

Arboreal Diversity and Aboveground Biomass in a Semi-arid Mediterranean Forest Ecosystem: Case of Kufur-khal Natural Reserve

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ABSTRACT

A recently protected semi-arid east Mediterranean forest ecosystem was investigated for its arboreal species composition, diversity and aboveground biomass productivity. Variability was investigated in response to the dominant forest type, the percent crown cover and the disturbance history. Dominant forest types were either *Quercus calliprinos* or *Pinus halepensis* in addition to gaps with no forest cover. Percent crown cover ranged from dense to sparse cover. The disturbance history of grazing and human land-use changes were moderate followed by protection measures. Results indicated that *P. halepensis* dominated blocks showed higher tree diversity and higher aboveground biomass productivity than *Q. calliprinos* dominated blocks. Protection significantly affected species composition with a much more positive impact on *Pinus* than on *Quercus* at least at the short run. *Q. calliprinos* is more adapted to moderate disturbance than *P. halepensis*. Short and long term implications for the protection and forestation of semi-arid east Mediterranean forest ecosystems on biodiversity were discussed.

Keywords: Species Composition, Disturbance, Grazing, Protection, Conservation, Carbon Sequestration.

1. INTRODUCTION

Forest ecosystems worldwide, which cover less than four billion hectares, (Dixon *et al.*, 1994; FRA, 2005) provide habitat for a large number of species and account for a significant portion of the carbon (C) flux (emission or sequestration) (IPCC, 2000; Binkley *et al.*, 2002; Cannell, 2003; Toan *et al.*, 2004). Despite their minute contribution to the world's forest area, mid-latitude forests, especially the Mediterranean forests, are of great

importance for both biodiversity conservation and carbon sequestration (Dixon *et al.*, 1994; Lavorel, 1999; Ehman *et al.*, 2002).

Eastern Mediterranean forests have evolved under various forms of disturbance such as grazing, fire, and human influence and in fact the history of these forests is rich with deforestation and fragmentation practices (Harlan and Zohary, 1966; Harlan, 1975; Hawkes, 1977; Naveh and Carmel, 2003; Hunt *et al.*, 2004). Resilience of these plant communities to a disturbance rich history was attributed to their high diversity and their extremely heterogeneous environments. In addition, efficient regeneration strategies may have contributed to the sustainability of these communities (Zohary, 1962; Lavorel, 1999; Naveh and Carmel, 2003). Despite their resilience, Mediterranean plant communities may be subjected to increasing disturbance pressure in the form

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of urbanization, overgrazing, and land-use changes. Mechanisms underlying the resilience of ecosystems need to be understood for an effective conservation (Lavorel, 1999; Cihlar *et al.*, 2002; Toan *et al.*, 2004). At the same time, the impact of forest conditions on biodiversity needs to be understood as well. Such information are usually lacking especially in developing countries (Binkley *et al.*, 2002) such as Jordan.

Forest ecosystems offer various means of mitigating climatic changes (Vine *et al.*, 1999; McCarl *et al.*, 2000; Binkley *et al.*, 2002; Canell, 2003). According to articles 3.3 and 3.4 of the Kyoto Protocol, the cheapest recognized method of controlling the increase of atmospheric CO₂ is afforestation (IPCC, 2000; Binkley *et al.*, 2002). Afforestation has a great potential in developing countries, where large arid and semi-arid barren lands exist (Keller and Goldstein, 1998; Cannell, 2003; Grunzweig *et al.*, 2003). The co-benefits of forest conservation, reforestation, and afforestation include biodiversity conservation, watershed protection, soil conservation, providing sustainable biomass energy and providing employment, development and rural livelihood protection and promotion (Binkley *et al.*, 2002; Carswell *et al.*, 2003; FRA, 2005). Thus, recent forestry strategies should be directed to the preservation of existing forest ecosystems, reforestation of degraded forestlands and afforestation of new land.

