ENVIRONMENTAL IMPACT ASSESSMENT OF VERNACULAR
THATCH BUILDING TRADITION IN MEXICO: *CASE STUDIES OF
THREE PALM SPECIES AND RELATED TECHNOLOGY ALONG THE
TRANS-MEXICAN VOLCANIC BELT*

BY

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Abstract

This project involves research into vernacular buildings, in particular traditional and contemporary coastal palm thatch buildings in the middle-west coast deciduous forest environments in Mexico. The fieldwork-based grounded theory research investigates the natural materials and techniques involved in constructing thatched vernacular buildings using three different palm species (*Attalea guacuyule*, *Brahea dulcis* and *Sabal rosei*) in different climatic contexts along the Trans Mexican Volcanic Belt (TMVB). The aim is to achieve a holistic approach to the environmental assessment of these building types through a life-cycle assessment.

The present research emerges from the premise that vernacular buildings are generally taken for granted as sustainable, and yet they are under-investigated meaning this assumption may not be correct. In general the performance of vernacular buildings in terms of sustainability and in relation to their embodied energy is under reported, particularly in terms of vernacular case studies in Mexico. However the deterioration of the environments where such buildings are located through anthropogenic causes is of world-wide importance, therefore it is a priority for this research to study the relationship of the vernacular traditions with their immediate environment.

The first section of the thesis analyses theoretical frameworks for sustainability and vernacular architecture. Both terms are widely used and carry many different meanings, so it is important to establish the definitions used in this research to better set the boundaries of the study as a basis for seeking the best methods for assessing the environmental impact of the selected vernacular thatch building technologies.

The second section undertakes qualitative and quantitative fieldwork on traditional practices of palm thatch buildings in selected regions of Mexico and related case studies, six in total. The fieldwork was combined with investigation into ethnographical, ethnobotanical and historical records and data for the three palms used for thatching and their related materials and technologies in order to derive data concerning yield factors, lifespan of the building materials, carrying capacities, embodied energy of transport and embodied energy of materials.

The third section applies the collected information for a life-cycle environmental assessment (LCA) of two typical buildings for each of the three different palm species and the diverse techniques involved. The assessment is carried out based on various assumptions that are commonly used in LCA to give a carbon account and an ecological footprint for each building component both after construction and for a 50 year building life.

However, during the research particular variables in the analysis were revealed, such as operating energy, recycling of building elements, durability of materials and transport practices, which can vary widely from case to case, therefore the limits and scope of the assessment excluded such data for a better comparative scenario of the building process itself. This suggests that a different way of life-cycle accounting may be needed when assessing vernacular structures.

The results show the environmental impact of these techniques in terms of carbon and ecological footprints, and reveal that the rural vernacular case studies had lower environmental impacts than the suburban and urban vernacular case studies as measured by their carbon content, energy expressed in Giga Joules (GJ) and their ecological footprints.

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CHAPTER 1

INTRODUCTION, DEFINITION AND STRUCTURE OF THE RESEARCH

1.1 Introduction

The present research emerges from the need to achieve local environmental sustainability in the face of environmental deterioration, a situation faced by many rural communities in developing countries. The focus here is on vernacular architecture and its profound connection with its immediate environment. Perhaps because it is taken for granted that vernacular buildings are very attached to their context, and because they are so old and have served many generations reliably, it is assumed that such building manifestations will always be there and will not change or disappear. Moreover, in relationship to architecture and particularly sustainable architecture, it also seems that vernacular expressions are conceived as sustainable per se. But are such buildings sustainable? Have they never changed or do they never evolve? On what basis can it be said that they are sustainable?

Some vernacular buildings might be all of the above, but it is also obvious that the native environment of many is under great threat of alteration or extinction, which must affect the future of these building traditions. Social factors are also changing, which will have an effect. At the same time the fact that vernacular building traditions are still recognized is proof of their value, and perhaps an indication of their sustainability, through their ability to serve their human communities over many years.

Vernacular architecture accounts for a wide variety of examples of building types, not just housing, and a huge legacy in terms of the many technologies, forms, principles, and materials involved. In spite of this, it appears to remain unattended and undervalued, and is thus misunderstood, particularly in relation to formal architectural education. It is the wide and diverse legacy of vernacular buildings that makes it impossible to narrow them all into one single subject area. This is one of the problems—all vernacular buildings are not the same. In order to narrow the scope of this research into vernacular buildings and because of the rising concern over human

environmental impact on local environments, the issue addressed here is that of sustainability related to particular vernacular building traditions, those of thatch buildings in a specific location in Mexico. This involves the depletion of native forest and its implications for climate change and carbon release, with particular focus on tropical forests as the value they have as ecosystems and carbon sinks has been argued (Brown & Lugo, 1992; Cairns et al., 2003; Clark et al., 2001; Dixon et al., 1994; Gibbs et al., 2007). Moreover, these forests are the source of these local vernacular building materials.

In this sense the following investigation approaches this problem in the form of developing models for measuring sustainability in vernacular buildings. The interest here is how this expands into the immediate impact on local forest ecosystems when materials are harvested. This is approached from the viewpoint of 'strong' sustainability rather than the political economic viewpoint or 'weak' sustainability that is reached by focusing on capital theory (Gowdy & O'Hara, 1997; Meadowcroft, 2007).

But what is meant by strong local sustainability? This set of principles has troubled many people as the definitions can be vague and ambiguous (Brown et al., 1987; (Leitch & Davenport, 2007; Parris & Kates, 2003; Reed & DeFillippi, 1990; Scoones, 2009). Basically, strong sustainability means taking a holistic view, and at the core of this principle are philosophical and moral values towards the environment, epitomized by the deep ecology movement of Arne Naess who set up the eight principles of environmental sustainability (Fox, 1990). There are also an increasing number of scientifically based ways to measure sustainability (Clark & Dickson, 2003) to the point that sustainable science has become an emerging field of enquiry (Charlafti, 2003; Levin, 1993).

Based on the above, the following work approaches these topics by setting out to measure the environmental impact of thatched vernacular buildings in tropical environments, with particular focus on deciduous forests in Mexico. Mexico is selected because it is a developing country that sits between the modern and the vernacular, and that faces increasing threats in the form of deforestation and land use change (Cairns et al., 2000). On the other hand Mexico is also part of Latin America, which, as a whole, measures well in most fields concerning sustainability (Butchart et

al., 2010; Loh, 2000; Moran et al., 2008; Wackernagel et al, 2006), although Mexico emerges as an ecological debtor in a cross comparison of countries for consumption of energy and other resources (Siche et al, 2008). Moreover, the biological diversity of regions of Mexico, such as the Mesoamerican forests, makes it fall within the richest bio-diverse regions in the world (Mittermeier et al., 1998).

The following work looks at the relationship between local tropical forests and vernacular buildings, materials and traditions in Mexico. The following section looks at the underlying topics that form the basis of this investigation.

1.2 Global Concerns, Local Solutions

An increasing and major current global concern is the worldwide environmental deterioration attributed to anthropogenic causes (Crutzen, 2002; Lutz & Qiang, 2002; Simon, 2006), specifically the release and effect of greenhouse gases caused by human activities and the repercussions these have for climate change (Huttunen et al., 2003; Liverman, 2007; Pan et al., 2011; Ruddiman, 2003; Vitousek et al., 1997). This has become a prime focus of scientific and academic research, which has resulted in understanding the important influence that carbon dioxide (CO₂) fluxes in particular have on climate change (Geider et al., 2001; Rodhe, 1990), while acknowledging other gases remain equally relevant. The accuracy of measuring carbon cycles has developed into a primary focus of concern; for instance, in most biogeochemical sciences focus is on the net carbon balance of an ecosystem (Running et al., 1999, pp. 108-127). However, while studying the natural environment is essential in order to understand how carbon cycles work, for architecture it is important to research the built environment, including accurate measurement of the energy involved in buildings and their related activities (Cole & Kernan, 1996; Spence & Mulligan, 1995). Therefore of general concern for this research is the relationship between environmental impact and methods for measuring the whole energy involved in making and maintaining buildings, with the focus here being on vernacular buildings and processes. The local focus is a priority in order to obtain limited but accurate information related to the usage of materials and technologies and therefore enable the determination of their potential sustainability or lack of it. Thus, to start defining the scope of this

investigation, the following section gives a general overview of the main concerns underpinning the research.

1.2.1 Anthropogenic Impact on the Environment

Only in recent decades has the impact caused by humans on the environment been generally recognized to have had unprecedented global consequences. The effect of these human induced changes on the atmosphere and biosphere has been referred to as a new geological epoch, the ‘Anthropocene’, supplementing the Holocene (Crutzen, 2002). The environmental impact caused by human development has been linked on the one hand to the increase in human population, as globally there has been a tenfold rise over 300 years and a fourfold increase in the twentieth century, to over 6 billion in 2005 (Lutz & Qiang, 2002, p. 1197) and over 7 billion now. On the other hand, human environmental impact has been linked to the emergence and spread of particular forms of human social organization, which have led to major changes in the ecological systems of the Earth (Simon, 2006, p. 206).

The first revolutionary social system was the appearance of a new form of organization based on plant and animal food domestication supplanting food gathering. This was initiated in South West Asia, although the region more favorable for its development was Eurasia. Subsequently it has been propagated almost globally over several thousand years (Diamond, 1997). However, the impacts of such a social organizational system were modest in terms of global environmental processes if compared to change in the last few centuries (Simon, 2006, p. 206). This was when a second form of social organization emerged from the sixteenth century onwards in the form of capitalist economic development in Europe, which was based on private property and the production of goods and services for sale in a competitive market to realize the maximum profit (Brenner, 1977; Wallerstein, 2011).

The internal logic and positive feedback of the pursuit of profits, of which some is used to generate more profits, has led to both the ever-increasing use of environmental resources, and an increasingly global search for exploitable resources for use in an ever expanding global economy. (Simon, 2006, p. 206)

The use of fossil fuels and land-use changes in human development, especially in the twentieth century, have been estimated to have increased atmospheric carbon dioxide concentrations by 25 per cent, while average global air temperatures have been estimated to have increased by 0.6 Celsius degrees (Houghton et al., 2001; Simon, 2006). It has also been accepted that carbon cycles are crucial in understanding the complexity of anthropogenic and ecological systems. The atmosphere, oceans, terrestrial ecosystems and the dominant mammal—*Homo sapiens*—all interact in highly complex ways. Understanding the links between components is, therefore, critical. For example, the rise in atmospheric carbon dioxide concentrations from fossil fuel use, and the resulting increases in air temperatures, and their impacts on the Earth's system and human welfare, can only be understood by understanding the complete global carbon cycle, including the oceanic, atmospheric and terrestrial components and how carbon moves between them. (Simon, 2006, p. 195)

Changes of carbon dioxide (CO₂) concentrations in the atmosphere largely determine the rate of increase in air temperatures and other features of climate change (Houghton et al., 2001). “The increase in atmospheric CO₂ is governed by four major fluxes, the carbon flux from fossil fuel use, the flux from land-use change, and the net fluxes to the oceans and terrestrial ecosystems” (Simon, 2006, p. 201). Current scenarios are not positive and will certainly worsen if humankind continues on its current trajectory, as even the most optimistic projections from the United Nations with moderate increases in population, and food and resources production and consumption, are all very likely to double the rate of CO₂ emissions by 2050 (Goodland & Daly, 1996, p. 1011). Even in the most anthropocentric view, the magnitude of overshoot threatens not only the loss of biodiversity, but also risks damaging the ability of the Earth's ecosystems to provide the resources and services on which humanity relies (Hails et al., 2006, p. 20).

For the specific purpose of this research, the role of tropical forests is of great relevance not only because they host a significant number of vernacular societies and their traditions, and are thus the prime source of the building resources involved, but also because problems in their ecosystems reverberate with bigger consequences. For instance, tropical deforestation is likely to cause population changes for many species, including driving some to extinction (Simon, 2006, p. 200). According to the World Atlas of Biodiversity regarding threatened losses, at the global scale there are 25 classified hotspots featuring several habitat types. Predominant are tropical forests (16

hotspots), which largely means they are in developing countries where threats to the environment are greatest and conservation resources scarcest (Myers et al., 2000, p. 855).

By far the most uncertain fluxes are the carbon emissions from land-use changes, which over recent decades have overwhelmingly been caused by tropical deforestation, and changes to the residual terrestrial carbon sink, part of which may be in tropical forests (Simon, 2006, p. 201). The poor understanding of carbon fluxes caused by deforestation is a major limitation on understanding the global carbon cycle and climate change (Houghton et al., 2001). However, although the magnitude is still uncertain, it is clear that tropical deforestation is a significant source of carbon in the atmosphere (Simon, 2006, p. 202). As a result, the relevance of undertaking research as proposed here is that by assessing vernacular building traditions insights into good or bad management in terms of land resource habits can be highlighted, especially for evaluating land-use implications.

Finally, measurement of CO₂ emissions, and global waste production and pollution are very relevant to sustainability. Measuring CO₂ emissions not only shows societal consumption trends but also highlights disparities between national trends (Goodland & Daly, 1996, p. 1015). Emissions are very uneven; for instance, India's per capita average annual tonnes of carbon emitted into the atmosphere are small compared to those of Canada or the United States, and this is true of most developing countries (Goodland & Daly, 1996, p. 1015). Among the economic and capitalist human systems of organization, development is a key concept of concern. Developmental ideals have led some countries to evolve better and faster in terms of bringing up the level of quality of life as measured by such things as education, healthcare, food security, social order, life expectancy, and growth. However, in order to achieve this high level of 'development', militarily powerful and economically strong nations as dominant (ex-colonizer) societies have had to rely on somewhat murky interactions between warfare and exploitation of resources and land by taking advantage of their more complex developed social systems to gain control over less powerful (ex-colonized) ones (Brundtland & World Commission on Environment and Development, 1987; Ould-Mey, 2003). This is an issue for countries such as Mexico, which is the focus of this research.

1.2.2 Development and Socio-Ecological Disparities

Development is an important concept for further investigation as it can show clear signs of disparity depending on how it is applied. Development is in fact a western concept that encompasses progress, but the way it is applied in modern societies implies a set of disparities within it. To begin dismantling its different connotations its etymology is a useful starting point. The word can be traced to roots in the word develop, hence development (Partridge, 1959, p. 159). Develop comes from the same roots as envelope from the French *enveloppe* derived from the Old French *enveloper*. In its turn, ‘to envelop’ is referred to as an alteration of the Old French *enveloper*; *en* for ‘in’ plus *volper* ‘to wrap’ hence ‘to wrap in’, and it can be traced back further to the Modern Latin *volvere* ‘to roll into a spiral or a ball’ (Partridge, 1959, p. 159). Therefore de-velop means in general ‘to unfold’ or ‘to open out’ (Skeat, 1901, p. 139). Another derivation (Klein, 1966, p. 437) suggests develop is formed by the prefix ‘des’ from the Latin *dis* ‘apart, asunder’ and a blend of the Latin word *volvere* ‘to roll’ and the Modern Latin word *faluppa* ‘fibre, straw, ball of corn’, and hence ‘to roll apart fibre or straw’.

Dismantling the word through its etymological meaning reveals that its root has a cyclical or spiral connotation, in rolling, wrapping, folding or unfolding. Also of interest is the close connection of the language with the engagement of management of nature, as in reference to fibre, straw, or ball of corn, which could possibly have played an important part in the ‘developing’ both of societies in the past and of the term. However, the modern perspective on the use of the term is far from this connection with nature, since the western kind of economic and technological oriented development has a straight tendency for progression based on increased capital, energy and resource consumption with little regard for the impact of this on the natural world.

This subtle and yet important observation is not enough to reveal a clear-cut categorization of economic worlds into rich and poor societies, or militarily and politically strong or weak ones when referring to ‘developed’ ‘developing’ and ‘underdeveloped’ nations. Disparity can only be appreciated by thinking about progress as being linear and not understanding the essence of meaning in the term ‘develop’, making it very difficult for the underdeveloped world to catch up with the

developing one, and then with the developed world respectively. This is particularly true given the limited nature of global resources and the increasing population, with their demands for goods and services. Most importantly, it is argued that development has to stop nations moving forward by increasing the gap between the rich and the poor (Dollar & Kraay, 2002; Ould-Mey, 2003; Sheehey, 1996; Stokey, 1991).

It has thus been maintained that the very same mechanisms which set off underdevelopment in the 'periphery' are prerequisite to capital accumulation in the 'core'. Capitalist development cannot take place in the core unless underdevelopment is developed in the periphery, because the very mechanisms which determine underdevelopment are required for capitalist accumulation. In the words of André Gunder Frank, 'economic development and underdevelopment are the opposite faces of the same coin'. (Brenner, 1977, pp. 27-28)

It has long been considered that overconsumption of resources and energy by developed countries contributes more to global un-sustainability than population growth does when comparing consumption patterns in developing countries (Parikh & Painuly, 1994, p. 434). An example using food patterns is the following comment on the 1992 world population and grain harvest:

Recent world harvests, if equitably distributed and with no grain diverted to feeding livestock, could supply a vegetarian diet to about 6 billion people. A diet more typical of South America, with some 15 percent of its calories derived from animal sources, could be supplied to about 4 billion people. A "full but healthy diet" (about 30 percent of calories from animal sources) of the sort eaten by many people in rich countries could be supplied to less than half the 1992 population of 5.5 billion (Chen, 1990 found in Ehrlich et al., 1993, p. 4).

This suggests that rising world population could have become a greater problem since Chen was writing unless agricultural production also rises significantly, as the global population has already exceed 7 billion. However, capitalist development models are everywhere focused on economic growth and progress while urban areas are the territories where this uneven development happens. This is alarming in the view of estimated population growth in the future, when half of the global population will live

in urban and suburban areas by 2000-2030 (Heilig, 2002, p. 5). According to the United Nations Population Division (Cohen, 2003, p. 1172):

...worldwide urbanization has taken place for at least two centuries and accelerated greatly in the 20th century. In 1800, roughly 2% of people lived in cities; in 1900, 12%; in 2000, more than 47%, and nearly 10% of those city dwellers lived in cities of 10 million people or larger. Between 1800 and 1900, the number of city dwellers rose more than 11-fold, from 18 million to 200 million; between 1900 and 2000, the number of city dwellers rose another 14-fold or more, from 200 million to 2.9 billion.

Stabilizing the increasing rate of population growth is essential in order to minimize the need for growth everywhere, especially where increased population has the greatest impact, as in high-consuming nations where the population has a doubling time projection of 162 years. This compares with a doubling time population projection of only 30 years in poor, low-consuming nations (Goodland & Daly, 1996, p. 1004). In addition the land this population will require to produce the resources to sustain such a development model must be considered, as even by the late 1990s over a third to half of the available land had been appropriated for human use (Vitousek, et al, 1997). It has also been argued that some localities, particularly cities, cannot by definition be sustainable, since they depend on their hinterland for resources and sustenance (Great Britain. Improvement and Development Agency. & Forum for the Future (Organization), 1999), and this hinterland is already being used to fuel current growth and consumption.

