A Methodological Approach to Model the Grass-Tree Relationship in *Quercus suber* Mediterranean Forest Ecosystems

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A methodological approach to model the grass-tree relationship in *Quercus suber* Mediterranean forest ecosystems

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Abstract. Livestock is socially and economically an important component for the livelihood of resource poor farmers in North Africa. A portion of livestock feed resources is forest rangeland. Unfortunately, the sustainability of this resource is threatened by anthropogenic pressures. In this study a number of silvo-pastoral management systems were proposed to maintain the ecosystem balance, and to cope with Mediterranean climate variability and the negative impacts of human activities and population pressure. For this reason it was important to examine the major relations within the North African forest ecosystems, which is composed mainly of *Quercus suber* trees. The aim of this work was to develop models relating fodder production as the dependent variable to the independent variables; *Quercus suber* canopy cover, ecological factors, and human pressure. This paper presents the methodological approach used in the Kroumiry-Mogody (Tunisia) and Mamora (Morocco) forests of North Africa. Initially, a forest inventory based on stratified sampling was conducted looking at density, height, and canopy cover. A comparative study was later established. In parallel, a survey was conducted in the surrounding agglomerations to assess the impact of human activities. The buffer technique was used to establish the relationship between fodder production and distribution, canopy cover, and human pressure. The methodology involved the creation of a specific zone around each agglomeration, which was mainly a function of the distance to the forest, the topographical features, and the number of domestic animals. The proposed approach will provide forestry managers with the ability to determinate different levels of anthropogenic pressure and to respond with contingency measures for each of these levels.

Keywords: Silvo-pastoral management, anthropogenic pressure, vegetation charting, VegMeasure.

Introduction

Cork oak is an evergreen species native to the Western Mediterranean Basin. Cork oak forests are mainly located in the coastal and precoastal areas from the Iberian and Italian Peninsula, South France to Northern Africa (Lopez de Heredia *et al*. 2007; Staudt *et al.* 2008). In North Africa, cork oak forests extend from the Atlantic Coast in Morocco (Mamora forest) through the Algerian Coast to the North Western of Tunisia with a scattered distribution over the two Mountain ranges of Kroumiry and Mogody. Excessive human pressure is usually pointed as the main cause of the reduction in cork oak forest ecosystems (Ben Mansoura *et al.* 2001).

Cork oak provides many products and services such as livestock grazing, fuel-wood, and acorns (Daly and Ben Mansoura 2009). A study recently conducted evaluating the economic valuation of goods and services of Tunisian forests showed that the forage production is the main direct benefit (38 %) of cork oak forest (Daly *et al.* 2012). For local populations, the income generated from animal production represents a major source of the household total income, primarily from sheep and goat enterprises. Overgrazing and a failure to use rotational grazing systems prevent the regeneration of cork oak and the associated herbaceous species (Daly and Ben Mansoura 2009).

An element for supporting decision-making for reciprocal protection of vegetation and human activities (Sedda *et al.* 2011) is the promotion of sustainable management of cork oak forests (Daly *et al.* 2012) which links livestock and forest. Analysing changing landscape patterns is one approach to better understand the ecological dynamics and the influence of natural and human disturbances in the cork oak forests (Turner 1990). Such approach offers a useful tool for natural resource managers to better manage woodland resources. This paper presents the methodological approach to develop models for predicting forage yield under cork oak forests across different regions of North Africa.

Methods

Study area

The study was conducted in Tunisia and Morocco. In Tunisia the three regions in Kroumiry-Mogody, viz. Bellif, Khroufa, Fernana, are located between 8°34’ and 9°44’ longitude E and 36°27’ and 37°20’ latitude N. In Morocco, Mamora, Canton A located between 6°34’ and 6°45’ longitude W, 34°00' and 34°16' latitude N was selected as the target site.

In Kroumiry-Mogody, the major soil groups are forest soils (leached brunified soils, mull soils) settled on the flysch oligocene zone of numidia and Mediterranean red soils, (Mtimet 2001). The climate varies from a semi-arid with moderate cool winters and dry summers in the southern of Kroumiry-Mogody to humid with cool winters and modest warm summers in the centre of the Mountain ranges, to finally a sub-humid climate with mild winters and moderate summers (Staudt *et al.* 2008).

