J. Agric. Sci. Technol. (2005) Vol. 7: 143-150

Relationships Between Characteristics of Plant Communities and Climatic Conditions at Qara Soo Catchment Area, Gorgan

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ABSTRACT

In order to understand the relationships between climatic factors and the biological variables of plant communities in the Qara Soo Catchment Area, a systematic sampling of natural plant community variables such as crown closure, diversity, reproduction rate and crown height has been taken. Information about physical components of the ecosystems such as climatic elements, soil properties and topographic characteristics was also collected for each plant community. By using the Numerical Taxonomy Model suggested by Sneath and Sokal (1963), the plant communities were classified and sorted according to a "development index" which indicates the plant community development toward the climax stage of ecosystem. Then the relationships between ecosystem physical components and the biological variables of communities (development index) were understood by using a multiple regression model. It was concluded that climatic elements are the dominant factor affecting on the formation, distribution, reproduction and stability of plant communities in the area. It was further concluded that the Numerical Taxonomy Model, which has been commonly used by social scientists, is a suitable tool for system analysis in plant communities and natural ecosystems.

Keywords: Climate, Ecosystem components, Plant community, Qara Soo.

INTRODUCTION

A plant community as a natural resource is a naturally occurring, sustaining, and interacting assemblage of plant living in the same environment and fixing, utilizing and transferring energy in same manner. The total range of physical conditions of the ecosystem within which the organism lives and reproduced is closely associated with the concept of competitive relationships among other species. The climatic elements can be considered as one of the dominant factors in formation, reproduction, competition and stability of plant communities.

This study was designed mainly to determine the variation of climatic elements over the Qara Soo Catchment Area in Gorgan. Also, it was designed to help us understand the relationships between the biological variables of natural plant communities and the physical variables of ecosystems in the Catchment Area. The results of this study can be utilized in two different ways. On the one hand, existing and eliminated plant communities can be determined by climatic elements and, on the other hand, the climatic conditions can be studied through determining the biological characteristics of plant communities.

One of the most notable major global classifications of plant communities was presented by Hodridge (1967) as the "Life Zone Classification Map ". He considered temperature and rainfall to prevail over other environmental factors, hence his focus was on these parameters in his classification scheme. Whittaker (1975), who superim-

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posed vegetation structural classification on to the Holdrich scheme, used a similar scheme.

Woodward (1990) has presented palaeoecological evidence that both climate and vegetation have changed over the last 32000 years and that these changes were worldwide. The correlation between the occurrences of plant species, as indicated by the pollen record, suggests that climate was the controlling factor.

The growth of a plant is directly related to its ability to intercept solar radiation and to convert the intercepted solar radiation to carbohydrates (Monteith, 1977). Any influences of climate on leaf area index will influence not only the growth of plants but also the ability to cast shade. Temperature exerts a strong effect through its influence on leaf expansion and leaf initiation, both of which increase with temperature to some optimum degree (Potter and Jones, 1977).

Grouzis *et al*. (1998) found that the proportion of legume species in the herbaceous stratum fell when passing from south to north in Senegal because of climatic changes, nutrient availability and root symbioses.

Kozlowsky (1976) has reported for the temperate zone that species such as *Ulmus americana*, *Tilia americana*, *Acer platanoides* and *Populus deltoides* show whole or partial defoliation during summers with extreme drought, as may also be observed for *Fagus sylvatica* in Europe. Larcher and Bauer (1980) suggest the poleward spread of species or a physiognomic type of vegetation is controlled by the minimum temperature which will be regularly experienced. These authors have constructed a world map describing those areas where different low-temperature thresholds will control vegetation distribution.

The availability of water, on the other hand, has a strong influence on leaf area index. Waring *et al*. (1978) have shown a clear positive correlation between leaf area index and rainfall in the northwestern coniferous forest of North America. Spurr and Barnes (1980) report that for the central area of the United States of America an annual rainfall of 380 mm is the lower limit of precipitation to support open woodland, about 500 mm. for an open forest and over 640mm. for a closed forest. Further north in Alaska, however, an annual rainfall of as little as 180mm. is sufficient for the development of forest. This suggests that the water budget (precipitation minus evapotranspiration), rather than precipitation alone, may be the critical climatic factor.

