Silvopastoral Systems in Arid and Semiarid Zones of Chile

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Abstract

In the semiarid Coquimbo Region, Chile, *Acacia saligna* is used particularly where reforestation has been promoted with the objective of recovery of degraded soils, production of fodder for livestock, fuel wood and control erosion. This exotic species also has potential use as an important source of human food, because the seeds of the trees could be harvested and processed for the production of breads and biscuits with nutraceutical properties. *Prosopis* is another genus, six members of which are common in Chile; they are adapted to areas with very low rainfall, infertile soils, and high variations between day and night temperatures. Because of their exceptional adaptability to such difficult conditions where most other species do not survive, *Prosopis* spp. are an important resource for the local peasants and indigenous communities, providing them with food and shelter for their livestock.

Keywords

Acacia saligna • Fodder • *Prosopis* sp. • Small landowners • Traditional practices

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7.1 *Acacia saligna in Chile:* A Forage Resource with Potential for Food Production

7.1.1 Introduction

Acacia saligna, an exotic species, mainly occurs in the semi-arid Coquimbo Region, Chile particularly where reforestation has been promoted with the objective of recovery of degraded soils, production of fodder for livestock, fuel wood and control erosion (Perret and Mora 2001) as seen in the work done at the Hacienda Huentelauquén of the Province of Choapa (Fig. 7.1).

Plantations were established in the semi-arid zone as a result of Decree Law 701 enacted the State of Chile in 1974 and implemented by CONAF,[1] that subsidized up to 75 % the total cost of establishing forest plantations. Currently it is estimated that an area of 7,500 ha of *Acacia saligna* plantations exists in the Coquimbo Region (González 2014). This law was intended to stimulate forestry activities on soil suitable for forestry, on degraded soils and to encourage afforestation, especially by small landowners. *A. saligna* come from the semiarid Western Australian "Wheatbelt" and is adapted to extremely dry conditions through their physiological mechanisms: form and distribution of stomata and a deep root system that allows the tree to access subsurface aquifers and withstand long periods of drought (Maslin 2011).

Plantations near the coast in the Region of Coquimbo allow the species minimize evapotranspiration and survive on coastal moisture. As a pioneer species in plant succession, *A. saligna* can fix atmospheric nitrogen improving the physical and chemical properties of soils, allowing increased fertility, restoration of degraded soils and possible reforestation with native species in a second rotation (Maslin 2011). The *A. saligna* resource represents an important potential food for humans because the seeds of the trees could be harvested and processed for the production of breads and biscuits with functional and nutraceutical properties (Yates 2014).

7.1.2 Diversity and Adaptation

A. saligna is extremely polymorphic in phenotypic characteristics such as phyllodes, growth habit cortex and also in ecological and biological

Fig. 7.1 Dunes control work in Huenteauquén farm. Province of Choapa, Coquimbo Region. Lat 31°37′38″ S and Long 71°33′03″ W (Source: Patricio Rojas 2004)

[1] Corporación Nacional Forestal.

attributes. It is endemic to south-western Australia where it occurs in areas with annual rainfall between 250 and 1200 mm. Taxonomic research indicates that polymorphic variation in *A. saligna* fits four sub species referred to McDonald (2007) and in other publications as: (1) the variety *saligna* "cyanophylla", (2) the variety *pruinescens* "Tweed River", (3) the variety *lindleyi* as "typical" and (4) the variety *stolonifera* "forest". This taxonomy offers a range of morphological and growth habits among subspecies and provenances that may yield specific advantages that are adaptable to specific production purposes. Intraspecific variation and growth habits associated are shown in Fig. 7.2.

As an example, those subspecies with a tendency to vegetative propagation such as stolonation (suckering) may not be suited to wood production since they will produce multiple stems of small diameter, however this characteristic may be highly desirable if the goal of production is fodder for animals, and might further the available phyllode biomass. Field observations in native distribution show that the subspecies *saligna pruinescens* have low occurrence of propagation by stolon, however this feature is very common in *saligna subspecies stolonifera.*

7.1.3 Forage Resource

Acacia saligna is considered a fast growing species, reaching 8 m high at 4–5 years at planting sites with limitations like low rainfall and poor fertility. In dry lands of northern Chile annual increases in height between 30 and 71 cm have been observed. Tree growth is lower in prolonged drought conditions, so that production varies between 1.5 and 10 m^3 ha^{-1} according to site conditions in rotations of 5–10 years and coppice management. In rural arid and semi-arid production systems, *Acacia saligna* are generally planted to provide supplemental or emergency food for prolonged periods of drought, shade for small livestock and protection and stabilization of degraded soils (Perret and Mora 2001). However, there are large variations in the nutritional value of this legume species (Maslin 2011), probably because of their genetic variability and/or ignorance of this subspecies in plantations in Chile (W. O'Sullivan, pers. comm. 2005). Typical shape and vegetative propagation of plantations in the Coquimbo Region can be seen in Fig. 7.3.