The Mamora soils are characterized by a sand layer with a variable depth covering a clay floor (Lepoutre 1965). The occidental Mamora is exposed to sub-humid climate with a mild winter and moderate summers. While, oriental part is characterized by a semi-arid climate with moderate cool winters and modest warm summers (Benjelloun *et al*. 1997).

Methodology

Forest inventory: The forest inventory is conducted on large circular plots, 1256 m^2 in area with 20 m radius (Gilliam 2007). In Tunisia, a total of 90 plots were assessed, 30 plots in each of the three regions. In the Mamora forest, 30 plots were also selected. The parameters measured were density, height, 1.3 m diameter and canopy cover.

Understory assessment: To study the understory, vegetation cover was measured using two methods: the quadrat point frame and digital vegetation charting technique (DVCT). The quadrat point frame used two perpendicular transects of 20 m, each with 100 observations. The DVCT images were taken with a digital charting apparatus composed of digital camera, a handled GPS, a bubble level mounted on a wooden platform attached to a Bogen-Manfrotto 3025 3D Junior Tripod Head (Louhaichi *et al.* 2010, 2012) in six subplots of 1 m² each, delimited on the ground with a PVC square (3 under the crown cover projection on the ground and 3 out in open sky). Captured images were analysed using a computerised vegetation measurement image processing software "VegMeasure"®.

Gilliam and colleagues (1995), in West Virginia hardwood, also used a 1 m² subplots nested within circular 400 m² plots to combine assessment of the tree and herbaceous strata in the same sample area.

Plant height was measured at five points (the four corners plus the middle) and the fresh weight after harvesting with shears was recorded. Herbage cover and height were used to develop a formula to predict above ground herbaceous biomass.

Results

To explain variation in fodder production in the cork oak forest resulting from human activities, we established several buffer zones with 500 m radius around the agglomerations using analyst module in geographical information systems (GIS) environment. This technique has been used for various purposes to study cork oak forests in Morocco and Tunisia (Torres *et al.* 2009; Cherki and Gmira 2012). Mathematical relationship will be tested in each buffer zone.

The mathematical expressions between the cork oak trees and the herbaceous understory do not explain the basic causes of the relationship; nevertheless, they have many useful applications (Jameson 1967). Generally, those expressions included measurement of trees as the independent variable (x) and measurement of herbage as dependent variable (y).

Jameson (1967) reported several models such as log y= a+bx, y=a+bx+cx² and for some cases y=a+bx+cx²+dx3 which would generate acceptable results. He also used a sigmoid expression given by Grosenbaugh (1965):

$$Y= H+A\ [1-e^{-B(X-G)}]^{M+1}$$

where "A and H are the upper and lower asymptotes, respectively. B provides the necessary curvature, M adjusts the inflection point and G adjusts the value of X so that X-G= 0 when Y=H" (Jameson 1967)

The North African forests are quite populated. In Tunisia, in the last recent years, the forest population was estimated to about one million habitants, which represents 10% of the Tunisian population (Saadani *et al.* 2012). In fact population density in forest areas is twice higher than the national Tunisian average which is about 61 inhabitants per km² (Daly and Ben Mansoura 2009). Thus population could be considered a composed independent variable (X), grouping the population size, the livestock population size and the agglomerations distance to the forest:

$$X= x_1 * x_2 * x_3 \ldots * x_n$$

where X: independent variable expressing the human factor, x_1: population size, x_2: livestock size and x_3 is the distance separating agglomerations to forest. x_n could be considered for human activities other than grazing such as cork, wood and non-woody products harvesting.

Cherki and Gmira (2012) used the agglomerations proximity and activities as independent variable (y=a+bx) to explain the number of forest fires in Mamora, Morocco. They demonstrated that if livestock grazing is implemented in a well-balanced manner, it could play a key role in reducing fire hazards.

In another study, Scanlan (1992) developed an ecological model based on the competitive and stimulatory relations between the eucalyptus and mesquite trees and the herbaceous layer respectively in Australia and United States. Ecological models could be useful in ecosystems with minor disturbance. In fact, Scanlan (1992) used ungrazed or lightly grazed sites to valid his model. North African forests are characterized by overgrazing and its impact on environmental degradation (Ben Mansoura *et al.* 2001). The competitive and stimulatory relations in such cases could not be properly identified.

