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Structural analysis and performance of helietta parvifolia (gray) benth. In southeastern Nuevo Leon, Mexico

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SUMMARY

In rural zones of Mexico the demand for timber and forest products continues to increase. Efforts are being made to meet the demand for timber by raising compensatory man-made plantations. At present, attention is given to growing indigenous premium quality hardwood species. One of the promising indigenous species among various fuelwood species is Helietta parvifolia (Rutaceae), which occurs naturally in the dry and subtropical zones of northeastern Mexico. This paper describes its structure, growth characteristics and economic yield in northeastern Mexico. H. parvifolia was sampled in seven study sites of native vegetation. The average population density was 1210 plants per ha. Three strata were found: a low stratum along with subchaparral less than 3m in height and a DBH (diameter at breast height) less than 3cm; a chaparral stratum with 3-5m height (3-6cm DBH) and a third stratum higher than 6m in height and 7-12cm in DBH. The economic yield was 1455 fence posts per ha, with a DBH superior to 7cm, corresponding to an income of US$ 1892 per ha.

RESUMEN

En las zonas rurales de México la demanda de leña como combustible y madera para construcción ha tenido un aumento considerable. Actualmente, las especies indígenas con madera de alta resistencia son las de mayor interés. Entre las especies nativas promisorias, de las numerosas especies leñosas de zonas áridas y semiáridas del noreste de México, se encuentra Helietta parvifolia (Rutaceae), la cual es una especie de alta calidad y densidad de madera. El presente trabajo describe la estructura de esta especie del matorral, así como los parámetros de crecimiento y rendimiento de H. parvifolia en el noreste de México. H. parvifolia fue muestreada en 7 sitios de estudio dentro de la vegetación nativa. La densidad poblacional promedio fue de 1210 plantas por ha. Tres estratos fueron determinados: un estrato bajo con subchaparral de menos de 3m de altura y un DAP (diámetro a la altura del pecho) menor a 3cm, un segundo estrato de 3-5m de altura y 3-6cm de DAP, y un tercer estrato con una altura superior a 6m y un DAP entre 7 y 12cm. El rendimiento de madera fue de 1455 postes por ha, con una altura superior a 7cm, correspondiendo a un rendimiento económico de US$ 1892 por ha.

Introduction

The screening of large numbers of shrub and tree species for high biomass productivity has arisen directly out of the growing recognition by the forestry research community during the 1980s concerning arid zones and rural economies (Foley and Bamard, 1984; Gregersen et al., 1989). There has been a significant shift in priorities toward concentration on non-industrial species grown or managed by farmers for products such as fuelwood, posts, animal fodder and house fencing. An increase in the yields of these and other products through the identification of superior genetic material is now a major research subject throughout arid and semi-arid zones (Glover and Adams, 1990).

The timber situation in developing countries can be improved by planting more trees and by better management of the existing forest resources. The tamaulipan thornscrub, a matorral type, is a low dry forest and shrubland complex covering about 20 million ha of the Gulf coastal plain in northeastern Mexico and southern Texas, USA. The tamaulipan thornscrub has been grazed by domestic livestock for about four centuries and is heavily exploited by subsistence farmers for fuel, timber and other resources (Reid et al., 1990a). In order to prevent further desertification and sustain agriculture, livestock and forestry production, the matorral must be conserved and, where necessary, enriched with planting of desirable multipurpose trees and shrubs (Foroughbakhch, 1992). Native shrubs and trees as Helietta, Prosopis, Pithecellobium and Acacia have been selected for agroforestry trials on the basis of the products

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RESUMO

Nas zonas rurais do México, a demanda de lenha como combustível e madeira para construção tem tido um aumento considerável. Atualmente, as espécies indígenas com madeira de alta resistência são as de maior interesse. Entre as espécies nativas provisórias, das numerosas espécies lenhosas de zonas áridas e semiáridas do nordeste do México, se encontra *Helietta parvifolia* (Rutáceas), a qual é uma espécie de alta qualidade e densidade de madeira. O presente trabalho descreve a estrutura desta espécie do mato, assim como os parâmetros de crescimento e rendimento de *H. parvifolia* no nordeste do México. *H. parvifolia* foi amostrada em 7 sítios de estudo dentro da vegetação nativa. A densidade populacional em média foi de 1210 plantas ha\(^{-1}\). Três estratos foram determinados: um estrato baixo com sobrelar de chaparal (subchaparal) de menos de 3 m de altura e um DAP (Diâmetro da altura do peito) menor a 3 cm, um segundo estrato de 3-5 m de altura e 3-6 cm de DAP, e um terceiro estrato com uma altura superior a 6 m e um DAP entre 7-12 cm. O rendimento da madeira foi de 1455 postes ha\(^{-1}\), com uma altura superior a 1,8 m e um DAP superior ou igual a 7 cm, correspondendo a um rendimento econômico de US$ 1892 ha\(^{-1}\).