Normally farmers use this resource to feed sheep and goats, especially during summer and autumn. They harvest acacia leaves and stems from young and mature trees during the dry season to provide a daily supplement to grazing (Meneses 2012). Other farmers permit that sheep and goats also eat directly on the shrubs without any silviculture management.

The recommended planting density for livestock systems is 4 × 3 m (833 trees ha^{-1}). A greater distance between rows, such as 6–10 m may allow for greater production of perennial grasses, herbs and crops under some conditions. The incorporation of silvicultural treatments such as pruning and thinning improves crop productivity. In arid areas the primary purpose is not to produce high quality wood, but rather to create and adapt the tree architecture to maximize the production of forage for livestock (Vita 1996). Pruning and tree management differ from traditional forestry methods. Crop management for fodder purposes may be accomplished by in situ grazing, managed to create a stump of 25–50 cm high after the third year, or by topping trees when they reach 2 m in height. The cutting intervention should be done in the time before the summer growth (Serra 1997). Bratti (1996) concluded that the trees cut to 50 cm height significantly differed better in vigor and growth of other cutting heights made.

The fresh foliage is palatable to animals and can be used as a food supplement for livestock (sheep and goats) containing up to 21 % crude protein in dry weight. Serra (1997) reported that phyllode material contains 10–19 % protein by dry weight, 24–27 % crude fiber and 20–26.48 % digestible organic matter in vitro. Plantations established by INFOR in the arid interior of the province of Choapa showed that forage production can reach a value between 0.8 and 2.2 Mg DM (dry material) ha^{-1} of dry forage at 3 and 4 years after planting (Perret and Mora 2001).

Meneses et al. (2012) concluded that *Acacia saligna* fodder has limitations as feed for goats. In