Between 2000 and 2030 the world urban population is projected to grow at an annual rate of 1.9 percent, nearly double the total world population growth rate of 1 percent per year, meaning the world's urban population will double in 38 years (Heilig, 2002, p. 5). Urban population growth is projected to be particularly rapid in less developed regions with an average of 2.4 percent per year and a doubling of population in 29 years. In contrast, from 2000-2030 the rural population of less developed regions is projected to grow at a very low rate of 0.2 percent per year (Heilig, 2002, p. 5). One consequence of this urban population exponential rate of growth is more migration of rural people to urban areas. The main concern here is that development of capitalist and 'economically successful' cities often depends on a policy of despair for the rural

poor since resources have to be obtained from outside the city, no matter what has to be done to secure them.

The shift required in order to balance developed and underdeveloped countries or to bridge the so called gap between the North and the South (Ould-Mey, 2003) is not a simple one.

The rich countries, which are responsible for most of today's global environmental damage (e.g., CO₂ accumulation, ozone-shield damage), and whose material well-being can sustain halting or even reversing throughput growth, must take the lead in this respect. Most local environmental damage (e.g., soil erosion, water pollution) occurs in developing countries. Poverty reduction will require considerable growth, as well as development, in developing countries. But global environmental constraints are real, and more growth for the South must be balanced by negative throughput growth for the North if environmental sustainability is to be achieved. (Goodland & Daly, 1996, p. 1004)

Wealthy nations must free resources for the growth and development so urgently needed by poor nations, "If overshoot is to end by a selected target date, economic analyses are needed to determine the percentage of world GDP that will have to be invested in reducing humanity's footprint" (Hails et al., 2006, p. 20).

Economic capitalist development tendencies and models all reverberate in the field of architecture, and this might be one of the major reasons that most of the work about sustainability and architecture concentrates on offering solutions to these increasing urban populations. However solutions must also envision non-urban problems and non-urban solutions although this area has been largely left unattended, as most studies about sustainable architecture barely cover vernacular architecture. For instance, although in formal education there is application of the idea of sustainable development to architecture and its related fields, most work is oriented towards urban development, with little consideration of rural development.

Lastly, a general definition of the term development needs to be made for the present research as it will appear several times. The term itself should not have a negative connotation, although the wrong use of the term does. For instance, generalizing differentiations between developed, developing or under-developed regions and

nations merely because of their different levels of economic or political order can misrepresent the level of ‘development’ a society has. Particularly, this happens when accounting fails to include social development, cultural development, and vernacular development, or the sum of all the tangible and intangible aspects of a social-ecological system as these will definitively account for some sort of ‘capital’. For instance, traditional indigenous knowledge is a valuable capital for ‘research’, and additionally environmental development should be accounted for in terms of natural capital, biocapacity, or productivity yield factors.

1.3 Vernacular Building as a Legacy for Architecture

In defining the research it is important to state that it is specifically architectural as it generally focuses on the relationship between architecture, vernacular building traditions, and sustainability. It is inspired by the many examples of buildings considered as vernacular architecture that have been shown to have evolved, been improved and adapted to be appropriate to specific climatic conditions, and made with local environmental awareness and cultural responsiveness (Coch, 1998, p. 68; Day, 1993; Kingston, 2003, p. 591; Rapoport, 1987, p. 11). For the present research, vernacular building traditions are understood as a type of dwelling practice that is native or well adapted to a specific climate, natural environment and cultural context, implying that the main part of the building involves local materials and traditional technologies related to an immediate culture and environment. This means the ‘vernacular thatch building tradition’ as used in the thesis title covers, but is not limited to, natural local thatch building technologies and related materials and activities.

An approximate functional definition of vernacular architecture can be described as the sum of considerations in which the design of a building is the result of taking into account the empirical knowledge of immediate ecosystems and adaptation to them, translated into the use of local materials that are abundant, easy to access and work with, and their related technologies, all being derived both from personal-communal experimentation and innovation, and the legacy of knowledge from past generations passed through oral traditions which constitute a cultural legacy.

With regard to architecture, research in the field should be approached as connected to, instead of separated from, other disciplines but most importantly as connected to nature itself. This is because the matter of architecture is the materials themselves and hence nature and the places where the materials are found, for these are the bridges that join them together. Vernacular architecture is one of these bridges that link architecture with nature and other disciplines as shown by Upton, 1981.

...it is not surprising, given the healthy egalitarianism that many academics have absorbed from popular culture, that scholars as diverse as historians and architectural historians, anthropologists, archaeologists and folklorists, geographers, architects and historic preservationists have found non-academic [ie vernacular] architecture (to use a common definition) a fruitful field of inquiry. (Upton, 1981, p. 58)

Upton's suggested participation of these many fields of research in looking at vernacular architecture helps in understanding the importance of its holistic approach which is so desirable for sustainability. It supports the view that the field of architecture should pay special attention to this vernacular bridge, something that is a key for the present investigation. Because the aim of this approach is to be holistic per se, it is clear that many related fields will also be of great support throughout the investigation.

The vast amount of vernacular building examples that serve as a legacy of the wide diversity of technologies and materials that have proven to be the best available solutions to specific environments, have contributed to a wide bibliography related to vernacular building and architecture (Armitage, 1986; Faegre, 1979; Groth, 1999; McCann, 1983; Oliver, 1969; Parsons, 1991; Prussin, 1974; Rapoport, 1969; Semper et al., 2004; Vale, 1973; Villegas Jiménez & Londoño, 2003). Although these studies are an important starting point for the present investigation, very little research has been done to assess fully the sustainability of specific vernacular building manifestations and traditions, especially if comparing the vast number of successful vernacular building examples documented from around the world, and the many paths to solutions suitable and even optimum for different climates that the vernacular legacy can offer, with the vast area of research measuring sustainability in conventional buildings.

1.3.1 Vernacular Architecture and Sustainability

Sustainability is seen as the other basic discipline for this research. Here it is regarded as a global movement and new paradigm that assumes an alternative holistic approach to ameliorate a series of threats and concerns related to current and future development models at local, regional, national and global levels, together with establishing human and environmental well-being. However, despite its inclusive scope, it is frequently mainly concerned with the western approach of relating development with progress and the need to move this towards a more sustainable path (Broadbent & Brebbia, 2006; Great Britain. Improvement and Development Agency & Forum for the Future (Organization), 1999; Wackernagel & Rees, 1996; Woolley & Kimmins, 2000). Although priorities vary between professionals and researchers, in general the big issues are seen as being to do with education, control of population, reduction in energy and fuel consumption, natural resources depletion, and with reducing the gap between the poor and the rich (Drexhage & Murphy, 2010, pp. 3-11). Two important aspects of sustainability are highlighted in this research as being different from common western developmental approaches. The first is that frameworks for sustainability are set within a holistic scope, increasing the variety of research and work related to sustainability that is needed, and the second is that sustainable developmental approaches are set within a scale and time frame that ranges from individual to local, regional, national, continental or global, and from the past, to the present with emphasis on the near to far future.

Because sustainability as an approach implies these holistic scale and time frameworks it relies heavily on two key aspects; the first is having a wide diversity of academic research and cross-disciplinary studies, and the second is developing specific in-depth methodologies. Sustainability as a newly emerging and fast growing discipline urgently needs research from a diversity of professional fields, similar to the case for the specific field of sustainable development: “the idea of sustainable development pushes management research toward inter and trans-disciplinary forms of inquiry” (Gladwin et al, 1995, p. 897). This is also relevant for sustainability and sustainable development in the field of architecture (Broadbent & Brebbia, 2006; Chiras, 2000; Edwards, 1998; Vale & Vale, 1975, 1980, 1991; Vale & Vale, 2009; Woolley, 1997).

Thus, one important point of departure for defining the present research is that architecture and sustainability are disciplines with a wide literature base, and they should seriously consider the vernacular as built heritage that is an expression of environmental awareness and cultural responsiveness. In turn this offers a useful opportunity to interact with and to learn from other related disciplines. For example, in the present study focused on agro-forestry materials, experts in biological and ethnobotanical sciences were consulted as they work with the endemic plants used in buildings.

In the current deplorable situation of many vernacular cultures, especially in the so called developing countries, cultures have been highly distorted and the formerly relatively sustainable environment exploited, usually in the name of modernity, progress and development (Fox, 1990; Galeano, 1974; Glasmeier & Farrigan, 2003; Robyn, 2002; Ziccardi, 1999). This suggests that the vernacular should be explored because it is endangered. Secondly, and more relevant for the present investigation, is that investigating vernacular buildings by assessing their sustainability could enable a better holistic understanding of the “built environment” in the vernacular context, and contribute towards better future designed environments related with these vernacular building traditions and natural environments. Architecture as a discipline for education and as an instrument of development and implementation could help to minimize the potential environmental and social impacts related with changing vernacular cultures.

Useful research has been done into vernacular architecture and sustainable design with a focus on relevant aspects by investigating materials, forms, layouts, and climatic properties in a general way (Coch, 1998; Morel et al., 2001). There are also an increasing number of studies assessing natural materials and their energy related environmental impact (Buchanan & Levine, 1999; Chiras, 2000; Coch, 1998; Endress et al., 2006; Morel et al., 2001; Puettmann & Wilson, 2005; Werner & Richter, 2007). While natural materials have raised interest in the field of architecture, the subject of this thesis, use of natural fibres in vernacular traditions of thatching, has remained much less studied, despite some useful bibliography about thatched roofs (Billett, 1988; Buchanan, 1957; Fearn, 2004; Hall, 1988; Moir & Letts, 1999; Peters, 1977; Yates, 2006). The focus has been study of the technical aspects of the craft, often leading to useful reference handbooks, although unfortunately very little has being

done about the use of palm in the tropics (Endress et al., 2004; Flores & Ashton, 2000; Johnson, 1983; Moriarty & Svare, 1976; Navarro et al., 2011), and less on impact assessment of the materials used. Most literature just covers palm use without linking this to the whole building (Calvo-Irabién & Soberanis, 2008; Coronel & Pulido, 2011; González-Marín et al., 2012; Macía et al., 2011; Joyal, 1996a, 1996b; Martínez-Ballesté et al., 2002; Martínez-Ballesté et al., 2006; Pérez & Rebollar, 2003).

When it comes to palm thatch vernacular building, there are useful studies from a biological and ethno-botanical point of view through the study of plants, their uses and their environmental implications (Chazdon, 1991; Endress et al., 2006; Endress et al., 2004a; Endress et al., 2004b; Flores & Ashton, 2000; Joyal, 1996a; Mendoza et al., 1987; Navarro et al., 2011; Oyama, 1990; Oyama & Mendoza, 1990; Rodríguez-Buriticá et al., 2005; Svenning & Macía, 2002; Zuidema et al., 2007). These studies are all considered useful for this thesis.

An important contribution of applying the ideas behind sustainability to vernacular architecture is that these provide models of measuring the environmental impact of the built environment. Additionally other fields, for instance sustainability frameworks from biogeochemical sciences, also provide methodologies for measuring the environmental pressures on ecosystems, with emphasis on measuring and understanding carbon cycles (Geider et al., 2001; Rodhe, 1990; Running et al., 1999). However for the field of architecture and building sciences it is more important to focus on models for assessing the energy demand made by buildings. Among these is the Ecological Footprint (EF) method first developed by Mathis Wackernagel and William E. Rees (Wackernagel & Rees, 1996) and the Embodied Energy Performance Indices (Siche et al., 2008, p. 630). The selection of an appropriate method for this research into vernacular buildings, materials and traditions, which greatly rely on drawing primary raw materials from the immediate land resources, depends on defining the research question and methodologies, which in turn depend on defining the area of research.

1.4 Defining the Research Problem

1.4.1 The place for the research

Mexico forms the primary area for the research, firstly because its particular vernacular and environmental situation tends to be vulnerable because of the political, economic, social and cultural situation. This reverberates in a series of obstacles to dealing with environmental issues, for instance, the lack of proper data and inconsistencies in keeping continuity in monitoring and environmental programs. According to comparative studies evaluating 12 countries, including Mexico, using three different sustainable indices, discrepancies in data and results related to Mexico are revealed while Argentina and Brazil showed consistency in the results (Siche et al., 2008, p. 632). These discrepancies are a reflection of the kind of obstacles that stop environmental programs moving forward.

In other national indicators Mexico does not figure as a sustainable country. Based on 2002 data from the European Environmental Agency and Global Footprint Network, Mexico's national average ecological footprint showed an overall population of 102.0 million people with an average 2.4 hectares per capita ecological footprint, which given a global capacity of 1.7 hectares per capita leads to an ecological deficit of -0.7 ha per capita (Wackernagel et al., 2006, p. 108).

In The Living Planet Report developed by the World Wildlife Fund (WWF) national average footprint indicators are shown based on 2003 indices of ecological demand and supply, expressed in global hectares (gha – a hectare of land of global average productivity) with a positive sign if a national average scores an ecological reserve, and a negative sign for a corresponding ecological deficit (Hails et al., 2006, p. 32). Mexico had a per capita ecological footprint of 2.6 gha and a biocapacity per capita of 1.7 gha, therefore creating an ecological deficit of -0.9 gha, which was the second highest in Latin America after Trinidad and Tobago (Hails et al., 2006). However, the problem acquires different dimensions when populations are compared, with 1.3 million for Trinidad and Tobago versus 103.5 million for Mexico (the second largest in Latin America), while Brazil has the largest population in Latin America (178.5 million) with a per capita footprint of 2.1 gha, just below the 2.2 world average gha balance for 2003, but with a total biocapacity of 9.9 gha. Thus Brazil has an overall biocapacity reserve of 7.8 gha (Hails et al., 2006, p. 32).

It is clear that though the sustainable indices are not consistent, Mexico figures among the less sustainable countries in Latin American. However, as a Latin American country it also falls within a macro region accounting for 26% of world total biocapacity, and within the macro region with the lowest average footprint, this being Latin America with its 8% of world total footprint averages (Hails et al., 2006, p. 25). This clearly is not a reflection of Mexico's situation.

Mexico has the second largest population in Latin America, and a usage of around 0.8 thousand cubic metres of water per person per year, where 85% is used for agriculture, 12% for domestic use and only 3% for industry, (Hails et al., 2006, p. 12). At the same time it is estimated that Mexico imports an estimated 40 billion cubic metres of water per year through the embodied water required for the overall balance of imports-exports, much of this embodied water being related to cereals and grains (Chapagain & Hoekstra, 2008, p. 30).

Additionally, the supply of water for large cities and the wastage this entails only worsens the problem. For instance, by the early 1990s the amount of water lost in Mexico City's supply system was estimated to equal the amount needed to supply a city as big as Rome (Falkenmark & Lindh, 1993 found in Gleick, 2000, p. 132).

Forest loss is another issue that increasingly affects the country's environmental situation. In 1997 among all Mexican forests, the rate of loss of tropical forest was estimated to be between 189,000 and 501,000 hectares per year, amounting to 0.8% to 2.0% of total forest per year (Klooster & Masera, 2000, p. 262), although the problem is not a recent one according to Janzen (1988). With the arrival of the Spaniards in America, there were about 550,000 square kilometres of dry forest in the Pacific coast of Mesoamerica, an area about five times that of Guatemala, or the size of France, extending from north Panama to western Mexico. Today, less than 1% of this region has official conservation status (Janzen, 1988, p. 130).

In studies carried out to find the potential distribution and the deforestation rates of seasonal dry tropical forest in Mexico, data images from Landsat MSS 1973 and 1989 were compared, analyzed and overlapped with 1990 data from the potential vegetation map. The results showed that at the beginning of the 1990s only 27% of the original area persisted intact, an additional 27% has been altered, while another 23% was

considered degraded, and the other 23% replaced by other land uses, primarily agricultural fields and cattle grazing (Trejo & Dirzo, 2000, p. 137).

Researching tropical dry forests in Mexico is not only important because of their threatened condition, but also because of their being one of the most diverse and rich ecosystems in terms of species (Ceballos & Garcia, 1995, p. 1349). It has also been stressed that social-ecological systems should be studied as a single interrelated entity (Holling, 1995, pp. 3-30), such as the forest areas of Mexico and the rural populations these support, and that mega-diverse bioregions are sometimes mega-diverse in terms of cultural groups (Toledo, 2001). For instance, if assessing linguistic and biological diversity, Mesoamerica is among the top ten regions in the world (Cantú et al., 2001; Gorenflo et al., 2012, pp. 1-6). Finally, according to an overlap of several global indicators, Mexico is considered both a mega-diverse country and a world prime ecological region, rich in biological species and wilderness areas, and a place where a vast extent of land is also suffering ecological crisis (Brooks et al., 2006, pp. 59-60).

The particular interest in palm and vernacular Mexican thatched dwellings fits into the seasonal dry tropical forest area, however in order to narrow the scope a macro region within the country is highlighted. This is the Trans Mexican Volcanic Belt (TMBV), (Ferrari et al., 2000), which accounts for parts of the current states of Colima, Jalisco, Nayarit, Michoacán, Guerrero, Morelos, Queretaro, Mexico, Puebla and Veracruz, in an imaginary horizontal belt that crosses the country from east to west. One aspect of defining this area is precisely because of its volcanic features, which account for its different building systems. Another reason is because this macro area is culturally recognized as Mesoamerica, and offers a wide variety of altitudes from sea level to highlands and mountain environments, with a consequent diversity in human groups, vernacular activities and palm traditions. However, in this thesis attention is focused on specific localities within this macro region that have also proven to have long uninterrupted evidence of palm thatch building traditions.

1.5 The Research Question

Vernacular architecture accounts for many successful examples of buildings made in response to well-being, climate and resource management, among cultures from the

past and present. One important branch of sustainable architecture focuses on assessing the anthropogenic impact caused by buildings and their related activities on the environment as an important instrument for better decision making concerning building practices, with particular emphasis on local solutions for global concerns. Hence, the main research question can be constructed in relation to vernacular architecture and assessing local sustainability.

Are vernacular palm thatch dwellings sustainable in Mexico?

1.6 Problem Statement

The research question also results from the need to investigate a topic that remains understudied. Very little investigation has been carried out in this field. To assess fully the socio-cultural-environmental system behind vernacular palm thatch building traditions in Mexico requires an in-depth analysis and survey of buildings and materials, processes, transportation methods and distances covered, land as a resource and the relative impact on ecosystems. Such work also entails identification of species, collection of sample materials and ethnobotanical field work for a better calculation of wood densities, palm populations and yield factors, and studying the social aspects of such traditions. These involve management considerations and techniques, diversity of treatments and technologies employed, line production and anything else involved in the particular building technology under investigation.