Conclusion

There is a gap in knowledge when it comes to understanding the grass-tree relationship in the Mediterranean forests in North African, and in the cork oak forest in particular. Analysing the response of the understory vegetation to the trees dominant layer and developing models to predict their production could help decision makers and land managers dealing with holistic resource management of forests. These models provide useful quantitative parameters leading to a more sustainable management of our natural resources.

References

Benjelloun H, Zine El Abidine A, Larhlam A (1997) Impact of different Plantations species, Cork oak and the absence of tree cover on the physico-chimical proprieties of soil in Western Mamora. *Annales de la Recerche Forestière au Maroc* **30**, 17-31.

Ben Mansoura A, Garchi S, Daly H (2001) Analyzing Forest users' destructive behavior in Northern Tunisia. *Land Use Policy* **18**, 153-163.

Cherki K, Gmira N (2012) Spatial distribution of forest fires analysis based on human activities and ecological and biophysical factors- Forest of Mamora-Morocco. *Spanish Journal of Rural Development* **3**, 87-102.

Daly H, Ben Mansoura A (2009) Private and social values and their distribution in Tunisian cork oak forests. XIII World Forestry Congress Buenos Aires, Argentina, 18-23 October 2009.

Daly H, Croitru L, Tounsi K, Jebari S (2012) Economic valuation of goods and services of Tunisian forests. General Directorate of Forests, Directorate of socio-economic development and forest people, Tunisia.

Gilliam FS, Turill NL, Adams MB (1995) Herbaceous-layer and overstory species in clear-cut and mature central Appalachian hardwood forests. *Ecological Applications* **5**, 947-955.

Gilliam FS (2007) The ecological significance of the herbaceous layer in temperate forest ecosystems. *BioScience* **57**, 845-858.

Grosenbaugh LR (1965) Generalization and reparameterization of some sigmoid and other nonlinear functions. *Biometrics* **21**, 708-714.

Jameson DA (1967) The relationship of tree Overstory and Herbaceous Understory Vegetation. *Journal of Range Management* **20**, 277-293.

Lepoutre B (1965) Régénération artificielle du Chêne liège et équilibre climatique de la subéraie en forêt de la Mamora. Station de la Recherche Forestière de Rabat. Annales de la Recherche Forestière au Maroc, Tome 9.

Lopez de Heredia U, Jimenez P, Collada C, Simeone MC, Bellarosa R, Schirone B, Cervera MT, Gill L (2007) Multi-marker phylogeny of three evergreen oaks reveals vicariant patterns in the Western Mediterranean. *Taxon* **56**, 1209-1220.

Louhaichi, M, Johnson MD, Woerz A L, Jasra AW, Johnson DE (2010) Digital charting technique for monitoring rangeland vegetation cover at local scale. *International Journal of Agriculture and Biology* **12**, 406-410.

Louhaichi M, Johnson MD, Clark PE, Belgacem AO, Johnson D (2012) Developing a coherent monitoring system for Mediterranean grasslands. New Approaches for grassland research in a context of climate and socio-economic changes. *Options Méditerranéennes*, Series A, **102**, 47-51.

Mtimet A (2001) Soils of Tunisia. *Options Méditerranéennes*, Série B No **34**.

Sedda L, Delogu G, Dettori S (2011) Forty-Four Years of Land Use Changes in a Sardinian Cork oak Agrosilvopastoral System: A Quantitative Analysis. *The Open Forest Science Journal* **4**, 57-66.

Saadani Y, Tounsi K, Ben Mimoun A (2012) Forest Population in Tunisia: Towards a National Socio-Economic referential framework. General Directorate of Forests, Directorate of Socio-economic Development and Forest People, Tunisia.

Scanlan J (1992) A model of woody-herbaceous biomass relationships in eucalypt and mesquite communities. *Journal of Range Management* **45**, 75-80.

Staudt M, Ennajeh A, Mouillot F, Joffre R (2008) Do volatile organic compound emissions of Tunisian cork oak populations originating from contrasting climatic conditions differ in their responses to summer drought. *Canadian Journal of Forest Research* **38**, 2965-2975.

Torres E, Béjar A, Boussaidi N, Hasnaoui B, Jiménez S (2009) How affect the anthropic actions on the cork oak forests of North West Tunisia? EFIMED Annual Meeting, Marrakech, Morocco, 28 April–1 May 2009.

Turner MG (1990) Landscape Changes in Nine Rural Counties in Georgia. *Photogrammetric Engineering and Remote Sensing* **3**, 379-386.