Coniferous forests (represented by *Pinus halepensis*) and evergreen oak forests (represented by *Quercus calliprinos*) are the most important constituents of Jordan's forests. *P. halepensis* forests are the southernmost and easternmost pine forest of the Mediterranean region (Zohary, 1962). These forests are remnant of a much wider distribution in the past (Zohary, 1962; Hunt *et al.*, 2004; Al-Horani, 2007). These forests may have declined due to human interference and low recruitment rates in addition to the impact of the changing environmental conditions during the Holocene. *P. halepensis* is short-lived, shade intolerant, and fire susceptible as an adult but requires fire for optimum

regeneration due to optimum site conditions after fire (Zohary, 1962; Tapias *et al.*, 2004). *P. halepensis* forests are sub-climax forests that may be replaced by *Qcalliprinos* and may be found in association with *Arbutus andrachne*, *Pistacia Palaestina*, and many other species (Zohary, 1962). *Qcalliprinos* forests are the most common forest type in Jordan. These forests are characterized by their ability to withstand human interference and animal grazing (Zohary, 1962). *Q. calliprinos* is a shade tolerant species but requires relatively large amounts of water.

Jordan's forests cover less than 1% of the total area of the country; however they harbor a disproportionate number of rare, threatened and endangered species (Al-Eisawi *et al.*, 1996; Tellawi, 2001). There has been no systematic study of the composition and dynamics of Jordan's forests. The lack of basic data had and still prevents the estimation of the importance of these ecosystems as biodiversity hotspots.

Jordan's forest area and quality are declining and degrading. Threats to Jordan's forests can be divided into: 1) increasing urbanization due to rapid population growth; 2) increasing shifting agriculture from forests to tree orchards mainly oliviculture; 3) increasing pressure of grazing especially browsing animals such as goats; and 4) increasing the negative impact of recent climate change including lower precipitation and/or higher summer temperatures. These threats have been identified by most researchers; however, recent observations indicated that grazing and climate change may have a different role in preserving biodiversity and enhancing the role of these forests and the whole arid Mediterranean lands as a carbon sink (Grunzweig *et al.*, 2003; Bernues *et al.*, 2005).

The current study aimed to survey an eastern Mediterranean forest to achieve the following objectives: 1) to provide basic measurements of arboreal composition, arboreal diversity, and total aboveground biomass; and 2) to illustrate the impact of forest ecosystem type, forest cover and land-use intensity and

grazing pressure on the studied characteristics and parameters.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The study was conducted within the boundaries of Prince Hamza Nature Reserve (PHNR) which is located at Kufur-Khal in Jarash governorate within the eastern Mediterranean forest ecosystem of Jordan (Fig. 1). The reserve is located at 32° 21' N and 35° 52' E with altitude ranging between 900 and 1100 m above sea level. The long term annual rainfall (average of 25 years) was estimated at approximately 500 mm. This reserve is recently administered by Jordan University of Science and Technology (JUST) for management and education purposes. Historic aerial photographs (since 1952) indicated that this forest and the surrounding areas are located within moderate distance from low populated human settlements and thus have been subjected to moderate human related disturbance pressures mainly

attributed to animal grazing and deforestation. This reserve is a 40-ha forest that has been under protection since 2002. This natural reserve contains two of the most common Jordanian forest ecosystems and presents an ideal case to study the composition and dynamics of eastern Mediterranean forest ecosystems.

2.2. Field Sampling and Data Collection

The PHNR was divided into blocks of 0.5 ha each. Blocks at the borders that were less than 0.25 ha in area were excluded, bringing the available blocks for sampling to 64 (Fig. 1). Percent crown cover of each block was estimated using the point transect method along two 20 m transects running east-west and north-south through the center of each block (Bonham, 1989; Husch *et al.*, 2003). The presence or absence of tree cover was recorded every one meter along these transects. Percent crown cover was then calculated by dividing the number of sampled points with the presence of crown cover over the total number of sampled points multiplied by 100%.

