Floristic study and assessment of the environmental factors governing the distribution of riparian plants in the Zat sub-Basin: Tensift Watershed, Morocco

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1. ABSTRACT

Measuring the phytodiversity and determining environmental factors affecting the abundance and distribution of riparian plants of Zat sub-basin in Morocco were carried out in this study. A hypothesis was tested whether there is any statistically significant difference in environmental parameters and plants communities among the Zat River and its tributaries. 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 17 stations along the Zat River and its tributaries during the periods (2018 and 2019). The Canonical Correspondence Analysis (CCA) and Pearson correlation were preformed to assess the relationship between environmental parameters, and the distribution and abundance of riparian plants inventoried. The presence of 113 species was recorded, distributed between 43 families and 97 genera, 9 of which were floating-leaved, 24 submerged, and 80 emergent plants. The rare and threatened species inventoried were represented by 7 taxa, whereas 6 species are reported as endemic. Raunkiaer classification showed a dominance of therophytes (38.39%) over the other groups. According to CCA, the abiotic parameters (DO, elevation, salinity and nitrate concentration) were statistically significant parameters governing the distribution and abundance of the riparian plants inventoried. The results obtained reveal the state of the riparian vegetation in the Zat sub-Basin, therefore we can consider them as a reliable component for the assessment of the ecological status of the aquatic environment.

2. INTRODUCTION

Aquatic plants represent an essential component of freshwater ecosystems (Lacoul and Freedman, 2006), they designate large aquatic plants (bryophytes, pteridophytes and spermatophytes) as well as filamentous algae that are visible and usually identifiable to the naked eye in the field (Haury *et al.,* 2001). Aquatic plants come in 3 different types: hydrophytes (fully submerged), helophytes (marsh plants growing "feet in the water"), and amphiphytes or Riparian vegetation (plants growing in the transition zone between the terrestrial and aquatic environment) (Adam, 2015). It is a well-known fact that the Mediterranean basin contains a high aquatic plants richness (Bubanja *et al.,* 2016), but even so, it has experienced nowadays a decrease in their composition, abundance, distribution and diversity (El Madihi *et al.,* 2017). One of the significant factors that have a strong impact on the decline of the species richness is the anthropogenic factors (Elo *et al.,* 2018) for instance; agriculture, drainage and human pressure (Rhazi *et al.,* 2012). Furthermore, other factors have an impact on the distribution and the composition of the communities of aquatic plants such as climate change, hydrology, geology, and physicochemical parameters of water (Dar *et al.,* 2014; Bubanja *et al.,* 2016). Aquatic plants are well known for their ecological importance. They perform many functions, including serving as shelters and feeding sites for certain life forms such as invertebrates, fish and some water birds, ensuring the moderation of stream water temperature via evapotranspiration and shading, in addition to that, providing a buffer zone that filters sediments, controls nutrients and stabilizes the stream banks (Richardson *et al.,* 2007; Thomaz and De Cunha, 2010; Rooney *et al.,* 2013). Moreover, they are considered as a bio-indicators (Dar *et al.,* 2014; Grand *et al.,* 2012) since they can provide valuable information on the health status of aquatic environments (Chauvin *et al.,* 2014). Hence the need to study them and to know the impact of all listed factors on their specific richness in order to better conserve and preserve them (Rhazi *et al.,* 2012). The Zat Sub-Basin is one of the most watered sub-basins of Tensift of High Atlas of Morocco, located 50 km south of Marrakech and unfortunately subject to a significant degradation of its surface and groundwater resources by different sources of liquid and solid pollution (AHT GROUPE, 2016). Therefore, it seems essential to assess the composition and understand the factors affecting the presence and abundance of aquatic plants in this sub-Basin for further management and maintenance perspectives. The general objectives were to elaborate a checklist of all the aquatic plants observed in different localities of Zat River and its tributaries, and figure out the environmental and anthropogenic factors that affect them. Specifically, this study sought to: 1) Assess the main factors that have a strong effect on the aquatic plant communities 2) Determine the specific richness and the abundance dominance of these aquatic plants according to these factors.

