Forest Ecology and Management 270 (2012) 85–93

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Allometries, biomass stocks and biomass allocation in the thermophilic Spanish juniper woodlands of Southern Spain

F.A. García Morote [a,*], F.R. López Serrano [a], M. Andrés [a], E. Rubio [a], J.L. González Jiménez [a], J. de las Heras [b]

[a] Departamento de Ciencia y Tecnología Agroforestal y Genética, Escuela Técnica Superior de Ingenieros Agrónomos, Universidad de Castilla-La Mancha, Campus Universitario s/n, 02071 Albacete, Spain
[b] Departamento de Producción Vegetal y Tecnología Agraria, Universidad de Castilla-La Mancha, Campus Universitario s/n, 02071 Albacete, Spain

ARTICLE INFO

Article history:
Received 14 July 2011
Received in revised form 28 December 2011
Accepted 7 January 2012
Available online 9 February 2012

Keywords:
Juniperus thurifera
Allometry
Aboveground biomass
Belowground biomass
Biomass allocation

ABSTRACT

The principal objective of this study was to investigate the variations of allometric relationships, biomass stocks and biomass allocation in a Spanish juniper thermophilic community (*Juniperus thurifera* var. *hispanica* Mill.) in response to two levels of woodland maturity: mature woodlands, which are situated in shallow stony soils with trees over 140 years old and low tree density, and young woodlands, with trees under 100 years old growing in deeper soils (generally, abandoned farmland). Branch- and tree-level allometric models were fit from measurements carried out on branches, stems and roots in 42 felled trees. Although age and site are confounded for this juniper community, it is expedient to utilize site-specific equations because the two woodlands showed distinct growth patterns as a result of their very different soil qualities and ages. At the branch level, the relationship was matched for foliage biomass depending on the site. At the tree level, site location significantly affected variables in allometric relationships that were not strictly cumulative (i.e., leaves, branch wood and fine-root biomass). Goodness of fit was improved by including the relative height of the first live whorl (pruning effect) as an additional predictor of crown and coarse root biomass. The young woodland supported more biomass stock across all components due to better soil. Biomass allocation measured in stems, coarse roots and fine roots was significantly higher in the mature woodland, although the young woodland did accumulate more dry mass in the crown. Differences in biomass allocation may be explained by both the age and strategies of *J. thurifera* to maximize nutrient and water capture for survival in poor soils (site quality effects). Our results also showed that, in mature woodlands, this species accumulates one of the smallest biomass stocks cited for temperate mature conifer stands (7.6 Mg ha^{-1}) but has a high root to shoot ratio (0.43) as a consequence of growing in poor soil conditions.

1. Introduction

The study of biomass provides information essential to defining the important features of forest ecosystems (Landsberg and Gower, 1997). Traditional techniques based on destructive sampling, allometric models and tree inventory data are necessary to accurately measure aboveground and belowground biomass (Parresol, 1999; Zianis and Mencuccini, 2004). To estimate crown biomass, samples of each branch component are taken and equations are implemented at the branch level (Kershaw and Maguire, 1995). The relationship between branch biomass and stem diameter can be used to estimate crown biomass at the tree level, and the accuracy of these measurements can be improved by adding variables that reflect tree structure, such as height or crown size (António et al., 2007). Other principal stock of C is belowground biomass, and it allows us to study biomass allocation and ecological responses. Allometric relationships are also useful to estimate biomass in species where destructive sampling is impractical or limited. The Spanish juniper (*Juniperus thurifera* L.; *Cupressaceae*), an endemic diecious species of the Western Mediterranean, is one such species, and it is protected in part of its habitat. The *Juniperus* genus is comprised of approximately 50 coniferous trees and shrubs species that are widely distributed throughout the temperate and subtropical regions of the Northern Hemisphere (Farjon, 2005). *J. thurifera* var. *hispanica* Mill. is only found in Spain and the French Pyrenees (López, 2001), and due to its rarity, it has been included in the Catalog of Endangered Species in the Castilla-La Mancha Region, where the felling or pruning of juniper trees is forbidden. Nevertheless, several decades ago, goat farmers removed some branches to improve grazing conditions and to supplement cattle feed, and this modified the depth of the tree crowns and consequently the allometries. Trunks are generally multi-stemmed (usually 2–3 trunks), and the adult scale-leaves are in shoots. Spanish

* Corresponding author. Tel.: +34 967599200x2873; fax: +34 967599238.
E-mail address: FcoAntonio.Garcia@uclm.es (F.A. García Morote).

0378-1127/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.foreco.2012.01.007

juniper stands can be classified into the two principal maturity levels that are traditionally used for the *Juniperus* genus (Eddleman et al., 1994). The first are old or mature woodlands, and these generally contain trees that are over 150 years old and are characterized by stony soils with a low tree density. The second level is young woodlands, and these are dominated by trees that are less than 100 years old. Young woodlands are generally found in abandoned farmlands (i.e., areas with better soils) and thus these forests have higher growth rates and tree density.

