Plant Biodiversity in the Semi-arid Zone of Tunisia

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Abstract: Plant biodiversity which is a base for supporting ecosystems brings not only contribution to our life as resource materials, but also various ecosystem services such as environmental adjustment functions. Plants in arid and semi-arid zones are very sensitive to climate change. For example, if there is a slight decrease in the amount of rain, the landscape is changed like a desert. On the other hand, vegetation with high biodiversity has plasticity to climate change. Therefore, it is important to manage the biodiversity in semi-arid zones to prevent desertification. In Tunisia, arid and semi-arid zones are distributed in the central and southern parts of the country. Field survey was carried out in November 2008 and November 2009. Field survey was conducted in the semi-arid zone of Tunisia wherein 17 study sites were set in locations with diverse vegetation types. Plant species composition and coverage were measured in 5×5 m quadrat. Results showed that the number of species richness ranges from two to twenty-two. The lowest species richness was found to be in steppe that is dominated by *Stipa tenacissima* or *Halocnemum strobilaceum*. The highest species richness was measured at steppe dominated by *Retama raetam*. We use diversity indexes (Shannon's *H'* and Simpson's 1 - *D*) to rate the important factors for biodiversity conservation.

Key Words: Biodiversity, Semi-arid, Species composition, Tunisia, Vegetation

1. Introduction

North Africa is characterized by specific ecosystems from Mediterranean Sea to Sahara desert. In particular, we are able to observe dynamic climate changes from Mediterranean climate to desert climate in Maghreb countries (Tunisia, Algeria and Morocco). This climate diversity produced various vegetation types along the graduation of aridity. For example, the cork forest distribution near the north part of Maghreb countries advance southward with the dominant species changing from cork tree to Pine tree. Further south, forest zone changed to steppe zone, then it gradually became a desert. We can see this dynamic change in vegetation within a short distance.

A huge area of the arid and semi-arid region is faced with the desertification crisis. Extensive land use was pointed out as one of the major factors that contributed to desertification in previous studies (Li *et al.*, 2000; Zhao *et al.*, 2005). North African countries do not regard this as a problem because all these countries include Sahara desert. The land use of arid and semi-arid area in North Africa has been historically used for arid tolerant crops including palm or olive, grazing, and use of natural bioresources. In fact, most flatland without salt accumulation area has been cultivated. Some areas with natural vegetation are being degraded by grazing and use of the natural bioresources. This means that high risk of desertification continues to grow in arid and semi-arid area.

In order to conserve the arid and semi-arid land ecosystems, it is important to detect when the degradation or desertification starts. The floristic composition has been believed to give the sign of any environmental changes (Vesk and Westoby, 2001). We attempted to know the extent of the arid and semi-arid land degradation by assessing the floristic composition, as an indicator of the condition of the ecosystems (Dyksterhuis, 1949; Nakamura *et al.*, 2000; Numata, 1975; Sternberg *et al.*, 2000; Vesk and Westoby, 2001). Bai *et al.*, (2004) also suggested that plant communities with high species diversity combat desertification process. However there is not enough information about arid and semi-arid land ecosystem in North Africa. It is necessary to measure the plant community structure in detail to know the basis of the ecosystem in the arid and semi-arid zones. In community scale research, species composition and biomass distribution of plant communities are essential data for ecological description. An accumulation of these fundamental data are important to describe ecological characteristics in community scale. However there are few studies about description of plant community structure of the arid and semi-arid zones in North Africa.

We examined floristic composition on different land use intensities, including the meteorological factor. We focused on comparison of vegetation structure among research sites to assess the effects of degradation on the arid and semi-arid land ecosystems. The objectives of this study were to compare species composition, species richness and species diversity of the study sites and make ecological interpretations of the

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semi-arid zone in Tunisia.

2. Materials and Methods

2.1. Study sites

vTunisia is situated at latitude 30°13' - 38°20' N, and longitude 7°31' - 11°35' E. The country covers a total land area of 163,610 km^2 and it has a population of 10,430,000 in 2009. The Atlas Mountain ranges run from Southwest to Northeast with the region being lower in the east. The highest point of Mts. Atlas in Tunisia is Mt Chambi (1,544 m), located at the Kasserine province, situated in west side of Tunisia. Here we can observe vegetation change, from the cork oak forest in the northern part to the Sahara desert in the southern part.