O'Brien (1998), by analyzing the macro-scale distribution of woody plant richness in South Africa, concluded that the climate-based water-energy dynamics was the first controlling factor. Using regression models of the climate's relationship to species richness was able to predict first-order macro-scale geographic variations in plant richness.

Miller (1977) has measured and computed average annual totals of evapotranspiration from vegetation. Annual totals extrapolated from a map which have been prepared from these measurements, compared with predicted values from four stations, in these vegetative zones. Close correspondence is again notable for vegetation types ranging from tundra, through boreal forest to grassland or steppe.

Most authors have emphasized the importance of climate in controlling the observed patterns of vegetation distribution. The natural result of this connection was a search for the mechanism by which climate could exert this control.

The main objective of this experiment was to test the following hypothesis:

"The dominant factors in formation, stability, reproduction and diversity of a plant community are climatic elements".

MATERIALS AND METHODS

To study the relationships between climatic conditions and biological characteristics of plant communities, a system analysis of ecosystem variables has been designed. The data about soil properties, geology, topography, vegetation and climatic elements were collected through a systematic sampling over all the selected area of watershed.

The types of plant communities were determined by using the phyto-sociological method suggested by Braun-Blanquet (1932). It should be mentioned that the Qara Soo Catchment Area is mostly covered by deciduous trees of the Caspian Sea forest region. Seven different types of plant communities with the largest coverage area were chosen for analyzing the data on vegetation and physical variables of ecosystems. Some plant communities with small acreage were omitted from the data analysis. The main plant communities of Qara-Soo watershed area are:

1. Querceto- Carpinetum (Quercus castaneifolia and Carpinus betulus).
2. *Parrotio- Carpinetum (Parrotia persica* and *Carpinus betulus).*
3. *Rusco- Fagetum (Ruscus hyrcanus* and *Fagus orientalis).*
4. *Fagetum- Ilexosum (Fagus orientalis* and *Ilex spinigera).*
5. *Querceto- Carpinetum orientalis (Quercus macranthera* and *Carpinus orientalis).*
6. Cushion type plants *(Onobbrychis arnacantha, Acantolimon sp.* and *Astragalus gossiopium).*
7. Grassland community *(Bromus tomentelus, Festuca ovina* and *Achillea sp).*

The ecological data of plant communities were collected by using distribution maps of soil, geology, isohyet, isotherm, and topography. Also, field data of vegetative cover has been completed by systematic sampling through 400 m^2 plots at 2000 m. intervals for this project.

Biological variables of the plant communities such as crown closure, crown height, number of plant species in the plots and seedling density were measured in sample areas in the field. The total amount of sample area in the nature vegetative covered parts of Catchment Area was 106. The average values of soil properties have been collected and are shown in Table 1.

To understand the relationship between biological variables of plant communities and physical characteristics of ecosystems in the area, the mean values for each plant community were calculated. Then, by using different mathematical models such as " Multiple Linear Regression", "Non Linear Regression" and "Logarithmic Correlation", the effect of climatic elements, topography and soil properties on the biological characteristics of plant communities were tested. A computer software called SPSS (Statistical Package for Social Sciences) was used for data analysis.

The plant communities were classified and sorted according to biological variables by the means of "Numerical Taxonomy" as suggested by Sneath and Sokal (1963). The Numerical Taxonomy is a multi-variable statistical tool that can be used for the sorting and classification of sub-units with different dimensional variables. For this purpose the Euclidean Distances between communities have been calculated using the following formula:

$$D = \sqrt{\sum_{i=1}^{n}(Zia - Zib)^2}$$

As D is the multi-dimensional distance between two communities, Z is the standard number of biological variables, a and b indicate plant communities and i relates to the biological variables. It is possible to obtain a numerical value to indicate the multi-dimensional distance from the case, which have the best situation from the standpoint of biological variables toward climax condition.

By using this method, each plant community gets a quantitative value, considered as its "development index" which indicates the development of the plant community toward the climax stage of ecosystem (Table- 1).