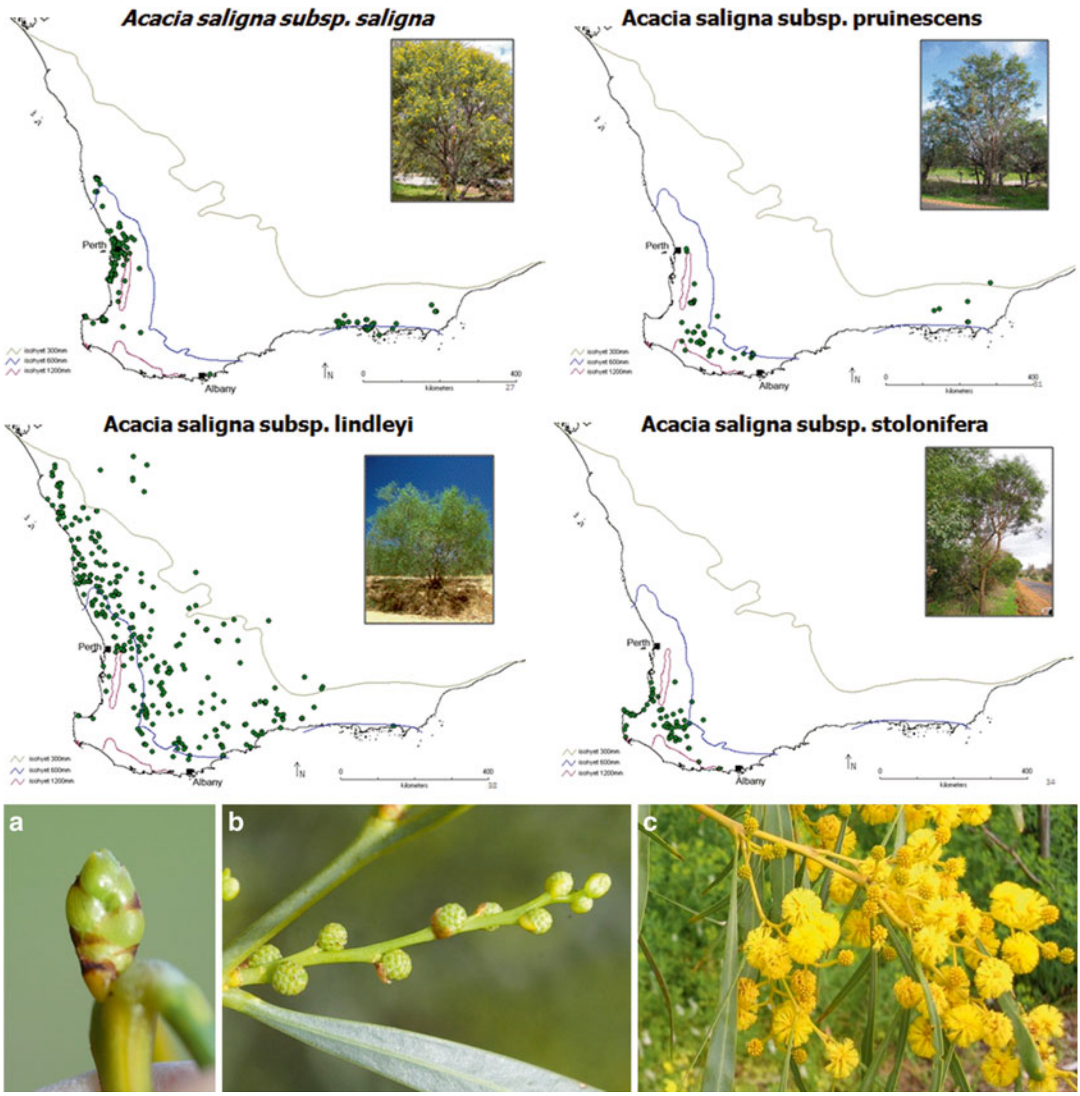

Fig. 7.2 Natural geographic distribution of the subspecies of Acacia saligna in Western Australia and differentiation of flower buds (**a**), juveniles (**b**) clusters and (**c**) flowers at anthesis in the subspecies saligna (Adapted from Maslin 2011)

pregnancy its acceptability as the sole forage, represented 65 % of that of alfalfa hay, but during lactation the intake was higher than alfalfa hay. Blood urea is affected with 50 % of acacia inclusion. The response of albumin is inconsistent and the other blood components did not present effects from acacia consumption. For this Acacia fodder should not represent more than 26 % of diet during the last third of pregnancy, according to body and birth weight. During lactation, acacia should not represent more than 25 % of diet to avoid affecting milk production, although the regression equation determined that it should not represent more than 7.3 %. A higher percentage in the diet would affect animal productivity and more than 50 % would affect body weight. Maximum DM intake is obtained with 24.8 % of acacia in the diet (Meneses et al. 2012).

7.1.4 The Food Potential of the Seeds, "Wattle Seeds"

The seeds of some species of the genus *Acacia* are a traditional food in Australia and these are processed

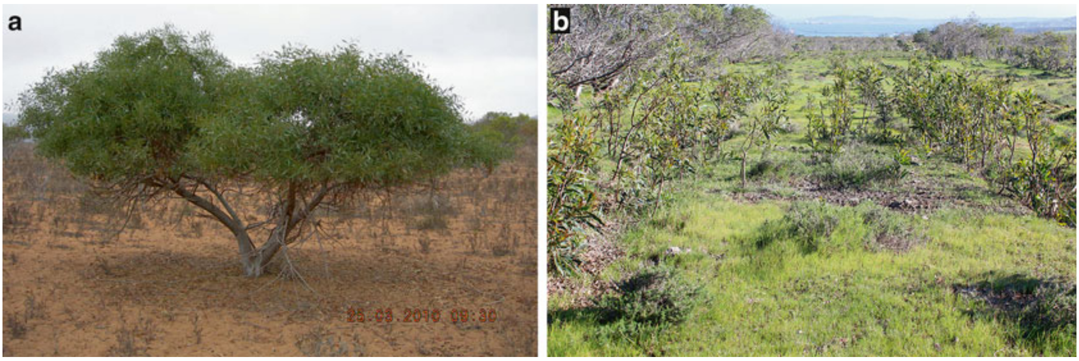

Fig. 7.3 *A. saligna* in plantations in the Region of Coquimbo **a** "typical" growth habit, **b** plants propagated vegetatively, by stolons (Source: Patricio Rojas 2010)

in the "bushfood" industry to create flavoring agents in confectionery, sauces and ice cream and flour for bread, pasta and biscuits. There is interest in the "functional food" potential of acacia seed in Australia due to the high-protein, low glycemic index meal that can be produced (Yates 2014). The glycemic index (GI) is a system for comparing the relative rapidity with which an energy containing food enters the bloodstream as sugars after consumption. A high glycemic index indicates rapid sugar (and thus energy) availability, which requires a relatively robust response from the insulin-endocrine system. Excessive, long-term exposure to foods with a high glycemic index has been implicated in diseases such as type II diabetes. Analyses of *A. saligna* seed from five farms in the Coquimbo region confirm the seed as being high in protein and that their fiber content is suitable for use in baking in combination with other flours (Quitral 2012). Studies are currently underway to ascertain whether *A. saligna* seed may have any beneficial effects on diabetes related illness (Yates 2014).