The seventeen study sites in the central area of Tunisia are shown in **Figure 1**. The sites were selected after preliminary surveys of representative areas in the semi-arid zone of Tunisia. The study sites were located at Gafsa and Kasserine province.

2.2. Field survey methods

Field survey was carried out in November 2008 and November 2009. We set nine quadrats in each study site. Each quadrat size was 5×5 m. After recording all the names of the species in the quadrat, we measured the coverage of the population of each species. We measured vegetation coverage using the Penfound-Howard method (Penfound and Howard 1940). The coverage class is divided into 6 classes: 4 for 75 - 100%, 3 for 50 - 75%, 2 for 25 - 50%, 1 for 5 - 25%, 1/ for 1 - 5%, + for less than 1%. Nomenclature follows Flora de la Tunisie (Cuenod *et al.*, 1954; Pottier-Alapetite 1979, 1981).

2.3. Data analysis

To estimate relative dominance of species i (*pi*) of all quadrats, we adopted the use of coverage class evaluated by the Penfound-Howard criteria. In calculation, the coverage mentioned above was converted as follows: 0.875 m^2 for 4, 0.625 m^2 for 3, 0.375 m^2 for 2, 0.15 m^2 for 1, 0.03 m^2 for 1/, and 0.005 m^2 for +.

We used Simpson's diversity index (1 - *D*) and the Shannon diversity index (*H'*) to assess multilateral species diversity. Simpson's diversity index is sensitive to the diversity of dominant species (Simpson, 1949):

$$1 - D = 1 - \sum pi^2$$

The Shannon diversity index (*H'*) is sensitive to the diversity of common species (Weaver and Shannon, 1949):
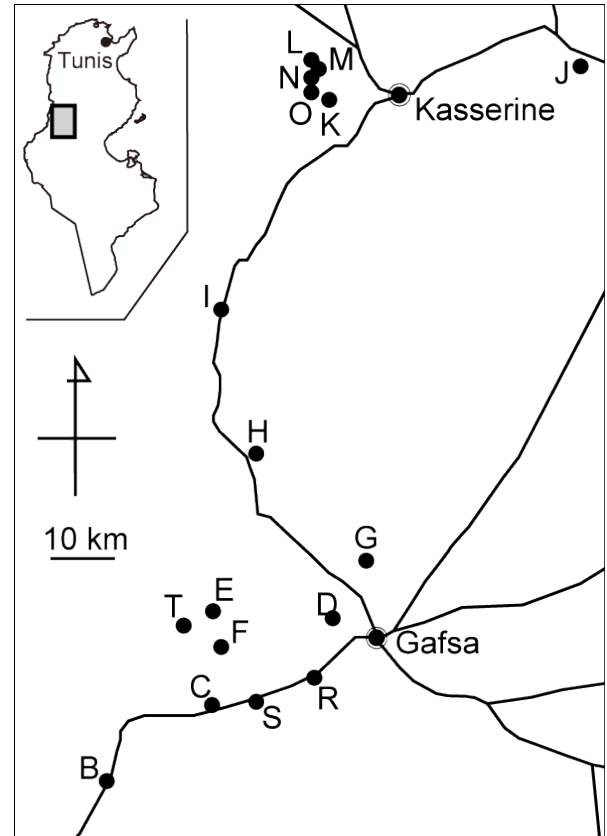
$$H' = -\sum Pi \ln Pi$$

Fig. 1. Location of study sites.

This unit is nat because we calculated *H'* using logarithm natural. To measure evenness, we used Pielou's index (*J*):

$$J = H' / \ln S$$

S denotes the total number of species (Pielou, 1969).

We used version 19 of SPSS for Windows (IBM, Armonk, NY, USA) for all statistical analyses. To test the relationship between coverage and evenness, we used arcsin conversion to these parameters. We then analyzed the correlation between alien species richness and native species richness using Spearman's rank correlation test.