By using Multiple Regression, a mathematical model the development index of communities and environmental variables has been developed.

Table 1 .The average values of biological variables in plant communities and development index.

Plant Communities	Crown Closure (%)	Plant Diversity (species N/ha)	Canopy height (m)	Seedling Density (N/ha)	Development Index
Quercto-Carpinetum .	99.5	23.1	29.8	1902.5	0.226
Parrotio-Carpinetun	97.5	25.2	26.7	1675.2	0.141
Rusco-Fagetum	89.7	27.1	24.9	1347.5	0.182
Fagetum-Ilexosum	87.6	27.3	21.9	1180.1	0.253
Querceto-Carpinetum	78.8	26.2	22.0	720.1	0.386
Cushioned Commun.	13.7	23.1	0.65	525.1	0.743
Grassland Commun.	11.2	18.1	0.51	325.2	0.604
Mean	68.29	24.14	18.01	1096.5	---
Standard Deviation	38.75	3.23	12.25	594.08	-----
CV%	56.74	13.30	68.02	54.18	

RESULTS AND DISCUSSION

The mean values of climatic variables in different plant communities are given in Table 2, which has been estimated from meteorological data from eight weather stations in the area. The average values of soil properties have been collected from a 1:50000 soil map prepared by the Gorgan Soil and Water Research Center are shown in the Table 3.

To evaluate the topographic variables, a 1:50000 topography map prepared by the Iranian Geographical Organization (1995) has been used. The variables have been controlled through a systematic sampling. The average values of the topographic data are given in Table 4.

The statistical values of the crown closure (vegetation density), plant diversity (number of species in community) and canopy height in different plant communities have been presented in Figures 1, 2 and 3. These diagrams indicate that the maximum amounts of crown closure and canopy height are related to the *Querceto-Carpineteum* and *Parritio- Carpinetum* communities.There was no significant variation in plant diversity among different plant communities of Area. Also, the maximum seedling density has been seen in *Querceto-Carpinetum* stands. Figures 1 and 2 show the mean values and variation of ecological factors at different communities.

After testing the different mathematical

Table 2. The average values of climatic variables in different plant communities.

Plant Communities	Annual precipitation (mm)	Mean Annual Temp. (C)	Potential Evaporation (mm)	Average Minimum Temp. (C)	Average Maximum Temp. (C)
Quercus & Carpinus b.	683.3	15.20	704.2	-1.5	29.8
Parrotio & Carpinus b.	592.5	12.80	620.0	-3.6	26.6
Ruscus & Fagus	599.2	12.00	527.5	-4.7	24.2
Fagus & Ilex	561.9	9.25	388.1	-7.5	21.5
Quercus & Carpinus or.	490.0	9.12	461.1	-7.7	22.4
Cashion Type plants	448.7	7.00	452.5	-8.68	21.1
Grassland Comm.	446.0	6.50	360.0	-9.97	19.6
Mean Values	545.9	10.27	501.93	-6.23	23.5
Standard deviation	81.22	3.19	124.31	3.04	3.56
CV %	14.90	31.06	24.77	48.8	15.15

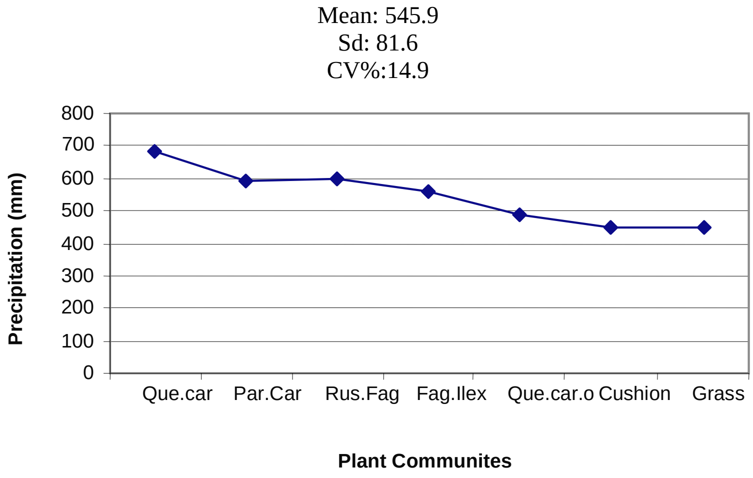

Figure 1. Annual precipitation at different plant communities.

