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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 an important social and economic component for the livelihoods of resource-poor farmers in North Africa. A portion of livestock feed resources is forest rangeland. Overgrazing and a failure to use rotational grazing systems prevent the proper functioning of forest ecosystems. To protect vegetation and to guarantee human activities, natural resources manager need tools for supporting decision-making. The North African forest ecosystems are composed mainly of *Quercus suber* trees. The aim of this work is 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 mountains (Tunisia). 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 mapping.

Approche méthodologique pour la modélisation de la relation herbe-arbre dans un écosystème forestier Méditerranéen de chêne liège (**Quercus suber*****)***

Résumé. *En Afrique du Nord, l'élevage constitue une activité économique et sociale importante pour les ménages à faible revenus. Les parcours forestiers contribuent à la satisfaction des besoins fourragers du cheptel. La durabilité de ces écosystèmes est, donc, mise en cause par la pression anthropozoïque. Nous avons étudié, en premier lieu, les relations qui existent dans un écosystème de chêne liège (*Quercus suber*) en Afrique du Nord. Notre objectif étant de développer des modèles d'estimation de la production fourragère herbacée sous le chêne liège en fonction du couvert arboré, des facteurs écologiques et de la pression anthropique. Un inventaire des paramètres dendrométriques et une appréciation de l'impact de l'activité humaine ont été réalisés. Des zones tampons ont été créées autours des agglomérations pour définir les différents niveaux de dégradation.*

Mots-clés. *Aménagement Sylvo-pastoral – Pression Anthropique – Cartographie de la végétation.*

I – 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 and North Africa (López de Heredia *et al*., 2007; Staudt *et al*., 2008). In North Africa, cork oak forests extend from the Atlantic Coast in Morocco 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 out 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.

II – Methods

1. Study area

The study was conducted in Tunisia in Kroumiry-Mogody, located between 8°34’ and 9°44’ longitude E and 36°27’ and 37°20’ latitude N. 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 a sub-humid climate with mild winters and moderate summers (Staudt *et al*., 2008).

2. Methodology

Forest inventory. The forest inventory is conducted on large circular plots, 1256 m^2 in area with 20 m radius (Gilliam 2007). A total of 90 plots were assessed. 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 *et al.* (1995), in West Virginia hardwood, also used 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.

III – 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 $\log y = a + bx$, $y = a + bx + cx^2$ and for some cases $y = a + bx + cx^2 + dx^3$ which would generate acceptable results. He also used a sigmoid expression given by Grosenbaugh (1965)

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

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).

North African forests are quite populated. In recent years, the Tunisian 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 doubles 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.

$$X = [x_1 + x_2 + x_3 + x_n]$$

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. xn could be considered for human activities other than grazing such as cork, wood and non-wood products harvesting.

Cherki and Gmira (2012) used the agglomerations proximity and activities as independent variables ($y = a + bx$) 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.

Ecological models, such developed by Scanlan (1992), could be useful in ecosystems with minor disturbance and need to be valid in ungrazed or lightly grazed sites. North African forests are characterized by overgrazing and its impact on environmental degradation (Ben Mansoura *et al*., 2001) and ecological relations in such cases could not be properly identified.

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