PLANTS USED AS CONSTRUCTION COMPONENTS OF VERNACULAR EARTHEN ARCHITECTURE IN LA RIOJA PROVINCE, ARGENTINA

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Building materials of plant origin are widely used in vernacular earthen architecture. Their significance is such that they can be found in a variety of applications, from auxiliary building components up to primary structural elements. The present paper identifies a variety of plant species, whose materials have been used in rural households in the province of La Rioja, Argentina. The study area is confined to the region of the province's valleys, located within the botanical geographic region of Monte. The material collected from houses was later identified in the laboratory, which was compared with known samples. Further information provided by the villagers was also taken into account. The aims of the study were to draw up a list of plant species used, and to establish which of their parts and what qualities are exploited for the purposes that they were employed. Plant material was identified in: a) adobe and lattice filler material, b) ceilings, c) structures of lattice walls, d) woodwork, e) roofing systems and f) supporting structures in general. Plant materials tend to be present with more variety and quantity in the roofs. The use of plants responds to three types of specific functions, as primary or secondary structural elements, surface finishing, and stabilizer. The results confirm that plant species have significant involvement in the shaping of earthen architecture in rural areas of this region in the province.

1. INTRODUCTION

As building materials, plant species, are employed in a very diverse way in vernacular earthen architecture. Their versatility is such that a wide range of situations occurred: integrating auxiliary building components, used as stabilizers, or forming main structural elements. In the latter, they are considered a constructive technology that various authors refer to as *lattice* or 'mixed technique"'(Flores, 1994; Maldonado and Vela, 1999; Minke, 2008). In these situations, the earth is generally incorporated as a secondary or auxiliary component in the form of filler.

Other fields of study, such as the Economic Botany and Ethno-botany, have also developed studies, where the use of plants is analyzed in areas of the building (Luoga, Witkowski and Balkwill, 2000). In particular in Argentina, Keller (2008) has performed interesting work with a detailed description of the lattice technique used by Guarani communities of Argentina's Misiones province, with a list of plant species used in the construction of their homes and temples. In the case of temples, an array of cultural guidelines restrict the use of construction materials to only natural resources, exclusively available in the immediate environment.

In a more difficult situation, due in part to the lack of evidence and the difficulty of conservation, archeologists are also interested in the use of plant species in the construction (Sánchez García, 1999; Ryan, 2011). Moreover, from works dealing with domestic architecture and restoration of the built heritage, some authors (Viñuales, 1981; Sosa, 2003) have provided descriptions of earthen construction techniques from the northwest of Argentina, showing the different ways in which plant materials were used in vernacular buildings. Viñuales (1981) only refers to the common names of the plant species used, without going into greater detail (1). Sosa (2003) is more thorough about addressing the different building systems, the names of the plant species commonly used, and the characteristics of these plant components employed. In these descriptions it is possible to infer, for example, the amount of plant materials involved in the construction of earthen roofs (Viñuales, 1981 p. 11; Sosa, 2003, pp. 84-85). Armellini, Cóppola, Iglesias Molli, and Rosso (1970) conducted a more detailed description for the Antinaco Valley, Los Colorados in the province of La Rioja, taking into consideration different types of earthen-built dwellings, mentioning the plant species traditionally used, and the function with which they are employed.

Until the mid-20th century, earth was the material predominantly used in much of the Argentinean vernacular