7.2 Silvopastoral Systems with *Prosopis* sp. in Chile

7.2.1 Silvopastoral Systems with *Prosopis tamarugo* Phil.

7.2.1.1 Introduction

The species *Prosopis tamarugo* (Tamarugo) grows endemically in the North of Chile and today is mostly present in an area called "Pampa del Tamarugal", 70 km east of the city of Iquique, in the Region of Tarapacá, but in the past it was found growing abundantly between the Regions of Arica and Copiapó (FAO 1984). It was used as fuel wood for the mining activities in the region, due to which it has become practically extinct, and today is considered threatened. In the 1960s, it was planted 20,550 ha of the species in national reserves under the system of Chilean Protected Areas (FAO 1984).

This tree mainly grows in the desert ecosystem of Pampa del Tamarugal under very particular conditions. The climate of the region corresponds to a normal desert climate with the major biological connotations of high temperatures during the day, great temperature variations, almost complete lack of precipitation, occasional occurrence of fog, low relative humidity and high sun radiation (FAO 1981). The mean rainfall varies from 0 to 80 mm per year, depending on weather events in the Los Andes Mountain. The soil is fluvial alluvium material from the Andes mountain range covered with a superficial salt crust of 0.1–0.6 m (FAO 1981).

The Tamarugo receives water from occasional fog and underground water, which typically is found at 1–10 m but can be as deep as 60 m or more (FAO 1984), and which the Tamarugo tree can extract thanks to its special root system up to 8 m (FAO 1984). Although the Tamarugo often grows on soils covered with a thin or sometimes rather thick salt crust with underground water at between 2 and 40 m deep, it has been observed that naturally it grows more frequently in areas where the underground water is at a depth of 20–40 m.

Mature trees have a root system consisting of a dense mass of shallow lateral roots, poorly lignified, of 40–80 cm thick, and one or several tap roots, which grow horizontally until a depth of 7–8 m (FAO 1984). These taproots then grow vertically down without ramifying, generally reaching depths of approximately 4 m. When the plant grows on very sandy soils, as is the case in the Canchones area, the taproots can grow as deep as 7 or 8 m. The moisture-absorbing root mass on the surface typically has approximately the same perimeter as the tree crown.

This species is used as forage by wild and domestic animals such as sheep and goats, feeding on its leaves and fruits. Its wood is also used as firewood, in handcraft and for floors. It grows on saline grounds where no other tree can grow. This makes this species a valuable source of charcoal and firewood for the local peasants.

Under the conditions in Pampa del Tamarugal (Fig. 7.4), a national reserve protected by the National Forest Corporation (CONAF), controlled grazing of goats and sheep is occurring during certain periods of the year supporting small-scale farmers of the adjacent communities.

7.2.1.2 Forage Productivity for Livestock Management with Tamarugo

This tree produces abundant forage mainly consumed by sheep and goats, occasionally also by cattle. Its productivity depends on factors such as tree age and development, density, underground water depth and quality. Its fruits and leaves fall off the tree and spread on the ground, mostly directly under the tree crown, providing a forage material that contains 10.5 and 10.9 % from fruit and leaves of raw protein respectively, 29.7–15.2 % of fibre and 0.46–1.46 % ether extract (CORFO 1984).

Based on measurements of 19 trees, Oyarzún (1967) describes that he obtained an average weight of 2.1 kg m^{-2} seedpods under the tree crown. With 30-year-old trees he observed an average yield of 3.4 kg m^{-2} dry matter of fruits and leaves per square meter under the tree crown. Latrille and García (1968) estimated the yield of leaves and fruits of this tree at 1 kg m^{-2} under the crown of adult trees, which could exclusively feed 3.5 sheep ha^{-1}. Furthermore foraging experiments with French Merino sheep have been carried out in Pampa del Tamarugal, comparing different diets with very interesting results as shown in Table 7.1.

It can be observed from data in Table 7.2, that free foraging in Tamarugo forests allows higher weight gains with yearlings and lambs compared to feeding with alfalfa hay and dried Tamarugo leaves and fruits, and lambing percentages are considerably higher under a free foraging system.

