SPRINGER BRIEFS IN PLANT SCIENCE

Maginot Ngangyo Heya
Ratikanta Maiti
Rahim Foroughbakhch Pournavab
Artemio Carrillo-Parra

Biology, Productivity, and Bioenergy of Timber-Yielding Plants

An Experimental Technology

Springer

SpringerBriefs in Plant Science

More information about this series at http://www.springer.com/series/10080

Maginot Ngangyo Heya • Ratikanta Maiti
Rahim Foroughbakhch Pournavab
Artemio Carrillo-Parra

Biology, Productivity and Bioenergy of Timber-Yielding Plants

An Experimental Technology

Springer

Maginot Ngangyo Heya
Faculty of Biological Sciences
Universidad Autónoma de Nuevo León
San Nicolás de los Garza, Nuevo León, Mexico

Rahim Foroughbakhch Pournavab
Faculty of Biological Sciences
Universidad Autónoma de Nuevo León
San Nicolás de los Garza, Nuevo León, Mexico

Ratikanta Maiti
Faculty of Forestry
Universidad Autónoma de Nuevo León
Linares, Nuevo León, Mexico

Artemio Carrillo-Parra
Instituto de Silvicultura e Industria de la Madera
Universidad Juárez del Estado de Durango
Durango, Durango, Mexico

ISSN 2192-1229 ISSN 2192-1210 (electronic)
SpringerBriefs in Plant Science
ISBN 978-3-319-61797-8 ISBN 978-3-319-61798-5 (eBook)
DOI 10.1007/978-3-319-61798-5

Library of Congress Control Number: 2017948654

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Contents

The original version of this book was revised. An erratum to this book can be found at DOI 10.1007/978-3-319-61798-5_3

About the Authors

Maginot Ngangyo Heya graduated from the Faculty of Sciences of the University of Yaoundé I, Cameroon, with a master's degree obtained with the mention "très bien" in botany-ecology; since February 2017, he is doctor in sciences with the honorific mention "summa cum laude" in management and administration of plant resources from the Faculty of Biological Sciences, Universidad Autónoma de Nuevo León Mexico. He has published six scientific articles in indexed journals and three book chapters and has participated in several national and international congresses. He has conducted research stays at the Faculty of Resources Management, University of Applied Sciences and Arts (HAWK), Göttingen, Germany, and at the Faculty of Engineering in Wood Technology, Michoacana University of San Nicolás de Hidalgo, Morelia, Michoacán, Mexico. He is a reviewer for indexed journals, including the *International Journal of Agricultural Policy and Research*, the *British Journal of Pharmaceutical Research*, and *Ciencia UANL*. His lines of research are related to renewable energies with emphasis on the quality and characterization of solid biofuels, sustainable development, climate change, and forest ecology.

Ratikanta Maiti is a renowned botanist of international repute who specializes in crop physiology and botany. He worked for 9 years as a senior botanist at the Jute Agricultural Research Institute, Barrackpore (ICAR), Kolkata, West Bengal, and for 10 years as a senior plant physiologist in ICRISAT, Patancheru, AP, India. Subsequently, Dr. Maiti was senior Professor and senior research scientist at CONACYT, Mexico, for 18 years and in two universities in Mexico for 20 years. During his scientific career, he has developed innovative techniques for the screening of salinity and drought of several crops. As author of more than 30 books, he has won several international awards, including the

International Scientist Award offered by IBC, Cambridge, the 2003 Ethnobotanist Award sponsored by Friends University, USA, and UNDP, and the 2008 gold medal for India offered by ABI.

Rahim Foroughbakhch Pournavab is a botanist from the University of Tabriz Iran, with a doctorate degree (Ph.D.) in quantitative applied plant ecology from the National Scientific Center (CNRS France) and a post doctorate degree in agroforestry systems from the National Agronomic Center (INRA France).

He is researcher-professor at the Silvicultural and Removable Resource Management Institute of the Universidad Autónoma de Nuevo León (UANL), Mexico (1981–1990), a member of the Mexican National Researcher System (1989–2030), coordinator and member editor of the journal *Ciencia UANL*, and chief of the Botany Department in the Faculty of Biological Sciences at the UANL, Mexico.