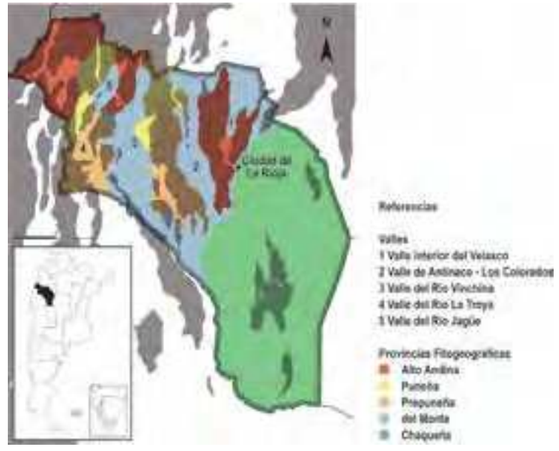

Fig.1 La Rioja Province in Argentina - area under study (source: Cabrera, 1976 (credits: Guillermo Rolón)

architecture in the province of La Rioja, both urban and rural. There is a significant usage of adobe masonry with single-pitched or completely flat earthen roofs. The materials of vegetal origin were used in a complementary manner in earthen construction. The abundance with which these exist in historic buildings confirms this. Numerous researchers have addressed the study of riojana vernacular architecture from various approaches (De Aparicio, 1937; Cáceres Freyre, 1946; Viñuales, 1981; Rolón and Rotondaro, 2010). However, in recent decades, this building tradition that used natural materials with little transformation experienced major changes, due to the increased communication with regional-service centers and the availability of new industrial building materials.

2. AREA AND PURPOSE OF THE STUDY

2.1 Description of the area under study

The area under study is confined to the valleys of the province, in the north and northwest sector of its territory. Specifically, it comprises the three main valleys of the region concerned, and two secondary valleys inside the Velasco, including the Valley of Antinaco, Valle-Los Colorados, Río Vinchina Valley, and the valleys of the rivers La Troya and Jagüé. These valleys are botanically within the geographic province of Monte (Cabrera, 1976), except for Río La Troya Valley, which also extends to the Prepubeña Province. In both areas, shrubby jarillas (Larrea sp.) and algarrobo (Prosopis sp.) are the dominant vegetation types. The climate is subtropical, arid, warm-temperate with an average annual temperature of 15°C. Precipitation ranges from 80 to 200 mm per year. Almost all of the rainfall occurs in the summer, between the months of December and February, in the form of torrential rains or downpours. This rainfall causes the course of rivers and streams to be of a temporary nature.

2.2 Aim of the study

The overall aim of the study was to establish a list of plant species of a constructive nature that are economically valuable to the rural population of the province of La Rioja. Thus, the study pursued a dual purpose: first, to draw up a list of plant species that have traditionally been used in the construction of rural housing in the region of the aforementioned valleys, and, secondly, to establish which parts and what qualities of the same plant species are exploited for the purposes for which they were employed.

3. MATERIALS AND METHODS

The collection of vegetal material was performed during several field surveys between 2009 and 2010, by taking representative samples in these five valleys (2). Primarily, a visual inspection in rural households that were in a state of abandonment was performed; in order to select what material to collect that had been used as a building component.

In addition, samples were also taken of the most common plant species of the natural vegetation detected while scanning adjacent areas of the sites of interest to be used as controls, in order to compare these materials with those from construction sites. The locations identified by locals where they sourced provisions were particularly taken into account. The resulting Herbarium specimens were compiled, taking care to preserve vegetative and reproductive structures, which could be potentially informative with respect to taxonomic identities. They were later identified on the basis of a literature survey of regional floras and monographs (Tortorelli, 1956; De la Peña and Pensiero, 2004) and by comparison with other previously identified herbal materials deposited in institutional herbaria.

The identification of the plant species used was accomplished two different ways depending on the nature of the collected material: either by the wood or other vegetative elements (branches, stems, leaves, etc.). Samples taken from a given location were used to determine species of wood. In addition, wood was cut into cubes of 2 cm, except where the dimensions of the material prevented it. The cubes were boiled daily for five hours over 10 days in water with detergent. Each cube was prepared so as to achieve transverse, radial longitudinal and tangential longitudinal cuts of 5 µm thickness with a sliding microtome. These were mounted on slides with a gelatin-glycerin mixture. They were then observed under an optical microscope and conclusively identified based on comparisons with known materials and bibliographic descriptions.