3. MATERIALS AND METHODS

3.1 **Study area:** The Zat Sub-basin belongs to the Tensift River hydraulic system; it is drained by Zat River, which measures 89 km with an average longitudinal slope of 3.83%. It is a part of the Tensift basin, which includes about ten sub-watersheds. It is bounded to the East by the Ghdat sub-Basin, to the South by the High Atlas Mountains, to the North by the Tensift River and to the West by the Ourika sub-Basin.
It is characterised by an arid to semi-arid climate in the downstream and sub-humid in the high mountains (Ait Mlouk *et al.,* 2015). The geology of this sub watershed is composed of Cambrian, Acadian and Ordovician Paradoxidic shales with predominantly schistose facies, Tournaisian Upper Visean with predominantly limestone facies, Permo-triassic sandstones and clays and Cenomanian and Senonian marl limestone structures (AHT GROUPE, 2016). The climate in this region is Mediterranean with a cold and rainy winter (an average annual rainfall of 382 mm) from October to April and a hot and dry summer (5.2°C-37.1°C) from May to September (Lovich *et al.,* 2010; AHT GROUPE, 2016). This study included 17 localities of different types (Figure. 1), from the downstream of the Zat River to its upstream, 3 of them are the most surveyed: stagnant water areas, springs and tributaries.

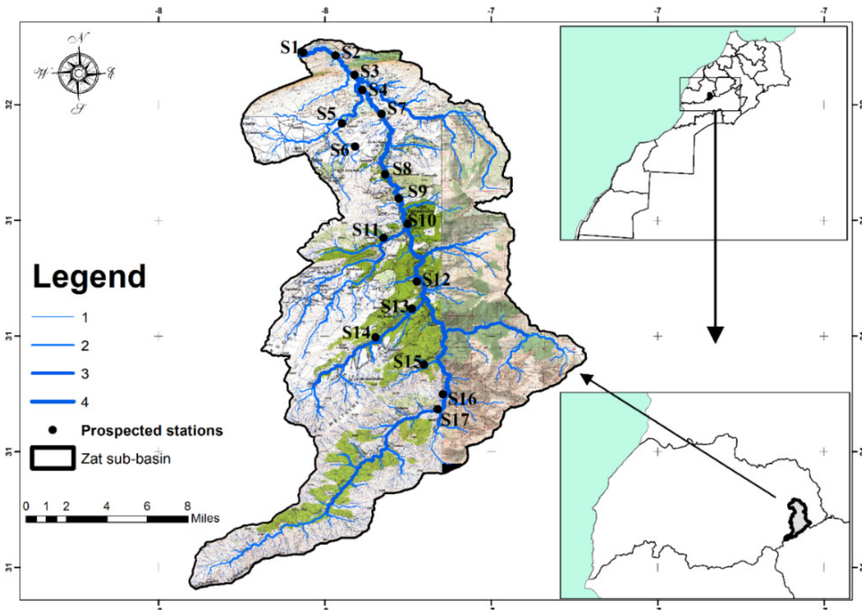

Figure 1. Geographical location of prospected stations in the Zat sub-Basin.

3.2 Floristic data: This study was conducted from March 2018 to February 2019. According to the European standard for the study of macrophytes in rivers (Känel *et al.* 2017), the census of the flora was carried out twice to thrice a month. The collections of the aquatic plants were essentially made during the spring and summer of 2018: this can be justified by the presence and the development of the reproductive organs of each collected species such as flowers and fruits in order to better identify it later. In addition to that, the stations have been chosen on the basis of the ecological and anthropogenic factors which affect the morphology and the health state of the plants and their habitat. Transects were made every 100 m, since some of the localities were devoid of vegetation due to the high flow of water. The collected samples were properly dried and pressed and well conserved in newspaper in the herbarium of the Museum of Natural History of Marrakech, and then their identifications were mainly done by using The Moroccan flora of (Fennane *et al.* 1999; 2007; 2014). Specific richness was figured out by calculating the total number of the identified species. As for the conservation status of the taxa a catalogue of vascular plants of Morocco developed by Fennane and Ibn Tattou (1998) has been used.