In order to answer this research question, it is necessary to define and classify the types of vernacular palms and thatch traditions. For the case of the area of research in focus, these can be established in terms of three main classifications of localities where vernacular palm thatch expressions are still common; these place classifications are generalized in terms of population size as urban (over 2500 inhabitants) sub-urban (defined as living in the periphery of an urban area) and rural (fewer than 2500 inhabitants) (INEGI, 2014). It is also important to determine what a sustainable building is, and how sustainability is measured.

Using the studies made on energy and the built environment and accepting that a priority for sustainable architecture is the environmental impact related to buildings, means it is important to investigate the energy and resources involved in a vernacular building throughout its lifetime. This leads to the relevance of applying appropriate

methodologies for measuring sustainability in architecture through accounting for the whole embodied energy over a building's life cycle, and assessing all products, processes and activities involved.

Furthermore, the alarming social, economic, and environmental situations of most developing countries, and the significance of tropical environments for global sustainability (Bonan, 2008; Melillo et al., 1993), implies that investigating vernacular traditions in such areas is a priority. This could lead on to the assessment of colonial and post-colonial impact (Jarosz, 1996; Merson, 2000; Myers, 2003; Pels, 1997), although this is currently beyond the scope of this thesis. The particular case of Mexico and its tropical palm environments has been chosen as the main region of research. Thus, in order to be able to answer the main research question, a more specific question first needs to be answered:

What is the energy involved in selected case studies of Mexican vernacular palm thatch dwelling traditions as measured through a life cycle assessment (LCA)?

1.6.1 Scope of the Research

The research focuses on assessing three specific palm species (*Attalea guacuyule*; *Brahea dulis*; *Sabal rosei*) used for thatched buildings, their construction traditions and the environmental implications of these.

The selection of regions is narrowed firstly because of the available historical evidence on thatch roofing, and secondly based on selected localities where palm seems to be an important product both for the clients or owners and for the local thatch weavers and palm harvesters. Then, through a fieldwork based inventory of building typologies and analyses of standard units, case studies are selected for each typology for more exhaustive analysis, by making an inventory of materials for more accurate embodied energy calculations and better comparison.

The main objectives of the research are focused on the construction process, and the materials and technologies of the vernacular tradition. Therefore, it is important to have a clear division between the energy that goes into the building construction, demolition and disposal or recycling and the operating energy used in the palm thatch buildings. In this research operating energy is not the focus (see section 1.9.3.3). For

the different case studies used in the research, the main research aim is to compare the building technology, the materials, and the process based on qualitative and quantitative observations related to the building traditions, rather than assessing the consumption patterns of users.

Once a quantitative and qualitative evaluation of the vernacular building technology and its related environmental assessment is achieved, a series of case studies of similar buildings using different materials will be made. This means a proper classification and accurate inventory of materials for each case study is required. Therefore, it is necessary to find out the important variables in the comparison, such as the distances materials travel, and the amounts and types of energy used in the construction process. Hence, it is possible to estimate the relative level of environmental impact and to suggest whether each type of building falls into the sustainable category, or if it exceeds the limits and is unsustainable.

1.7 Theoretical Framework of the Research

In order to answer the research questions, the thesis involves two main research areas; one on sustainability, architecture and vernacular buildings with relationship to energy accounting methods and models; and a second one on vernacular palm thatch buildings, materials and traditions in selected environments in Mexico.

Each of these areas involves and deals with particular and sometimes very diverse approaches, methodologies and goals. Each encompasses a particular set of challenges, tasks and procedures in order to achieve specific goals that contribute to the investigation. This invariably leads the investigation to deal with diverse areas of knowledge; for instance, looking at economic and mathematical models when researching how sustainability can be measured, or at historical and ethnographical studies when carrying out investigation into specific vernacular traditions and their environments.

The thesis is structured in three sections. The first section is *Part 1: Theoretical Framework* which comprises Chapters 2 and 3. In Chapter 2 a literature review is made, defining sustainability and sustainable buildings and available methods for quantitative assessments of these as well as investigating the role of vernacular

buildings and their use of natural materials in sustainability. In Chapter 3 the historical origins are explored to demonstrate continuity in vernacular traditions and make it possible to establish whether the modern uses of palm thatch are part of these traditions or should be considered as something different. The research then investigates the historical origins of vernacular traditions of the Trans-Mexican Volcanic Belt and the particular role of palm thatch.

The second section of the thesis is *Part 2: Data Collection* and comprises Chapters 4 and 5. This section involves applied research, starting with Chapter 4 (qualitative analysis), which deals with the ethnographical and ethnobotanical aspects of valuable plants as building materials related to palm thatching technologies. Chapter 5 (quantitative analysis) covers the architectural fieldwork, the surveyed case studies, guided interviews, and life cycle inventories.

The third section is *Part 3: Life Cycle Analysis* comprising Chapters 6 and 7. In section three the environmental assessment of the selected case studies is carried out in Chapter 6 followed by the conclusions and discussion of the results which form Chapter 7.

1.8 Aim and Objectives of the Research

1.8.1 Aim of the Research

The aim is to discover how sustainable palm thatch is in urban, suburban and rural contexts for the selected case studies and selected localities along the Trans-Mexican volcanic belt. This information could be useful for builders, users and architects in making better decisions concerning these building traditions.

1.8.2 Objectives of the Research

- To measure the environmental impact of specific vernacular palm thatched buildings and traditions in selected regions of Mexico.
- To amass useful data related to whole energy accounting and sustainable indicators for specific vernacular palm species and related building traditions and materials for selected regions in Mexico.

- To contrast the results of the different case studies to determine their level of environmental impact in a comparative form.

1.8.3 Fieldwork on Three Thatching Palm Species along the Trans-Mexican Volcanic Belt

There are six case studies, designated CS in this research. Three palm species will be investigated, *Attalea ssp.*, *Brahe ssp.* and *Sabal ssp.* They are referred to in this study as (A), (B) and (S) respectively, and to distinguish whether the building location is urban, suburban or rural the reference R is used for rural, SU for suburban and U for urban locations. Each palm species has been and is still used by local people for thatching their buildings. Two case studies were analyzed for each palm as listed below.

CS:A-R1 (*Attalea ssp.*) palm specie with common name Cayaco in rural Jalisco

CS:A-R2 (*Attalea ssp.*) palm specie with common name Cayaco in rural Jalisco

CS:B-R (*Brahea ssp.*) palm specie with common name Jalapita in rural Puebla

CS:B-SU (*Brahea ssp.*) palm specie with common name Jalapita in suburban Puebla

CS:S-R (*Sabal ssp.*) palm specie with common name Palapa in rural Colima

CS:S-U (*Sabal ssp.*) palm specie with common name Palapa in urban Colima

ENVIRONMENTAL IMPACT ASSESSMENT OF VERNACULAR THATCH BUILDING TRADITION IN MEXICO:

Figure 1-1: Flow chart of the research

1.9 Methodology

The thesis makes use of a grounded theory approach as developed initially by Glaser and Strauss in 1967, constructing theory from the analysis of data (Glaser & Strauss, 1973) as there are no other comparable studies from which to draw. The vernacular building traditions of specific locations are regarded here as a whole, complex and interlaced socio-cultural-environmental system, and not just as isolated built manifestations. Therefore, to avoid general assumptions, the methodology of this thesis embraces two main traditions. The first is a review of frameworks and selection of calculation methods to measure sustainability in buildings, and particularly models suitable for measuring the whole energy involved in buildings and building processes. However, because the thesis does not just have a quantitative focus, the second involves the qualitative research tradition in carrying out in-depth fieldwork by undertaking building surveys and an inventory of palm thatch buildings in selected localities. Additionally, structured interviews with experts on the buildings and the plants involved in the construction will be carried out to obtain a better insight into the process and the materials used. Finally, this work is complemented with ethnographical and ethnobotanical studies in order to understand fully the resources used and their dependent environments.

1.9.1 Qualitative research

The approach for this thesis requires the selection and adoption of whole academic traditions rather than using information only related to the elements of enquiry (vernacular thatched building traditions). For instance, adopting the posture of the social sciences means being aware of the qualitative research traditions applied in ecological psychology, holistic ethnography, cognitive anthropology, ethnography of communication, and symbolic interaction (Jacob, 1987, pp. 1-51), all of which have their own traditional forms and coherent whole comprising internally consistent assumptions about human nature and society. These are suggested as essential for a holistic approach and methodology (Kuhn, 1996). After reviewing qualitative research traditions in education Jacob's analysis may offer a fuller understanding of the ability for either basic or applied research to address new problems. Moreover, he stresses

that educators who wish to perform qualitative research should seek to employ the totality of a tradition, hence avoiding generic assumptions or methods (Jacob, 1987).

The more holistic approach an academic tradition has, the better will be the understandings of the questions being studied. For instance, the relevance of reviewing past and present cultural examples regarding the anthropogenic relationship to environmental degradation rests in the capability for human adaptation (or lack of it), which fits more into the theory of resilience (Gunderson, 2000; Holling, 1973). In turn, this has reverberations for other fields such as studying human behavior in the social sciences (Greene, Galambos, & Lee, 2004), or the adaptability of socio-ecological systems through ecological and social sciences (Gómez-Baggethun et al., 2012; Walker et al., 2004), natural and biological sciences (Peterson et al., 1998), and anthropological and archaeological disciplines (Redman, 2005, p. 71; Redman & Kinzig, 2003, pp. 1-19) when studying the resilience of past cultures and environments. More relevant here is how the reality of vernacular architecture fits into the theory, with the aim of discovering whether or how those involved in its creation and maintenance have handled pressure and stress when facing adversity related to the carrying capacity of their lands.

1.9.2 Quantitative Research

The energy accounting of any activity can be measured by either of two general analytical methods, these being process analysis or input-output (I-O) analysis. Both require the same data and would yield the same result; however, in the real world, each technique is more useful for a particular type of problem. For instance, composited, nationwide concerns are well suited to I-O analysis, while process analysis is more suited to specific processes, products, or manufacturing chains for which physical flows of goods and services are easy to trace (Bullard et al., 1978, p. 269).

Life Cycle Analysis (LCA) accounts for all the energy that goes into a product including the direct and indirect energy, transportation and energy in all processes of all materials from extraction, manufacture, distribution, use, and their disposal or recycling (Klöpffer, 1997, 2003; Simonen, 2014) through an input-output analysis (Hendrickson et al., 2010; Udo de Haes & Heijungs, 2007). The boundaries of this can be 'cradle to grave' or 'cradle to cradle' (McDonough & Braungart, 2002), or several

intermediate sections of it such as ‘cradle to gate’ or ‘gate to gate’ depending on the limits and scope of the study (Simonen, 2014). Hence it is a suitable model that has been applied to buildings (Cole & Kernan, 1996; Huberman & Pearlmuter, 2008).

Embodied Energy Performance Indices (EMPIs) analysis, or ‘eMergy performance indices’ (written with “M” with the meaning of “EMbodied enERGY”) is also called “EnERGY Memory” (Scienceman, 1987 in Siche et al., 2008, p. 630). Emergy analysis was formally developed from previous methods of ecosystem valuation from the point of view of the biophysical economy (Lotka, 1925; Bertalanffy, 1968; and Odum, 1986 found in Siche et al., 2008, p. 630).

Finally the Ecological Footprint (EF) method developed by (Wackernagel & Rees, 1996) is another accounting tool for estimating the resource consumption and waste assimilation requirements of a defined human population or economy in terms of a corresponding productive land area (Wackernagel & Rees, 1996, p. 9). This last method is useful in the sense that it is complementary to other assessment methods such as LCA or embodied energy (EE) analysis. Its relevance consists in its estimating the biologically productive land and water required by any anthropogenic related activities and products (Huijbregts et al., 2008).

All of these methods are relevant for the research methodology, and are also part of its theoretical frameworks. However, there are other useful methods for considering issues which will be described in further chapters. These include ways of assessing wood and non-timber materials related to certain ecosystems and their carbon cycles, or coefficients to translate yield factors of ecological or land units to energy units.

One problem with the assessment of environmental impact is the lack of an agreed best method, which can be I-O, process line or hybrid analysis and determined by the type of product to be measured. However there are certain limitations and weaknesses to be taken into account to avoid misinterpretations of the results. “A number of difficulties arise in environmental assessment; there is no established set of indicators; there is no agreed system for weighting one indicator against another; there are few existing criteria for individual indicators; there are few targets for individual indicators” (Harris, 1999).

However, despite the method selected, in order to achieve a set of useful results, some assumptions will have to be made. Although specific assumptions will be described

where they occur in the thesis, general assumptions of concern for the research topic and structure are introduced below.

1.9.3 Use of case studies

1.9.3.1 *Case Studies selection*

The present research attempts to assess the sustainability of specific vernacular palm dwelling traditions in selected regions of the Trans-Mexican Volcanic belt. However, since micro environments, and hence plant species, vary widely in this macro region, technologies and building methods also differ considerably. In order to avoid general assumptions about building traditions, which can distort the results, specific case studies will be assessed for the same region and technique in order to achieve true variables for the environmental assessment of the same building traditions, to then build a more general picture of the impact of each palm thatch tradition.

1.9.3.2 *Life Span of the Building and the Building Materials*

For the analysis the default assumption for the life span of specific vernacular palm case study buildings is set at a minimum of 50 years because of the lack of monitoring studies and data related to the lifetime and durability of vernacular palm thatch roofs and materials. However, collecting specific data related to this issue is part of the aim of this research, as some materials and building features will vary as to lifetime and durability because of issues such as exposure to climatic forces, cultivation practices, and maintenance practices. Therefore alternative scenarios will be discussed in the conclusions (Chapter 7).

1.9.3.3 *Operational Energy*

Life cycle analysis of a building accounts for all processing and transportation energy from the extraction of raw materials, their transformation into primary materials, manufacture of all intermediate and primary materials, assembly, fabrication and construction, maintenance, demolition and disposal or recycling, including all indirect energy involved in these processes. However, it is also necessary to estimate the

operational energy (OE), which accounts for the sum of all energy used in running the activities associated with the building during its existence. This requires monitoring all types of energy inputs, sources and quantities during a building's lifetime. OE enables insight into energy use and consumption patterns rather than the energy (and in vernacular building traditions, the land) involved in the materials of the building as a product. Therefore, the energy considered in this analysis is only concerned with that associated with construction (EE) and not what is consumed during the occupation of the buildings (OE).

1.9.3.4 *Embodied Energy*

While direct energy is easier to quantify the indirect or embodied energy (EE) is more difficult to calculate without avoiding assumptions or relying on exhaustive analysis and quantification of all the inputs involved. However, no matter how in-depth the fieldwork is, some assumptions cannot be avoided. For instance, the embodied energy coefficient of a building material will vary with the type of transport used in the specific process related to the building or building material, such as motor vehicle or donkey. In order to minimize the risk of poor assumptions affecting the final outcome, specific scenarios will be given when required.

1.10 Hypothesis

Since achieving sustainability inevitably depends on the balance between the bio-energetic capabilities of the lands yielding the resources and the overall energy demand of a product or activity, then sustainability implicitly marks a boundary, where one product is or is not sustainable within such limits. This condition however is dynamic, as it depends on variables such as carrying capacities and yield factors or population densities, ecological, social and behavioral patterns, which are all related to differing local scenarios.

To measure sustainability in buildings accurately, both the whole energy that goes into the physical construction and maintenance processes throughout a building's life cycle, and the operational energy used throughout the building's existence need to be known. However, there will be interaction between the two, since operational energy can be

reduced by increasing embodied energy through the use of insulation to cut heat loss or heat gain. This has a bearing on palm thatch, which is effectively such an insulation material. However, this is not the focus of this research.

Construction energy is generally estimated to be around 15% to 20% of a conventional building's total life-cycle energy compared to operational energy (Pullen, 2000; Sartori & Hestnes, 2007), however this can vary according to location, building type and life span of the building. For instance, in an assessment of case studies from 9 different countries (Sweden, Canada, Australia, Germany, Norway, USA, New Zealand, Japan and Switzerland) with 40 houses surveyed, the ratio between operational and embodied energy varied from almost 1:1 in low energy houses using about 30kWh/m²y to 1:40 for a conventional house using 1150kWh/m²y (Sartori & Hestnes, 2007, p. 253). In the vernacular particular traditions arise that provide the best comfort conditions within the resources available, without the use of additional sources of energy. Hence, in the vernacular the embodied energy may be more important than in conventional buildings meeting modern comfort standards. The figure for operational energy may differ greatly when modern urban scenarios are compared to rural scenarios. For instance Mexico's population distribution in the 2014 census (INEGI, 2014) shows 50.5% of the population live in the largest cities, whereas settlements of 100 to 2,500 people, which are considered rural, account for 20.5% of the total population. However, according to INEGI it is still impossible to calculate the difference in energy consumption and services between urban and rural settlements due to the lack of specific research.

Notwithstanding the methodological obstacles set out above, by applying a qualitative research approach and through accounting methods related to energy involved in the construction materials and processes, the overarching objective for the present research is:

Through assessing the environmental impact of vernacular palm thatch building materials, traditions and processes using selected case studies, the figure for the total energy involved in the construction can be determined. By comparing the rural-suburban-urban scenarios, it will be possible to identify if specific vernacular palm building traditions are sustainable in selected regions of the Trans-Mexican Volcanic belt.

Thus the hypothesis underlying the research becomes:

The palm thatch traditions of selected regions of the Trans-Mexican Volcanic belt are sustainable because the materials and processes have very low environmental impact.

The proof or otherwise of this hypothesis will be discussed in the last chapter of the thesis, along with the answers to the research question. The framework, objective and methodologies above will be used to analyze palm building typologies and units, to provide exhaustive inventories of building materials and plant species, and to enable a better accounting method to be derived to test if and when selected vernacular building technologies are sustainable.

SECTION ONE

CHAPTER 2

SUSTAINABLE DEVELOPMENT, ARCHITECTURE AND THE VERNACULAR

Sustainable development can be considered a relatively new field of study. Increasing attention is being paid to it by diverse disciplines because of human impact leading to environmental deterioration, particularly in terms of greenhouse gas emissions, climate change, and population control (Brown & Plume, 2004; Meadows et al., 2004; Turner, 2007). Although sustainability, and in turn the idea of sustainable human development, has gained increasing attention due to the urgent need to approach and overcome such problems, as a new and emerging field of research it suffers from the problem of ambiguous definitions. Despite the work and effort to define sustainability, controversy prevails, since the most widely accepted definitions and fields of application have been those of economics and politics (Dixon & Fallon, 1989). Discrepancies around the meaning of sustainability and sustainable development are also found in the natural and social sciences, for instance in biological and environmental sciences (Brown et al, 1987), anthropology (Croll & Parkin, 1992; Sillitoe, 1998; Veteto & Lockyer, 2008), sociology (Buttel, 1993; Chen et al., 2012; Dempsey et al., 2011; Dobson, 1999; Utting, 1993) and psychology (McKenzie-Mohr, 1999; Myers, 2003; Pelletier et al., 2008).