For the remaining materials, special care was taken to include the reproductive structures of the respective branches collected (flowers, fruits, seeds), as the vegetative elements are highly variable within plant species groups, and

Muestra	Nombre cientifico	Nombre vulgar	Valle	Relev.
Vigas y soleras	Prosopis sp.	Algarrobo	Río la Troya	ZAP2
	Prosopis sp.	Algarrobo	Bermejo	CON1
	Populus sp.	Álamo	Bermejo	CON1
	Salix sp. o Populus sp.	Sauce o álamo	Bermejo	CON2
	Salix sp. o Populus sp.	Sauce o álamo	Velasco	ANL1
	Zuccagnia puntacta	Lata, Pus-pus o Jarilla macho	Río la Troya	ZAP2
	Populus sp.	Álamo	Río la Troya	ZAP2
	Geoffroea decorticans	Chañar	Río la Troya	ZAP2
Cubierta (cielorraso)	Arundo donax	Caña de Castilla	Bermejo	CON1
	Arundo donax	Caña de Castilla	Antinaco	BCA1
	Arundo donax	Caña de Castilla	Antinaco	PIT1
	Arundo donax	Caña de Castilla	Antinaco	ANT1
Cubierta (enramada)	Arundo donax Prosopis aff. argentina	Caña de Castilla Algarrobilla	Bermejo	CON3
	Atriplex aff. suberecta		Antinaco	BCA1
	Chenopodium cordobense	Quinoa corbesa	Antinaco	BCA1
	Cortaderia sp. Prosopis aff. argentina	Cortadera ¿Algarrobilla?	Jagüe	JAG1
	aff. Poaceae ('Gramineae)	¿Gramínea?	Antinaco	BCA1
	Larrea cuneifolia	Jarilla	Velasco	ANL1
	Larrea divaricata	Jarilla	Antinaco	CON1
	Physalis viscosa	Camambú	Antinaco	BCA1
	Solanum elaeagnifolium		Antinaco	BCA1
	Symphyotrichum squamatus		Antinaco	BCA1
	Triticum aestivum	Trigo	Antinaco	BCA2
	Xanthium spinosum var. spinosum Eragrostis aff. mexicana		Antinaco	BCA1
	Zuccagnia puntacta	Lata, Pus-pus o Jarilla macho	Antinaco	BCA2
	Zuccagnia puntacta	Lata, Pus-pus o Jarilla macho	Antinaco	BCA1
Cubierta (enramada fina)	¿Cyperaceae?		Antinaco	ANT1
	Jarava ichu	Ichu, Paja ichu, Paja brava o Aibe	Velasco	ALT1
Cubierta (enramada gruesa)	Cercidium australe	Brea	Bermejo	VIC1
	Cercidium australe	Brea	Antinaco	PIT1
	Larrea divaricata	Jarilla	Antinaco	PIT1
	Prosopis aff. argentina	¿Algarrobilla?	Bermejo	CON3
	Prosopis aff. flexuosa	Algarrobo	Antinaco	ANT1
	Tessaria aff. dodoneifolia	Chiica	Antinaco	PIT1
Cubierta (en torta)	Triticum aestivum	Trigo	Jagüe	JAG1
Cubierta (película de contención)	Arundo donax	Caña de Castilla	Antinaco	PIT1
	Poaceae (=Gramineae) (aff. Sporobolus rigens)		Bermejo	VIC1
	Triticum aestivum	Trigo	Bermejo	CON1
Aberturas	Prosopis sp.	Algarrobo	Bermejo	CON3
	Prosopis sp.	Algarrobo	Velasco	ANT1
	Prosopis sp.	Algarrobo	Bermejo	CON1
Horcón	Prosopis sp.	Algarrobo	Bermejo	CON2
	Salix sp. o Populus sp.	Sauce o álamo	Bermejo	CON2
Muro	Arundo donax	Caña de Castilla	Bermejo	CON1
	Tessaria aff. dodoneifolia	Pájaro bobo, Chilca o suncho negro	Bermejo	CON3

Table 1. Taxonomic original table with reference to plant species used in construction elements (credits: Sonia Rosenfeld, Pablo Picca and Guillermo Rolón, 2011)

taxonomically uninformative. In many cases, the finding of such structures permitted identification at the species level of some components. Other materials, however, have only been identified within more inclusive taxonomic levels (genus, family) or could not even be identified. The identification of these materials was primarily accomplished by using technical literature, together with, comparing them to the organized reference collection.