which they provide and their expected productivity (Stewart and Dunsdon, 1994). Knowledge of their ecophysiological characteristics would facilitate the selection of the species most suitable for silvicultural management under specific conditions. In the semiarid environment of the Gulf coastal plain, the water deficit, drought and extreme temperature frequencies limit the growth and productivity. *Helietta parvifolia* (Rutaceae) is a perennial shrub or small tree 6m in height, with a thin trunk 15-20cm in diameter and thin brown scaly bark. It has 3 opposite ovoid 1-5cm leaflets, sessile or almost sessile. Flowers are white, perfect and small in terminal panicles, 3-4 stamens, fruit about 6-8mm (Standley, 1920, Martínez, 1979, Correll and Johnston, 1970). It is native to northeastern Mexico, ranging from southeastern Texas through central Mexico, e.g., San Luis Potosí, Guanajuato, yet concentrated in Nuevo Leon, Tamaulipas and parts of Coahuila. Studies on management of *H. parvifolia* in northeastern Mexico show that it grows best in gentle slopes and on hills with up to 20° slopes in northern or northeastern directions (10°-30°) and on rocky hills of 15 to 70°. The favorable soils for this species are well drained dark gray silty-clay vertisols, with pH 7-8 and a depth of more than 60cm (Rovalo et al., 1983).

This shrub has a variety of uses, the main one being timber for housing construction, fences and corrals for animals in rural areas. Its wood is highly valued for its durability and resistance to rotting. The leaves are used as forage for cattle. The deep root system makes it an appropriate species for erosion control and soil conservation. Furthermore, due to the shape of the crown, *H. parvifolia* can be used as an ornamental plant in urban areas (Reid et al., 1989).

This study of *H. parvifolia* is devoted to improving knowledge of the structure of the vegetation regarding the development of the physical characters like height, diameter, canopy and biomass in relation to its potential use as a source of wood.

**Material and Methods**

**Study area**

The study was conducted in the tamaulipan thornscrub, situated at 35km southeast of General Terán, Nuevo Leon, Mexico, 25°16’N and 99°21’W, with an altitude of 200-800m.

The study area has a semideciduous climate with very low winter precipitation. It belongs to (A)C(Wo) type, with two periods of summer rainfall. The long-term mean annual precipitation is 800mm, with two peaks in the spring and late summer and drought periods in midsummer and winter (Stienen, 1990). The mean annual temperature is 22.1°C with a large difference between winter and summer (Min. 12°C, Max. 45°C) and even within the same month. Hail and frost usually occur each year, sometimes even after the beginning of the growing season in February-March. The water budget is unbalanced, the ratio of precipitation on free evaporation being 0.48 and precipitation/potential evaporation 0.62.

The soils of the region are basically a rocky substrate of Upper Cretaceous lutite or siltstone. The dominant soils are deep, gray, lime-clay vertisols, which are the result of complex processes of aluvial and coluvial types. They are characterized for high clay and calcium carbonate content (pH 7.5-8.5) and relatively low in organic matter, phosphorus and nitrogen.

**Methods**

In order to determine the plant density, timber and firewood volume of *H. parvifolia* in a representative area of tamaulipan thornscrub (400ha) of 5-8m height, which consists of some 30 woody species growing in vertisol soil, 7 sites ranging in size from 2-3ha each were selected. The selection of the sites is based on the height and the slope which are considered as factors influencing the density and growth of *H. parvifolia*. The length of each site a transect was established in a systematic form having 15 plots of 25 m² (5x5m) as sample size. We took uniform samples according to Braun-Blanquet (1979) and Mueller-Dombois and Ellenberg (1974).

To determine the height, diameter and plant canopy parameters, we used 25m² plots commonly employed in forests as well as high submamitorial matorral studies (Goor and Barney, 1976).

On the basis of the vegetation characteristics and the case of determination as well as information records, quadratic squares were taken. From each plot and site the number of plants, its total height (m), basal diameter (cm), diameter at the breast height (cm) and plant canopy projection (m²) were recorded, and its importance value registered.

The wood volume (m³/ha\(^{1}\)) for *H. parvifolia* was determined in each site according to the Smalian formula for all cylindrical trunks (Meskimen and Franklin, 1978). We considered as commercial trunk stand any stand with a minimum length of 1.8m and a superficial diameter of 7cm in both extremes.