3.3 Water sampling: The water samples were collected from 17 localities from March 2018 to February 2019. The mean values of physicochemical parameters were used in further statistical analysis. The parameters that were mainly assessed are: the pH, water temperature, salinity, conductivity and Dissolved Oxygen (DO), nitrate concentration (NO3) and water level. All these measures were carried out in the field by using portable meter the *Hanna Multiparameters HI9829*.

3.4 Statistical analysis of data: The statistical tools such as correlation test and the Canonical Correspondence Analysis (CCA) were performed in this study using *Past software version 3.23* (Hammer *et al.,* 2001). Pearson correlation (*r*) test was carried out to identify the association between pairs of variables for sampling stations and the number of species, while the CCA was preformed to identify the relationship between environmental variables for sampling stations and riparian plants inventoried affected each by the maximum abundance coefficient using the Braun-Blanquet scale (1932) (five classes : 1- cover < 5% : 2- 5-25% : 3- 25-50% : 4- 50-75% : 5- >75%).

4 RESULTS

4.1 Floristic composition: In the 17 phytoecological surveys carried out in the Zat River and its tributaries, the specific richness of the sampled areas is estimated at 113 species grouped belonging to 97 genera and 43 families (Appendix 1). The families contain the highest number of species (Figure 2) are: *Poaceae* (11.50%), *Asteraceae* (10.62%), *Apiaceae* and *Fabaceae* (7.96%) each, *Lamiaceae* (5.31%), and 3.54% for each of the following families: *Brassicaceae, Polgonaceae, Salicaceae, Scrophulariaceae*, the following 19 families are represented by a single species: *Apocynaceae, Callitrichaceae, Characeae, Cistaceae, Frankeniaceae, Fagaceae, Geraniaceae, Juncaceae, Lemnaceae, Malvaceae, Moraceae, Polygalaceae, Polypodiaceae, Potamogetonaceae, Primulaceae, Rhamnaceae, Residaceae, Rubiaceae* and *Typhaceae*.

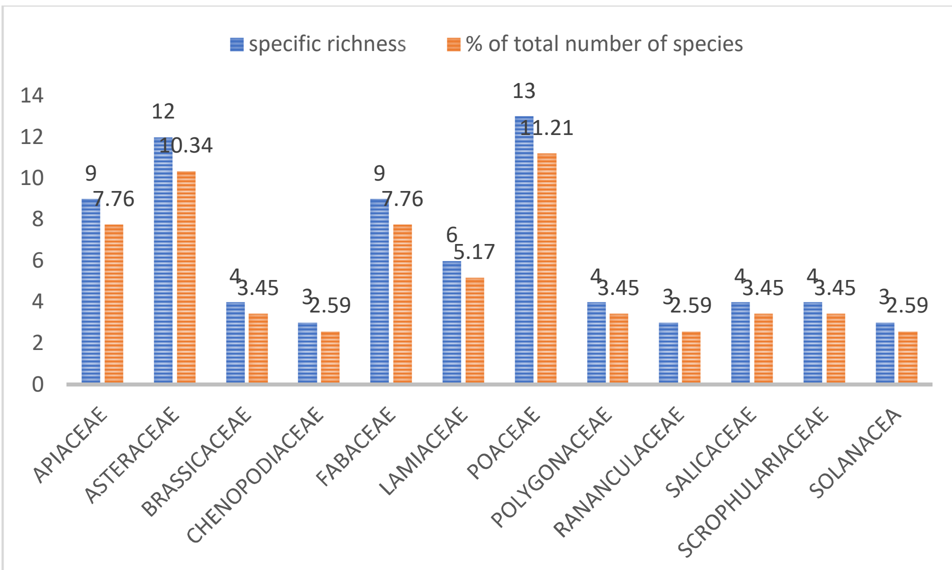

Figure 2. Specific richness and proportion relative of first twelve families of the riparian plants of Zat sub-Basin.

According to Raunkiaer's classification (1934), this floristic list is dominated by therophytes with 43 species (38.39% of the total population), followed by hemicryptophytes with 24 species (21.43% of the total population), phanerophytes with 17 species (15.18%), chameaphytes with 13 species (11.61%), hydrophytes with 12 species (10.71) and geophtes with only 4 species (Figure 3).