He is also a research scientist and professor in the Faculty of Biological Sciences at the UANL, Mexico (1993–present), and has received awards from CONACYT and UANL, Mexico for his research contributions. For 4 years, Dr. Pournavab has been research advisor and coordinator at Multiceras S.A. de C.V. industry in a research project on seed biology, genetic productions, and vegetative propagation of candelilla (*Euphorbia antisyphilitica* Zucc.) under abiotic stress in arid zones of Northeastern Mexico.

His basic objective is to create new and low-cost technology for research and development and to find techniques and solutions for enhanced forestry productivity. He has successfully published more than 200 papers in national and international journals, conferences, symposia, and seminars, including articles and books/chapters at the national and international levels.

Artemio Carrillo-Parra received his Ph.D. in biology and wood technology from the Georg-August Universität Göttingen, Germany, in 2007. He is a member of the SNI (National System of Researchers), Level I.

He is professor with Profile PRODEP, professor-researcher, and coordinator of the Wood Technology and Industry Area of the Institute of Forestry and Wood Industry at Juárez University of the State of Durango, Mexico. He is director and advisor of about 30 doctoral theses and master's and bachelor's degrees. Further, he is a reviewer of indexed journals, including the *American Journal of Plant Sciences*, the *Journal of Wood Chemistry and Technology*, *Madera y Bosques*, *Revista Mexicana de Ciencias Forestales*, *Nova Scientia Electronic Magazine*, and the *Scandinavian Journal of Forest Research*.

Chapter 1
Timber-Yielding Plants of the Tamaulipan Thorn Scrub: Forest, Fodder, and Bioenergy Potential

Maginot Ngangyo Heya, Rahim Foroughbakhch Pournavab, Artemio Carrillo Parra, Ratikanta Maiti, and Lidia Rosaura Salas Cruz

Abstract The current energy crisis generated growing interest for alternatives to fossil fuels, presenting lignocellulosic materials as promising resource for sustainable energy. Mexican scrubs represent important forest resources to satisfy the population's needs. There, forage potential was determined, to establish strategies for vegetation optimal use; forest potential, to assess biomass productivity; and bioenergy potential, to encourage new, promising, and integral use of this resource. Two locations were selected, experimental plantations and natural areas, where shrub coverage, timber volume, leaf biomass, litterfall, and chemical composition were determined. The data were statistically analyzed using SPSS program, applying Tukey's test. Native vegetation of *E. ebano* and *A. berlandieri* presented greater

The original version of this chapter was revised. An erratum to this chapter can be found at DOI 10.1007/978-3-319-61798-5_3

M.N. Heya (✉) • R.F. Pournavab
Facultad de Ciencias Biológicas, Departamento de Botánica,
Universidad Autónoma de Nuevo León, Nuevo León, México
e-mail: nheyamaginot@yahoo.fr; rahimforo@hotmail.com

A.C. Parra
Instituto de Silvicultura e Industria de la Madera,
Universidad Juárez del Estado de Durango, Durango, México
e-mail: acarrilloparra@gmail.com

R. Maiti
Facultad de Ciencias Forestales, Universidad Autónoma de Nuevo León,
Nuevo León, México
e-mail: ratikanta.maiti@gmail.com

L.R. Salas Cruz
Facultad de Agronomía, Campus de Ciencias Agropecuarias,
Universidad Autónoma de Nuevo León, Nuevo León, México
e-mail: biolidiasalas@yahoo.com.mx