Unlike disciplines that have approached and debated definitions from their own perspective and through inter-disciplinary studies, architecture as a field of research has done very little to overcome the problem of definition, notwithstanding that sustainable architecture is an increasing field of concern. Rather than starting by defining the problem and then seeking for solutions, architecture tends to ‘borrow’ ideas and apply these to the design of buildings almost without thought for their appropriateness. An example from theory would be the late 20th century interest in deconstruction, and more pragmatically the use of materials such as asbestos or the plasticisers used in modern synthetic coatings, without thought to long term

consequences (Pacheco-Torgal et al., 2012). When it comes to sustainability and the built environment the most widely used definition in architecture is the one from the Brundtland Report: “Development that meets the needs of the present generations without compromising the ability of future generations to meet their own needs” (Brundtland & World Commission on Environment and Development, 1987, p16). This definition of sustainable development is repeated amongst architecture academics as a definition of sustainability (Kibert, 2013; Szokolay, 2014) without questioning it to the level seen in other disciplines.

Perhaps, because architecture is so attached to the concept of development, and particularly urban development, this is easy to understand. Most architectural programmes focus on the built environment as the sole goal of architectural endeavour and the relationship between built environment and urban studies or rural studies is generally absent from architectural education. At the same time, the concern over the amount of land needed to support cities and the fact this is far greater than the land they occupy has been highlighted for some time (Rees, 1992). The focus on urban development as the only viable way of approaching the problem of architecture thus ignores the fact that in the first decade of the 21st century half of the world’s population lives in rural areas (Cohen, 2003, p. 1172) and without these rural populations to produce their food, urban dwellers would not survive.

To begin to address this within the discipline of architecture the present chapter of this thesis is devoted to investigation of sustainable development approached from the perspective of the rural vernacular. It starts with an investigation of attitudes towards sustainable development and goes on to offer a definition of sustainable vernacular development through looking at the meaning of sustainable architecture and its relationship to the vernacular. It then examines the most suitable methods for assessing the environmental impact of architecture in this context and proposes a method suitable for assessing the environmental impact of vernacular palm dwellings in the selected case studies.

2.1 Sustainable Development

Although the term sustainable development is quite recent, the term sustainability is not. “The term 'sustainability' (in German: 'Nachhaltigkeit') originates from silviculture

and means that only as much wood is removed from the forests as grows again in the long term given a particular production cycle (Von Carlowitz, 2000 [1713], in Klöpffer, 2003, p. 157). The word is attributed to Hans Carl von Carlowitz, who in the early 18th century recognized the economic and social implications of the industrial revolution towards the environment, with his statement that “cultivation and care are the prerequisites of sustainable forestry”. It is important then to highlight that this first use of the concept of sustainability was connected with the land and the rural production of resources.

This approach has been used by some of the critics of the Brundtland Commission definition of sustainable development. Perhaps because the Brundtland Commission was articulated within a rhetoric in which western standards were implied as the benchmark of development, critics have challenged this meaning of the term. In particular the original discussion has been disparaged because it ignores the underlying problems of existing patterns of development, including inequality, poverty, and environmental degradation (Glasmeier & Farrigan, 2003, p. 133). Although the definition of sustainable development in the Brundtland report is widely used including in architecture, it is still unclear whether it represents a political rallying point (or even simply development rhetoric) or a concept that can be used to define the operational norms for the future behaviour of mankind (Wiersum, 1995, p. 321).

Researchers have also attempted to define sustainability by setting up a distinction between “weak” and “strong” sustainability. The weak sustainability diagram gives equal weight to the environment, society and economy and only where these three circles intersect does sustainability occur (ICLEI, 1996). In contrast the strong sustainability diagram has the economy contained within society and society then contained within the environment (Naess, 1997) (see figure 2.1). In these terms the Brundtland definition is a weak sustainability model as it does not prioritise the environment. These diagrams are simplifications of a complex situation although they are popular precisely because of this (Connelly, 2007).

Figure 2-1: Diagrams of strong and weak sustainability

Although there is no real agreement on the meaning of sustainability, attempts to develop methods to measure it, and hence give it a definition, have been more successful, for example of life cycle assessment methods applied to architecture (Simonen, 2014), and these are relevant for this research

The emphasis in this study is on measuring resources as natural capital in the form of how much a plot of land can produce over many years without the land suffering degradation. This is translated into sustainable yields and carrying capacities, and converted into an ecological footprint (Wackernagel & Rees, 1996). To better clarify the meaning of natural capital it can be regarded as renewable resources as opposed to the non-renewable resources, like fossil fuels, on which many societies currently depend (Barbier, 1994, p. 292 in Wackernagel & Rees, 1997, p. 4). This is an operationally useful definition when it comes to looking at the sustainability of rural buildings as it could be applied to vernacular case studies. In resource terms, non-renewable capital is represented by fossil fuels such as oil and gas, and other mineral extractions, such as ore to produce steel. In contrast renewable natural capital consists of forestry materials such as wood for building and burning, and feed for animals that provide transport.

Since vegetative materials account for most, and in some cases all, of the materials employed in thatched buildings, it is important not only to assess the buildings in terms of the land to grow their materials, but also to study the impact of making these buildings on their immediate environments by looking at how the materials are extracted and transported. However, first it is important to establish a definition of vernacular architecture and why it is important to measure its environmental impact.

2.2 Architecture

Architecture has such profound effects on the human being, on place, on human consciousness, and ultimately on the world, it's far too important to be shaped by short-lived fashion appeal.....Anything with such powerful effects has *responsibilities*- power unchecked by responsibility is a dangerous thing! Architecture has responsibilities to minimize pollution and ecological damage, responsibilities to minimize adverse biological effects on occupants, responsibilities to be sensitive to and in harmony with surroundings, responsibilities to the human individualities who will come in contact with the building (Day, 1993, p. 13).

Architecture is both a very old discipline and a practical one. In helping people to have shelter but also concurrently develop well-being it achieves comfort and satisfies needs. Its relationship with nature is intrinsic through its use of materials, whether grown or extracted from the earth. However, the buildings and structures it creates can also have an impact on the environment both locally (through destroying habitat) and globally (through greenhouse gas emissions associated with heating, cooling and operating a building). There are also diverse interpretations of how nature and architecture, which is essentially something man-made, interact (Rios-Calleja, 2008, pp. 102-103). Apart from damaging the habitat of other species, buildings can also be harmful to the humans that use them, either through exposure to toxic substances in materials or through sick building syndrome (Redlich et al., 1997). Moreover, architecture as official building and as an important means of communication has served as a tool of power, control and manipulation (DeMarrais et al., 1996, p. 16). This is something architects should be aware of, particularly in the search for sustainability and the need to face the current unequal distribution of resources.

Moreover architects should not only be aware of and take responsibility for the impact that buildings have on biological and ecological systems and human health, but also of the fact buildings are long life products. For sustainability a long building life is desired so that maximum benefit is obtained from the materials used to make the building. Architecture lasts beyond the moment of its conception and future generations will have to deal with such building manifestations (Rios-Calleja, 2008). Within a vernacular building tradition this is not a problem as the buildings of one generation will be similar to the buildings of the next, not least because they are made of materials harvested from the same locality. For current architecture, however, its impact is even more evident when the architect becomes immersed in the philosophical dilemma of what should distinguish him/her or his/her architecture from the run of ordinary buildings, something that seemed not to trouble many of the vernacular builders of the past. The ensuing quest for novelty and innovation for a product that has a long life returns to a recurrent question of “what is architecture?” As its locus of evolution is a way of distinguishing architecture from buildings (Koch, 2010, p. 2) this further helps to explain the move of the discipline of architecture away from interaction with the rural and vernacular world. Yet, despite this quest for novelty modern cities are more impersonal than ever (Dubos, 1968 in Lennard & Lennard, 1992, p. 37).

2.2.1 Vernacular Architecture

The attempt to separate vernacular building from architecture is perhaps a mistaken perception of the true vernacular expression.

In vernacular buildings, the configurational, or non-discursive, aspects of space and form are handled exactly like the grammar of language, that is, as an implication of the manipulation of the surface elements, or words and groups of words in the language case, building elements and geometrical coordinations in building. In the vernacular the act of building reproduces culturally given spatial and formal patterns. This is why it seldom seems ‘wrong’. Architecture, in contrast, is the taking into conscious, reflective thought of these non-discursive and configurational aspects of space and form, leading to the

exercise of choice within a wide field of possibility, rather than the reduplication of the patterns specific to a culture. (Hillier, 2007, p. 16)

This statement not only explains misunderstandings about the vernacular, but also reveals the different path that architecture has taken, with architects distinguishing themselves from the rest of the population through complex and abstract thinking. This has led architecture away from what can be made using local resources, to use of materials only limited by cost, without thought given to their origin and environmental impact

In the vernacular context the sense of belonging to a place is more present, notwithstanding that being vernacular does not necessarily mean there is a lack of possibilities in configuring aspects of space and form. Without the evolution of the vernacular and its improvement, architecture would not exist as a discipline and profession. This raises the question of why the vernacular is considered as lacking the conscious exercise of choice within a wide field of design possibilities.

Additionally, why should modern urban architecture be regarded as the only approach to successful architecture, or the only hope for future generations, and why do architects focus so much on cities without paying equal attention to the rural context? Even more, why should there be an intrinsic distinction between the rural-urban vernacular and modern urban architecture, particularly when approaching sustainability. It would seem the former might have much to offer the latter (Pearson, 1995) while noting that the modern cities of westernized societies are hardly a model for sustainable living.

This is not to suggest that all architecture is wrong. Rather it criticizes generalizations around vernacular architecture as being ‘inferior’ to real or ‘official’ architecture, although it must be acknowledged that official architecture has often served as a tool of power in many cultures in both the Old and the New Worlds. Here architecture becomes the physical manifestation of the power and control of the less powerful hinterlands, which are where vernacular architecture has survived.

DeMarrias et al., (1996) pointed out the relative positions of official and vernacular architecture from an archaeological viewpoint:

Because symbols are material objects, their distributions and associations, preserved in the archaeological record, reflect broader patterns of social,

political, and economic activity. These patterns inform archaeologists about unequal access to symbols of status or authority, the efforts of one social segment to promote its ideology over others, and the effects of these strategic activities on the dynamics of social power. (DeMarrais et al., 1996, p. 16)

This situation applied to the study area of Mexico, as can be appreciated in Pre Columbian architecture. For instance in reference to Monte Alban as the core of its civilization in the Mixteca cultural region of Oaxaca province in Mexico: “Monte Alban's political and ritual importance was reflected in its monumental architecture, high-status burials, and carved stone monuments, including some of the earliest examples of hieroglyphic writing known for Mesoamerica” (Joyce & Winter, 1996, p. 36). It is this monumental architecture that people associate with the history of Mexico rather than its vernacular traditions.

However, the rural hinterlands with their own vernacular architecture have always supported and contributed to urban societies, either by choice or by coercion, and thus have helped these gain and retain power. This has also had consequences in terms of the environmental impact of current societies towards achieving sustainability, which necessitates the use of hinterland resources. This reliance on the rural has had a long tradition all over the world, including Oaxaca. “Archaeological data suggest that the rising status of the elites at Monte Alban was built on tribute in the form of labour and resources provided by non-elites, especially those living in the core region” (Joyce & Winter, 1996, p. 36). In the modern context this can be interpreted both as the vernacular architecture of the rural hinterlands being viewed as being of less importance than modern urban architecture, and as those wishing to aid the former being, “...overwhelmed by the exercise of private economic power or politics” (Forester, 1982).

2.2.2 Sustainability Theory and the Vernacular Tradition

Sustainability theory related to architecture, especially in terms of energy and materials, stresses that longevity in buildings is desired, and that premature demolition will affect the sustainability of the building, as this is directly proportional to the sum of all energy that goes into the building over its whole life (Thomsen & van der Flier,

2009). However, this idea must be revised for vernacular traditions, as buildings and materials in different contexts, including those of many vernacular traditions, do not fit well with it. Some vernacular buildings are dismantled and rebuilt often and some vernacular materials have a short life, whereas others such as hardwoods will be recycled and used in other buildings. Often the same vernacular building will have a short life span (but not always) and might be rebuilt many times, without necessarily meaning that the building is not sustainable, as often the materials are harvested as by-products from food crops and would, in other situations, be classed as waste.

Also the lack of knowledge about a material can influence the life of the building as not properly understanding a material can lead to its incorrect use. This is especially true of natural materials whose underlying lifecycle includes recycling through rotting or being eaten. For instance, bamboo is widely used as a building material in tropical areas, but comes with serious problems. One is that it rots easily in contact with soil or water, and another that it attracts beetles and other insects which are hostile to both the material and to people. Bamboo cannot stand direct exposure to the sun and again this means it will not last long.

In the other hand bamboo as a tensile material like steel works well, although there has been little research about this property (Jain et al., 1992; Nugroho & Ando, 2001). Bamboo can substitute for steel as a reinforcing material, even in concrete (Pacheco-Torgal & Jalali, 2011), where it has the added advantage of not rusting in coastal environments. The problem with using these natural materials in conventional architecture is that the accumulated wisdom about the structural properties of bamboo learned from experience with using the material is insufficient, and the material has to be subjected to the same tests as man-made materials to prove it is strong enough. Thus it may not be possible to substitute natural materials for conventional ones in order to make more sustainable buildings. In vernacular architecture this is never a problem.

2.3 Sustainable Architecture

Material choices are one way to approach making sustainable architecture, but there is also the cultural approach that can be traced back to many vernacular buildings and their builders that have faced their own environmental dilemmas. These builders made the buildings they could from the materials at hand and achieved the best possible

comfort conditions within these constraints. In so doing they often set up cultural patterns in how buildings are used, such as the Mediterranean tradition of the early afternoon siesta, keeping people out of the sun when at its hottest. This is different from the deliberate design of modern architecture, which often strives for particular visual effect and also by the use of mechanical climate control systems specifies what conditions are to be achieved within the building. Most designers and builders (architects in all but name) in the past remained anonymous (Rudofsky, 1964) meaning most of their knowledge in how to achieve the most within the given resource constraints has been lost. In contrast sustainable buildings now have to be part of modern industrialized and consumer lifestyles.

One such piece of work, with a focus on energy and local sustainability, was the autonomous house as described and later built by Brenda and Robert Vale (Vale and Vale, 1975). They designed a house to gain its energy from its site through using solar energy and wind power, as well as considering the energy in the building materials. However, they later concluded that it could be more convenient to produce energy on site while still connected to the grid instead of being completely independent (Vale & Vale, 1991), making a net zero energy building. Other also attempted to make sustainable buildings for modern urban societies (Broadbent & Brebbia, 2006; Hagan, 2001), and this included research into the environmental impact of building materials, although little of this was to do with natural materials (MacDougall, 2008; Pearson, 1998; Woolley, 1997; Woolley & Kimmins, 2000). In turn this has led to increasing attention being paid to assessing sustainability in buildings through other indicators, such as indoor air quality and occupant health (British Medical Association, 1998; Brown, 2005; BurrIDGE & Ormandy, 1993; Fraser et al., 2001; Loftness et al., 2007). The relationship between architecture and social and environmental health has also been explored (Chiras, 2000; Day, 1993).

2.3.1 Natural Materials and Sustainable Architecture

Natural materials are an important part of the discussion of sustainable architecture. As a reactive movement against modernity there has been a resurgence of interest in the materials used in the past, particularly earth in its many forms, such as rammed earth,

adobe, cob, and the use of natural plasters (Evans et al., 2002; Guelberth & Chiras, 2003; Harrison, 1999; Keefe, 2005; Minke, 2006; Oliver, 1983; Weismann & Bryce, 2006). Use of bamboo, which is more related to the tropics, has increasingly attracted scholars and professionals in Latin America (Hidalgo, 1981; Kumar & Rao, 2002; Vegesack et al., 2000; Villegas Jiménez & Londoño, 2003; William McDonough Architects, 1999). Finally this resurgence of interest has also led to the development of new technologies as a response to environmental impact problems, such as the use of straw bale (Lacinski & Bergeron, 2000; Minke & Mahlke, 2005; Steen, 1994) or earth bag building (Barnes et al., 2009; Hunter & Kiffmeyer, 2004; Wojciechowska, 2001). However, the study of natural materials in vernacular buildings and how these were essentially 'sustainable' because of being constructed within the local resource limits has remained understudied. This is especially true of palm, the subject of this research. Most of the time vernacular palm thatched buildings has been addressed through a historical or conservation approach (see section 2.3.2). Furthermore the natural materials related to the vernacular are often approached through the investigation of a single material rather than seeing the building holistically and understanding how all its materials derive from the local environment.

2.3.2 Historical and conservationist approaches to vernacular architecture

Historians approach the topic of vernacular architecture in two different ways, the first for its value in explaining an earlier culture, and the second from the conservationist approach of what should be retained and preserved. As an example of the former, the Mongolian yurt is a demountable dwelling that evolved in response to the need of herdsmen to travel in search of grazing, but that also responded to being prefabricated so it could be transported, made of materials to hand (fibres from animals), and with an interior that reflected how the family was organised (Zhang et al., 2007). More importantly, examining these vernacular traditions, including the buildings, showed that the nomadic way of life was the sustainable one in this area of China. For the latter, when referring to vernacular building conservation in England, Bowyer (1980) points out that little attention is paid to small buildings and towns.

Where groups [of small buildings] have survived they are often lumped together in 'conservation areas' as a convenient method for preserving the local

scene while individual or isolated buildings of similar style and possibly greater architectural merit are destroyed by improvement or unsuitable alterations by unsympathetic hands. (Bowyer, 1980, p. 2)

Bowyer further suggests that traditional architecture in England is often destroyed because there is a false perception that the supply of locally produced materials to maintain such buildings is limited. This is either due to the ignorance of manufacturers and suppliers or their intention to sell their own stock of products, even when these are unsuitable 'foreign' products. Secondly there is also ignorance of the availability of craftsmen, particularly in the countryside, who are capable of carrying out the job of traditional building to the highest standards. Third are the difficulties of obtaining information about the restoration of conservation details as this is fragmentary and often found in many diverse sources (Bowyer, 1980, pp. 2-3). However, neither of these approaches treats vernacular architecture as something living and still culturally relevant, as are the palm thatch buildings which form the focus of this thesis.

2.3.3 Thatch and vernacular buildings

Vernacular buildings have been categorized as unofficial buildings, moving them outside the scope of architects, designers, professionals, academics and scholars, particularly, but not exclusively, in industrial westernized societies. One of the reasons offered for the lack of attention towards vernacular buildings, in this instance a discussion of log houses, is that "...they are unpretentiously functional and were usually built with the intention of eventually being abandoned" (Rempel, 1984, p. 34 in Noble, 2013, p. 86). This immediately puts them outside the realm of prestigious and permanent architecture. The statement is also only partially true, as even if such buildings appear unpretentious in form they are not in detail. For instance the house of a chief in Indonesia will contain much symbolic carving, so it seems a major misconception to think of such buildings as simple and not long lasting, even though some building techniques, like thatch appear to have a short life.

