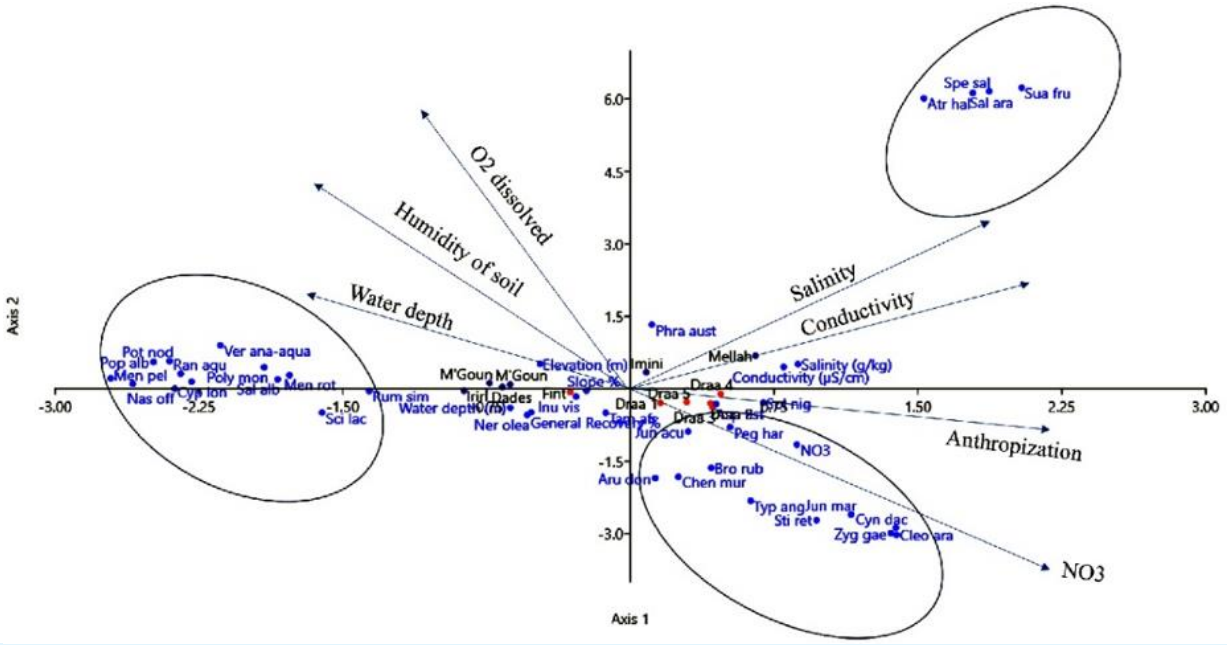

Fig. 3. Relationship between riparian plants species and environmental factors obtained by CCA

pulverulenta L, *Spergularia salina* Presl and *Salicornia arabica* L) and species supporting only a low salt content (*Atriplex halimus* L, *Dittrichia viscosa* L, *Suaeda fruticosa* Forssk, *Plantago coronopus* L, *Phragmite australis* L, *Scirpus lacustris* L, *Sonchus maritimus* L). *Chenopodiaceae* represent the family that includes the majority of halophilic species with three species, which confirms the ability of these species to resist to the salinity of the environment (Hammada *et al*. 2004), This high proportion (12.8%) of halophilic species reflects the salinity of the physical environment.

Typology of plant groups

The CCA revealed the existence of three main axes representing 89.93% (p< 0.05) of the total variability of all the data analyzed **(Fig. 3)**. The first CCA axe that represents the dispersion basis of phytoecological surveys accounting on the 63.05% of the total variance, shows a strong correlation with variables related to salinity (*r= 0.95*) and conductivity of water (*r= 0.88*) (Figure 1). While the second CCA axe accounting on 19.74% of the total variance, was mainly correlated to the water depth (r= 0.71) and O2 dissolved (*r=52*). Finally, nitrate concentration (NO3) was strongly correlated to the third CCA axe (*r=0.90*) accounting on the 7.75% of the explained variance.

For the positive side of axis 1 CCA (63.05%), the higher concentration of salinity and conductivity were positively related to the presence of *Salicornia arabica*, *Frankenia pulverulenta*, *Spergularia salina* and *Sueada fritucosa*, while species like *Arundo donax* L, *Populus alba* L and *Vitex agnus-castus* L, were distributed in the negative side of axis 1 CCA with a low concentration of salinity and conductivity **(Fig.3)**.

Moreover, the axis 2 CCA (19.74 %) reveals the spatial organization of riparian plants related to the depth of water and therefore to the duration of submergence, the examination of the positive side of this axis shows that *Nasturtium officinale* L, *Potamogeton natans* L, *Lemna minor* L, *Vitex agnus castus* L, *Populus alba* L*, Salix sp*, are positively correlated to the water depth and oxygen dissolved, as well as, in the negative side *Phragmite australis* L,

Typha angustifolia L and *Cynodon dactylon* L are found on the sites with a high degree of submersion **(Fig.3).**

Finally, for the positive side of axis 3 CCA (7.05 %), it clearly reflects highly anthropized sites that are essentially dominated by ruderal and nitrophilic species such as, *Chenopodium album* L, *Solanum nigrum* L and *Dittrichia viscosa* L, while for the negative side of axis 3 CCA, there are species with low pollution tolerance, including *Cyperus longus* L*, Scirpus lacustris* L and *Polypogon monspeliensis* L **(Fig.3)**.