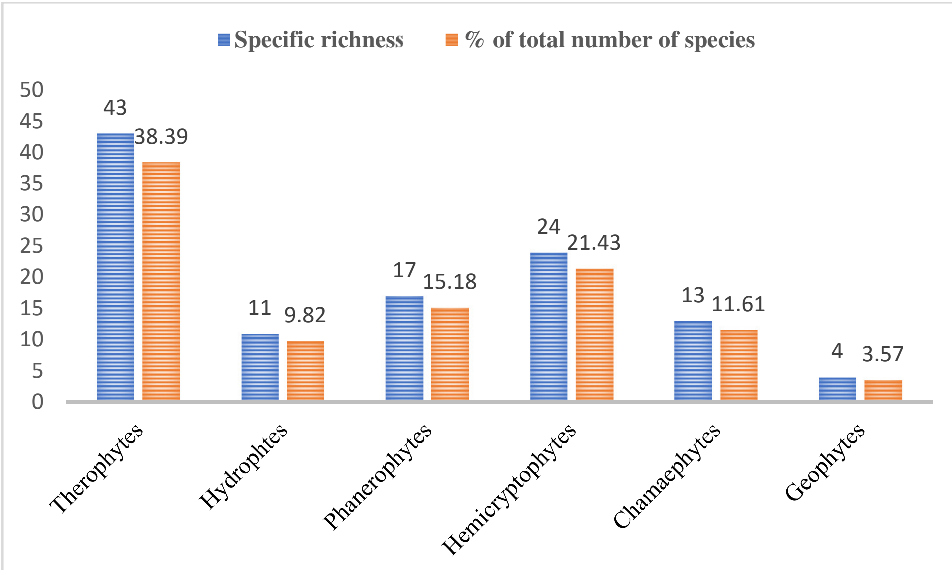

Figure 3. Biological spectrum and proportion relative of inventoried riparian plants of the Zat sub-Basin.

Based 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 Zat River and its tributaries were represented by 7 taxa, whereas 6 species are reported as endemic. The sampled area has five halophilic species belonging to 4 different families according to the halophil flora (Hammada *et al.* 2004). These are: *Juncus acutus* L, *Suaeda vermiculata* J. F. Gmelin, *Atreplix halimus* L, *Frankenia laevis* L, *Asphodelus microcarpus* Salzm. & Viv, *Plantago coronopus* L and *Sonchus maritimus* L. These species are located mostly in the stations 5 and 6, which reflects the salinity of the physical environment of these stations.

4.2 Pearson Correlation (r) test: The correlation matrix indicate that the salinity was strongly positively correlated with electrical conductivity *(r=0.996, N=17, p<0.01)* and nitrate concentration *(r=0.975, N=17, p<0.01)*, likewise for salinity and specific richness (*r= -0.726, N=17, p<0.01*). Moreover, a strong positive correlation between electrical conductivity and nitrate concentration (*r=0.959, N=17, p<0.01*), nitrate and water temperature (*r=0.72, N=17, p<0.05*), was found. A negative correlation was found between nitrate and specific richness (*r=-0689, N=17, p<0.01*), and between nitrate and dissolved oxygen (*r=-0.781, N=17, p<0.05*). Also, dissolved oxygen was strongly correlated with pH (*r=0.986, N=17, p<0.05*), with water level (*r=0.876, N=17, p<0.01*) and with specific richness (*r=0.846, N=17, p<0.05*) (*Table 1*).

Table 1: Pearson correlation coefficients matrix between the environmental parameters and specific richness of study area

	NO_3 (mg/l)	**O_2 dissolved (mg/l)**	**Water temperature (°C)**	**Water level (m)**	**pH**	**Salinity (ppt)**	**Conductivity (ms/cm)**	**Altitude (m)**	**Species**
NO_3 (mg/l)	1	-	-	-	-	-	-	-	-
O_2 dissolved (mg/l)	-0.8194	1	-	-	-	-	-	-	-
Water temperature (°C)	0.72118	-0.83306	1	-	-	-	-	-	-
Water level (m)	-0.73477	0.87679	-0.941**	1	-	-	-	-	-
pH	-0.77261	0.9868*	-0.88386	0.91255	1	-	-	-	-
Salinity (ppt)	0.9752*	-0.79039	0.7414	-0.75574	-0.79869	1	-	-	-
Conductivity (ms/cm)	0.95971*	-0.77867	0.74975	-0.75326	-0.79534	0.99627*	1	-	-
Altitude (m)	-0.42073	0.60373	-0.82476	0.79342	0.64477	-0.4263	-0.44274	1	-
Specific richness	-0.68918	0.84677*	-0.86357	0.77529	0.89303**	-0.72663	-0.74349	0.65965	1