Despite their ecological importance, studies of Spanish juniper woodlands are incomplete in many aspects, and previous studies on biomass have focused only on *J. thurifera* var. *africana* M. (Montès et al., 2000, 2002; Bertaudière et al., 2001). In addition, most of the data on evergreen perennials in semi-arid environments are based on sclerophylls and shrubs. Hence, the objectives of this paper were to (i) develop allometric models for above- and belowground biomass components in Spanish juniper trees and analyze the effects of woodland maturity (i.e., the site or the woodland type) on allometric relationships at the branch and tree level; (ii) estimate biomass stocks for all components in the two woodland types; (iii) analyze the differences in biomass stocks and biomass allocation between the two woodland types.

2. Material and methods

2.1. Study area

Data collection was carried out at the El Campo de Montiel juniper woodlands (Castilla-La Mancha Region), one of the main populations of thermophilic Spanish juniper (Costa et al., 1993; Fig. 1). The climate in the study area is cold semi-arid (type BSk; Köppen, 1936). Using a 30-year average, the mean annual and growing season temperatures at the site are 12.8 and 17.9 °C, respectively, and the mean annual and growing season precipitation are 452 and 234 mm, respectively. Temperature extremes range from 43 to −21 °C (data from El Bonillo climatic station: 38° 57′ N, 01° 09′

Table 1
Characteristics of soils and vegetation in the two juniper woodlands.

Characteristics	Young woodland on abandoned farmland	Mature woodland on shallow stony soil
Site (soil quality)		
Dominant soil type (FAO, 1988)	Calcaric cambisol	Lithic leptosol
Mean effective soil depth (cm)	45 ± 10	10 ± 1
pH	8.3 ± 0.5	8.7 ± 0.4
Total N (%)	0.59 ± 0.2	0.37 ± 0.2
C/N ratio	15 ± 0.6	11 ± 0.5
Clay (%)	20 ± 1.1	12 ± 2.3
Sand (%)	47 ± 3.1	55 ± 3.4
Water-holding capacity (mm m^{-1})	274 ± 7.7	125 ± 6.1
Stand		
Mean density (trees ha^{-1})	308 ± 40	95 ± 12
Canopy cover (%)	65 ± 23	32 ± 14
Multi-trunk trees (trees ha^{-1})	26 ± 7	9 ± 3
Mean of trunks per multi-trunk trees	2.5 ± 0.2	2.2 ± 0.2
Defoliated trees (trees ha^{-1})	6 ± 2	13 ± 3
Female trees (trees ha^{-1})	70 ± 29	18 ± 9
Mean diameter (cm)	13.3 ± 0.7	16.7 ± 0.5
Mean height (m)	4.8 ± 0.2	4.0 ± 0.2
Mean age[a] (years)	66 ± 4	170 ± 5

Errors: standard error of mean. Number of soil samples: six per site. Values for soil characteristics are pooled by sampling both under juniper trees and without vegetation cover.

[a] Tree age was estimated by using dendrochronological techniques on sample trees.

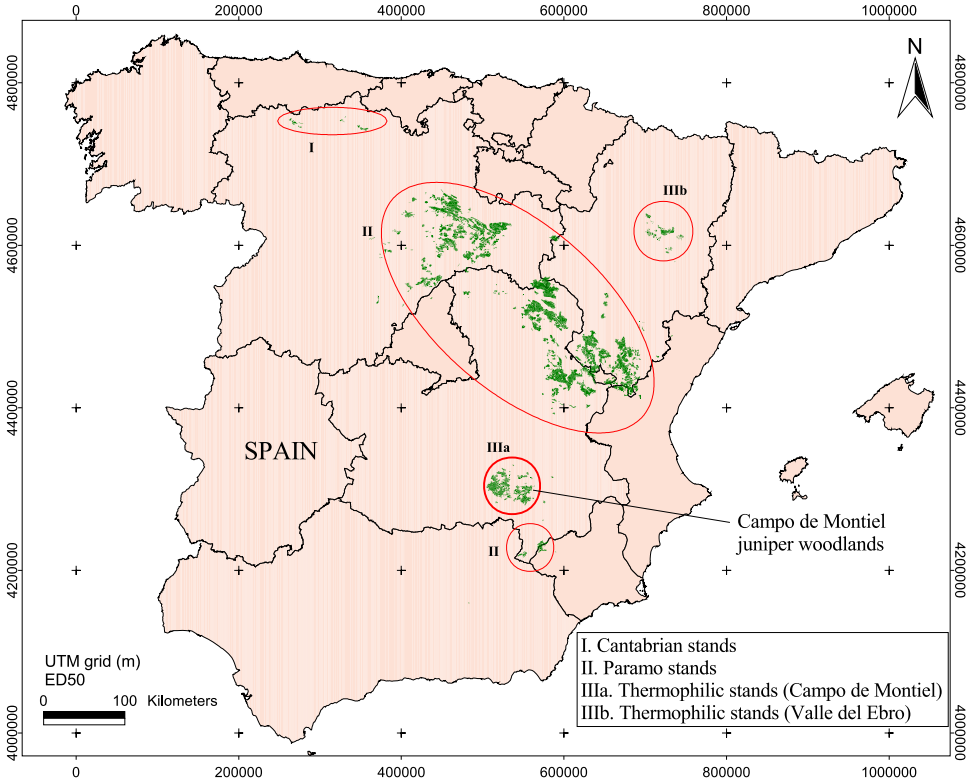

Fig. 1. Distribution of *Juniperus thurifera* var. *hispanica* Mill in Spain. The three principal Spanish juniper communities (Costa et al., 1993) have been identified in this map, along with the study area.