M. Ngangyo Heya et al., *Biology, Productivity and Bioenergy of Timber-Yielding Plants*, SpringerBriefs in Plant Science,
DOI 10.1007/978-3-319-61798-5_1

coverage value (19.68 m^2/individual). The higher foliar biomass was recorded in summer (9029.322 kg ha^{-1}) with *E. ebano*. The litterfall accumulated more in spring with *A. berlandieri* (273.73 kg ha^{-1}) and *A. wrightii* (296.45 kg ha^{-1}). The timber volume was greater in plantations (0.8287 m^3/ha/year for *H. parvifolia* and 0.2740 m^3/ha/year for *E. ebano*) than in native vegetation (0.1468 m^3/ha/year for *H. pallens*, 0.1225 m^3/ha/year for *A. wrightii*, and 0.1200 m^3/ha/year for *A. berlandieri*). The inorganic elements varied in trunks (1.09–2.29%), branches (0.86–2.75%), twigs (4.26–6.76%), and leaves (5.77–11.79%), and the highest proportion occurred in Ca (57.03–95.53%), K (0.95–19.21%), and Mg (0.88–13.47%). The higher extractable contents (3.96–17.03%) were obtained in methanolic solvent. Lignin recorded ranks 28.78–35.84% (trunks), 17.14–31.39% (branches), and 20.61–29.92% (twigs). Calorific value ranks were 17.56–18.61 MJ kg^{-1} (trunks), 17.15–18.45 MJ kg^{-1} (branches), 17.29–17.92 MJ kg^{-1} (twigs), and 17.35–19.36 MJ kg^{-1} (leaves). Lignin showed moderately strong relationship ($r = 0.66$) with calorific value.

Keywords Forest potential • Fodder production • Phenology • Litterfall • Bioenergy • Timber-yielding plants • Tamaulipan thorn scrub

1 Introduction

Mexico is a country well known for its rich forest resources (Cruz-Contreras 2012), occupying 11th world place in forest area with 70% of national territory and 26th place in forest production (SEMARNAT 2012). It is estimated to occupy 126.6 million hectares of forest surface among which 25.8 occupy forest, 8.8 of forest with secondary vegetation, 13.1 of tropical forest, and 21.2 of tropical forest with secondary vegetation, and 57.6 possess vegetation of arid zones (SEMARNAT 2010). In the arid and semiarid zones representing more than 50% of total surface of the country (Rzedowski 1991; INEGI 1997; González 2012), there exist large variations in climatic and edaphic conditions, which exhibit different types of extremely diverse plant communities in terms of composition, plant height, canopy cover, density, and associations (Battey 2000; Eviner 2003). In these communities, the scrub stands as the most abundant forest resource and historically the most utilized (García and Jurado 2008). This occupies an extension of 125,000 km^2 in the coastal plain of Mexican Gulf in Northeast of Mexico and extreme south of Texas, USA (Ruiz 2005).

The Mexican scrub communities have been classified from practical point of view as xerophytic scrub by Rzedowski (1978). This is based mainly on the origin of its structure and composition. This highly diverse ecosystem, consisting of trees, shrubs, and subshrubs, varies in density and also in plant height (Heiseke and Foroughbakhch 1985; Alanís 2006). It has been a provider of important plant products (Rojas 2013), which are used for a wide variety of purposes such as the production of forage, firewood, timbers, materials for construction, human food, and traditional medicine and extraction of spices (Foroughbakhch and Heiseke 1990). Besides, this resource is used for the production of charcoal and, above all, the establishment of crops and pasture (Correa 1996).

Although the Northeast Mexico scrub has provided great benefit to populations, the anthropic activities have caused loss of a large extension of vegetation leading to soil erosion and a decrease to its productivity. Since soil is the basic component of an ecosystem because of its influence on productivity, any attribute of vegetation related to the reduction of erosion and stability of soil surface characteristics should be measured primarily. In this respect, the plant canopy cover which offers the interception and absorption of rain drops favors the infiltration and reduces the flow of rainwater and loss of soils as well as vegetation soil stability (Branson et al. 1981; Gaither and Buckhouse 1983; Thurow et al. 1988; Simanton et al. 1991).