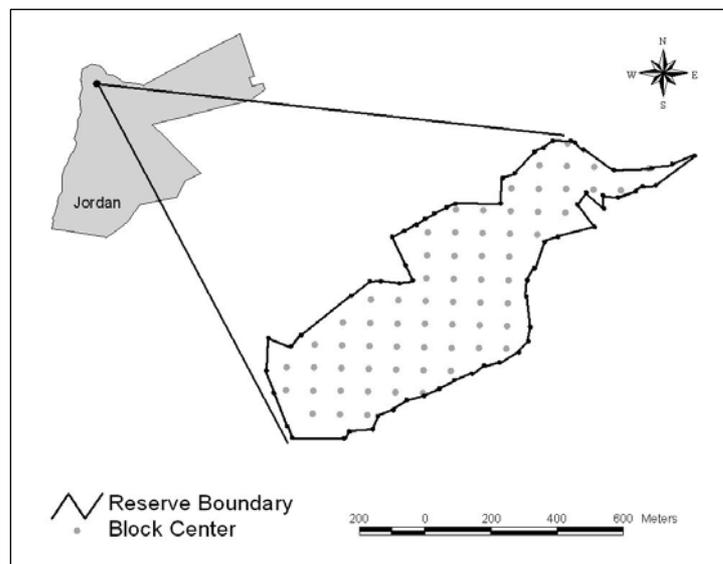


Fig. 1. Location of the study area at Prince Hamza Nature Reserve (PHNR) in the northwestern part of Jordan. Sample locations within the study area are shown.

At the center of each block, three concentric circular plots were used. The first and smallest plot had an area of 1 m² and was used to collect herbaceous species and tree litter. These materials were oven dried at 72 °C for 72 h and weighed separately. The second plot had an area of 5 m² and was used to count seedlings. Seedlings were identified as tree species of less than 1 m in height. The third and largest plot had an area of 100 m² and was used to measure tree parameters (number of stems per rootstock, diameter at breast height (DBH; 1.37 m), total height (Ht), and crown diameter (CD)) and to count shrubs of more than 1 but less than 2 m in height. DBH was recorded for stems of more than 5 cm and was measured using a diameter tape. Total height was measured using a telescopic rod. Crown diameter was calculated as the average of two perpendicular measurements using a tape (Bonham, 1989; Husch *et al.*, 2003).

2.3. Estimation of Aboveground Biomass

Herbaceous and tree litter biomass were pooled to indicate total forest floor (ground) biomass. Tree biomass was calculated from the volume of sampled trees. Tree volume was calculated using specific volume tables developed under Jordanian conditions (DOF, 1995). Total tree biomass was calculated based on the Biomass Expansion Factor of 1.25 for *Quercus* and similar species and 0.7 for *P. halepensis* (Garcia *et al.*, 2004).

2.4. Statistical and Diversity Analysis

Descriptive statistics for each of the measured parameters for each species were calculated (Sokal and Rohlf, 1995). Arboreal species richness was estimated by counting the number of various arboreal species in the largest plot while evenness (*E*) was calculated using Shannon diversity index divided by the natural logarithm of richness (Magurran, 1988; Krebs, 1989; Hernandez-Stefanoni and Ponce-Hernandez, 2004). Frequency, relative frequency, density, and relative density of each species were also calculated (Bonham, 1989).

The 64 sampled blocks were divided into three forest ecosystem types based on the dominant species,

representing the majority of forest ecosystems in Jordan. These types are: 1) *Quercus calliprinos* dominated forests; 2) *Pinus halepensis* dominated forests; and 3) Gaps that were completely lacking any tree cover but may contain shrubs or seedlings. Analysis of variance and mean separation using LSD (Sokal and Rohlf, 1995) were used to test the significant differences between forest ecosystem types in their arboreal diversity and aboveground biomass.

Based on the percent crown cover (regardless of the forest type), the sampled blocks were divided into three classes; 1) dense cover (50%-90% tree cover), 2) intermediate cover (10%-50%), and 3) sparse cover with rare or no forest cover (<10%). Analysis of variance and mean separation using LSD (Sokal and Rohlf, 1995) were used to test the significant differences between these three classes in their arboreal diversity and aboveground biomass.