In order to establish which parts and what qualities of vegetal material were being used, the construction system for houses was analyzed from the graphic and photographic perspective, which was accomplished in the field. At first, it was performed at the level of components and construction elements, in order to determine types of solutions. At a later stage, the various building systems and their different variations were determined, so as to decide how the components and elements were connected between themselves. Thus, a broader picture on the distribution of vegetal material in construction was provided.

4. RESULTS

In this study, 34 rural houses, mostly in a state of abandonment, were surveyed. Earth constituted, to a greater or lesser extent, as one of the building materials. In all situations, the vegetal material collected was part of a construction system, where earth

a) b) c)

Fig.2 *Quincha* walls with Castile cane and carob lattice (credits: Guillermo Rolón, 2011)

was the main component. To systematize the study, the origin of the vegetal material was indicated by the constructive element where it was integrated: roofing, linear structural elements (beams, wooden slats, etc.), woodwork (doors and windows), walls or plasters.

A total of 95 samples of vegetal material were collected. Building components samples corresponded to: 49 samples of the materials of different layers of roofing, 13 of structural elements, three of woodwork, and two of wall materials. The leftover materials collected corresponded to 28 samples of plant species from sourcing sites indicated by locals. So far, a total of 60 samples have been identified, of which 43 correspond to samples taken from construction elements (Table 1).

The analysis of the housing components and structural elements found the presence of vegetal material in all case studies, and virtually in all parts of construction with the exception of foundations and plinths, with different levels of development of the materials used. The observed wood was mainly used in *horcones* (wooden vertical beams), roofing structures (beams and slabs), and woodwork. Other types of plant species material (branches, reeds, leaves, grasses, etc.) were identified in walls, roof coverings, plasters and mortars. In the walls, the vegetal material was found serving two different functions: first, forming the lattice structure of *quincha* walls (wattle and daub), and secondly, as a stabilizer incorporated as herbal fibers in the raw earthen material. In the case of *quinchas*, the columns or main *horcones* that make up the framework are usually logs or large branches of algarrobo (Prosopis sp.) with little or no transformation, though with variable dimensions (diameters ranging from 8 to 25 cm). *Caña de castilla* (Arundo donax) (giant reed or cane) was typically used for the skeleton of the vegetable framework. In all observed cases, the fabric of *quinchas* was resolved through skeletal frameworks filled in with vertical reed, largely due to the dimensional regularity of the reeds used (3). Thus far, five timber species were identified amongst the structural elements (wooden columns, beams and slabs). These included Prosopis sp. (algarrobo, mesquite), Populus sp. (cottonwood), Salix sp. (willow), Geoffroea decorticans (Chilean palo verde) and Zuccagnia (Jarilla, creosote bush). In terms of woodwork, the collected samples corresponded in all cases to algarrobo (Prosopis sp.).

Among the constructive elements discussed, roofing was the most complex element, in terms of diversity of the observed plant species material (4). Twelve kinds of reinforced roofing, grouped into two main patterns, were identified: lightweight covering and heavy covering. The types and subtypes were then established taking into account the number and function of the different layers that make up the roof, differentiating nine types of layers. Plant species material was observed in eight of them:

a) *Torta:* This consists of a layer of rustic earth of varying thickness. It is always the top layer, and it is intended for the evacuation of rainwater, thermal insulation and solar protection. The vegetal material present in this layer is crop-waste material; preferably fine fibers (e.g., wheat or alfalfa chaff).