Additionally, in the National Reserve “Los Flamencos” in the Antofagasta Region, located 27 km south of San Pedro de Atacama at an approximate altitude of 2,300 m above sea level, there is a Tamarugo plantation implemented by CORFO in 1970 on a surface of 805 ha, known as Sector Tambillo. This area of the Reserve has historically been used for silvopastoral activities by the local communities, being this the only way to provide their livestock with the necessary food and shade under the harsh local conditions (González and Maraboli 1997). Moreover, as of 1994 six families from nearby Talabre have been authorized to make use of this sector, as they had been doing historically before that date (CONAF 2008). This plantation was implemented with a distance between trees of 15 × 15 m, in an area without trees, banning any livestock during the first 6 years, allowing the trees to grow free of animal impact in order to safeguard their survival, achieving an average of 4 ft per plantation cell (González and Maraboli 1997). Although no evaluation on the capacity of animal load has been made until the date, nor has any management been applied to the tree crowns, it has been possible to maintain a certain amount of sheep,

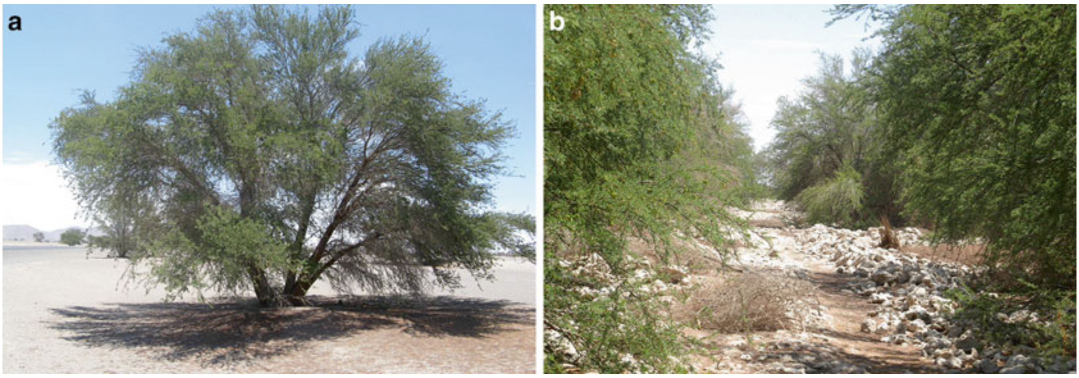

Fig. 7.4 (**a**) Isolated tamarugo (*Prosopis tamarugo*) tree, growing in the Pampa of Tamarugo, located 70 km east of the city of Iquique, Tarapacá Region, Chile; and (**b**) Tamarugo plantation, Pampa of Tamarugal, Chile (Source: Alvaro Sotomayor)

Table 7.1 Comparison of results obtained with French Merino sheep in Pampa del Tamarugal Reserve, located 70 km east of the city of Iquique, Tarapacá Region, Chile, fed with Tamarugo leaves and fruits (kg day^{-1}), alfalfa hay (kg day^{-1}) and free foraging in Tamarugal (Lanino 1966)

Variables	Feedlot production of sheep according to type of forage (weight gains in kg live weight per animal)		
	Dried Tamarugo leaves and fruits, 2 kg day^{-1}	Alfalfa hay, 1.5 kg day^{-1}	Free foraging of leaves and fruits in the Tamarugo forest
Lamb weight at weaning:			
Yearlings (kg)	15.0	21.5	26.7
Lambs (kg)	14.0	25.0	29.6
Fleece weight (kg)	2.81	3.18	3.77
Fiber length (mm)	5.90	6.44	–
Lambing (%)	48	63	111

Note: Fleece, set of wool that is cut from a sheep at shearing time

goats, horses and lamas in the place during short time of the year, in spring, to browse leaves and eat fruits, but supplemented with hay.

7.2.1.3 Conclusions

The results presented above indicate that this type of native forest, with adequate management and maintaining a certain limit of animal load based on the forage production of leaves and fruits per season, would allow sustainable livestock management for the benefit of the local peasants and indigenous communities of this area in Chile. Furthermore, it is recommended to generate public policies allowing the recovery of this species, both for the benefit of the environment and the livestock economy of the local communities, both related to domestic and wild animals.