Thatch can be defined as the craft of roof covering using a variety of weaving techniques and plants that are generally found in the locality of the building. Thus in the UK houses in Scotland were traditionally thatched with heather, whilst those in

East Anglia were thatched with the local Norfolk Reed (Brunskill, 1971). Because a variety of materials can be used thatch is generally classified according to the material employed, although the most used material is the family of grasses (Poaceae) such as reeds (*Phragmites*) (Björndahl, 1985; Stant, 1953) or straw (Jain et al., 2012, p. 28; van der Veen, 1999, p. 218). However, there are thatched roofs of sedge (*Cyperaceae*) (Glimn-Lacy & Kaufman, 2006, p. 2; Sievers & Muasya, 2011, p. 83) and heather (*Ericaceae*) (Bunce, 1989, p. 24; Macdonald et al., 2005, p. 48).

Thatched buildings lost popularity with industrialism despite the fact that some countries have a long tradition of using the technique. England and Japan are outstanding for their thatching, but almost all over the world traditional thatched buildings can still be appreciated, from Scandinavia to South Africa, and from East Asia to the New World.

Perhaps palm is under-researched as a thatching plant due to its many other productive uses, such as for food or oil, however, some areas, especially rural ones, are still engaged in such traditions, as in Polynesia (Hamilton & Murphy, 1988; McClatchey & Cox, 1992; McClatchey et al., 2006; Rodman, 1985) and this has had reverberations along the Mexico Pacific coast (Hough, 1900).

2.4 Palm thatching tradition

Palms (*Arecaceae*) are a vast family, and diverse species can live in different climatic conditions, from desert, arid, and semi-arid, to sub-tropical, tropical and temperate. Some palms can withstand drought and some need high levels of humidity, and there are also palms suited to different soils (Balick & Beck, 1990; Johnson, 1983; Pan et al., 2006; Tomlinson, 1979; Wehncke et al., 2010). As a result within the tropics palms are considered one of the most productive and exploited species.

Since palms are mostly limited to these geographical zones, most of this review draws from traditional tropical architecture (Agoudjil et al., 2011; Morrison et al., 2012; Piesik, 2012). Although there are palms that survive in temperate climates their populations are limited and do not have the same productive value as in the tropics. Moreover, since most countries within the tropics are developing and under-developed

countries, palm thatch has survived in their vernacular settlements due to the lack of policies and regulations from governments toward this material.

Polynesia and Southeast Asia are among the cultures with a wide tradition of using palms in their architecture but there is little research on palm as a contemporary building material, and the research focus has remained on the anthropological, archaeological, and ethnobotanical aspects (Ewing, 1962; Fox, 1993; Hockings, 1989; Rull et al., 2010; Waterson, 2009). In the case of Latin America and in particular Mexico, most research interest is concerned more about the economic and environmental value of palm, and disregards thatching (Bridgewater et al., 2006; Calvo-Irabien & Soberanis, 2008; Endress et al., 2004b; González-Marín et al., 2012; Joyal, 1996a, 1996b; Kahn & Castro, 1985; McClatchey & Cox, 1992; McKillop, 1996; McSweeney, 1995; Moore & Uhl, 1973; Pavón et al., 2006; Pulido et al., 2007; Tejero-Díez et al., 2008). Any mention of palm in architecture literature normally ignores the environmental aspects of using the material and most references are limited to a few sentences or at most a few pages (Dmochowski & Moughtin, 1988; Fearn, 2004; Koenigsberger & Lynn, 1965; Lauber et al., 2005; Moya Rubio, 1984; Noble, 2013; Pearson, 2005; Rudofsky, 1964). This has led the present research to focus on thatch building traditions in Mexico, since Mexico has a wide diversity of landscape scenarios within the tropics and within these a variety of palm species have adapted to different climatic conditions, from high altitude drought conditions to those of low humid coastland. The same region also accounts for a wide diversity of surviving vernacular traditions in buildings that use palm. However, no work has been done from an architectural perspective regarding the sustainability of such buildings.

2.5 Measuring sustainability

This chapter opened with a discussion of the lack of agreement over a definition of sustainability. There is a similar disagreement on the best way to measure the degree to which a building could be termed “sustainable”. Following from the 1970s energy crisis the first interest was in making buildings which use very little or no fossil fuels (Borasi et al., 2007). This led to making buildings much better insulated and to proper orientation either to let the sun in for heating, or to keep it out to avoid cooling. The advantage of this approach was that it was very easy to measure energy in use and

hence to know how successful the design was. Measuring energy in buildings, especially in terms of reducing fossil fuel energy, has also been linked to sustainability through trying to mitigate the greenhouse gas effect by reducing carbon dioxide (CO₂) production. Although some CO₂ production is natural, such as that from volcanic activity (Robock, 2000), the human burning of fossil fuels remains a major source of global warming and thus the type of energy used to achieve a human purpose is also related to this effect (Vitousek, 1994, p. 1862). There is therefore a need to find more sustainable energy sources, such as the renewable sources of sun and wind, to support human activities.

2.5.1 Energy and Buildings

Energy can be defined as the capability for doing work, and can be used to measure phenomena such as light, heat and movement (del Río et al., 2013, p. 28). For human activities it is what can be done with the energy that is important, not what type of energy it is. Thus people want light in buildings when it is dark and heat in buildings when it is cold. They also need energy to move them from home to place of work, whether this is energy in the form of food for walking or cycling, energy to power a car stored in petrol or diesel, or energy to power an electric trolleybus. Most people are unaware what primary energy source they are using (coal, oil, hydro, wind) when they turn on a switch, even if they think they are using 'electricity'. This is also true of the embodied energy in the products people use every day, including buildings. This leads on to another way of measuring sustainability in buildings, which is accounting for all the energy that goes into a building over its life, known as life-cycle assessment (LCA).

2.6 Life Cycle Assessment

Ecological responsibilities involve energy conservation at all levels from strategic to detail, careful selection of building materials, with regard both to occupants' and manufacturing and building workers' health, and to their cradle-to-grave environmental impacts. Such wider criteria cast a new light on, for example, timber sources, especially tropical hardwoods; on plastics, with their

huge trail of manufacturing pollution and long post-use life and on water, already the subject of international disputes. (Day, 1993, p. 13)

For buildings Life-Cycle Assessment (LCA) attempts to provide a measure of their overall environmental impact, and this is achieved through considering the whole set of resource input outputs throughout their lifetimes (Häkkinen, 1994 found in Fay et al., 2000). The life cycle analysis takes into account not only the embodied energy, but all the inputs and outputs, such as the share of the energy to make the machines to make the products. However, to do that for something as complex as a building in use, boundaries have to be drawn and often assumptions have to be made.

2.6.1 Operating and embodied energy

In most modern buildings the operating energy will be the highest proportion of the life-cycle energy use (Mithraratne, et al., 2007). However, as buildings become low energy or even zero energy the importance of the energy embodied in the materials used to construct and maintain a building over its life increases (Ibn-Mohammed et al., 2013, p. 237). As an example a study of a low energy house in North Italy showed that although the heating energy reduced by a factor of 10:1 the total lifecycle energy was reduced by a much lower factor of 2.1:1 (Blengini & Di Carlo, 2010). This occurs because more materials have to be put into the building in the form of insulation and higher quality windows, which increases the energy going into the building.

CASE STUDIES OF THREE PALM SPECIES AND RELATED TECHNOLOGY ALONG THE TRANS-MEXICAN VOLCANIC BELT

EMBODIED ENERGY ESTIMATIONS (COMPARATIVE TABLE FROM DIVERSE AUTHORS)				
STUDY	REGION	TYPE OF BUILDING	LIFE SPAN OF THE BUILDING	EMBODIED ENERGY in % compared to TOTAL LIFE CYCLE ENERGY
Sartori and Hestnes (2007)	60 case studies across diverse countries	Low Emission Buildings Conventional Buildings	Not stated	2-38% 9-46%
Ramesh et al. (2010)	73 case studies across 15 countries	Residential and Office Buildings	Not stated	10-20%
(CSIRO, 2006 found in Dixit et al. 2010)	Australia	Average house	100 years	(15%) 15 years of the total energy over its life
Athena (2007)	U.S.A.	Not specified	60 years	9-12%
Thormark (2002)	Sweden	Low Energy Building	50 years	45%*
Huberman and Pearlmutter (2008)	Negev Desert (Israel)	Climatically responsive building	50 years	50%
(Plank, 2008 found in Ibn-Mohammed et al., 2013)	Heating dominated region	Not specified	Not specified	10%
(Lee & White, 2008 found in Ibn-Mohammed et al., 2013)	U.K.	different building types	100 years	3-35%
(Eaton & Amato, 1998 found in Ibn-Mohammed et al., 2013)	U.K.	Not specified	60 years	37-43%
10) (Smith, 2008 found in Ibn-Mohammed et al., 2013)	U.K.	Not specified	Not specified	80%
Yohanis and Norton (2002)	U.K.	Single storey office building	25 years	67%
Hamilton-MacLare et al. (2009)	U.K.	Not specified	Not specified	20% of total energy
(CIBSE, 2010 found in Ibn-Mohammed et al., 2013)	U.K.	Office building	60 years	42%
(Battle, 2010 found in Ibn-Mohammed et al., 2013)	Hypothetical projections **	Not specified	Not specified	42-68%**

* With potential of 40-45% recycling of materials

** If emissions from the grid are reduced by decarbonization from 0.5 kgCO₂e/kWh to 0.1 kgCO₂e/kWh, by 2030 there would be a shift from 42-68% (embodied energy & operation energy respectively)

Table 2-1 Comparison of different studies related to embodied and operating energy in buildings

Maintenance is another factor as high levels can increase the energy embodied in materials relative to the operating energy. Another study of a low energy apartment building in Sweden found embodied energy accounted for 45% of total energy and maintenance 12% (Thormark, 2002). Maintenance may be more of an issue for natural materials as they need replacing more frequently but no study has been found addressing this issue.

Table (2.1) shows a summarized comparison of diverse studies by different authors in different places and for different building types.

It illustrates the wide range in the ratio between estimated embodied energy and operation energy, ranging from 2% to 68%. To understand this it is necessary to know about the aspects of the building: such as if the building is conventional, or low emission, a residential or commercial building, or a low energy or climatically responsive building. No study looks at vernacular building using vegetative materials. Therefore, the present study will focus on measuring the embodied energy of the thatch and other agro forestry materials in order to discover the energy embedded in the building as first constructed and over an hypothetical lifespan of the building including its maintenance.

2.6.2 The trade in materials

Unlike the vernacular situation where the majority of building materials are local, modern urban buildings are part of a global trade in building materials. This makes the LCA more complicated. As an example, a recent study found that China was a net importer of embodied energy, despite its economy being focussed on exports (Li et al., 2007). Different manufacturing nations have different primary energy supplies and this will affect not so much the energy going into a material but whether it has a high greenhouse gas potential. As yet Mexico has no national database of the embodied energy coefficients of materials. However, because this study is concerned with natural building materials harvested and transported by either animals or small vehicles, the impact of these in terms of land take and energy use will be calculated from first principles, rather than using a known set of embodied energy coefficients. Where

materials like concrete occur in the analysis an appropriate value will be selected and the reasons for the selection discussed at the time.

2.6.3 Users, boundaries, and building life

The major impact in most building LCA analysis comes from the operation sector, and involves all the energy required to run the building, for heating, light, and even for water supply. Much attention has been paid to reducing the impact caused by building energy sources, especially in the developed world, and hence this aspect can be said to have been well understood for some time (Pears, 1997), although as buildings become more efficient in reducing operational energy, embodied energy increases in importance (Dixit et al., 2010; Ibn-Mohammed et al., 2013, p. 237). Also recognised is the effect that the habits of the users have on the total operational energy (Nguyen & Aiello, 2013).

However, there are few studies of the energy involved in running vernacular buildings. In fact, a study of vernacular houses in Indonesia showed that the occupants never felt too warm despite living in houses where no energy was used for cooling and the only energy used was for cooking (Karyono et al., 2010). As this thesis represents the first study of its kind, operational energy, and the effect of user habits on life-cycle energy in the vernacular palm thatched Mexican case study houses will not be considered.

LCA studies also face difficulties and uncertainties around the boundaries of the studies, as these can differ considerably “in terms of completeness (life cycle stages included, assessment methods), transparency (description of methodological assumptions, characteristics of the products, available data, etc.) and scientific rigor (e.g. related to the functional equivalency)” (Werner & Richter, 2007). This study will concentrate on the primary materials that go into the building, how long these take to grow, harvest, prepare and transport to the site. It will not consider the food that people and animals eat and the land to grow this.

It should also be noted that operational energy varies widely not just from user habits but because of cultural practices, and this will affect the LCA. For instance, while temperate developed countries have had a focus on building thermal efficiency, hot climate developing countries do not. Most LCA work has been in developed countries

in Europe, Asia, America and Oceania, with little being done in developing countries, such as Mexico, and where figures for building, operation and disposal energy can vary greatly (Ali & Al Nsairat, 2009). Environmental assessment in developing countries must then be approached in a very different way due to the social-cultural, environmental and economic conditions of each place. This is because such countries lack research, and since there is also a lack of research into vernacular buildings, assessing the latter in terms of an LCA tool will be the core of this study.

One important boundary is the assumed life of the building and its materials and the maintenance schedule for their replacement over the whole building life (Acquaye, 2010; Dixit et al., 2012; Gustavsson & Joelsson, 2010; Langston & Langston, 2008; Treloar et al., 2001). In developed world studies building life is often assumed or taken as the life of the structure in the relevant national building code, but each material choice comes with a life that will affect the final building life-cycle energy (Haapio & Viitaniemi, 2008). However, the aim in this research is to establish the life of the natural materials used in palm thatched vernacular buildings by asking those involved in the process. Where assumptions are made about the life of other materials involved these will be discussed in the relevant sections.

2.6.4 Recycling

Materials that go into a building should ideally last as long as possible so the energy over the building's lifetime is diminished. This has led to the idea of making buildings that can be disassembled so their materials can be recycled at the end of the useful life of the building (Thormark, 2006). However, such techniques were common in vernacular architecture. A study by Herva describes the recycling of building materials in traditional houses in the northern Baltic region (Herva, 2010). In developed world LCAs this has led to research into how to account for the recycling of materials and products (Werner & Richter, 2000). In turn this has led to the idea of a product being considered from 'cradle-to-cradle' (McDonough, 2002). In the best case scenario cradle-to-cradle aims to recycle the old product into a new life. However, it is not always possible to recover all the energy that went into the product due to the many facets of the process, such as the collection of the 'waste' materials, separation of

them, and the efficiency of recycling a material, as there is energy loss in each step. For instance aluminum, one of the most available and easiest materials in the world to be recycled needs a small percentage of new alumina to be recycled into a marketable product, as well as energy (Das, 2011). In vernacular buildings recycling will not be as systematic as systems in the developed world, and one aim of this project is to discover when and how materials are recycled.

In conclusion, while Langston and Langston (2008) suggest that measuring operating emissions is straight forward, determining embodied emissions is more complex. Furthermore, there is currently no generally accepted method available for computing embodied energy and its associated emissions accurately and consistently (Battle, 2010; Crowther, 1999; Miller, 2001) and as a result, wide variations in measurement are inevitable. This project will therefore attempt to investigate the energy that goes into vernacular buildings by measuring the materials and the land taken to grow them, as well as how they are transported to site. It will also discover the life cycle of materials by talking to those involved in the building process.

CHAPTER 3

VERNACULAR PALM THATCH BUILDING TRADITIONS IN THE TRANS-MEXICAN VOLCANIC BELT

In this chapter the research moves from the global to the local, because of narrowing the scope of the research to specific places in the region of interest, and because the resources related to the vernacular agro-forestry materials investigated here are focused on the endemism of plant species, their uniqueness to a defined geographic location. This again emphasises the local environments and context over a global perspective, this local focus being central to the research.

Vernacular as an expression is primarily understood as being native, aboriginal or endemic, in other words, vernacular is related to place, and should therefore be regarded as a true legacy of knowledge and wisdom regarding local solutions. Although there is often a gap between the field of academic investigation and the real world, at the core of any research involving vernacular expressions, three intrinsic fields of enquiry cannot be dismissed or divided, as they serve as a bridge to the real world, these being linguistics, biology and architecture. All are significant for the vernacular, as they are the threads of the same cultural braid.

The main structure for the historical review is the division of material into the three major periods of Pre-Columbian, Colonial, and Modern. This offers a clear classification of the building types, typologies, environment and materials.

There is another consideration when investigating natural building materials from the past and this is their perishable condition, as most of the materials being investigated here are organic, therefore they decompose quickly and have a shorter life span than other longer lasting materials, as would be the case of a thatched roof versus a rock terrace. Well preserved historic organic fibres are very rare and those that exist occur in an archaeological context (Follensbee, 2008, p. 88), particularly for tropical settings (Chase et al., 2008, p. 127). Though there are still some difficulties in accurately dating organic archaeological materials (Boaretto, 2009, p. 276), those that have been recovered over the last century collectively confirm that the use of fibres in

Mesoamerica, for instance in textile technology, reaches back to Paleo-Indian times (Follensbee, 2008, p. 88).

However, investigation of natural fibres with specific building purposes, such as for thatching, seems a harder task for archaeologists and ethno-botanists, as in most cases archaeological findings about such fibres are frequently related to other human uses, such as food (Lentz et al., 1996), clothes (Chase et al., 2008; Follensbee, 2008; Halperin, 2008; Lentz et al., 1996; McCafferty & McCafferty, 2000), and utensils such as baskets (Follensbee, 2008, p. 88; Lentz et al., 1996, pp. 255-256). The preservation of organic building materials is often related to unique and rare archaeological contexts. Examples are El Cerén in El Salvador (585-600 A.D) (Lentz et al., 1996, p. 247) and Tetimpa in Puebla (700 A.D. and 850 A.D.) (Plunket & Uruñuela, 1998, p. 287) where organic materials have been preserved in ashes (tephra) following volcanic eruptions (Lentz et al., 1996; Plunket & Uruñuela, 1998). Finally there are a number of relevant studies on Mesoamerican houses, house units and villages (Flannery & Sabloff, 2009) and though limited in number and scope, they are all of great importance for this chapter.

Nevertheless, it is clear for the case of Mexico with particular focus on Mesoamerica that a region that hosted some of the biggest and most developed civilizations from the past, the Olmec, Toltec, Mayans and the Aztecs, also developed very rich pictorial and useful records of such fibres, materials and their uses. These records reveal the great economic importance such fibres had, for instance the textile and weaving fibre technologies that existed from formative times among the Olmec (Follensbee, 2008, p. 37).. These sets of artefacts can show evidence of the uses and customs of the cultures that created them, of particular interest being the west coast cultures and their ceramic house models related to the shaft tomb tradition of west coast Mexico (Olay & Reyes, 2001, pp. 5-80; Young-Sánchez, 1992, pp. 244-247). Although there are obvious issues related to shaft tomb culture, such as the lack of research in this area and the related problem of interpretation and timing, and the consistent looting of these mortuary sites (Mountjoy & Sandford, 2006; Taladoire, 2005; Taylor, 1970) they are still of great value as historic, archaeological and ethnographic material.