3. Results and Discussion

3.1. Species composition

We recognized 152 species that included unidentified species in the study sites. Most of the unidentified species were in germination or seedling stage, and were, therefore, not dominant species. The dominant species in each study site are shown in **Table 1**. Site K, L, M and N located at *Pinus halepensis* forest, however our results did not include crown tree. Other sites were dominated by shrub or perennial species. Some of the dominant species such as *Arthrophytum schmittianum* (in site B and H), *Salsola villosa*, *Salsora vermiculate* (in site F), *Salsola tetrandra* (in site R), *Arthrocnemum indicum* (in site S) and *Halocnemum strobilaceum* (in site T) are halophyte or salt-tolerant species.

Table 1. Dominant species of each study sites.

Site	Dominant species
B	*Arthrophytum schmittianum*
C	*Moricandia arvensis*
D	*Anabasis articulata*
E	*Gymnocarpos decander, Helianthemum hirtum*
F	*Salsola villosa, Salsora vermiculate*
G	*Thymelaea microphylla, Aristida plumosa*
H	*Arthrophytum schmittianum*
I	*Stipa tenacissima*
J	*Retama raetam, Artemisia campestris*
K	*Stipa tenacissima*
L	*Rosmarinus officinalis*
M	*Rosmarinus officinalis, Quercus ilex*
N	*Stipa tenacissima, Rosmarinus officinalis*
O	*Stipa tenacissima, Artemisia herba-alba*
R	*Salsola tetrandra*
S	*Arthrocnemum indicum*
T	*Halocnemum strobilaceum*

Table 2. Species richness and species diversity of each study sites.

Site	Species richness	Shannon(H')	Simpson (1-D)	Pielou (J)
B	7.1 ± 0.4	0.8 ± 0.1	0.4 ± 0.1	0.4 ± 0.1
C	14.6 ± 0.7	1.5 ± 0.1	0.7 ± 0.0	0.6 ± 0.0
D	7.0 ± 0.4	1.9 ± 0.1	0.9 ± 0.0	1.0 ± 0.0
E	4.7 ± 0.3	0.9 ± 0.1	0.6 ± 0.0	0.6 ± 0.0
F	10.6 ± 0.6	1.4 ± 0.1	0.6 ± 0.1	0.6 ± 0.1
G	10.2 ± 0.6	1.2 ± 0.0	0.6 ± 0.0	0.5 ± 0.0
H	9.4 ± 0.8	0.3 ± 0.0	0.1 ± 0.0	0.1 ± 0.0
I	15.0 ± 0.7	1.5 ± 0.0	0.7 ± 0.0	0.6 ± 0.0
J	14.9 ± 1.1	1.4 ± 0.0	0.7 ± 0.0	0.5 ± 0.0
K	3.4 ± 0.4	0.4 ± 0.1	0.2 ± 0.1	0.3 ± 0.1
L	6.6 ± 0.7	0.9 ± 0.1	0.5 ± 0.0	0.5 ± 0.0
M	7.1 ± 0.8	1.0 ± 0.1	0.5 ± 0.0	0.5 ± 0.0
N	6.1 ± 0.4	0.9 ± 0.0	0.5 ± 0.0	0.5 ± 0.0
O	6.7 ± 0.5	0.8 ± 0.1	0.4 ± 0.1	0.4 ± 0.0
R	3.3 ± 0.2	0.4 ± 0.1	0.2 ± 0.0	0.4 ± 0.1
S	11.8 ± 1.0	1.2 ± 0.1	0.4 ± 0.0	0.5 ± 0.0
T	2.9 ± 0.3	0.4 ± 0.1	0.2 ± 0.1	0.3 ± 0.1

Fig.2. Ratio of total coverage in study sites.

Stipa tenacissima
Rosmarinus officinalis
Arthrophytum schmittianum
Retama raetam
Aristida plumosa
Halocnemum strobilaceum
Thymelaea microphylla
Quercus ilex
Artemisia herba-alba
Plantago albicans
Others

20.68
10.72
6.17

Fig. 3. Relationship between evenness and coverage.