On the basis of the population density and the calculated commercial stands, we determined the economic return per ha from the standpoint of the sale of the product, taking into account the unit price (Mex.$10 = US$1) of each stand in the regional level multiplied by total number per ha.

Data were analyzed statistically (Statgraphics 6.0) using one way analysis of variance to determine the differences among sites. Means comparisons for specific groups on each site were made using the Tukey test (Zar, 1996).

The measurement of growth parameters (height and diameter) was done once per year.
Results and Discussion

Physical structure

In total 30 woody species are registered from seven sites of the study area. The results on the similarity analysis showed a clear dominance of *H. parvifolia*, which accounts for 34.16% of the important vegetation (Table I). According to these observations we could consider *H. parvifolia* as the species of higher dominance, prevalent in deep rocky soil with an inclination of 10-30°, and relatively rich in nutrients with a favorable water regime.

According to Thomas (1989), physical structure analysis provides information on the plant composition, number of species and their ecological behavior, i.e. their dynamic interaction with the environment. This analysis also generates information on parameters such as the density, height and crown area, as well as basic data on the evaluation of the usage of natural resources. The results on the population density of *H. parvifolia* as a function of different study sites are given in Table II. These data demonstrate significant differences (ANOVA, p<0.05) among the study sites, demonstrating a progressive increase in the density at higher elevation in each study area.

The results of plant heights and diameters suggest the existence of three distinct strata on the basis of the mean of these two parameters, as follows: a) a lower stratum 0.1-3m height (DBH <3cm), b) an intermediate stratum 3-5m tall and 3-6cm DBH, and c) a higher stratum with heights over 7m and DBH between 7-12cm.

One way analysis of variance showed significant differences between the heights (F test= 3.87, p<0.01) and DBH (F test= 2.64, p<0.05) among the plants and sites. Mean diameter was essentially more constant than height ranging from 7.1cm for the sites of 200 to 500m, to 8.6cm for 800m.

*H. parvifolia* with a low growth rate of 0.4cm per year in DBH and 13-24cm in height (Foroughbakhch and Heiseke, 1990) is not a desirable species to be used in mixed plantations, because a species with a rapid rate of growth can become dominant when different species in the mixture have different rates of growth.

Under normal conditions, wood production is a function of the crown size in the arborescent dicotyledons in which the lateral branches grow more quickly than the central apex. This growth habit gives rise to a broadly dispersed canopy, especially in poor or dry sites (Daniels et al., 1979).

The analysis of the development and environmental responses of *H. parvifolia* using commonly accepted criteria such as the survival and growth in height, diameter and projected foliage cover, suggest that *H. parvifolia* has different growth characteristics as compared with other firewood species of matorral (Reid et al., 1990b).

In the accounting of biomass, trunks and woody branches are the principal components (Table III). Biomass shows a differential behavior among the sites that were sampled, as trunks, branches and total biomass were greater at an elevation of 400m, although the foliage was greater at 300m. Thus, the biomass diminished significantly above and below 300-400m.

Wood volume determination

To quantify wood volume, data on height and DBH of all primary and secondary trunks of all plants per study site were taken. Stand refers to all trunks between 1.7-2.0m height and DBH >8cm. Wood (volume) is classified as any woody branch with thickness of more than 3cm (3-7cm). Table III shows how shrubs with diameters between 8 and 12cm have an estimated volume of 10234m³·ha⁻¹, which is the most recommended size to begin harvesting the shrubs (25-30 years) as given in Reid et al. (1990a). *H. parvifolia* wood volume can reach up to 13m³·ha⁻¹.

Based on the results, in general terms, each plant produces 2-3 primary trunks (primary) and 4-6 secondary stems. One ha of *H. parvifo-
produces approximately 1455 primary trunks, corresponding to an income of US$ 1892 (US$ 9.66 per shrub) which is considered a very good production of wood per ha in Nuevo Leon, according to the landowners.

Adding the incomes from the sale of firewood and other products (forage), we get a net income per ha of US$ 1980 for the study sites (Table IV).

On the basis of the growth parameters and production (Table IV), *H. parvifolia* is considered a dominant timber plant of economic importance in the region. More than three years of study on physical structure of the tamaulipan matorral (*Felli* et al., 2001) indicated that *H. parvifolia* has the highest yield in this community and constitutes an important potential source for timber and fuel wood for the region, providing the rural community with hard, durable posts for fences and construction.

It should be noted that any evaluation based only on wood production may give a misleading impression of the money value of a species. *H. parvifolia* occurs in south Texas, USA and northeastern Mexico as scattered plants in matorral, due to its allelopathic characteristics in the shrubland, and provides valuable forage which is used for animal feed. Fuelwood is a by-product of the community of *H. parvifolia* in northeastern Mexico. This community is not well exploited and does not receive adequate management.