The reserve was subjected to two different levels of human disturbance and ungulate grazing resulting in two recognized strata. The first stratum is the mature trees reflecting forest composition under the pressure of historic human disturbance and grazing (determined to be of moderate interference). The second stratum is the young seedlings that are less than three years old representing the response of forest composition under complete protection from human disturbance and from grazing. The relative density of each of the major species was compared between the two strata (trees and seedlings) using ANOVA and LSD (Sokal and Rohlf, 1995). This comparison is based on the assumption that these two species have similar mortality rates and that their composition at the seedling stage will become their composition at maturity. All statistical analyses were conducted using JMPIN version 5.1.2 (SAS, 2003).

3. RESULTS

This study is the first to report important information about east Mediterranean forest ecosystems in Jordan in

terms of arboreal species composition, richness and evenness, the first study to estimate aboveground biomass and finally to indicate the impact of human disturbance and animal grazing on these ecosystems.

3.1. General Description

Results indicated that PHNR has an average percent crown cover of $52.5\% \pm 1.9\%$ (SE) but ranging from 0% (gaps) to 90% (dense cover). The reserve is dominated by two forest types; *Quercus calliprinos* and *Pinus halepensis*, in addition to the gaps. The most frequent and dense species was *Q. calliprinos* with a frequency of 82.8% and a relative density of 73.7% (Table 1). The second and third most frequent species were *P. halepensis* and *Arbutus andrachne* usually associated

with each other and occurred in 26.6% and 23.4% of the sampled blocks with relative densities of 10.5% and 9.3% respectively (Table 1). In addition to these three species, five more species were found with low frequencies and densities. These are *Quercus infectoria*, *Rhamnus palaestinus*, *Pistacia palaestina*, *Crataegus aronia* and *Pyrus syriaca* (Table 1).

Diameter for the three most dominant species showed high variability. *Phalepensis* trees varied in their DBH from 17 cm to 50 cm with average of 31.9 cm while DBH for *Q. calliprinos* varied from 5 cm to 34 cm with an average of 12.8 cm and DBH for *A. andrachne* varied from 6 cm to 20 cm with average of 11.6 cm (Table 2).

Table (1): Frequency, relative frequency, density and relative density of all tree species found in Prince Hamza Nature Reserve (PHNR).

Species	Freq. (%)	Relative Freq. (%)	Density (tree/ha)	Relative Density (%)
<i>Quercus calliprinos</i>	82.8	54.5	284	73.7
<i>Pinus halepensis</i>	26.6	17.4	41	10.5
<i>Arbutus andrachne</i>	23.4	15.4	36	9.3
<i>Quercus infectoria</i>	9.4	6.1	9	2.1
<i>Pistacia palaestina</i>	7.8	5.1	11	2.4
<i>Rhamnus palaestinus</i>	1.6	1.0	5	1.0
<i>Crataegus aronia</i>	0.5	0.4	0.8	0.6
<i>Pyrus syriaca</i>	0.3	0.1	0.5	0.4

Table (2): The number of stems per rootstock (RS), diameter at breast height (DBH; 1.37m), total height and crown diameter of the most dominant tree species found in Prince Hamza Nature Reserve (PHNR). Means were separated using LSD.

Species*	Stems/RS	DBH (cm)	Height (m)	Crown Diameter (m)
<i>Pinus halepensis</i>	1.1 b	31.9 a	8.8 a	7.1 a
<i>Quercus calliprinos</i>	2.0 a	12.8 b	4.1 b	4.0 b
<i>Arbutus andrachne</i>	1.8 a	11.6 b	4.4 b	3.3 c

* Numbers within the same column that are followed by different letters are significantly different at the 0.05 significance level.