models, the multiple linear regression (step-wise method) provided a linear correlation between the biological variables of plant communities and the environmental factors, such as climatic elements, topography and soil properties at a significant level. In the other term formation, distribution, reproduction and stability of a plant community in Qara Soo Catchment Area depended significantly on some of the physical components of ecosystems over which climatic elements are dominated.

The model produced a simple formula showing the relationship between the development index and the physical components of ecosystem. The development index of a community is the function of annual precipitation, air temperature, sea level elevation and slop aspect as below:

$$Y=-0.0033X1-0.251X2-0.0003X3+ 0.36X4 + 0.15X5- 0.0096X6+ 0.97$$

Where,

Y = Development Index of Plant Community

X1= Annual Precipitation

X2= Mean Monthly Temperature

X3= Minimum Temperature

X4= Maximum Temperature

Table 3. Average values of soil properties in different plant communities.

Plant Communities	PH	T.S.S (%)	EC. 1000 (m.mos)	Organic Carbon (C%)	Depth of Topsoil (cm)
Quercus & Carpinus b.	6.91	0.926	0.50	3.89	130.8
Parrotio & Carpinus b.	6.97	0.031	0.72	2.45	103.7
Ruscus & Fagus	6.86	0.044	0.85	3.48	111.7
Fagus & Ilex	7.25	0.033	0.57	1.82	98.7
Quercus & Carpinus or.	6.43	0.036	0.96	5.17	120.1
Cashion Type Plants	6.55	0.017	0.64	4.53	48.7
Grassland	6.99	0.016	0.73	3.70	36.0
Mean	6.85	0.029	0.72	3.58	92.8
Standard Deviation	0.29	0.010	0.15	1.14	36.22
CV %	4.23	34.94	20.83	32.02	39.03

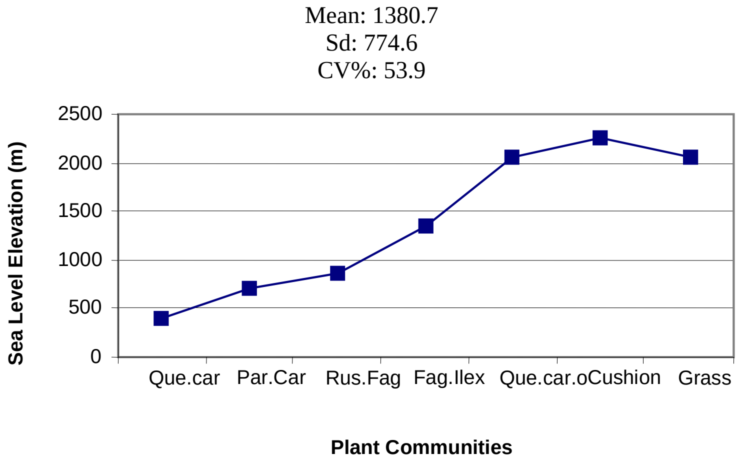

Figure 2. Mean elevation of different plant communities.

X5= Elevation
X6= Slope Aspect
R2 = 0.899.

There is a significant level of correlation between physical and biological variables of a plant community, especially climatic elements.

CONCLUSIONS

The study of the biological and physical variables of plant communities in the Qara Soo watershed and systematic analysis of the data, has provided numerous detailed conclusions that can be useful for ecological investigation and conservation practices. It is quite necessary to introduce plant species for afforestation, range improvement, bio-engineering practices in soil conservation and desert reclamation according to the ecological requirements of the plants. Furthermore, understanding the relationship between plant community variables and climatic elements can be very useful in paleobotany and paleoclimatic studies.

According to Table 2, the Querceto-Carpinetum (Oak and Hornbeam) community has the maximum amount of annual precipitation, the highest temperature over the year and the deepest topsoil profile. The minimum level of precipitation, the lowest temperature and the shallowest topsoil are related to the grassland community.