7.2.2 Silvopastoral System with *Prosopis chilensis* (Mol.) Stuntz

7.2.2.1 Introduction

The Chilean Algarrobo tree (*Prosopis chilensis* (Mol.) Stuntz) is a woody leguminous species widely distributed in arid and semi-arid regions in Latin America (Pinto and Riveros 1989). According to Peralta and Serra (1987), its wide distribution area reaches from the South of Peru to the northern and central part of Chile, the South-West of Bolivia to the northwestern, western and central part of Argentina. As to its geographical distribution in Chile, FAO (1997) points out that the Algarrobo tree grows in the arid and semi-arid regions of the northern and

Table 7.2 Estimation of total production of Algarrobo fruits (kg of seed pods), in the Metropolitan Region, Chile, considering individual trees growing under different conditions, according to the current soil use, surface (ha), production (kg pods tree^{-1}) and density (trees ha^{-1})

Type of formation	Surface (ha)	Production (kg pods tree^{-1})	Density (trees ha^{-1})	Total annual production according to formation type (kg pods)[a]
Natural formations	7,419	15	28	720,524
Associated to agricultural production	3,213	61	1	195,214
Protection areas	609	15	12	25,330
Plantations (including wind curtains)	66	2	254	8,035
Urban	521	5	16	9,397
Total	11,828			958,499

[a]Considering that 23 % of the trees are under production each year, except for formations in association with agricultural production

central part of the country in the provinces of Copiapó, Elqui, Limarí, Choapa, San Felipe, Los Andes and is particularly abundant in the northern part of the Santiago watershed. Algarrobo is the most abundant *Prosopis* species in Chile, covering more than 50 % of the national surface in the Metropolitan Region (INFOR 1986). Altamirano (2012) distinguishes it as the southernmost *Prosopis* genus in South America, growing in Chile between latitudes 22°46′ and 33°40′ S (from the Metropolitan Region to San Pedro de Atacama in the Antofagasta Region).

This species occupies a very specific habitat with a well-defined ecological position, it can be found in valleys or in areas with relatively superficial underground water and on the bottom of gullies with more effective water accumulation. It occupies limestone and salty soils, where the species develops under conditions of high aridity (Peralta and Serra 1987). It can be found in the Central Valley and the lower parts of the coastal mountains, as disperse individual trees or in small patches of forest (Altamirano 2012).

The Chilean Algarrobo grows in environments with an average annual precipitation rate of 28–356 mm, concentrated mainly in winter, reaching zero precipitation in dry years, with torrential rainfalls occurring in few occasions, but a dry period of 8–12 months as a rule. The natural habitat of the species is characterized by very high temperature variations between January and July, as the hottest and the coldest month respectively, as well as extreme temperature changes between night and day. The species can endure occasional frosts with temperatures of −5 °C. Annual average temperatures vary between 14.3 and 14.9 °C, absolute maximum temperatures reach 27.4–30.6 °C. In the North as well as in the distribution area further south, relative humidity is always below 78 %, being these very dry environments with high potential evapotranspiration, intense sun radiation and high luminosity. Algarrobo prefers thick, often stony and normally alkaline, secondary soils of volcanic origin with a sandy or loamy-sandy texture. It is very resistant to salinity and can grow on soils with a pH value between 7.6 and 8.9, rich in sodium. It occupies well-drained soils, on gentle to steep slopes in valleys and gullies between 500 and 1,500 m above sea level (FAO 1997). It is never found above 1,800 m altitude and when growing on grounds that occasionally receive irrigation, its development and lushness can be quite impressive (Ortiz 1966).

7.2.2.2 Productivity of *Prosopis chilensis*

According to González (2013), density of natural formations (number of trees ha^{-1}) of Algarrobo *s* in the Metropolitan Region is very low due to its devastation and over-exploitation in the past, being used as firewood, construction wood, production of charcoal and as fuel wood for metal foundries. The surface covered with Algarrobo in

Fig. 7.5 Cattle using adult Algarrobo tree (*Prosopis chilensis*) for shelter from the sun, Fundo Quilapilun, Province of Chacabuco, Metropolitan Region, Chile (UTM (19H) 345412–6337171, Altitude 804 m) (Source: Marlene González 2013)

2013 was determined to be 11,828 ha, located in Chacabuco Province and differentiated into five types of formation considering different uses, densities and productivity: natural for silvopastoral system, associated to agricultural production (annual crops and fruit production) (Fig. 7.5), protection areas, plantations and urban environments (parks and residential areas) (Table 7.2).