**Correlation is significant at the 0.01 level,*
***Correlation is significant at the 0.05 level*

4.3 Typology of plant communities: The CCA results showed that the DO, elevation, water temperature and nitrate concentration (NO_3), constitute the main axes representing 92.11% ($p<0.05$) of the total variability of all analysed data (Figure 4). The first CCA axes, explained 61% of the total variance, was positively correlated with the DO ($r=89\%$) and elevation ($r=73\%$), but negatively correlated with nitrate concentration (NO3). However, the second CCA axes, accounting on the 19.88% of the explained variance, was positively correlated with salinity. Finally, nitrate concentration (NO_3) was strongly correlated with the third CCA axe ($r=90\%$) accounting on the 7.75% of the explained variance.

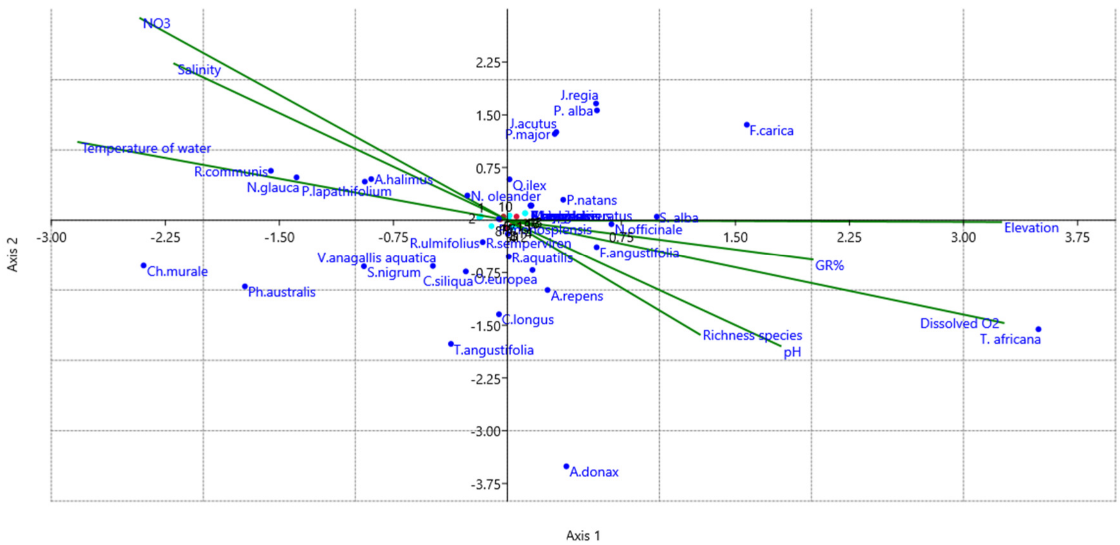

Figure 4. Relationship between riparian plants species and environmental factors obtained by CCA.