The development index of plant communities decreases by increasing mean annual temperature, annual minimum temperature and slope aspect (northward bearing in degree). The effect of annual precipitation and annual maximum temperature on the plant community development index are not considerable. Also, the development index of a plant community increases with the sea level elevation of its sitvation.

The maximum amount of crown closure, canopy height and seedling density have been measured at the *Querceto-Carpinetum* community which has the maximum amount of soil depth in the Catchment Area. There was a positive linear correlation between the crown closure of stands and annual precipitation at the level of 95% significance. Seedling density and crown height increased with mean annual temperature and potential evapo-transpiration. The variation of plant diversity in different plant communities was not significant (CV = 13.3 %).

Table 4. The mean values of topographic variables in different plant communities.

Plant communities	Sea Level Elevation (m.)	Slope Gradient %	North Angular Aspect (Dg)
Quercus & Carpinus b.	405	7.4	41.3
Parrotio & Carpinus b.	710	12.5	39.4
Ruscus & Fagus	860	26.6	45.0
Fagus & Ilex	1340	28.7	45.0
Quercus & Carpinus or.	2050	38.7	67.5
Cashion Type Plants	2250	28.7	101.2
Grassland	2050	30.0	40.5
Mean	1380.7	24.67	54.27
Standard Deviation	744.6	10.86	22.84
CV%	53.9	44.03	42.08

Climatic factors exert the dominant control on distribution, stability, and development of plant communities in Qara Soo area, according to the findings of Kozlowsky (1976), Larcher and Bauer (1980) and Spurr and Barnes (1980). Within the selected macro-climatic area, a small-scale variation in plant community distribution may be controlled by some features of the physical condition of ecosystem such as soil properties, climate and topography. However, at all spatial scales the response of the community to climate is a crucial feature in its formation and stability.

It is most suitable to refer the proposal of Sabeti (1969): "A plant can be known as a indicator of climatic condition in the area and the rate of accuracy increases by decreasing the range of ecological variables."

It was further concluded that numerical taxonomy, which has been commonly used by social scientists, could be applied for the systematic analysis of plant communities for ecological and geographical investigation as a tool of data processing. This method has a high potential for sorting, classification and optimum selection of units in a system.

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بررسی رابطه بین شرایط آب وهوایی و متغیرهای جوامع گیاهی حوزه آبخیز قره سو در گرگان

ن. بیرودیان

چکیده

جهت درک روابط بین آب و هوایی و متغییرهای زیستی جوامع آبخیز رودخانه قره سو ابتدا اقدام به نمونه برداری سیستماتیک از متغییرهای زیستی شامل تراکم تاج پوشش، تنوع زیستی، زادآوری و ضخامت تاج پوشش گردید. همچنین متغیرهای محیطی شامل عناصر آب وهوایی، مشخصات خاک پستی و بلندی و وضعیت زمین شناسی هر یک از جوامع گیاهی جمع آوری شد. سپس با استفاده از مدل ریاضی تاکسونومی عددی جوامع گیاهی به گروههای همگن تقسیم و شاخص توسعه هر یک از جوامع محاسبه گردید. آنگاه با استفاده از مدل همبستگی چند عامله رابطه بین توسعه یافتگی جوامع و متغییرهای محیطی بررسی گردید و مشخص شد که در این حوزه عوامل آب و هوایی بیشترین همبستگی را با متغییرهای زیستی دارامیباشند. بعبارت دیگر آب و هوا عامل برتر کنترل کننده تشکیل، توزیع، تجدید حیات و پایداری جوامع گیاهی است. همچنین مشخص گردید که مدل ریاضی تاکسونومی عددی که قبلاً بیشتر توسط جامعه شناسان و محققین علوم انسانی بکار گرفته می شد می تواند بعنوان ابزار علمی در تجزیه و تحلیل اکوسیستم ها بکار گرفته شود. نتایج این بررسی میتواند کارشناسان و محققین حفظ جوامع گیاهی و احیاء جوامع تخریب شده را کمک نماید.