In relation to fruit production, FAO (1997) indicates that an adult Algarrobo tree can produce 100 kg of seedpods; however this is not the rule, as it can be affected by factors such as sun radiation, tree age and growing site. Vásquez et al. (1991) mention that average annual fruit production varies between 30 and 40 kg of pods per plant. However, on sites with less favourable conditions it can lie below 10 kg. On the other hand Serra (1997) points out that some trees show variations in production between 10 and 200 kg per tree. Studies carried out in Pampa del Tamarugal by CORFO (1984) show that forage obtained from fruits and leaves of *Prosopis chilensis* contain between 7.6 and 13.5 % protein and 26.0 and 19.9 % raw fibre respectively, indicating that it would have to be complemented in order to guarantee a balanced diet for sheep and goats, especially during pregnancy and lactation. When analysing its energy input it can be compared to medium-quality (CORFO 1984).

For the Region of Valparaíso, in the commune of Calle Larga, an average of 2.8 trees ha^{-1} can be found in a situation of dry slopes mainly integrated into mixed agricultural/forestry systems, where the average productivity per tree reaches 6.13 kg of seedpods per square meter under the tree crown. It is important to bear in mind that

Algarrobos growing inside silvopastoral system fields have the highest fruit production per tree, but the lowest density (number of trees ha^{-1}).

7.2.2.3 Conclusions

Prosopis chilensis continues to be a good alternative as forage for livestock management, in particular on small-scale farms in the Metropolitan Region, where trees are well managed in order to provide shelter for the cattle held in this area. Its importance becomes evident through its traditional use as complementary forage, especially in critical periods, for 3 weeks to 1.5 months each year, when the fruits are collected and stored to be used when needed (G. Trivelli, pers. comm. 2012). The same situation was also reported by Contreras (1983), who by quoting the National Academy of Sciences (1979), indicated that the fruits or pods were collected and stored to be used later as feed for the cattle during 1 or 2 months of the year, with a nutritional value comparable to barley and corn. Hence it is recommendable that this species be included in the regional development silvopastoralism strategies and promotion policies, destined to support its recovery for the purposes of soil protection and livestock shelter and forage for small-scale farms and local communities in the central part of Chile.

7.3 Traditional Agroforestry Practices in Chile: From Practice to Science

7.3.1 Introduction

Agricultural activities associated with trees have existed in Europe since the Middle Age (King 1987). A variety of agroforestry practices have also existed in the Americas since pre-hispanic times (Reynel and Morales 1987; Carlson and Añazco 1990; Budowsky 1994). Unfortunately, most of them have been replaced by the high-tech productive models seen today, with a high degree of artificialization to ensure greater productivity. However, it has become clear that even if these models are successful in economic terms, one of the greatest challenges is their environmental and social viability, that is why it has not been possible to replicate these models on a small scale, and this has generated an enormous gap between large-scale production and family farming.

On the other hand, when one observes rural smallholdings, it is possible to identify different uses and distribution in the field where multiple activities and diversity of products can be found, which responds to a strategy for survival, where the productive rationale is to guarantee the livelihood of the family with minimal risk. As a matter of fact, according to several studies, the hypothesis that would explain the extensive diversification present in small-scale farms in Latin America is the aversion to risk (Reca and Echeverría 1998). Therefore, rural production systems involve a combination of a certain amount of labor and various means and factors of production within a given space carried out by the producer, based on available resources, in order to obtain certain crop and animal goods, hence, the rural production system chiefly consists of agricultural, livestock and forestry subsystems.

The diversified uses of the land come from the "*how it is done*" transmitted from one generation to the next, with the incorporation of new technologies, only if the economic resources are available, but always using the space in a variety of ways and with the interrelation of productive sectors. Farmers, whether they possess the technical knowledge or not, and regardless of the size of their property, plan their activities and the use of the space and resources they have to satisfy their production or consumption needs, and to generate income. Farmers determine how they will combine uses in one plot and how they will make the best use of it; this is nothing more than planning for and diversifying the use of farmlands, in other words, agroforestry (Benedetti 2012).

Therefore, this interrelationship between the sectors stems from historic and empirical knowledge that is not based on scientific studies; therefore, these forms of "doing" are classified as practices. In this sense, agroforestry is a technique known and commonly used by farmers since ancient times, with an enormous variety of combinations since they have to understand and combine the potential and limitations of the ecosystems they inhabit and adapt them to their social and economic conditions and culture (Benedetti and Valdés 1996). However, it was only a few decades ago that agroforestry began to emerge in the scientific-technical scenario as a science that can underpin the failure of the prevailing agroforestry model to meet the basic demands of the rural population. This is also the case in Chile where issues such as integrated production systems, land and property use management, productive diversification and multipurpose species are becoming increasingly important, but have been the subject of very limited research and developments that have focused primarily on forest grazing models.