Higher concentrations of DO were positively related to the presence of *Populus alba* L., *Salix pedicellate*, *Ficus carica* L., *Polypogon monosplensis* L., *Cyperus longus* L. and *Rubus ulmifolus*, as well as, *Persicaria lapathifolia* L, *Dittrichia viscosa* L., *Chenopodium album* L. and *Cynodon dactylon* L. that are found on the sites with low DO (Figure 4). Moreover, *Suaeda vermiculata, Atreplix halimus, Frankenia laevis*, *Asphodelus microcarpus*, *Plantago coronopus,* and *Sonchus maritimus* were found in the stations with the higher value of salinity and conductivity (S1, S2, S5. S6). Furthermore, species that cannot tolerate a high salinity level are found on sites with the lowest value of this axis (S11, S12, S13, S14, S15, S16 and S17), including *Tamarix africana, Populus alba, Salix pedicellate, Arundo donax, Ranunculus trichophyllus.* Adversely, the higher concentration of nitrate NO_3 and phosphorus PO_4 were positively related to the presence of *Chenopodium album, Persicaria lapathifolia*, *Nicotiana glauca* L. and *Ricinus communis* L. While species such as *Populus alba* L., *Salix pedicellate, Cyperus longus* L.*, and Polypogon monosplensis,* were found in stations with lost nitrate and phosphorus concentration (S12,13,14,15,16 and 17). *Nerium oleander, Phragmite australis, Cynodon dactylon* were closely registered in all stations affirms the ecological plasticity of these three species.

5 DISCUSSION

The floristic study of the Zat sub-basin shows a great specific richness estimated at 113 plant species with 97 genera and 43 families, which shows a species richness proportionally similar to other Moroccan wetlands provisionally studied, Such as Sebou River with 121 species, Oum Errabia River with 102 species and Bas Loukkos with 85 species (Hammada *et al*., 2004; Hammada, 2007). From this study results, it can be seen that *Poaceae* are the most abundant family, which is in agreement with the work of Hammada, 2007, on the riparian flora of the Loukkos River. On the other hand, some taxa are particularly important (nationwide) as they are considered rare (*Carum asinorum* Litard. & Maire*, Chaerophyllum atlanticum* Cosson*, Matricaria aurea* (Loefl.) Sch. Bip, *Diplotaxis ollivieri, Trifolium cernuum* Brot*, Poa pratensis* L*, Rumex ginii* Jahandiez & Maire), the number of recorded rare species was high compared to the one found in the Oasis of Tafilalt with 4 rare species (*Chamaemelum eriolepis, Utricularia minor, Populus euphratica, Ruppia maritima*) and the Oum Er Rbia River with only 1 rare species (Persicaria maculosa) (Hammada, 2007). In addition, the high level of therophytes observed (48.84%) which reflect the drying trend of the Zat River and its tributaries (Figure 3) and their adaptation to fluctuating ecological conditions. These constraints favour colonisation by species that reverse themselves more in sexual reproduction than in vegetative development (Grime 1985; Warwick and Brock, 2003). This paper finds that the composition and the abundance of the plant communities inventoried in the Zat sub-Basin is influenced by several environmental parameters such as dissolved oxygen, elevation, salinity and nitrate NO_3 concentration. The distinction of these factors has already been established by several authors (Lacoul and Freedman, 2006; John *et al.