High variability was found between and among species for height. Based on the observed tree heights,

two strata were recognized. *Pinus halepensis* trees averaged 8.8 m in height significantly greater than all

other tree species (Table 2). The height of the second stratum ranged between 4.4 m and 4.1 m for *Arbutus andrachne* and *Quercus calliprinos*, respectively. Crown diameter for *Pinus halepensis* was the largest with an average of 7.1 m which is significantly greater than all other species. Crown diameter for *Q. calliprinos* averaged 4.0 m and was significantly greater than CD for *A. andrachne* that averaged 3.3 m (Table 2). Significant differences were also found between these tree species in terms of number of stems per rootstock. The shrubbier *Q. calliprinos* and *A. andrachne* averaged about two stems per rootstock whereas *P. halepensis* trees mainly grow as a uni-stem species (Table 2).

3.2. Effect of Forest Type and Percent Crown Cover on Diversity

Overall arboreal species richness was 2.5 species per plot (100 m²) and evenness (E) was 0.52 (Table 3). Arboreal richness but not evenness was significantly affected by forest type. Arboreal richness was higher in *Pinus* plots (3.3 species/100 m²) than *Quercus calliprinos*

plots (2.0 species/100 m²). Gaps harbored similar diversity as *Q. calliprinos* plots (Table 3) contributed mainly from shrubs and seedlings. Arboreal richness was significantly different among crown-cover-types but evenness did not differ significantly among those types. Arboreal richness was greater for dense plots as compared to sparse plots (Table 3).

3.3. Effect of Forest Type and Percent Crown Cover on Biomass

Overall average herbaceous biomass (± standard error) was 41±1 g/m² while tree litter biomass averaged 1,210±12.9 g/m² with average total ground biomass (herbaceous plus tree litter biomass) of 1,251±12.6 g/m². Overall tree and shrub biomass averaged 4,883±80 g/m² and total above ground biomass (ground plus tree biomass) averaged 6,134±81 g/m². Analysis of variance showed that there is a significant difference in all biomass variables among forest types and crown-cover-types.

Table (3): Arboreal species richness and evenness within three forest types and three crown cover classes at Prince Hamza Nature Reserve (PHNR). Means were separated using LSD.

<i>Stratification basis</i> [†]	<i>Class</i>	<i>DBH</i>	<i>Height</i>	<i>Richness (spp./100m²)</i>	<i>Evenness (E)</i>
Forest Type	<i>Pinus halepensis</i>	17.7a	5.5a	3.3a	0.55a
	<i>Quercus calliprinos</i>	13.6b	4.2b	2.0b	0.56a
	Barren forestland	0.0c	0.0c	1.7b	0.58a
Crown Cover	Dense (50%-90%)	13.7b	4.2b	2.7a	0.51a
	Intermediate (10%-50%)	16.2a	5.0a	2.2ab	0.48a
	Sparse (<10%)	0.0c	0.0c	1.7b	0.50a

[†] For each stratification base, numbers within each column that are followed by different letters are significantly different at the 0.05 significance level.

Table (4): Herbaceous biomass, tree litter biomass, total ground biomass, tree biomass and aboveground biomass as affected by forest types and percent crown cover at Prince Hamza Nature Reserve (PHNR). Means were separated using LSD.

<i>Stratification basis</i> [†]	<i>Class</i>	<i>Herbaceous Biomass (g/m²)</i>	<i>Tree Litter Biomass (g/m²)</i>	<i>Total Ground Biomass (g/m²)</i>	<i>Tree and shrub Biomass (g/m²)</i>	<i>Aboveground Biomass (g/m²)</i>
Forest Type	<i>Pinus halepensis</i>	2.60 c	465 b	467 b	8937 a	9404 a
	<i>Quercus calliprinos</i>	27.9 b	1737 a	1765 a	3943 b	5708 b
	Barren forestland	212 a	8.9 c	221 b	410 c	631 c
Crown Cover	Dense (50%-90%)	18.0 b	1357 a	1874 a	8269 a	9617 a
	Intermediate (10%-50%)	30.5 b	1331 a	1700 a	2635 b	4022 b
	Sparse (<10%)	147 a	396 b	576 b	470 c	1013 c
Average		41±1.0	1210±12.9	1251±12.6	4883±80	6134±81

[†] For each stratification base, numbers within each column that are followed by different letters are significantly different at the 0.05 significance level.