In this context, it is suggested that Chile's rich traditional agroforestry practices, which are a result of the country's environmental and cultural diversity, contribute enormously to the development of agroforestry models that take into account cultural and social elements to facilitate their adoption. This is why it is so necessary to recover, analyze and understand them.

7.3.2 Traditional Silvopastoral Practices in Chile

Family farming in Chile is represented by various types of producers from different ethnic and cultural backgrounds and environmental conditions, namely from highland communities in the north, farm communities in the center-north region, Mapuche communities in the south and small landholders throughout the country. Their productive practices are based on crop and livestock production models in which trees can play either a passive or active role, depending on the agro-climatic conditions. In areas with limited soil and water, there is a low proportion of arboreal elements, and these are mostly associated with crops and fodder. In sectors with better environmental conditions, trees play a more prominent role in maintaining productivity and in contributing to family income. Even if these traditional practices are common to all groups, they often differ in terms of the interrelation and space arrangements, which depend on the environmental conditions and socio-cultural characteristics of each group. The following are some of the most common agroforestry practices identified in Chile.

Protein banks: these are shrub species used for fodder grown in soft and steep slopes, on platforms or terraces where they are used to demarcate and protect plots. The fodder is harvested and fed to the livestock in their barns.

Grazing in croplands: on soft slopes and plains, in structures known as "melgas" or windrows. These windrows resemble terraces but are larger in size and are used for crop or fodder production. Each sector is separated by rocks, cobblestone fences, or live fences made of shrubs. Animals are brought in to each sector post-harvest to graze for a limited period of time on harvest residue. This is done to control grazing and replenish the soil with organic fertilizer.

Family gardens: one of the most common practices in the Chilean highlands. These gardens are located on land close to the farmer's home or outside their family farms in small plots known as *hijuelas* or *tablones*, which are generally square or triangular in shape. Windrows are built using mud or a combination of mud and rocks. These structures are used as entrances and irrigation channels. Fruit trees are planted over them to be used for feed or wood, and to provide shade and protection from low temperatures or frost. The areas used to grow crops are located between the windrows. These areas are demarcated using live fences with trees or bushes. This practice involves fallowing, crop rotation and organic compost and animal guano to cover the earth.

7.3.2.1 Agroforestry Practices in Valleys and the Desert in Chile's Norte Grande Region

Windbreaks and live fences: trees on land used for crop or fodder production are a common sight in the desert valley. Trees are situated along the boundaries of the farms as a form of demarcation and to protect crops from the wind. For this, the trees are planted perpendicularly to the direction of the wind. This practice is classified as agroforestry if it involves crop production, and silvopastoral farming if forage crops are being produced, or consumed on site by livestock.

Mixed tree and grassland farming: Considers grassland cultivation in sectors of valleys and oasis with irrigation possibilities, using trees or fodder shrubs along the grassland boundaries. The farming areas are rectangular-shaped pasturelands. The trees, normally leguminous, are used for firewood and their fruit for animal or human consumption. The tradition is to plant two or three trees for each tree that has been harvested.

7.3.2.2 Agroforestry Practices in Farming Communities

Farming communities are a form of community-based land tenure that began in colonial times in the Coquimbo and Valparaíso regions, primarily in areas with severe environmental limitations. The following agroforestry practices have been identified in this group:

Rainfed croplands: these are plots that the community supplies to a member of the community for dryland farming. The amount of land provided depends on the farmer's and their family's capacity to work the land. The plots are demarcated with live fences with cacti that form an impenetrable live barrier. This fence is essential since the main productive activity is goat farming. Traditionally, these rain fed croplands have been used for growing coriander, anise and wheat for a period of several years until productivity dwindles, after which they are used for grazing. Currently, as a consequence of the drought, these lands have been converted to forests for fodder using species such as *Atriplex nummularia* and, or *Acacia saligna*.

Protective and productive forest areas: generally found in shared community fields, especially in ravines where natural forests already exist or trees are planted to shelter animals from the sun or rain, for firewood or to protect water sources.

7.3.2.3 Agroforestry Practices in the Central Region of Chile

Grazing in the Espinal: grazing in espino (*Acacia caven*) steppes is a practice that has existed throughout history in the Central Region. Espino is a nitrogen-fixing leguminous tree that provides a natural canopy under which goats and cattle can graze on the wide variety of high quality fodder that grows beneath it. Espino is also used to produce charcoal, which, together with the extensive grazing, has caused serious degradation in this ecosystem.

7.3.3 Conclusions

The traditional agroforestry practices represent an important knowledge-base and contribution to developing promising agroforestry technologies.

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