A) Clay model of a temple from El Chanal Culture, Post-classic Colima, 20x22cm;
B) Clay model of houses from El Chanal Culture, Post-classic Colima, 16x23cm;
C) Clay model of house with family scene from west coast Mexico (unknown location) 22x18x30cm, G. Brockmann particular collection.

Figure 3-1: Drawings of scale models based on (Olay and Reyes, 2001, p.38 A) photos by Karla Sandoval, edition and drawings by Jaime Rios C.

Another record forming a source of information is the Pre-Colonial codex, which are bi-fold books made from deer skin painted in colours (Sisson, 1983, p. 653). Of particular interest are the Borgia group of codex, and the Vindobonensis group of codex belonging to the Mixtec group of codex (Jansen & Pérez Jiménez, 2004, p. 267) (figure 3-2).

A) Codex Fejérváry-Mayer, Plate 30, B) Codex Borgia, Plate 19, C) Codex Borgia, Plate 65, D) Codex Zouche-Nuttall, Plate 9, E) Codex Laud, Plate 13 (12), F) Codex Egerton-Sánchez, plate 27, G) Codex Zouche-Nuttall, Plate 45, H, I) Codex Vaticanus B, Plate 71.

Figure 3-2: Detail of houses from the Borgia and the Vindobonensis group of codex plates. Drawings Jaime Rios C.

These are considered to be true pre-colonial documents and fall within the scope of this research. All of the above confirm the main historical evidence and foundations for the fieldwork investigations of this research. They also help in identifying relevant places for the case studies and their environmental assessments based on current thatch technologies for buildings.

Before reviewing the historical evidence of thatched buildings in the past that might lead to current vernacular traditions in the area of research, the vernacular as a key term is first explored as a concept, since although it tends to be little considered within the field of architecture it has so many examples that can show features of sustainability. This should enable a better understanding of its role within the field of architecture and sustainability (see section 3.1). Subsequently, the main related technologies, such as the weaving arts, are also explored following the work of Gottfried Semper (see section 3.2). This is followed by a summary of the Pre Columbian and Colonial era evidence related to thatched buildings (see section 3.3).

3.1 Vernacular Building: An Un-Official 'Slang' Expression

Vernacular at first sight is a term that implies being native (Skeat, 1901, p. 591). It is mostly used in linguistics, although architecture is another field familiar with the term. However, the term seems to have ambivalent, unfavourable but consistent connotations within its etymological origins within the field of architecture. For instance, some etymological definitions of vernacular related to architecture are literally: belonging to a home-born slave (Skeat, 1901, p. 591), born in one's master's house (Partridge, 1966, p. 3673), or concerned with domestic and functional rather than public buildings (Stevenson & Waite, 2011, p. 1607).

Even definitions from professionals concerned with the vernacular in the field of architecture appear to have the same negative connotations. For instance, Upton stated that "As recently as five years ago, vernacular architecture might have been defined succinctly as 'traditional rural domestic and agricultural building'." (Upton, 1981) He goes on to define the term more widely.

Today, people who take the vernacular as their subject matter are interested in buildings of all places, all eras, and all types, from 17th-century New England

farmhouses to 20th-century tract housing, from barns to hamburger stands, from individual structures through farmsteads to whole landscapes. Williamsburg, Lowell and Los Angeles, Levittown and the Strip all fall within the territory claimed for vernacular architecture. (Upton, 1981, p. 57)

Another very poetic and simple definition within the field of architecture by Bernard Rudofsky (1964) is 'architecture without architects', although even this is perhaps not as clear as it seems. For instance, is everything not done by architects, even a public structure or building designed by engineers, to be considered vernacular? Such wide and open ended definitions perhaps partly explain why vernacular is undervalued by architecture academics, as being the architecture of the architecturally and academically illiterate.

In addition, people now are far more familiar with modernism, supposedly the first international style in architecture, a term first coined in the book title *International Style: Architecture Since 1922* (1932) by Henry-Russell Hitchcock and Phillip Johnson, written in 1932 to accompany an exhibition with the same name at New York's Museum of Modern Art (King, 2006, p. 65). International is a relatively recent word first used in 1780 (according to Bentham found in King, 2006, p. 65) implying relations between nations. However for architecture:

It presupposes the notion of the "national." What is being assumed here, therefore, is that architecture, which I gloss here simply as referring to buildings designed by designated architects, is best understood in relation to the territorial nation state where it exists or where it originates. International, therefore, must imply something that is present in and/or appropriate to all nations, irrespective of culture, religion, level of economic or technological development, or geographical location. Yet in the Hitchcock and Johnson book, illustrating the work of some forty architects - most prominently Corbusier, Oud, Gropius, and Mies van der Rohe - a mere fifteen countries were represented. Except for Japan, all were in the West, and apart from a few names in the United States, Europe, especially Germany dominated (King, 2006, p. 65).

Consequently the so called modernist or international style was started by a few architects in a few, generally highly developed, places and has today become a common expression that belongs nowhere, and hardly fits into any context different

from metropolitan life. This means the vernacular is equivocally left behind as an expression of rural context.

Part of the problem regarding this academic dichotomy between official and unofficial architecture relies on the western approach of having an industrial lifestyle, which has resulted in the last century in the population moving from a rural to an urban situation. Urbanization has since accelerated worldwide in the 20th century, with the expectation that more than half of the global population will be living in cities by 2030 (Cohen, 2003, p. 1172). In Mexico the situation by 2014 is over 70% of the total population living in urban areas (where a locality with more than 2500 inhabitants is considered to be in the urban category) (INEGI, 2014).

Finally, the vernacular carries another disadvantage within the field of academic study, which is its perceived condition of being old or from the past, implying being out of architectural fashion. This also reverberates with the root of its meaning, as vernacular implies an expression where domination by the taste of the elite and avant garde is absent. This negative set of meanings within the term vernacular in architecture is seen in the emphasis on dividing one category from another: the aboriginal and the civilized successor, the slave and the master, the illiterate and the literate, the dialect and the official language, the rural and the urban, and even the poor with the rich.

For instance, the gap between the poor and rich has widened in the last 25 years (Reardon, 2011), and this is also reflected in children's education patterns. "The achievement gap between children in high- and low-income families is roughly 30 to 40 percent larger for children born in 2001 than for those born twenty-five years earlier" (Reardon, 2011, p. 91). The growing gap in income in cross country studies shows that the relationship between education levels, population growth, and the stock of available technology is, in a generalized way, one of the major factors behind this increase (Ardıç, 2006, p. 554; Sheehey, 1996, p. 1379; Wade, 2004, pp. 581-582).

All this impacts directly on the vernacular as it is closely linked to the rural. Since the increasing tendency is for more rural population migration into urban areas (McGranahan & Satterthwaite, 2003, p. 245), this increases the problem of servicing the latter, as it has being strongly demonstrated that cities rely on their rural hinterlands for their survival (McGranahan & Satterthwaite, 2003, p. 244; Rees, 1992, p. 124).

The undervalued perception and unofficial view of vernacular architecture have together preserved within academia an internationalist, imperialist, post-colonialist, and globalized set of frameworks for the vernacular (King, 2006), whereas a better meaning and sense of vernacular building relies on precisely the opposite. Such buildings seem very logical and functional for the local conditions. Vernacular building materials and technologies as investigated for this research rely on endemic plants and local materials, as well as on the use and knowledge of building design principles suitable for specific local climatic conditions (as defined for this thesis in section 1.3). Those involved select the best available resources that are abundant, fast growing, easy to collect, reproduce and harvest, simple to work with, and reliable, safe and effective for their purpose.

This is the intended meaning of vernacular building which should be considered at least equal to its counterpart, “official” architecture. Using this perspective, vernacular architecture should be taken more seriously within academic fields and should be regarded as integral to any architectural project that looks to a future of resource shortages and the need to make more use of local resources. Vernacular architecture plays a key role in this approach and can be regarded as the path to successful local building manifestations.

3.1.1 The Vernacular Expression as a Strand of Culture

This misconception of the meaning of the vernacular in architecture has greatly affected and is still impacting the vernacular expression, as very often vernacular traditions around the world are being threatened to extinction or struggle to adapt to cultural change. Those that do exist are often condemned to be considered heritage or even distorted to become museum objects (McKay & Walmsley, 2003, p. 92; Rodman, 1993, pp. 243-244; Young, 2006, pp. 321-322).

To better explain the above statement, the Māori architecture of Aotearoa or ‘The land of the long white cloud’ (the Māori name for New Zealand) works well as an example. Māori architecture can be traced to east Polynesian island cultures (Austin, 1976, p. 234), and despite the problem of establishing a particular origin for Māori migrations, which have clear archaeological difficulties far beyond the scope of this research

(Davidson, 1983, pp. 292-293), its Polynesian ancestry can clearly be traced in Māori architecture.

Nevertheless, Māori building also acquired particular features from its adaptation to a new climatic challenge. Their buildings, which came from a more tropical environment, had to cope with cooler weather (Awatere et al., 2008, p. 3). To do this they developed shallower semi underground buildings to avoid winds and cold, and they reduced building volume to greatly reduce ventilation, keeping just one door (McKay & Walmsley, 2005, p. 70). The Māori also strongly focused on thermal insulation, for which they used diverse natural materials, such as bundles of various reeds for thatching walls and roofs (Awatere et al., 2008, p. 5; Cumberland, 1949, p. 408; Simmons, 1997, p. 11).

The contact process between the Māori and Europeans following Cook's rediscovery of the country in 1769 (Austin, 1976) has been assumed to have been (relatively) peaceful, with the Māori mostly continuing to live in rural settlements until the 1940s (Austin, 1976, p. 229). The typical Māori settlement was a rural communal fortified terraced settlement called a Pa, derived from the verb meaning to obstruct or block up (Cumberland, 1949, pp. 413-414). This was a response to brief forays and sporadic raids from regular and annual intertribal warfare (Cumberland, 1949, p. 413), although it was common to live outside the Pa for periods, sometimes in temporary shelters.

Abundant evidence remains in the form of tiered linchets, terraces, ditches, and high ramparts...Although it is doubtful whether all the pa in a locality were occupied simultaneously...many of them would have taken a Maori population far larger than that now living in the same region and even considerably larger than the first observers found in many of the pa or their vicinity. (Cumberland, 1949, p. 415)

These common fortified settlements consisted of a small number of repeated elements, such as layers of timber stockades, in terraces, and a common open and ceremonial space called the marae (Sissons, 1998, p. 36). "Today Maoris use the term *marae* in two related senses: first, for an open space reserved and used for Maori assembly, and secondly, for the combination of this open space with a set of communal buildings which normally includes a meeting house" (Austin, 1976, p. 232). The meeting house is also called *whare nui* (large house) or *whare whakairo* (carved house) (Sissons,

1998, p. 36). However, the meeting house is a structure that has evolved from the houses of chiefs during the time of European settlement and is currently a communal building set on the marae in which the hapu (a common group of the community, sub clans or sub tribes) gather (McKay & Walmsley, 2003, p. 91).

These communal Māori places are perceived as more than a physical set of buildings, as it is believed that each building embodies the mana (spirit) of its own hapu (Sissons, 1998, p. 36). So the perception of space and time through architecture, landscape and the building itself is rather different from the westernized object-centred point of view; the building has to be lived in over time to retain its meaning, and an uninhabited building would not be a building in these terms (McKay & Walmsley, 2003, p. 94).

Consequently the whare whakairo, translated as the meeting house, is considered sacred to the Māori and works well as a vernacular official building, and indeed, is a building which assembles much Māori culture and philosophy and its sacredness within it. Some of its features reassemble this intrinsic vernacular condition. For instance, the materials of the panels of the meeting house are carefully selected, collected, processed, dyed and woven with a meticulous and profound knowledge of the local plants used, their availability and abundance. Also, in the meeting house language plays an important role as a cultural instrument, as it is reflected in all building parts. All the elements have particular Māori names and meanings which resemble parts of the human body (Harrison, 1988) and work as an open book for passing knowledge on to the next generations.

Nonetheless, certain other elements of the building have evolved differently; for instance, the thatched roof techniques have been completely lost and replaced by other more modern technologies as thatching is considered unsafe and a fire risk, as in the Compliance Document for New Zealand Building Code Clauses C1, C2, C3, C4 Fire Safety (Department of Building and Housing, 2011, Section 7.11.1). As a consequence the roof covering of the meeting house is now mostly corrugated steel, suggesting more the idea of 'a helmet' rather than 'plaited hair'.

Western society prefers its buildings to be permanent, durable and lasting and the epitome of this is our preservation of 'historic' buildings, where Western society removes the inhabitants and freezes a building at a certain moment in time. There are numerous examples world wide of this mummification of architecture.

Much of the architecture of the South Pacific shows a transience of form and materials that has been commented on by writers...The Samoan 'fale' for instance is designed to allow a cyclone to strip its thatch, then it is repaired. (McKay & Walmsley, 2003, p. 94)

The housing of the indigenous Maori has always constituted a "problem" in the predominantly white (*pakeha*) society, but this was only a statistical difference so long as the Maori was a rural dweller. Recently this problem has become manifest with substantial migration to the cities. (Austin, 1976, p. 230)

It is apparent that for Māori housing, questions of standards, appearance, maintenance, and issues like overcrowding seem to constitute the problems underlying cultural assumptions about vernacular buildings (Austin, 1976, p. 230). In response many vernacular traditions were eradicated, for instance no individual houses are now fully thatched using raupo reed. Moreover, the westernized idea of the individual family house assumed a different lifestyle and social structure in New Zealand which was called by Māori people *pakeha*, and differed from their own view of communal lifestyle, making a clear distinction of the two lifestyles, *pakeha* or Māori (Austin, 1976, p. 230).

In general the impact of colonization and external influences on vernacular culture are extensive, as plants, building parts, materials, forms, and techniques encounter disruption in the face of new, official conditions, with names being translated into other official languages. For instance in biology local names of plants become formal taxa, or are simply expressed by substituting or translating the materials in the case of the building into a single general category 'thatch', whereas the materials of vernacular Māori building were more complicated.

A whare consisted of a framework of timber, carefully notched, and lashed together with flax, the wall spaces being filled in with screens made chiefly of kakaho, the reeds of the toetoe plant (*Arundo conspicua*), the whole being covered with bundles of raupo (*Typha angustifolia*), bound on with strips of flax (*Phormium tenax*). (Williams, 1896, p. 145)

Māori architecture changed under a modern New Zealand colonial regime, as new regulations and building codes shaped and established it according to new rules, interests and values. In consequence, some of the former vernacular building traditions

became extinct, or were seen as a relic from the past rather than a local functional solution for the present and future. In such cases, governments facing vernacular traditions foreign to them prefer to focus on avoiding and banning what they consider a problem, rather than promoting research, improvements and ways to meet safety requirements through adaptation and preservation.

This can directly affect the approach towards vernacular traditions making them evolve differently, although the evolution of the vernacular is not always through imposition, and can also happen through adoption of the new. For example, New Zealand corrugated iron architecture has become a modern New Zealand style, and is often referred to as New Zealand vernacular (Chapple et al., 1983), though this is outside the scope of this research.

The ambivalence present in the vernacular example of the whare whakairo can be seen in many places and cultures that underwent a period of colonial rule. In order to adapt and preserve vernacular traditions within a new set of rules and models, such buildings have changed, and whether for better or worse is a subject of debate for each case, including the present study of Mexico. However before describing the particular expressions of the localities involved it is proper to set the context of the field of research. Since its focus is on natural fibres, in turn forming a whole collection of natural materials, it is useful to explore the relationship between the use of such fibres in building and in other cultural expressions, such as language and the arts of weaving.

3.2 Vernacular Languages, the Arts of Weaving and Buildings

Anthropology and architecture are strange bedfellows: their relationship has never been made very clear. Yet culture and environment are interrelated, interwoven, and integrated: they invariably complement each other. It was in the first half of the nineteenth century, through the work of architects Gottfried Semper and Eugene Emmanuel Viollet-le-Duc that the cultural and anthropological aspects of architecture were brought into focus...Anthropologists who first looked carefully at the built environment were Lewis Henry Morgan and Victor Mindeleff, who included the built environment in reconstructing the socio cultural reality of some groups of

North American Indians. The relationship between architecture and anthropology, however, remains asymmetrical. (Turan, 1996, p. 355)

It is not surprising therefore that vernacular architecture finds bedfellows in diverse fields outside architecture, such as archaeology, anthropology, history, ethnography, and biology. For instance, there appears to be more current research and literature about natural building materials through the study of certain plants, such as palm and its use in buildings, within biology than in architecture, although information from both sources is complementary.

Despite the scant attention paid by architects to the vernacular, there are still remarkable studies that have greatly influenced its perception. One of the first was by Gottfried Semper in the 19th century. He was well known for the architectural theory he developed in England after being exiled from Germany because of his support for popular movements in the mid 19th century (Mallgrave et al., 1983, pp. 5-7). Semper's investigation focused on the relationship of the artistic form with a set of rules that aim to provide the basis of an empirical theory of art connected to the beginnings of architecture (Semper et al., 2004, p. 3). His theory argued that architecture developed in relationship with the beginning of textiles and other handcrafts, thus he both drew upon and in turn influenced other disciplines such as archaeology, ethnography and linguistics (Semper et al., 2004, p. 3). His 19th century academic work became an important influence on early twentieth century debates (Wigley, 2001, p. 100).

Semper's London period proved very fruitful for his theory (Mallgrave et al., 1983, p. 7). The publisher Eduard Vieweg had commissioned him to write the book that later became his masterpiece: *Der Stil in den technischen und tektonischen Künsten; oder, Praktische Aesthetik: Ein Handbuch für Techniker, Künstler und Kunstfreunde*, which was published in 1860 in two volumes. *Der Stil* became a shorter paper containing the kernel of many later ideas entitled *Die Vier Elemente der Baukunst (The Four Elements of Architecture)* published in the autumn of 1851 and largely written in London (Mallgrave et al., 1983, p. 7).

While in London between 1853 and 1854 Semper gave many lectures and some have been recovered and compiled (Semper & Mallgrave, 1986, p. 33). He delivered at least eleven formal addresses to Henry Cole's Department of Practical Art at Marlborough

House (Semper & Mallgrave, 1986, p. 33), one of which given on November 18, 1853, *The Development of the Wall and Wall Constructions*, constitutes one of his earliest efforts “to posit his principle of *Bekleidung*: his thesis that the wall (and its architectural treatment) gains its existential footing through its metamorphoses as “dressings,” emanating in their origin in the mat-walls of the primordial dwelling” (Semper & Mallgrave, 1986, p. 33).