Considering forest type, herbaceous biomass was highest in gaps and lowest under *Pinus* plots. *Quercus calliprinos* dominated plots were intermediate in their herbaceous biomass (Table 4). Tree litter biomass and total ground biomass showed a different trend than herbaceous biomass among the 3 forest types. *Q. calliprinos* plots contained the highest tree litter biomass followed by *Pinus* plots followed by gaps (Table 4). Total ground biomass was similar among gaps and *P. halepensis* forests and it was significantly greater for *Q. calliprinos* than both forest types. Tree and shrub biomass was highest in *Pinus* plots followed by *Q. calliprinos* plots. Adding all sources of aboveground biomass, *Pinus* dominated plots contained significantly higher biomass than *Q. calliprinos* plots which in turn contained significantly higher biomass than non-forested gaps (Table 4).

Considering crown cover classes, herbaceous biomass was significantly highest in sparse plots and significantly

lowest for plots with dense and intermediate cover which did not differ significantly from each other (Table 4). Tree litter biomass and total ground biomass were highest under plots with dense and intermediate cover and lowest under sparse cover (Table 4). Tree biomass was highest under dense cover followed by intermediate cover followed by sparse cover (Table 4). Accordingly, total aboveground biomass showed a similar trend as tree biomass due to the dominance of tree biomass values (Table 4).

3.4. Protection Impact on Species Composition

Analysis of variance of the relative densities of trees and seedlings (as surrogate to moderate and protected land-use and disturbance history respectively) was highly significant. ANOVA and LSD indicated that relative densities of trees and seedlings of *Q. calliprinos* and *P. halepensis* but not *A. andrachne* were significantly different from each other. Relative density of *Q. calliprinos* was significantly higher under moderate land

use than under protected conditions (Table 5). Relative density for *P. halepensis* was highest under protected conditions and lowest under moderate use (Table 5).

Table (5): Mean relative densities of the three most dominant species as affected by land-use intensity at Prince Hamza Nature Reserve (PHNR). Means were separated using LSD.

Land use intensity [†]	<i>Q. calliprinos</i> (%)	<i>P. halepensis</i> (%)	<i>A. andrachne</i> (%)
Moderate	73.7 a	10.5 b	9.3 a
Protected	60.9 b	27.5 a	2.6 a

[†] Numbers within each column that are followed by different letters are significantly different at the 0.05 significance level.

4. DISCUSSION

The study revealed that the eastern Mediterranean forest understudy is very heterogeneous and diverse which may explain its known resiliency throughout long history of animal grazing, fire, and human impact. This forest consisted of trees from several species and several dimensions, growing adjacent to each other. Disturbance levels that may generate such forests are more likely to be of a moderate intensity happening frequently at a small spatial scale. Forestation programs should consider imitating natural forests by establishing more diverse plantations to provide for better wildlife habitat and biodiversity conservation as well as aid in the resilience of these forests in the face of future disturbances. Afforestation programs should focus on these native species and the protection of their genetic diversity.

4.1. Factors Affecting Arboreal Diversity

Biodiversity loss does influence ecosystem function and resilience (Bolger, 2001). In general, measures of arboreal diversity in the study area are considered moderate to high and are significantly affected by the dominant forest type. *Pinus halepensis* dominated plots provided more hospitable and equitable habitat for other tree species which was reflected in higher richness and evenness. *Quercus calliprinos* dominated plots were less

diverse possibly due to the high dominance of this species. Arboreal diversity was also affected by the percent crown cover. Dense plots harbored the greatest arboreal richness and evenness. This could be an artifact of the higher tree density in dense plots providing higher chance for the existence of more species. Facilitation rather than competitive exclusion may explain these results. Under semi-arid Mediterranean conditions, tree cover might help in alleviating extreme conditions that prevail under the long arid and hot summer of Mediterranean climates.