In this context, the increasing demand of the population for the products and services has motivated the plantations of forests, to supply timbers and its products to local and global markets, thereby contributing significantly to the rural and industrial progress (FAO 2013). From the viewpoint of technical perspectives, and on the basis of the knowledge on silviculture, economy, social aspects, and ecology, there are sufficient arguments to hypothesize that the plantations of forests in Mexico are viable options with possibility to contribute to the economic growth of the country (Zamudio Sánchez et al. 2010). Besides, the forest plantations favor the productivity of forests and at the same time reduce the pressure and the use of natural forests and also enable for better exploitation of areas which have been altered by the agricultural or animal husbandry (INE 2007).

This productivity of forests has direct relation with the biomass, which according to Ledesma et al. (2010) is a fundamental variable for tree. Its estimation is an important parameter for the application of models based on the growth of trees (West 1987; McMurtrie et al. 1989; Bassow et al. 1990; Korol et al. 1991). This is necessary for the studies on the production of vegetation, nutrient cycles, hydrology, habitat of wild fauna (animals), and patterns and occurrence of forest fire (Waring 1985; Long and Smith 1988). The majority of quantitative analysis on biomass potential in the wooded regions has only been referred to the tree stratum, leaving aside the bushy shrubs, excluding from its quantification, an important amount of biomass, present equally, both under woodland and open forest land (Sánchez et al. 2008). Mittelbach et al. (2001) recommend undertaking studies on shrub species which are the least studied in the world. Although the proportion of non-woody vegetation in total biomass of a forest may be very low, this does not mean that they are not important in their structure (Álvarez 1993). Therefore, the quantification of herbaceous biomass is of great importance from the viewpoint of forage which is considered to reach to 40% of the surface area of herbaceous strata (Benavides 1993). For greater precision in the estimation of biomass, the aerial biomass as well as necromass should be also considered, since according to McDicken (1997) and Marquéz et al. (2000), the necromass is one of the biomass compartments.

On the other hand, it is calculated that of the timber production of a tree, only 20% is exploited, but 40% is left in the field, which include branches, tips, and roots; the remaining 40% is wasted during the sawing process, in the form of chips from bark and sawdust (Enciso 2007). These residues are potential source of prime matter for the generation of energy by the process of silvicultural management or subproducts of the industry transformation (PNUMA 2010). Therefore, it is considered that the correct management of the forests and forest plantations and the utilization of the materials derived from wood industry are alternatives for the production of prime matter for the development and production of biofuels (Goche-Télles et al. 2015). According to the data provided by Wu et al. (2011), 50% of the population of the planet utilizes biofuels for obtaining heat, owing to the environmental politics that seek to reduce the pollution derived from the combustion of fossil fuels. In Mexico, firewood and charcoal represent the third place in volume of extraction, with 9.9% (SEMARNAT 2007).

For the determination of the main characteristics of the energy of these materials, the physical and chemical variables that define them should be considered. The chemical characteristics of the wood that mostly influence its behavior as biofuel are the elemental chemical composition, the chemical composition by compounds, and the calorific value (Camps and Marcos 2008). Under these premises and in search of improvement of bioenergy efficiency, it is of great importance to determine the yields and to evaluate the quality of biofuels from different components of timber species of the Tamaulipan thorn scrub, including twigs and leaves that are considered as residues and trunks and branches that are the most commonly used parts, generally more suitable for exploitation. At the same time, the knowledge of the characteristics of Tamaulipan thorn scrub would provide an integral vision of the silvicultural opportunities for adequate application in each area, considering the growth and the productivity for a good planning of the management, improvement, and utilization of these resources.

2 Objectives

2.1 General Objective

Analyze and determine the forest, forage, and bioenergy potential of five timber species of the Tamaulipan thorn scrub, which allow to demonstrate the environmental and economic benefits derived from its utilization as a source of renewable energy in the Northeast Mexico.

2.2 Specific Objectives

- Study the phenological variations of the timber-yielding species of the Tamaulipan thorn scrub, in relation to climatic conditions.
- Quantify the necromass (litterfall) of the tree-shrub stratum, for characterizing the variability of the soil-plant system as indicator for their sustainability.
- Quantify and characterize the herbaceous biomass for the establishment of an integral system and of greater precision in forage potential of the Tamaulipan thorn scrub.
- Determine the leaf biomass of the woody vegetation as simple tool for the monitoring and following process.
- Evaluate the growth and the volumetric production of the selected timber species of the Tamaulipan thorn scrub.