$r = -0.617$
$P < 0.05$

$r = -0.928$
$P < 0.01$

● Normal site
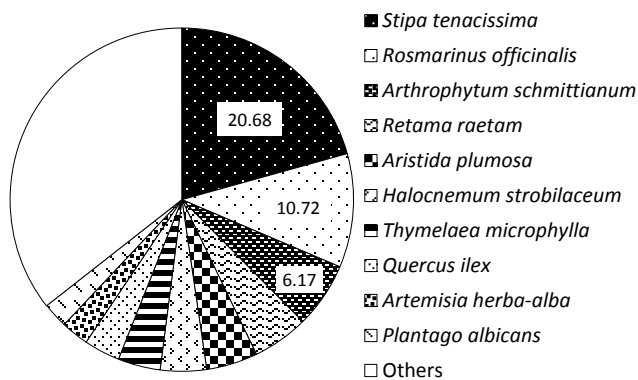▲ Saline site

Figure 2 shows the ratio of total converted coverage of this study. The species listed ranked in the top 10, and it dominated about 65% of the total cover ratio. *Stipa tenacissima* dominated the highest ratio of coverage. However *S. tenacissima* appeared at site H, K, L, M, N and O. The secondary dominant species *Rosmarinus officinalis* is also distributed at site K, L, M and N.

3.2. Species richness and species diversity

The range of species richness was from two to twenty-two species per 25 m². The lowest species richness was measured at steppe, in a zone dominated by *Stipa tenacissima* (in site K) or *Halocnemum strobilaceum* (in site T). The highest species richness was measured at steppe, in a zone dominated by *Retama raetam* and *Artemisia campestris* (in site J).

The average species richness and species diversity in each site are shown in **Table 2**. The lowest species richness was measured at site T, while the highest species richness was at site I. Meanwhile, the lowest species diversity was measured at site H and the highest species diversity was measured at site D.

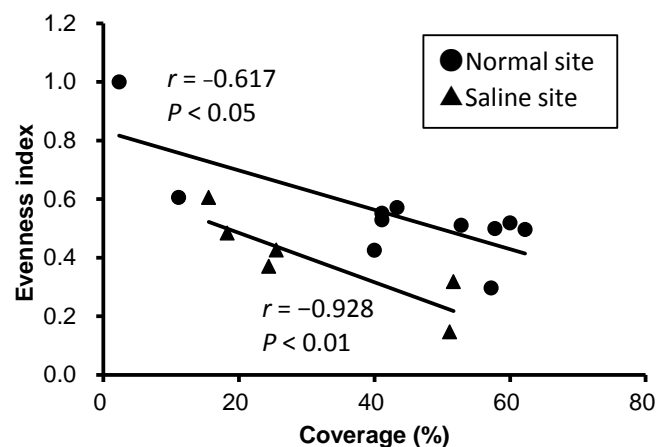In all saline sites, halophyte or salt tolerant species dominate, while in a normal site, the vegetation coverage has negative correlation with evenness of distribution (**Fig. 3**). It means that vegetation coverage is caused by the growth of a single or a few specific species. A decrease of evenness is directly linked to decrease of species diversity from this relationship.

4. Discussion

The species diversity in the semi-arid zone of Tunisia seemed to be uncorrelated with latitude. The results of our study showed that the species diversity varied enormously in the semi-arid zone of Tunisia. It is affected by various local environmental factors such as soil, water, microclimate, grazing, and so on. We considered that one limiting factor of species diversity is salinity. We measured the lowest species diversity in site H which is dominated by *Arthrophytum schmittianum*. This species is well known for its high adaptation to saline conditions. Other halophyte or salt-tolerant species were dominated at sites B, R and T. These plants can indicate land condition of salinity but each species has different adaptation ability to salinity. For example, *Halocnemum strobilaceum* is able to adapt to high

concentration of saline soil, while the *Salsola* genus is not able to adapt to the same concentration as *H. strobilaceum*. We can therefore prospect that salinity is an effective factor on species diversity.