* 2012; Adam, 2015; Bubanja *et al.,* 2016). First of all, dissolved oxygen has been shown to be important for the distribution and species richness of plants in the aquatic environment (Vestergaard and Sand-Jensen, 2000; James *et al*., 2005). In Moroccan naturel water, a minimum DO concentration of 5 mg/l for warm water species and 6 mg/l for cold water species is recommended (MDDEFP, 2013). In the present study, a maximum of 12.05 ± 0.25 mg/l DO was recorded at the station 14, while a minimum of 4.88 ± 0.1 mg/l DO was recorded at the station (S1, S2, S4, S7, S8 and S10) indicating the degree of water pollution due to wastewater discharges at these stations. These pollutants act as a food source for bacteria, which biodegrade these organic materials using dissolved oxygen, thereby reducing the level of DO in the surrounding environment. Low and high levels of DO can remove the most sensitive species from an ecosystem, resulting in a decrease in species diversity. Also, the finding of this study revealed the effect of salinity and conductivity level on distribution and abundance of riparian plants. The characteristic species of this group are *Suaeda vermiculata, Atreplix halimus, Frankenia laevis*, *Asphodelus microcarpus*, *Plantago coronopus,* and *Sonchus maritimus.* The majority of these species show the presence of salts in the environment (Hammada *et al.,* 2004), hence the increase in the measured value of conductivity and salinity. The effect of salinity influences the vegetation structure of both the right and left banks in stations S5 and S6, with a total overlap of 10-15% and a total absence of trees and shrubs. The negative reworking of river salinity on the specific richness of aquatic plants is designated by Chahma *et al*., 2005. In addition, our results showed that nutrient enrichment, especially nitrates and phosphorus, has a significant impact on the distribution and composition of plant species in the aquatic environment of the Zat sub-Basin. According to the standards described in the MDDEFP (2013), the maximum nitrate concentration should not exceed 10 mg/l in naturel water. In our study, the nitrate concentration NO3 ranged from 4.13 ± 0.1 mg/l to 11.23 ± 2.05 mg/l. In terms of species richness, our study found that stations (S3, S6, S13 and S15) with intermediate nitrate concentrations generally have a high species richness (more than 17 species), while stations with high or low nitrate concentration have a low species richness, as in the case of the stations (S1,S2, S5, S6, S10, and S14) with a species richness of less than 9 species, since only stress tolerant (low nutrient content) or highly competitive (high nutrient content) species should be found in the community. This is due to competitive interactions that generally increase with nutrient levels. In aquatic or riparian ecosystems, this relationship between nutrient levels and species richness has been demonstrated by several authors (Huston, 1979; Bornette *et al.* 1998; Pollock *et al.* 1998; John *et al.* 2012), with the greatest species diversity being observed at intermediate nutrient levels. Indeed, the negative effect of increased nitrate concentration on the invasion of the environment by ruderal and nitrophilic species such as *Nicotiana glauca, Dittrichia viscosa, Chenopodium album and Persicaria lapathifolia*. These latter have been confirmed by Ennabili and Ater, 1996, Hammada, 2007 and Libiad *et al.,* 2014 as species adapted to wastewater discharges and wet substrates laden with solid waste. The presence of uncontrolled discharges, industrial sites for olive production, infrastructure and agricultural activities near the lower Zat River could be responsible for the abundance of these ruderal species.