DISCUSSION

The riparian plants inventory of the upper and middle Draa Basin, indicates a rich floral diversity **(Fig. 2A)**, which counts 86 aquatic and semi aquatic species apparently similar to the other Moroccan wetlands, listed in sites of international importance (Ramsar site) (Atbib 1979, Allport *et al*. 1994, Ennabili and Ater 2005). The Merja Zerga wetland has an estimated diversity of 120 hygrophilic species, including marsh species, dunes and transition zones, followed by the Sidi Boughaba Marja with 80 species (Atbib 1979). On the other hand, what is remarkable in this study area is the large proportion of rare and threatened taxa estimated at 9.30% of the rare

flora of Moroccan wetlands as well as the fairly high rate of endemism which reaches 15.11% (Fennane and Ibn Tattou 1998). The highest stationary specific richness in the upstream part of the basin can be explained by the soil humidity rate which ensures the good development of aquatic plants (Atbib 1979, Allport *et al*. 1994, Ennabili and Ater 2005).

Furthermore, the high rate of therophytes (48.84%) observed reflect the drying trend of the Draa River and its tributaries **(Fig.2B)** and their adaptation to fluctuating ecological conditions. These constraints favor colonization by species that reverse themselves more in sexual reproduction than in vegetative development (Warwick and Brock 2003).

The results obtained by using CCA reveal that the spatial organization of the riparian vegetation of the surveyed stations clearly reflects a physicochemical gradient of the water, either of natural origin or as a result of human activities related to the construction of the dam and pollution effect.

These gradients were controlled by three groups. The first group represents the physical parameter related to the degree of submersion due to the dam effect. Several researches have been carried to evaluate the effects of water level variation on the distribution of riparian plants (Schwarz and Hawes 1997, Rhazi *et al*. 2006, Kors *et al*. 2012). The second group referred to the chemical parameters such as salinity and the conductivity of water reflected at the origin of the nature of the substrate, while the third group was related to the nutrient gradient, including nitrate (NO3) concentration.

Ionic charge, including salinity and conductivity, is as demonstrated by a lot of research as a key factor for the distribution of riparian plants (Grillas 1990, Christia and Papastergiadou 2007, Bubanja *et al*. 2016). Moreover, the negative reworking of river salinity on the specific richness and structure of riparian plants is designated by Coring et Bäthe (2011). As reported in this study, the extension of the two types of halophilic formation, based on *Spergularia salina* and *Frankenia pulverulenta* in the Mellah River influences the composition and structure of riparian vegetation. Actually, Chehma *et al*. (2005) suggest that plant communities in saline soils are generally poor in terms of specific richness and characterized by the predominance of species specially adapted to soil salinity.

Moreover, it has been shown that hydrological conditions influence the distribution of riparian plants, mainly through water levels fluctuations and therefore the degree of submersion (Makin *et al*. 1976, Spence 1982, Coops *et al*. 1996). In our study, the construction of Mansour Eddahbi dam has an effect on the lowering of the water levels, the degree of submersion and modification of the groundwater supply conditions (Labiad *et al*. 2012), which is why there is an abundance of species that tolerate a high degree of submersion located in downstream of Mansour Eddahbi dam including: *Tamarix Africana* L, *Nerium oleander* L, *Typha angustifolia* L, *Phragmite australis* L, *Juncus acutus* L and these last two species are considered by Atbib (1979, 1980) and Hammada (2007) as species that have a wide ecological amplitude with respect to submergence. Ennabili et Ater (1996) found the same finding for *Typha angustifolia*. While, in the upstream of Mansour Eddahbi dam, we have highlighted the development of emerging species that cannot tolerate a high degree of submersion such as: *Nasturtium officinale, Potamogeton natans, lemna minor, Cyperus longus and Scirpus lacustris*. Kashmir and Pandit (2008) revealed that the depth of water is a significant factor in the abundance, distribution and diversity of these emerging species.

In addition, many studies have proved that nutrient gradients, including nitrate concentration impact significantly the distribution and species composition of plants in aquatic environment (Vestergaard and Sand-Jensen 2000, James *et al*. 2005). Namely, high concentration of nitrates has a negative impact on some species of riparian plants that are sensitive to eutrophication, causing a difference in the distribution of species as well as species richness (Lougheed *et al*. 2001). Our study suggests negative impact of the nitrate concentration on the species richness and the environmental invasion by ruderal and nitrophilic species such as *Chenopodium album, Solanum nigrum and Dittrichia viscosa.* These laters was confirmed by Ennabili and Ater (1996) and Labiad *et al*. (2012) as species adapted to wastewater discharges and wet substrate loaded with solid waste, the presence of the infrastructure and agriculture activities near to the downstream of Draa River could be responsible for the abundance of these ruderal species. Wolff (1987) and Hammada (2007) also highlighted the effect of wastewater discharge on river vegetation, decrease in specific diversity and increase in the number and recovery of ruderal species.

CONCLUSION AND RECOMMENDATIONS

The analysis of the phytodiversity of the Upper and Middle Draa Basin identified 86 vascular species, belonging to 76 genera and 30 botanical families. Endemic species are represented by 13 taxa and the rare or threatened flora consists of 8 taxa. The riparian vegetation of the study area is influenced by several ecological and anthropogenic factors, predominated by salinity, conductivity, degree of submersion and nitrate concentration. These factors are responsible for the appearance and distribution of riparian vegetation. These results open up ways for better management and conservation of the aquatic ecosystem.

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