On the other hand, species richness and species diversity were not related. It suggests that evenness is a major contributor to species diversity. We also considered that the distribution pattern of appearance species decide species diversity. The landscape of steppe in North Africa is far different from that of the Eurasian steppe. The distribution pattern of vegetation in North Africa is like a patch (Cerdà, 1997). However, in the Eurasian steppe it is carpet-like (Nakamura *et al.*, 2000; Kawada *et al.*, 2005). In consequence, Shannon's species diversity index of *S. tenacissima* -dominant sites varies from 0.30 to 1.90, meanwhile the diversity indexes of steppe in other regions were 2.98 in Ukraine, and 1.98 in Inner Mongolia (Kawada *et al.*, 2005; Wuyunna *et al.*, 1999). The species diversity of steppe in Tunisia is lower than that of the Eurasian steppe.

5. Conclusion

Plant biodiversity in the semi-arid zone of Tunisia varies enormously but is generally lower compared to other semi-arid environment. It suggests that the ecosystem in North Africa have low ability to adapt (flexibility) to environmental change. It is important to manage the biodiversity in the semi-arid zone to prevent desertification.

References

Bai Y., Han X., Wu J., Chen Z., Li L. (2004): Ecosystem stability and compensatory effects in the Inner Mongolia grassland. *Nature*, **431**: 181-184.

Cerdà A. (1997): The effect of patchy distribution of *Stipa tenacissima* L. on runoff and erosion. *Journal of Arid Environments*, **36**: 37-51

Cuenod A., Pottier-Alapetite G., Labbe A. (1954) *Flora de Tunisie Gyptogames vasculaires, Gymnospermes et Monocotyledones*, Imprimerie S. E. F. A. N., Tunis.

Dyksterhuis E.J. (1949): Condition and Management of Range Land Based on Quantitative Ecology. *Journal of Range Management*, **2**: 104-115.

Kawada K., Vovk A.G., Filatova O.V., Araki M., Nakamura T., Hayashi, I. (2005): Floristic composition and plant biomass production of steppe communities in the vicinity of Kharkiv, Ukraine. *Grassland Science*, **51**(3): 205-213.

Li S.G., Harazono Y., Oikawa T., Zhao H.L., He Z.Y., Chang X.L. (2000): Grassland desertification by grazing and the resulting micrometeorological changes in Inner Mongolia. *Agricultural and Forest Meteorology*, **102**: 125-137.

Nakamura T., Go T., Wuyunna, Hayashi I. (2000): Effects of grazing on the floristic composition of grasslands in Baiyinxile, Xilingole, Inner Mongolia. *Science*, **45**: 342-350.

Numata M. (1975): *Methods of biological description of vascular plants*.

Penfound W.T., Howard J.A. (1940): A phytosociological study of an evergreen oak forest in the vicinity of New Orleans, Louisiana. *American Midland Naturalist*, **1**: 165-174.

Pielou, E.C. (1969): *An introduction to mathematical ecology*. New York, Wiley-Interscience.

Pottier-Alapetite G. (1979) *Flora de Tunisie Angiospermes - dictyledones *Apetales - dialypetales*, Ministere de l'Enseignement Superieur et de la Researche Scientifique et le Ministere de I'Agriculture, Tunis.

Pottier-Alapetite G. (1981) *Flora de Tunisie Angiospermes - dictyledones *Gamopetales*, Ministere de l'Enseignement Superieur et de la Researche Scientifique et le Ministere de I'Agriculture, Tunis.

Simpson E.H. (1949): Measurement of diversity. *Nature*, **163**: 688.

Sternberg M., Gutman M., Perevolotsky A., Ungar E.D., Kigel J. (2000): Vegetation response to grazing management in a Mediterranean herbaceous community: A functional group approach. *The Journal of Applied Ecology*, **37**(2): 224-237.

Vesk P.A., Westoby M. (2001): Predicting plant species' responses to grazing. *Journal of Applied Ecology*, **38**(5): 897-909.

Weaver W., Shannon, C.E. (1949): *The Mathematical Theory of Communication*. University of Illinois Press, Illinois.

Wuyunna, Nakamura T., Hayashi I. (1999): Species Diversity and Phytomass of the Grasslands in Inner Mongolia, China. *Grassland Science*, **45**: 140-148.

Zhao H.L., Zhao X.Y., Zhou R.L., Zhang T.H., Drake S. (2005). Desertification processes due to heavy grazing in sandy rangeland, Inner Mongolia. *Journal of Arid Environments*, **62**(2): 309-319