Semper, who later became the most important architectural theorist of his day, discovered the “*Caraib Cottage*” [sic] referring to the Caribbean bamboo hut displayed in the colonial division at the London Exhibition of 1851, and this became ethnological proof for his theory (Semper & Mallgrave, 1986). He argued that the original form and techniques of architecture are found in the ethnographic record, and in the handcrafts and ritual of tribal societies.

After London, Semper returned to Zürich where the ideas he had formulated while in exile flourished among his pupils and friends, including Richard Wagner. The latter lent *Der Stil* to Nietzsche who was attracted by Semper’s theories (Mallgrave et al., 1983, p. 7).

Nietzsche was lent *Der Styl* [sic] by Richard Wagner at the beginning of their friendship and confessed himself fascinated by it; the book had an enormous influence outside architectural and art-historical circles, as through the anthropological teaching of Franz Boas in the United States. (Mallgrave et al., 1983, p. 7)

The basic differentiation made by Semper in *Der Stil* is between technical and tectonic arts. In a general classification of the technical arts he made four categories of raw materials.

1) pliable, tough, highly resistant to tearing, of great absolute strength; 2) soft, malleable (plastic), capable of being hardened, easily shaped and formed, and retaining a given form when hardened; 3) stick-shaped, elastic, principally of *relative* strength, that is resistant to forces working vertically along the length; 4) strong, *densely aggregated*, resistant to crushing and compression, thus of significant *reactive* strength. It thus suited to being worked into any required

form by removing parts of the mass or by inserting regular pieces in strong systems, constructed on principles of reactive strength. (Semper et al., 2004, p. 109)

On the basis of classifying raw materials and the four categories above, he extracted a further four main craft groups: 1) textiles, 2) ceramics, 3) tectonics (carpentry), 4) stereotomy (masonry) (Semper et al., 2004, p. 109). What really matters here is that Semper clearly considered textiles as the primary art (Semper et al., 2004, Contents), making these volume one, while volume two covers all other crafts.

But why are textiles treated first and with such distinctive attention? It is hard to establish which branch of the crafts was practiced first in the natural course of human development, however, it seems the first two manifestations were textiles and ceramics, by embellishing functional objects through a conscious choice of form and decoration (Semper et al., 2004, p. 113). The weaving arts are found within textiles, from basic fibre work in basket and mat making, to fine techniques of fibre extraction, dying, twining, cording, and from there to a wide variety of textile forms, including carpets, curtains and tapestry work.

The transition from plaiting branches to plaiting bast [the fibrous part of trees] for similar domestic purpose was natural and easy...Next came the invention of weaving: first with grass stalks or natural plant fibres, later with spun threads made from vegetable or animal stuff. The diversity of natural colour in the stalks soon led to their use in alternating arrangements, resulting in the pattern. These natural art materials were soon improved with synthetic preparations; dyeing and weaving were invented to create colourful carpets for wall dressing, floor covering, and canopies. (Semper et al., 2004, p. 248)

There are some striking insights into the roots of architectural elements found in the vernacular languages as a point of departure from the above premise. Language and architecture share close connections in the vernacular expression. For instance, Semper used the closeness of the German language in the words for wall *Wand* and dress *Gewand* in which walls, the first element of architecture, were conceived of as a kind of ceremonial dress and involved the craft of weaving. Likewise cladding *Bekleidung* is a kind of clothing *Kleidung*. Also in English it is possible to find a close relationship

between *fabric* as a woven material for clothing and *fabrication* as a process of construction, or *curtain walls*, making the connection between *curtain* (textile) and *wall* (building element). Language here is essentially a related technical expression, which means symbols are not necessarily applied to buildings at a later stage but are clear indications of the textile origin of these building elements (Semper et al., 2004).

Some etymological roots found in English are also good support for the relationship between textile origins, weaving, clothing, building and its thatching (roofing) relationship. These include terms like hood, hat and hut. Following the etymological origin of these words it is possible to find their roots in Germanic terms also related to weaving techniques. For instance, a hut is a ‘covering structure’. The word has been traced back to the old form of Germanic *khūd*, which also produced English *hide* and probably *hoard*, *house*, and *huddle*. Also it is the source of Middle High German *hutte*, which eventually found its way into French as *hutte* –whence English *hut* (Ayto, 1990, p. 290). Ultimately *hood* and *hat* are the same word, and both denote literally ‘head-covering.’ They go back to an old form of Indo European *kadh-* ‘cover, protect,’ and the West Germanic derivative *khōdaz* as hood and *khadnus* latter *khattus* as hat. From the former are descended the German *Hut* ‘hat,’ Dutch *hoed* ‘hat,’ and English *hood*, and from the latter the English *hat* and also Swedish *hatt* and Danish *hat* (Ayto, 1990, p. 285).

The common house of ancient Greece had walls of wattle and daub, a mat of woven branches daubed with clay or mud (Faegre, 1979, p. I). The root of architecture from the Greek *arkhitekton* ‘master builder,’ comes from *arki-* (chief), derived from the root *archon* or *arkhos* (ruler), or *arkhein* (to begin, command, to rule), and *tekton* (builder, carpenter), linked directly with the Latin *textere* (to weave), or from the Greek *tekhne* (art, skill, craft, method, system).

So there is an interlinkage between language, architecture, materials, plants, forms, and building parts, and the weaving arts can be regarded as a compound of traditional knowledge closely linked to vernacular expressions and landscapes. The following section looks into the historical, ethnographical and archaeological data of vernacular expressions, despite their continuous struggle against oppression and division.

3.3 Historical Evidence and Vernacular Thatch Building Tradition in Mexico

The following section on evidence from the past related to the vernacular thatched roof house is divided into two periods: Pre-Columbian (1492 and earlier), and Colonial (1492-1821), noting that certain thatched roof dwellings traditions in the Modern Period (1821 onwards) will be covered in chapter 5. Each period involves important changes in culture, which reverberate in architecture and housing.

As the research area is confined to particular places along the trans-Mexican volcanic belt of Mexico, which fits into Mesoamerican geography, a general definition of Mesoamerica is needed for a better understanding of the general environmental and cultural aspects of the areas of research.

The region of Mesoamerica is very diverse both culturally and environmentally. It has a vast diversity in the range and size of various cultural groups and was home to some of the major civilizations of the past: Olmecs, Toltecs, Mayans, and Aztecs. Mesoamerica is a land defined by an imaginary line dividing Mexico from the Tropic of Cancer latitude 23°26' south as far as Costa Rica in Central America (Creamer, 1987).

According to Creamer (1987, p. 35), as a cultural area Mesoamerica consists of a large geographic unit throughout which agricultural and sedentary societies diffused, along with some shared religious or philosophical concepts, like the basis of the calendar (Adams, 1977, p. 12; R. Blanton et al., 1981, p. 246; Browman, 1978, p. ix; Creamer, 1987, p. 35; Willey, 1966, p. 460).

Globally language is a major common cultural linkage, and the basic first connection proposed to unite the group comprising Mesoamerica was language (Macro-Mayan, Macro-Otomange and Uto-Aztecan) (Johnson, 1940). Kirchhoff (1943) first defined Mesoamerica based on Johnson's definition of language in addition to other general traits such as ethnic composition, cultural characteristics and geographic limits (Creamer, 1987, p. 35). This became Mesoamerica's first defining parameter, largely based on sixteenth century documents. This had led scholars and researchers to question the definition, and some recent research has suggested a review of the concept, especially in terms of geographical limits (Creamer, 1987), or the western influence on Mesoamerica in the Formative period (see section 3.3.1.1.5 western regions and figure 3-3). Aside from such debate, it can be said that architectural

features are shared throughout Mesoamerica, like the stepped pyramid, and also craft specialities, for example obsidian blade production, specific ceramic types, and fabrication of hematite mirrors (Creamer, 1987, p. 35; Hammond, 1974; Healan et al., 1983, p. 416).

To date, very early human evidence found in Mexico in Valsequillo, Puebla (Irving, 1985, pp. 541-543; MacNeish, 1976, p. 319; Rouse, 1976, pp. 602-603) dates back to 9000 to 11,000 radio carbon years before the present (rcbp). Artefacts consist of knives, scrapers, burins, and obsidian 'flints' and various extinct horse and antelope bones, first excavated by Cynthia Irvin Williams (1967) and later by Steen-McIntyre et al. (1981).

Mesoamerica as part of the Middle Americas has been studied as a centre of plant domestication (Harlan, 1971, pp. 472-473), a core of agricultural societies which sustained large populations (Sanders, 1962, pp. 34-43), and as a centre of urban development (Wiley, 1955, p. 576; Sanders & Webster, 1988). Ceramics have also been regarded as key to understanding the periods and evolution of such societies, making the classification of pre-ceramic and ceramic cultures important in cataloguing the historical chronologies of diverse cultures within the area.

Far from solving the origins and peopling of the Americas, the focus in this thesis remains on evidence related to architecture and thatch building technologies in Mesoamerica. Of particular interest is the set of archaeological records of houses as found in the codex or bi-fold books, vessels, pottery, wood and rock carving, as from each can be understood glimpses and fragments of the cultures that produced them. This data is relevant as it can provide a more realistic idea of the materials and technologies used in building houses according to a particular culture, place, and its relationship with the climate.

3.3.1 Pre-Columbian Evidence of Thatched Buildings in Mesoamerica

The earliest houses in Mesoamerica are found in the pre-Columbian era, which comprises the time of Spanish discovery (1492) and earlier. The Pre- Columbian era can be divided into Pre-Ceramic and Ceramic cultures, although metal was known in many forms and alloys by the time of the Spanish discovery, particularly in the west

coast cultures due to contact and transfer of technology with cultures from Ecuador, Peru and Colombia (Willey, 1955, p. 584), the use of metal was neither fully propagated nor considered sufficiently important to cause cultural changes. Thus attention here is paid to the Ceramic time as it is then when agriculture and a sedentary lifestyle emerged and became fully developed, and consequently building forms were also adapted to a more domestic demand. The Ceramic era has also been divided into the three general periods of Formative, Classic and Post Classic (figure 3-3).

Evidence of Mesoamerican houses is difficult to find firstly because there is little research on the topic, and only in the last 100 years has there been an increasing awareness of the value of past cultures. Secondly, research in Mesoamerica has largely been centralized and the central valleys of Mexico and certain Mayan regions in the Yucatán peninsula have remained largely uncovered. Moreover, when research has been undertaken, the focus has been the monumental architecture and the many complex and beautiful artefacts that these sites offer, rather than domestic houses. Additionally, there has been a lot of looting and little care taken of the archaeological evidence that sometimes appears, as developers prefer to remain silent and carry on building rather than inform the national authorities (INAH or the National Institute of Anthropology and History) since by doing so their building permit could be revoked and the land expropriated if the archaeological evidence is deemed important.

ENVIRONMENTAL IMPACT ASSESSMENT OF VERNACULAR THATCH BUILDING TRADITION IN MEXICO:

Figure 3-3: General historical chronology of western cultures and Mesoamerica based on (Schöndube, O. 1995; Olay and Reyes, 2001) with highlights of some examples from this research. Drawings Jaime Rios C.

Even when archaeological projects occur, wrong professional practices have also prevailed, missing evidence on more ordinary houses, and sometimes obliterating this so it is completely lost. However, more money has been put into Mesoamerican archaeology since the 1950s, which has contributed to more and better research (Blanton et al., 1993, p. 2). For the purposes of this research, there are enough examples with a focus on reconstructing past houses from a systemic viewpoint (Binford, 1965; Flannery & Sabloff, 2009; Struever, 1971) that have contributed proper findings on houses.

To better explain the above statement, study of the household as a unit, through smaller units such as pits or granaries, or the house itself, which is central to this research, fits the methodology and scope of the systemic cultural approach used in archaeology. “For the systemic theorist, culture is made up of parts, structurally different from each other, but articulated within the total system” (Struever, 1971, p. 10). Following Struever’s theory and analysis of culture, the smallest analysis unit is the activity area as a single locus of activity of one or more individuals, for instance, a storage pit. The next level adds those portions of the house floor composed of the many features or activity areas which often also distinguish the male and female activity areas of a household. The next larger unit of analysis is the house and the household cluster, which include all the associated elements such as storage pits, burials, middens, and other features associated with the household (Flannery & Sabloff, 2009, p. 5).

Beyond the level of the individual household it may be possible to find, at least in some settlements, several houses sharing a common patio (courtyard), which fits into the largest unit of relevance for this research. However, and beyond the scope of the investigation, the next level of analysis for larger villages in Mesoamerica, may be the *barrio* (residential ward), which is “composed of related courtyard groups whose architecture, material remains, and other attributes may distinguish them from neighbouring *barrios*” (Flannery & Sabloff, 2009, p. 5). Beyond this level is the village itself.

Examples of settlements can be found in archaic Mesoamerica where the houses were of wattle-and-daub and had storage pits adjacent to them (Flannery, 2002, pp. 417-418). Archaeological examples include Early Formative Mesoamerican sites where

villages of rectangular, nuclear family houses tended to replace settlements of small, circular huts over time (Flannery, 2002).

Most houses in early Mesoamerican villages were of wattle-and-daub, making them harder to find...After 850 B.C. (uncalibrated), however, elite families began increasingly to build adobe houses, often over a foundation of field stones. From that point on the growth of extended households becomes easier to document (Flannery, 2002, p. 29).

The first solid evidence in Mesoamerica belongs to what has been considered the Formative Period, which occurred between 1500 and 500 B.C. (Flannery & Sabloff, 2009, p. 2), a millennium of relevance for this investigation, as it is the transition period from nomadic to sedentary life, with its demands for different building and settlement forms. “It was at the start of this period that true, permanent villages of pole-and-thatch (wattle-and-daub) houses first became widespread in Mesoamerica” (Flannery & Sabloff, 2009, p. 2).

Since the 1920s, increasing research has been undertaken in Mesoamerica, and yet the issue of reconstructing houses and households remains incomplete. “This fact can be demonstrated in absolute terms, by a simple search through the literature: There is no single published plan of a complete Early Formative house” (Flannery & Sabloff, 2009, p. 13). In contrast, there is abundant information on house plans from the Woodland period of the Midwest or the Pueblo period in the Southwest, both sites located in the United States, noting that village life in the North American continent owes much to Mesoamerica (Flannery & Sabloff, 2009, p. 13).

Mesoamerica’s bewildering richness also makes reconstructing the past complicated, as those who worked in the Central Valleys of Mexico found, as many of the sites offer a vast number of shards and figurines (Flannery & Sabloff, 2009, p. 15).

Lambityeco, an Early Post-classic site of only moderate size in the Valley of Oaxaca, has over *60 million* potsherds on the surface of the ground alone. Think of the difficulty in trying to find out the important facts; imagine the possibilities of being enticed away from the main goal and becoming mired forever in a Myriad of minutiae. (Blanton et al., 1993, p. 7)

Another example is the case of the archaeologist George Clapp Valliant who in the 1920s worked with the important archaeologist Alfred Vincent Kidder at Pecos pueblo

(Flannery & Sabloff, 2009, p. 15) on an excavation that offers detailed work on houses and the first regional synthesis of Southwest North America (Kidder, 1924). Valliant's later work set the historical sequence of pre-Columbian cultures in Mexico (Vaillant, 1938). However, he also lost track of house evidence when excavating in the valleys of Mexico (Flannery & Sabloff, 2009, p. 15).

Valliant dug his way through Zacatenco, Ticomán, and El Arbolillo without recovering a single house. In his book *Aztecs of Mexico* (1941), he refers occasionally to all three sites as "middens." Perhaps, in some strange way, Valliant regarded Zacatenco as equivalent to the stratified refuse heaps that occurred outside the rooms at Pecos. Valliant noted burnt chunks of cane impressed daub in this refuse, but whatever he had learned from working with architecture at Pecos evidently faded from his mind as Zacatenco began to rain figurines. (Flannery & Sabloff, 2009, p. 15)

3.3.1.1 *Earliest Evidence of Thatched Buildings in Formative Mesoamerica*

Notwithstanding the efforts described above, there are a few reliable traces of houses worth noting. The first remarkable piece of information about an Early Formative Period architecture came to light in 1948 when archaeologist Richard S. MacNeish excavated at el Pánuco Veracruz one of the earliest traces of Formative houses that was dated and catalogued to the Chila phase (Flannery & Sabloff, 2009, p. 15).

3.3.1.1.1 *Pánuco Veracruz*

One clay toy or model from Pavon's collection tells much concerning the everyday architecture of the people of the early periods...The floor plan of the house is apsidal, with a door in the one of the long sides. The walls of the house are vertical, smoothed and painted white. At the apex of the roof there is a depicted long pole, which at either end fits into forked poles (evidently roof supports or pillars coming from within the house). Brushing or scratching on the surface of the roof radiates out from this exterior ridge pole and evidently is meant to depict thatch or grass. (MacNeish, 1954, p. 601)

Moreover, evidence of real architectural features was reported in an excavation of the Formative Chila (Abejas period) that correlated with the occurrence of this clay figurine house (figure 3-3 and 3-4) type (MacNeish, 1954). The evidence was four post holes, describing a semicircle that “may well be part of a round, oblong, or apsidal house like the clay model described (see figure 3.4). Wattle and daub...reveal the type of wall structure in use at the time” (MacNeish, 1954, p. 602).

Figure 3-4: Clay house model at Pánuco Veracruz from Ponce Aguilar period taken from (MacNeish, 1954, p. 602).

However, there is still no evidence of an earlier pre-ceramic house, with the closest evidence similar to a house recovered from a site in the Tehuacán valley (MacNeish n.d. in Flannery & Sabloff, 2009, p. 15).

The site, in a tributary canyon some 2 km west of the village of Chilac, belongs to the Abejas phase and dates to ca. 3000 B.C. There MacNeish recovered part of an oval shelter 3.9 m by 5.3 m in extent, with its base excavated 60 cm into sterile clay. The flat "floor area" within the excavated base was only 6 sq m in extent-about one-fourth the size of the smallest Early Formative houses for which we have any evidence...On the basis of the postmold pattern, MacNeish...reconstructs the shelter as having a central ridge pole supported by two uprights only 15 cm in diameter, and accompanied by "leaners" coming in at an angle from the sides of the shelter. No evidence of daub or plastered mud

was found, and a dozen more test excavations at the site failed to produce another shelter. In other words, as late as 3000 B.C., we still have no evidence for the 24-35 sq m, rectangular, wattle-and-daub house with four corner posts which was so abundant in Mesoamerica by 1000 B.C. (Flannery & Sabloff, 2009, pp. 15-16)

Other information related to the research can be found from regions where there is evidence for the earliest model of peasant housing. The evidence of later stages suggests that the model persisted without much change for millennia, and this can be found by comparing a database of house types, units and forms, such as prepared for this thesis with current vernacular techniques, showing that these have persisted in rural areas without much change despite the increasing pressures of modern life. The following regions offer good evidence for this approach.