b) *Enramada:* This consists of a layer of branches of shrubs, or plant parts without any transformation. Generally, the materials selected are as flat as possible are selected to facilitate their placement and the shaping of the layer itself. It combines the functions of containment of the earthen roof (*Torta*), as well

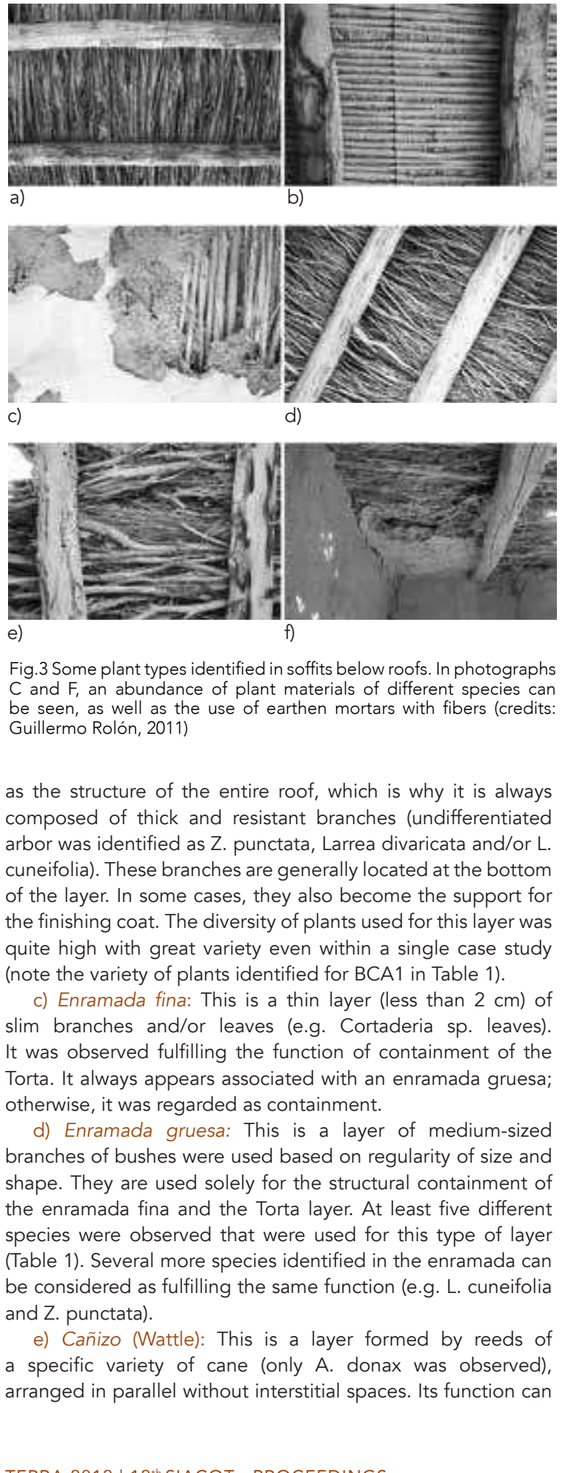

Fig.3 Some plant types identified in soffits below roofs. In photographs C and F, an abundance of plant materials of different species can be seen, as well as the use of earthen mortars with fibers (credits: Guillermo Rolón, 2011)

as the structure of the entire roof, which is why it is always composed of thick and resistant branches (undifferentiated arbor was identified as Z. punctata, Larrea divaricata and/or L. cuneifolia). These branches are generally located at the bottom of the layer. In some cases, they also become the support for the finishing coat. The diversity of plants used for this layer was quite high with great variety even within a single case study (note the variety of plants identified for BCA1 in Table 1).

c) *Enramada fina*: This is a thin layer (less than 2 cm) of slim branches and/or leaves (e.g. Cortaderia sp. leaves). It was observed fulfilling the function of containment of the Torta. It always appears associated with an enramada gruesa; otherwise, it was regarded as containment.