6 CONCLUSION

The present study is based on the analysis of plant biodiversity of the Zat sub-basin and identifies the environmental factors that influence the abundance and distribution of riparian vegetation along the Zat River and its tributaries. The phytoecological study revealed an important specific richness estimated at 113 species of aquatic and sub aquatic plants, belonging to 43 families and 97 genera. This flora has also an endemism rate of 5.30% taxa, of which are specific to Morocco and rare or threatened species 6.19%, which makes this site more valuable in terms of biodiversity. Therefore, this study shows that the environmental parameters, such as DO, elevation, salinity and nitrate concentration, are considered as one of the most important factors that are capable of influencing the abundance and distribution of riparian plants along the Zat River and its tributaries. The results obtained reveal the state of the riparian vegetation in the study area, which is exposed to the different degradation namely drought, land clearing, overgrazing and pollution. It is therefore essential to sustainably manage this aquatic ecosystem through the implementation of a management and conservation plan.

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Appendix I: Floral list of riparian plants of the Zat River and its tributaries:
E: endemic in Morocco, **A**: endemic in Morocco and Algeria, **R**: rare, **R?** suspected rare, **RR**: very rare, *: halophilic species.

APIACEAE
Apium nodiflorum (L.) lag.
Apium repens (Jacq.) Lag
Carum asinorum Litard. & Maire **E-RR**
Daucus carota L.
Chaerophyllum atlanticum Cosson. **E-R**
Heracleum sphondylium L.
Eryngium varifolium Cosson. **E**
Phoeniculum vulgare L.
Thapsia transtagana Brot.
APOCYNACEAE
Nerium oleander L.
ASPARAGACEAE
Asparagus horridus L.
Asphodelus microcarpus Viv. *
ASTERACEAE
Asteriscus aquaticus (L.) Less
Bellis caerulescens Cosson ex Ball. **E**
Calendula algeriensis Boiss. & Reuter
Centaurea calcitrapa L.
Dittrichia viscosa (L.) Greuter
Launea arborescens L.
Matricaria aurea (Loefl.) Sch. Bip. **RR**
Onopordon sp.
Pulicaria arabica (L.) Cass.
Scolymus hispanicus L.
Sonchus maritimus L.*
Xanthimum spinosum L.
BORAGINACEAE
Echium confusum Decoincy.
Heliotropium europaeum L.
BRASSICACEAE
Diplotaxis ollivieri Maire **R**
Diplotaxis tenuisiliqua Delile.
Hirschfeldia incana (L.) Lagrèze-Fossat
Nasturtium officinale R. Br
CALLITRICHACEAE
Callitriche stagnalis Scop.
CHARACEAE
Chara sp.
CARYOPHYLLACEAE
Stellaria alsine Grimm.
Paronychia argentea Lam.
CHENOPODIACEAE
Chenopodium album L.
Atriplex halimus L.*
Suaeda vermiculata J. F. Gmelin*
CISTACEAE
Cistus salviifolius L.
CONVOLVULACEAE
Convolvulus althaeoides L.
FRANKENIACEAE
Frankenia laevis L.*
CYPERACEAE
Cyperus laevigatus L.
Cyperus longus L.
EUPHORBIACEAE
Euphorbia peplis L.
Ricinus communis L.
FABACEAE
Ceratonea siliqua L.
Lotus hispidus DC.
Lotus sp.
Ononis natrix L.
Ononis repens L.
Melilotus indica (L.) All.
Retama monosperma L.
Trifolium cernuum Brot. **R?**
Trifolium fragiferum L.
FAGACEAE
Quercus ilex L.
GERANIACEAE
Geranium robertianum L.
JUGLANDACEAE
Juglans regia L.
JUNCACEAE
Juncus acutus L.*
LAMIACEAE
Lamium flexuosum Ten.
Lavandula multifida L.
Marrubium vulgare L.
Mentha longifolia (L.) Hudson.
Mentha suaveolens Ehrh.
Mentha pulegium L.
LEMNACEAE
Lemna minor L.

MALVACEAE
Malva sylvestris L.
MORACEAE
Ficus carica L.
OLEACEAE
Fraxinus angustifolia Vahl.
Olea europea L.
PLANTAGINACEAE
Plantago coronopus L.*
Plantago major L.
POACEAE
Arundo donax L.
Briza minor L.
Bromus rigidus Roth.
Cynodon dactylon L.
Festuca sp.
Glyceria maxima (Hartm.) Holmb.
Holcus lanatus L.
Panicum repens L.
Phragmite australis L.*
Polypogon monosplensis L.
Polypogon viridis (Jouan) Breistr.
Stipa capensis Thunb.
Poa pratensis L. **RR**
POLYGALACEAE
Polygala balansa Cosson. **E**
POLYGONACEAE
Persicaria lapathifolia (L.) S.F. Gray
Rumex pulcher L.
Rumex conglomeratus Murray.
Rumex ginii Jahandiez & Maire. **E-R**
POLYPODIACEAE
Adiantum capillus-veneris L.
POTAMOGETONACEAE
Potamogeton natans L.
PRIMULACEAE
Anagallis arvensis L.
RANANCULACEAE
Ranunculus trichophyllus Chaix.
Raunanculus aquatilis L.
RHAMNACEAE
Ziziphus lotus L.
RESIDACEAE
Reseda alba L.
ROSACEAE
Potentilla reptans L.
Rubus ulmifolius Schott.
RUBIACEAE
Galium aparine L.
SALICACEAE
Populus alba L.
Populus nigra L.
Salix pedicellata Desf.
Salix purpurea L.
SCROPHULARIACEAE
Scrophulaira auriculata Loefl. ex L
Verbascum sinuatum L.
Veronica anagallis aquatica L.
Veronica hederifolia
SOLANACEA
Hyoscyamus albus L.
Nicotiana glauca L.
Solanum nigrum L.
TAMARICACEAE
Tamarix africana L.
Tamarix sp.
TYPHACEAE
Typha angustifolia L.
ZANNICHELLIACEAE
Zannichellia palustris L.

Appendix II: Digital photographs of sations with low and high specific richness in the study area

Photo 1: Ikkis station (S15) indicate a high aquatic plants richness estimated at 21 species

Photo 2: Community plants dominated by *Nasturtium officinale* in Ikkis station (S15).

Photo 3: Tighadouine station (S10) indicate low specific richness estimated at 9 species

Photo 4: *Persicaria lapathifolia* dominated in altered stations located especially in downstream of Zat sub-Basin.