A highly positive correlation was found between the population density and the elevation of study site (r = 0.95 and p = 0.001). We have registered a greater number of seedlings in sites with elevations of 600-800m, resulting from the natural regeneration, as compared to the plain sites. Nevertheless, this relation changes inversely with the volume of the wood per ha (r = -0.76 and p = 0.04) and the number of fence posts (r = -0.81 and p = 0.02) as a function of the elevation. On the other hand, the sites with lower density present highly developed plants with a higher production of wood and fence posts.

**Conclusions**

This study was conducted in only seven sites of submountainous matorral with 25-30 woody species, where *H. parvifolia* are the dominant plants. This presents limitations on the interpretation of the results, especially if it is desired to extrapolate inferences on the regional or national scale.

The elevation and inclination of the study site has a notable influence on the population density and wood volume per plant. The density of plants increases with an increase in elevation, but the volume of wood and the number of posts present a reverse tendency.

There is no control or evaluation to determine how many plants can be cut and how many young plants should be planted per cut shrub. Proper vegetation management techniques must be employed, which will aid in the sustained and rational management of *H. parvifolia*. In this context, other species of rapid growth and commercial value must be involved in order to prevent damage both to the ecological balance and to the economic activity in these areas where *H. parvifolia* plays a decisive role, with the probable negative impact on the economic state of many families who depend on the products of this dwindling species.

The soils, slopes and elevations of sites gradually influenced plant development such as the number of trunks and the foliar mass. Foliar biomass production and wood volume of *H. parvifolia* is greatest at 200-500m, having deep soils with good drainage (Reid et al., 1987). Rocky soils that increase with elevation lower production. The production of trunks, foliar biomass, height and diameter are influenced by elevation.

From the ecological as well as management perspectives, the tamaulipan matorral of northeastern Mexico is extremely dynamic, suggesting that attempts to preserve the stand structure at this stage may not be an appropriate or a practical conservation objective. Rather, priority should be placed on protecting a sufficient range of community types, so that the disturbance of any particular site may be considered acceptable as a functional process in the preservation of the entire natural area.

<table>
<thead>
<tr>
<th>Site Elevation (m)</th>
<th>Trunks</th>
<th>Woody branches</th>
<th>Leaves</th>
<th>Dead leaves on soil</th>
<th>Total biomass per plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>12.04 ± 2.46</td>
<td>14.80 ± 3.69</td>
<td>5.48 ± 1.64</td>
<td>2.10 ± 0.95</td>
<td>34.42</td>
</tr>
<tr>
<td>300</td>
<td>14.31 ± 3.07</td>
<td>16.08 ± 1.30</td>
<td>6.69 ± 0.85</td>
<td>2.49 ± 1.10</td>
<td>39.57</td>
</tr>
<tr>
<td>400</td>
<td>16.10 ± 10.37</td>
<td>18.31 ± 12.53</td>
<td>7.81 ± 4.64</td>
<td>1.33 ± 1.64&lt;sup&gt;c&lt;/sup&gt;</td>
<td>44.46</td>
</tr>
<tr>
<td>500</td>
<td>13.98 ± 7.25</td>
<td>14.58 ± 3.56</td>
<td>7.02 ± 2.87</td>
<td>1.78 ± 1.21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>37.36</td>
</tr>
<tr>
<td>600</td>
<td>10.60 ± 2.91</td>
<td>11.56 ± 4.69</td>
<td>4.68 ± 2.18&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.23 ± 0.54&lt;sup&gt;c&lt;/sup&gt;</td>
<td>28.07</td>
</tr>
<tr>
<td>700</td>
<td>12.89 ± 8.10</td>
<td>12.30 ± 3.87</td>
<td>4.11 ± 1.05&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.65 ± 0.24&lt;sup&gt;d&lt;/sup&gt;</td>
<td>29.95</td>
</tr>
<tr>
<td>800</td>
<td>12.22 ± 3.74</td>
<td>10.93 ± 2.87</td>
<td>4.02 ± 1.81&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.85 ± 0.83&lt;sup&gt;d&lt;/sup&gt;</td>
<td>28.02</td>
</tr>
<tr>
<td>Mean</td>
<td>13.16</td>
<td>14.08</td>
<td>5.68</td>
<td>1.49</td>
<td>34.55</td>
</tr>
</tbody>
</table>

* Average dry weight in kg ±SD. E/plant. n: 10 per elevation.

Different letters in columns indicates significative differences (Tukey, p<0.05).
REFERENCES