Results of the arboreal diversity in the current study can not be generalized to overall biodiversity since this study was conducted during the dry season where all herbaceous species were dead and thus were not surveyed. *Pinus halepensis* which harbored higher arboreal diversity is known to secrete allelo-chemicals that retard the growth of other species while *Quercus calliprinos* may not have such an allelopathic effect (Peñuelas and Llusia, 1998; Nektarios *et al.*, 2005; Alrababah *et al.*, 2007). This is partially supported by lower herbaceous biomass under *P. halepensis* dominated plots as compared to *Q. calliprinos* dominated plots (Table 4).

4.2. Factors Affecting Biomass

Jordan's natural forests which are mainly composed of *Quercus* with moderate cover may contain approximately 60 tones of biomass per ha (6,000 g/m²). Given that the area of natural forests in Jordan is about 26,000 ha with percent cover of approximately 50% (DOF, 1995), the total forests of Jordan may contain approximately 1.5 million tons of biomass. *Pinus* forests showed a larger capacity to produce aboveground biomass than *Quercus* dominated forests in accordance with results of atmospheric monitoring stations (Aubinet *et al.*, 2002). Thus, planting *Pinus halepensis* in these forests may improve their biomass productivity; however, caution should be given to the herbaceous plants and the allelopathic effect of *Pinus* on herbaceous plants (Alrababah *et al.*, 2007).

Improving the crown cover of these forests may even produce more aboveground biomass. Higher crown cover can be achieved by having higher number of trees per unit area and/or by having larger trees with larger crowns. Growing larger trees may be limited by the potential productivity of native tree species. Therefore, aboveground biomass can be possibly increased by increasing tree densities. Tree density can be enhanced through management practices including protection, planting or providing favourable conditions for regeneration such as the use of water harvesting techniques.

The current forestation policy (reforestation and afforestation) of barren forestlands executed by the Department of Forestry at the Ministry of Agriculture is underutilizing the potential of these lands. Forestation programs use single species plantations mainly as *Pinus halepensis* which is expected to have lower biomass than the natural multistory *Pinus* forests. The potential exists to enhance these *Pinus* plantations as a C sink by planting a mixture of other tree species in between such as *Quercus* or *Arbutus* or other native species such as wild *Pistachia*, *Pyrus*, *Prunus*, *Crataegus* and others. This will contribute to the conservation of local agrobiodiversity and of important species in the gene pools of fruit trees and may contribute to the diversification of income of local communities by exploiting these under-utilized and neglected species. The area of the existing *Pinus* plantations is around 50,000 ha (DOF, 1995) offering the potential to produce more aboveground biomass. There is a dire need to estimate biomass and C content of *Pinus* plantations in Jordan to estimate the potential of sequestering more C by mix-planting other species.

Forestation of barren forestland is an important avenue to sequester a large amount of carbon estimated by similar studies (Burrows *et al.*, 2002). The area designated as forestland but have no forest cover in Jordan is around 60,000 ha (DOF, 1995). Successful forestation of these areas can potentially harbor an additional 4.6 million tons of aboveground biomass; almost three folds the current aboveground biomass content of natural forests in Jordan.

4.3. Protection Impact

Livestock production in the highlands of the Mediterranean areas depends on forest grazing resources, which in turn can have a great impact on vegetation (Perevolotsky and Seligman, 1998; Casasus *et al.*, 2003) not only in terms of productivity and quality but also in terms of vegetation dynamics (Rook and Tallwin, 2003; Alhamad, 2006; Alrababah *et al.*, 2007), species and community diversity (Collins *et al.*, 1998; Sternberg *et al.*, 2000) and landscape (Hartnett *et al.*, 1996; Adler *et al.*, 2001; Kramer *et al.*, 2003). Continuous browsing of Mediterranean forest trees by animals resulted in the production of bushy growth form instead of a tree habit (Zohary, 1962, page 210). In general, grazing impact on forest regeneration and development ranges from negative (Jorritsma *et al.*, 1999) to positive (Bernues *et al.*, 2005).