- Evaluate the quality as biofuels of different components of the selected timber species, both for the biomass without treatment and for charcoal.
- Determine correlations among ecological parameters with seasons, dendrological data, and bioenergetic parameters.

3 Justification

The consumption of energy in the world has increased constantly with increasing population and industrialization, being the derivatives of fossil fuel; the currently predominant energy sources, petrol and natural gas, are becoming limited resources which will be exhausted in some moments in the near future. Although there are debates on the exact year of the peak period of the production of petrol, it appears that it may occur before 2025, after which the production of petrol will start falling in the whole world (Campbell 2013). This exhaustible nature of the actual resources, associated with the greater demand of energy, has accelerated the search for alternative source energy to satisfy the demand of the society in sustainable manner. This situation has provoked an interest to find nonfossil, renewable, and low-contaminant fuels. The motivation of this change of posture is not only for the necessity to search an alternative to petrol owing to its finite character associated with an increase in demand for energy but also for care of the environments and a necessity to reduce the emission of greenhouse gases (Wackett 2008).

Other important aspects of renewable energies are, in addition to the environmental component, the backbone and social effect that these technologies can have. Therefore, they are considered as key technologies for various reasons beyond the energy security or the preoccupations of environments such as increase of divisas and socioeconomic conditions of rural sector (Demirbas 2008), owing to the creation of local employment and activation of the economy of these regions.

Most of the large energy-consuming countries are adopting very active policies aimed at a much greater use of biofuels for the coming decades (Kojima and Johnson 2005). In Mexico, they are looking at how to introduce biofuels into the energy matrix, in a sustainable manner with national producers, and thus be able to impulse the rural development (Valle and Ortega 2012).

The renewable energy production systems have delivered a reduction of contamination load generated by fossil fuels. In the case of biomass, there are other benefits such as promoting rural development and providing adequate waste treatment, in some cases polluting, or managing waste from pruning, thinning and waste from harvesting, limiting the propagation of fires (Rincón and Silva 2014). The use of residual forest products as fuel for biomass boilers is one of the solutions to facilitate the forest healths (IDAE 2007).

The most important sources of biomass are the areas of forest and crop fields; these produce residues which are generally left in the field (Camps and Marcos 2008). The forest industry generates large volumes of residues during the process of exploitation up to the obtainment of final product. It is calculated that the residues are 28% of the volume of harvested wood with bark in the forest, per cm^3 (Martín 2001). The forest residues derived from silvicultural activities and/or forest industries consist of branches, stumps (when they are not used due to economic reasons), bark, chips, and sawdust.

The energetic use of these forest residues, derived from silvicultural activities such as pruning and cleaning, sometimes not economically profitable, implies an integral management of the forest masses (Borja 2006). The high availability and low price of forest subproducts, sawdust, viruta, and wattage, among others, encourage the search for new productive alternatives. Bioenergy production is an economically and ecologically viable option (García et al. 2012). However, it is necessary to determine that these subproducts fulfill the international quality standards. For these, it is needed to evaluate moisture content (MC) and some physicochemical characteristics such as ash percentage and types and percentage of inorganic elements (García et al. 2012; Vassilev et al. 2012). The knowledge of the chemical compositions of different structures of the timber-yielding species is an important aspect, necessary to find alternative of the economic benefits that these resources provide for the different industries (García et al. 2004).

Beyond these qualitative aspects mentioned above, it is necessary to take into account the quantitative dimensions of the forest production for its better management, leading to the optimization of exploitation. The relevance of applying it to Tamaulipan thorn scrub lies in the interest of knowing the diversity of species that are part of the structure of this plant community and evaluates its productivity in order to be in a position for taking the best management decisions, seeking to take advantage of sustainable forage for wildlife.