d) *Enramada gruesa:* This is a layer of medium-sized branches of bushes were used based on regularity of size and shape. They are used solely for the structural containment of the enramada fina and the Torta layer. At least five different species were observed that were used for this type of layer (Table 1). Several more species identified in the enramada can be considered as fulfilling the same function (e.g. L. cuneifolia and Z. punctata).

e) *Cañizo* (Wattle): This is a layer formed by reeds of a specific variety of cane (only A. donax was observed), arranged in parallel without interstitial spaces. Its function can be structural, for containment of the Torta, for the soffit of a ceiling, or for substrate to apply a finish to a ceiling.

f) *Capa de Acabado* (Finish Coat): Consisting of an earthen-plaster material and fine vegetal fibers (similar to the torta), it is applied to the ceiling or to the timbers when it is a reinforced ceiling.

g) *Película de contención* (Containment Film): This consists of a continuous and thin material. When composed of plant materials, it is always observed with leaves, preferably those having ribbon-like sheets or parallel ribs.

h) *Sujeción:* This is an open layer, consisting of a transverse linear element to the cañizo for holding them. The most frequently used vegetal material is Castilla cane (A. donax).

5. CONCLUSION

Due to the abundance and diversity of vegetal materials observed in roofs, the focus of the study centered primarily on this construction element. Viñuales (1981) describes two types of roof coverings used in the province of La Rioja, differentiating them according to the characteristics of the layers of vegetal material that comprise them: characterized by the presence of a thick layer of Pus-pus branches (Z. punctata), which locals call *enramada*. While the presence of the Pus-pus is confirmed in many case studies, it is not the only vegetal material observed in these layers that perform this function. It is also necessary to redefine the arbor, not only by its morphology, but also by its function. In addition, different degrees of complexity in constructing the arbor were observed, depending on the number of layers, and the layout and function of each one. The thin arbor is a layer of thin branches containing the earth layer. The thick arbor underneath provides a structural function for the entire roof, and is prepared with thicker branches. It should be clarified that this basic pattern of arbor-layer arrangement was also observed in more complex construction, presenting other perfectly distinguishable layers.

Given the complexity of the roofing layers, it was possible to establish 12 types that take into account morphology, arrangement and function. Of these types, five of them lack the light earthen roof covering, and have the simplest configuration of this constructive element. Whereas, tree boughs used in a roof are more complex, because they involve selection and procurement of materials at earlier stages.

By focusing the work on the diversity of plant species used in the earthen architecture of the region studied, it was possible to confirm that their use was more diverse than expected, even if the botanical geographic area of the study has a reduced plant-species variety. Clearly, builders acquired a very precise knowledge of the physical characteristics and economic value of various plants growing in the region, and how to use these to their advantage in the construction of houses.

Notes

(1) "*We saw that there is a system called quincha or estanteo that is supported by a previous framework; as the case of champas, whose framework is constituted by the very same roots of grasses cropped from the soil. In the case of adobes, the rammed earth and the plaster in general, the fibers are chopped. The most common use in our country is straw, which is incorporated with different lengths for each type of application, and which will be of one or another grass from those the place offers [...] To the vizcachera, ichu, brava, are added the remains of linen, corn, cotton, rice and cereals in general, apart from bark, shavings and sawdust*" (Viñuales, 1981, pp. 27)
(2) The number of samples per valley includes seven from Valle interior del Velasco, 43 from Valle Antinaco – Los Colorados, 28 from Valle del Río Vinchina, seven from Valle del Río Jagüe, and 18 from Valle del Río La Troya.
(3) The nomenclature of the components from mixed construction techniques was based on Hays and Matuk, 2003, pp. 140-197.
(4) Other complementary aspects of this construction element are described and analyzed in the paper "Constructive techniques of the earthen vernacular housing in the valleys region of La Rioja, Argentina" presented at Terra 2012.

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