Grazing in Mediterranean forest ecosystems may mitigate fire hazard and provide economic and social benefits (Bernues *et al.*, 2005). In the current study, grazing impact on forest composition was significant and varied between species. This change in species composition in some aspects may be viewed as positive and in other aspects it may be viewed as negative. There is a great need for continued monitoring and quantification of these changes.

The impact of protection on composition was studied under the assumption that *Quercus* and *Pinus* have similar mortality rates. Under such assumption it was noticed that *Pinus* benefited more than *Quercus* under protection. This conclusion is considered conservative since *Quercus spp.* has higher mortality rates than *Pinus halepensis* under Mediterranean conditions (Broncano *et al.*, 1998) indicating that *Quercus* will be affected more than *Pinus*.

Quercus calliprinos is a long-lived tree adapted to sprout after disturbance and is negatively affected by complete protection (personal observation). It is adapted to human practices such as fuel wood cutting and animal grazing. The higher relative density of *Q. calliprinos* was found under moderate grazing pressure and the lowest was found under protection. Similar observation on a

nearby reserve that has been protected for more than 20 years showed that *Q. calliprinos* trees are suffering a significant decline accompanied by low regeneration rates. The dominance of *Q. calliprinos* in the majority of Jordan's forests may have been a response to both climatic and management-related factors mainly grazing. The existence of such a tree may have contributed largely to the resilience of these forests despite their intensive utilization by humans and animals. Thus, protecting these forests may be viewed as negative and some management allowing regulated access might be needed.

Pinus halepensis is a species that benefited most from protection. Animal grazing may play a role at the very early stages of the plant's life. The lowest relative density of this species was found under moderate use and the highest under protection (Table 5). The historic moderate human interference was not severe enough to eliminate this species. Under no protection, *Pinus* seedlings were adversely affected by grazing pressure, whether through direct feeding by browsers or by the impact of animal hoofs. Therefore, under protection, *Pinus* seedlings are booming and may grow into mature trees. Although the pine trees gave the highest total above ground biomass, the herbaceous biomass underneath were sharply reduced (Table 4) making it difficult to judge whether this change is positive or negative.

Furthermore, the sustainability of *Pinus* dominated ecosystem is questionable under no grazing system, since *Pinus* is a sub-climax species that is shade intolerant, short lived and vulnerable to fire (Zohary, 1962). Under no grazing, *Pinus* will be replaced by *Quercus* since seedlings of *Quercus* and other species can grow slowly under the shade of *Pinus* but *Pinus* seedlings can not grow in the shade. If grazing is prevented, *Quercus* and other species will establish under *Pinus* and then replace it after its death. This indicate that despite the observed booming in *Pinus* seedlings, the future change in species composition will not last more than the estimated age of *Pinus* (Zohary, 1962). The study results indicated that the complete protection as an approach to conserve

biodiversity and/or produce more aboveground biomass needs to be revised and intensively investigated (Alrababah *et al.*, 2007). A management plan taken into consideration these findings and allowing sustainable use by local communities should be developed.

5. CONCLUSIONS

Semi-arid Mediterranean forest ecosystems are very diverse and heterogeneous which evolved under various pressures of human disturbance and animal grazing. These forest ecosystems, if properly managed, can provide various benefits for conserving biodiversity, mitigating carbon emissions and provide grazing resources for livestock. Forest gaps provide a promising avenue for C sequestration while existing forests could be enhanced to sequester more carbon. The rational behind excluding grazing from natural forests needs to be revised and investigated more. Rational grazing is a natural factor that shaped the composition and productivity of natural forest stands. If the current projections of species composition under complete protection continue at the same trend, significant implications on biodiversity and aboveground biomass will be expected in the near future. Under protection, arboreal diversity and aboveground biomass is expected to improve in the near future, while the biomass of under-story vegetation is expected to decline. These results should be interpreted with caution. Fire hazard, grazing, and overall biodiversity are expected to show a different response as well. The results of this experiment also emphasized the importance of revising forestation programs in Jordan and to investigate more alternatives.

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