The management of these resources must be based on the observation and interpretation of different characteristics, which allow estimating as precisely as possible the availability of fodder, understood as the amount of dry matter delivered daily to each animal. This is the starting point for a series of high-impact decisions on productive results in forage-based livestock systems, with the fundamental objective of establishing strategies that can be adapted by means of modifications according to the place and in order to achieve optimum management and utilization of the vegetation and wildlife. Therefore, the study and analysis of the vegetation cover should be the first step to follow. According to Wilson and Tupper (1982), the relevance of selecting vegetation cover as an indicator of the impact of some breeding practice is because any change in it is the first symptom of changes in environmental processes such as erosion, soil, and botanical composition. In addition, the coverage parameter indicates, better than any other parameters, such as abundance or dominance, occupied volume or soil surface covered by a species (Huss et al. 1986).

It is also considered the fall of litter, as something of great importance, especially where the vegetation depends on the recycling of nutrients coming from its deposition (Bernhard-Reversat et al. 2001). At the same time, the phenological changes (the appearance of new leaves, flowers, and fruits) represent adaptation to biotic and abiotic factors (Van Schaik et al. 1993), under existing climatic conditions. These parameters may exhibit reliable instrument for the evaluation of the native populations of the species of Tamaulipan thorn scrub and its associated species and could serve as the base for the elaboration of adequate management or for modification of actual practices of exploitation and at the same time for the conservation, improvement, and sustainable use of these important forest resource ecosystems in arid and semiarid regions (Meza 2002).

4 Review of Literature

4.1 General Aspects of Tamaulipan Thorn Scrub

In Northeast of Mexico, a large extension of area is found occupied by scrub (approximately 200,000 km^2), which is an association of 60–80 species, known for its low height, distributed in the states of Coahuila, Nuevo Leon, and Tamaulipas (Udvary 1975). There exist a large number of scrubs with diverse composition and structure. Among the names which have been largely utilized are xerophytic scrubs (dry), cardonals, tetecheras, izotals, nopales, thorn scrub, scrub without spines, *parvifolia* (small leaves), magues, lechuguilla, guapillal, and chaparrals (INEGI 2005). In order to contribute more precise knowledge of this vegetation, García (1999) evaluated ecologically the submontane scrub areas with pristine vegetation in Linares municipality, through the characterization of the sites, based on their composition and structure.

The Tamaulipan thorn scrub is a dominant community in coastal plain of Mexico and is present in Northeast of Mexico, in the states of Coahuila, Nuevo León y Tamaulipas, as well as in south of Texas. According to Muller (1947), the Tamaulipan thorn scrub is an ecological system of great floristic diversity, with spinous species in high lands. According to Heiseke (1984), this ecosystem consists of a great source of forages where the pastures have been practiced in extensive forms since 350 years.

Jurado and Reid (1989) have described the composition and structure of Tamaulipan thorn scrub in Northeast Mexico and evaluated the importance of edaphic, topographic, and anthropogenic factors on the distribution of the plant species; they registered the presence of 51 species, mainly shrubs and succulents; the vegetation has an average height of 4 m, distinguishing three strata in the same. The analysis of association showed that the 37% distribution of species is associated with one or more of the environmental factors considered.

Foroughbakhch and Heiseke (1990) mentioned that from the viewpoint of productivity and under the current schemes of exploitation, scrub presents very low productivity, which constitutes the main cause of its degradation and destruction in favor of agricultural land and artificial prairies. They carried out a study about the application of silvicultural management methods and techniques in the scrubland in order to increase forest and livestock production, managing techniques such as thinning, enrichment, and controlled regeneration in an area of Tamaulipan scrub in Linares, N.L.

Reíd et al. (1990) studied structural and floristic variation in Tamaulipan thorn scrub in Northeast Mexico and concluded that the regional variations in climate, substrate, and topography are responsible for the main differences in vegetation and also found evidences that the changes of vegetation are caused by overexploitation of pastures and also selective cutting of timber-yielding species or combustibles.

Carrillo (1991) undertook a study in an area of Tamaulipan thorn scrub at Linares, N.L., with an objective to determine and compare the effects of some silvicultural treatments and also the abiotic factors on the regeneration of scrub, in order to