3.3.1.1.2 *The Valley of Oaxaca*

The valley of Oaxaca includes many large, medium and small sites that have sustained a vast population in a wide territory. It is also an area that has sites which have been continuously excavated and where information about houses has been properly excavated. It is thus possible to have information related to Early Formative houses in Oaxaca, with some proper estimation of forms, building elements, and even the organic materials used.

In the period we call the Tierras Largas phase (1400-1150 B.C.), there was a tendency to use small posts (10-15cm in diameter) and more of them (up to an estimated 20-25 posts per house in some cases). This might be because these early houses developed out of still-earlier shelters...which used multiple small "leaners." At any rate, during the subsequent San Jose phase (1150-850 B.C) there was a trend toward the use of fewer posts and larger ones (20-25 cm in diameter). The four corner posts in a San Jose phase house were normally the largest, and where additional posts were added for stability or to frame a doorway, they were usually smaller (15 cm or less). (Flannery & Sabloff, 2009, pp. 18-19)

In the San Jose phase, all of the identifiable burnt posts recovered were of pine, being a resistant material due to its high resin content and because it can easily be found in large straight shapes, although it was not an immediate material to hand and a 20 km trip to the hills would be needed (Flannery & Sabloff, 2009, p. 19). Also there is some evidence of burned daub fragments with pole and rope impressions, and burned samples of reed canary grass (*Phalaris sp.*) suggesting the roof might well have been thatched with this type of grass and that roof joists were lashed with rope to upright corner posts (Flannery & Sabloff, 2009, p. 19).

The walls of Early Formative houses in Oaxaca were built of finger-sized reeds or canes lashed together in bundles. Once again, *Phalaris* seems to have been used, although *Phragmites* is also a possibility for some of the larger canes. Over these "wattle" walls went a layer of clay "daub" which was smoothed and sometimes even burnished. Some burned fragments show that house corners were square. Although some builders were content to leave the clay surface smoothed or lightly burnished, many others added a layer of limey whitewash, apparently over the entire house. This whitewash, which has sufficient lime in it to react to hydrochloric acid, often has the thickness and gloss of a pottery slip; its colour varies from true white to ivory, yellowish, or pinkish white. We have not yet determined whether the difference between plain and whitewashed houses is functional (for example, between residences and cook shacks) or social (that is, between higher- or lower status families). (Flannery & Sabloff, 2009, p. 19)

3.3.1.1.3 *Valleys of Central Mexico and Puebla*

In the central valleys of México and Puebla similar examples can be found. In the Valley of Tehuacán excavations on villages of the Ajalpan phase (1500-850 ac) and the Santa Maria phase (up to ca. 500 ac.) have revealed burnt daub fragments similar to those from the Valley of Oaxaca (MacNeish, 1962 in Flannery & Sabloff, 2009, p. 21). Also some partial house plans from the Early Formative village of Coapexco in the Valley of México, at 2600 m on the lower slopes of Mt. Ixtaccihuatl have been recovered. Most suggest rectangular floor plans, and a large example recovered gives estimates of roofed/unroofed area (Flannery & Sabloff, 2009, p. 21). "Depending on certain assumptions concerning the ratio of roofed area to unroofed courtyard,

Structure 4 can be estimated between 4 by 4 m and 6 by 7 m” (Tolstoy and Fish, 1973 in Flannery & Sabloff, 2009, p. 21). A floor recovered in the Valley of México shows a well defined hard packed layer of mud with fragments of pumice, black volcanic sand, gravel and shards suggesting a deliberately created pavement (Flannery & Sabloff, 2009, p. 21).

Recent excavation has been undertaken at Tetimpa Puebla (Plunket & Uruñuela, 1998) at an elevation of 2350 m on the slopes of the Popocatepetl volcano, where well preserved households have been recovered after two volcanic eruptions of yellow pumice buried whole settlements. Based on 12 radiocarbon dates remains are estimated to belong to the pre Columbian period between 700 to 850 A.D. (Plunket & Uruñuela, 1998, pp. 287-291). The relevance of such evidence is that the Late Tetimpa phase, which belongs to Late or Terminal Preclassic in central Mexico, was completely buried and abandoned and has thus survived looting or modern development, and also that it falls at the threshold of the urban life period. This site can inform about family size, household patterns, food processing and technology, domestic ritual activity and economic organization (Plunket & Uruñuela, 1998, pp. 291-292).

The remains of this period are particularly interesting because the rapid abandonment of the settlement in the face of disaster and the preservation of the buildings and activity areas under layers of volcanic deposits provide an extraordinary, almost ethnographic, view of a 2,000-year-old setting... Although we cannot yet calculate the maximum extent of the occupation, we have tentatively estimated that the minimum area covered by the Tetimpa settlement was at least 2 km². Given the variation in household density, this suggests a population of perhaps 400 to 600 families, or between 2,000 and 3,000 people. (Plunket & Uruñuela, 1998, pp. 291-293)

Ten domestic structures or groups of structures have been explored near Tetimpa and the compounds follow a standard pattern: “They consist of two to three structures set at right angles to one another around a central patio” (see figure 3-5) (Plunket & Uruñuela, 1998, pp. 293-294).

Shading indicates burned areas or ash; slanted lines denote pottery fragments. Number refers to individual artifacts. Features 5 and 6 are cuexcomates. Highlight of cuexcomates for this research only

Figure 3-5: Plan of house compound at Tetimpa, taken from Plunket & Uruñuela, 1998, pp. 297, Figure 8.

They are wattle-and-daub structures, 70-90 cm high, in a talud tablero system (sloping wall topped by a carved horizontal panel) (see figure 3-6) and with a central staircase framed by simple alfardas (rafters) (Plunket & Uruñuela, 1998, pp. 294-295). The compounds are aligned, with the bigger room opposite to the entrance to the compound and the other two rooms flanking the main room. Where there are only two buildings

the left flank was usually occupied “...by a group of small individual mud and wicker storage bins known as *cuexcomates*” (Plunket & Uruñuela, 1998, pp. 295-296).

Figure 3-6: Diagram of talud-tablero

The reconstructed room sizes in most cases are based on the evident symmetry of the buildings and the observation that the interior room area is usually about 45 percent of the basal dimensions of the platform itself, although there is some variation in this relationship (between 39 and 47 percent), depending primarily on the height of the platform.

The size of main rooms has a bimodal distribution, one group ranging between 7.5 and 9.5 m² and the other between 16 and 17.5 m². Operation 8, in the Petlachica area, appears to be a special case. The main room had about 43 m² of roofed space, more than twice the size of the largest rooms at the other compounds. (Plunket & Uruñuela, 1998, p. 296)

Although much work and discussion has been carried out about many building features and elements, there is no evidence of a thatched roof or of other organic materials used. Although wattle-and-daub is mentioned, neither patterns of post-moulds or cane and rope impressions, joist elements nor particular building plants have been identified or reported. Although roofed structures are mentioned, the technique or material they used to build the roofs is not known.

The households of Tetimpa provide evidence for the development of new storage systems that are probably a consequence of the need for increased productivity. In the Early Tetimpa houses storage was primarily subterranean, either in bell-shaped pits or in large ollas embedded in the patio floors, but during the Late Tetimpa phase we have documented a greater variety of storage systems

including bell-shaped pits, partially underground roofed storage structures, and most significantly, the above-ground *cuexcomates* that can still be found in the more remote villages around the volcano. The experimentation involved in the development of new types of storage facilities evident in the Late Tetimpa phase may reflect new possibilities for the accumulation of wealth in a changing political environment. (Plunket & Uruñuela, 1998, p. 306)

3.3.1.1.4 *South East Regions*

Other relevant evidence of early houses comes from the southeast regions in the central depression of Chiapas, at Chiapa de Corzo, a region neighbouring the nodo Mixteca (Mixteca knot). Early to Middle Formative houses were made of wattle-and-daub with well finished surfaces, also presumed to be rectangular in outline, and some have fieldstone foundations (Lowe, 1979 in Flannery & Sabloff, 2009, p. 23). Also along the Guatemalan Pacific Coast there is evidence of daub chunks that belong to the Middle Formative (Conchas phase) at la Victoria Chiapa de Corzo (Coe, 1961 in Flannery & Sabloff, 2009, p. 23), where corner fragments of daub show rounded corners and impressions of finger sized canes lashed close together and touching each other (Flannery & Sabloff, 2009, p. 23). Also nearby in Salinas La Blanca, three postmolds of a house were found, two of which were 70 cm apart and a third lay almost 3 m away in a near perpendicular position related to the others. Here post diameters were 10-15 cm, tapering to a pointed base (Flannery & Sabloff, 2009, p. 23).

Additionally, in the northeast limits of Mesoamerica in an area of transition with the northern cultures in the Sierra of Tamaulipas, twenty-one sites from the Almagre to the Los Angeles phases reveal wattle-and-daub houses (MacNeish, 1958, p. 130). “Circular boulder house-platforms without steps were confined to the Laguna Phase, while circular masonry house-platforms occurred from Laguna through La Salta times...and evidence of circular post structure was found at a Los Angeles component” (MacNeish, 1958, p. 130). Wattle-and-daub evidence shows the beginning of relatively permanent structures in the Almagre phase, while the Laguna phase reflects a variety and number of diverse structures, although wattle-and-daub houses endure (MacNeish, 1958, p. 130).

3.3.1.1.5 *Western Region*

Another less explored but highly remarkable area in terms of house evidence is the middle-west region in the westernmost limits of Mesoamerica. The western region is relatively new to archaeologists and despite increasing research undertaken in the last half of the twentieth century, debate among scholars and archaeologists exists concerning whether this region belongs to or developed separately from Mesoamerica (Hers, 1991; Nelson, 2004, pp. 61-62; Pollard, 1997, p. 348; Schöndube, 1987; Weigand, 1985, 1991). Moreover, the issue has moved scholars to question, “the significance of the trait list for Mesoamerica as a cultural region originally proposed by Kirchhoff, which relied heavily upon sixteenth-century documents and biased the definition towards those traits associated with Aztec society” (Pollard, 1997, p. 348).

To better explain the above statement, in 1939 Isabel Kelly found some ceramic remains related to the Teotihuacan style of the central valleys of Mexico in a looted grave in the coastal plains of Colima (Reyes & Barrientos, p.1). Previously it had been assumed that the western area of Mexico remained excluded from the Olmec influence (the Olmec were the first civilisation of Mesoamerica) so marked in the later cultures that succeeded them in the rest of Mesoamerica. For instance, in the Mayan peninsula the valleys of Chiapas, and Central valleys of Oaxaca, Puebla and Mexico were outside the Aztec, Tarascan, and Quiché empires, and consequently were viewed as being backward or degenerate. “The earliest horizon was identified with Gulf Coast Olmec society, often characterized as the sole source of Mesoamerican elite ideology” (Pollard, 1997, p. 349).

Some of the Olmec traits not found in the western cultures during early phases are monumental sculpture, colossal heads, jade carving, atlante-like (totemic) stone columns, stone graves, mosaic floors, concave stone mirrors (of obsidian and hematite), midden work, terrace work, platforms above terraces, urban planning particularly aligned to astronomic calculations, and a shared calendar system (Piña Chán, 1978, in Reyes & Barrientos, pp. 1-2). Because of this Otto Schöndube proposed a cultural sequence different from the rest of Mesoamerica (Schöndube, 1976 in Reyes & Barrientos, p. 3). This sequence had two main phases: Phase I, subdivided into Phase Ia (2400 to 1500 B.C.) and Phase Ib (500 B.C to 600 A.D.) (Reyes & Barrientos, p. 3; Schöndube, 1995). These phases show singular features and evidence of a distant

relationship with the northern cultures of South America. For instance, ceramic hollow figurines, or certain vessel types (gourd shaped) and shaft tomb funerary traditions relate with the Capacha Culture of west coast Ecuador and Colombia (Lathrap, 1973; Reyes & Barrientos, pp. 3-4; Willey, 1962) (see figure 3-7).

Figure 3-7: Pottery house from la Totila Ecuador, after Estrada and Meggers, 1961, p. 922, figure 2,a. Drawing Jaime Rios C

Phase II, also subdivided into IIa (600 to 900/1000 A.D.) and IIb (900/1000 to the Spanish Conquest) comprises the time when influence from Mesoamerica becomes more evident in a shift in ceramic and mortuary traditions, in the appearance of a variety of deities from the Mesoamerican pantheon, as well as in an increase in population, urban development, and thus a more complex social organization. These are all traits that are linked with Mesoamerica (Reyes & Barrientos, p. 4).

The first large archaeological project in the middle-west region was carried out in 1956. It showed the first solid evidence of formal architecture from the Formative period (approx 500 B.C., see figure 3-3), called by Dr. Charles Kelley the Gauchimontones (circular stepped pyramids) (Reyes & Barrientos, p. 7). There is also

evidence of clay model houses with thatching appearance similar to the Capacha shaft tomb ceramic model tradition, sometimes arranged in a circle round on one of these pyramids (Kelly, 1980) (figure 3-8).

Figure 3-8: Clay model of four houses round a circular stepped pyramid from Nayarit, approx 500 B.C. Drawings after von Winning (1996, p. 152)

Most of these models are now found in art collections and museums and very possibly have been obtained by illegal excavation, and probably without scientific control (Furst, 1965). Additionally, extensive counterfeiting has also questioned the authenticity of such collections (Meighan, 1974, p. 1254). However, many of these clay models have, through the study of art history, been correlated with archaeological excavations of the architectural tradition of these circular stepped pyramid complexes (figure 3-9) (von Winning et al., 1996, p. 15). Hasso von Winning has made an extensive study and compilation in this regard (von Winning, 1996) (see figure 3-8 and

3-9). The models also show clear evidence of thatched pitched roofs, as can be seen in the Formative to Classic period examples in figure 3-3 (see section 3.3.1.2).

Figure 3-9: Map after Von Winning (1996, figure 3) showing how houses are arranged around circular stepped pyramids.

3.3.1.2 Evidence of Thatched Building in Classic and Post-Classic Mesoamerica

Most of the reliable ceramic figurines of house models are related to the later phases of the Classic (500 B.C. to 800 A.D.) to Postclassic (800 A.D. to 1500 A.D.) periods. There are some striking examples from Colima (see figure 3-10). In this art some of the features of the houses, such as terraced structures, the use of four-sided pitched roofs, circular, semi-circular and square walls, open walls and the lack of windows are all present.

(A) Temple and brazier, Postclassic, El Chanal, Colima; (B) Temple, Postclassic, El Chanal Colima; (C) Top of vessel in form of house, Late Classic, Colima, Colima; (D) Houses, Postclassic, El Chanal, Colima; all in Museo Regional de Historia de Colima.

Figure 3-10: Clay models after Olay & Reyes (2001). Drawings Jaime Rios C.

Apart from the clay figures of the west coast, there are other ethnographical records of many structures used as buildings found in “amoxтли” codex (bi-fold books). For this research particular interest is paid to the so called Mixtec group of codex (Sisson, 1983). The Mixtec group of codex are the only group of evidence in the form of painted books attributed to the areas of the research and that are dated and accepted as Pre-Columbian, the other defined group of codex are either from a different area such as Mayan or belong to a latter chronology already influenced by the Spanish contact.

Although the focus remains on the study of architectural forms from ethnographic records there is useful discussion on how these painted landscapes relate to archaeological patterns (Pohl & Byland, 1990). There is increasing literature about the

codex and the many approaches to studying them (Smith & Boone, 2005), but for the present chapter a review and identification of house types seems to be the most effective approach (figure 3-11).

A) Codex Fejérváry-Mayer, Plate 30, B) Codex Zouche-Nuttall, Plate 9, C) Codex Zouche-Nuttall, Plate 45, D) Codex Egerton-Sánchez, plate 27, E) Codex Vaticanus B, Plate 71.

Figure 3-11: Examples of thatch roof typologies from Pre Columbian codex

The codex under focus are Codex Fejervary-Mayer (Jansen et al., 1994), Codex Borgia (Anders et al., 1993), Codex Nuttall (Nuttall, 1974), Codex Laud (Anders & Jansen, 1994), Codex Egerton-Sanchez (Jansen, 1994), Codex Vaticano-Rios (Anders & Jansen, 1993). All are considered pre Columbian bi-fold books, and all are related with the Mixteca group of Codex which fall into the central valleys of Oaxaca and Puebla.

In reviewing such documents many types of buildings related to thatch can be found, although there are other building forms, such as those related to flat roofs, which are not discussed here. Some of the representations of thatched buildings are over steep platforms, others show smaller platforms, some with and some without stairs, and some which seem to have no type of foundations. Some have walls that suggest solid

material with finished surfaces, while others have detailed carved images, although this might be as much part of the language of the printed books rather than a building feature. Finally, and the most interesting part for this research, is the richness in which roofs are represented. Some are very steep, some look conical, some have two and four pitches, and some are elaborate enough to suggest a roof structure with top-window ventilation. This suggests that by this time thatched roofs were in widespread use with many architectural and structural variations.

3.3.2 Thatching During the Colonial Period in Mexico (1510-1821)

For this research the Colonial period has been defined as lying within two major events that defined what later became known as Mexico. The beginnings of this period start with the discovery of America by Christopher Columbus in 1492 and the subsequent arrival of Hernán Cortés in 1510 to pursue the military and ideological conquest of what is Mexico today. The end of the period is the achieving of independence as a Republic by Mexico in 1821. Here the colonial period is relevant because of the phenomena of intercultural exchange that this region of the world experienced within this period. This resulted in these external influences contributing to local architectural expressions, something that can be recognized culturally and architectonically as syncretism (Edgerton & de Lara, 2001; Moreno, 1999, pp. 263-264).

The first forms of syncretism are found in many forms of art and certainly in some colonial codex (Moreno, 1999), as the result of the use of old principles, such as a pictographic system found in pre-Columbian codex or amoxltli (book in Nahuatl, the Aztec language), and the new principles that influenced the former canons and systems (Moreno, 1999, pp. 263-264). This corpus of colonial codex in addition to the extensive surveys carried out by the first missionaries served to create the first chronicles, which are now regarded as the first true anthropological and ethnographical works (Marzal, 1993, p. 11). Outstanding amongst these is the work of the Franciscan Friar Bernardino de Sahagún, with his *Historia General de las Cosas de la Nueva España* (de Sahagún et al., 1975). Originally written in Nahuatl and Spanish this is mostly about the cultures of the central Mexican Valleys. Also of note are the works of the Dominican Toribio de Benavente “Motolinía” (de Benavente, 2010; Duran, 1994; de Landa; 2011; del Castillo et al., 2012).

These chronicles cover a vast number of topics and in general can be catalogued as military, political, religious and common day chronicles. However, despite the great historical value of these documents, overall there is in them scant information related to houses, less about roofs and barely anything about thatching materials and techniques. Nonetheless, the information they contain is useful and relevant as some ethnographic record of thatch uses in buildings can be found.

Syncretism was a new form of communication (a type of communion between two or more styles) to use the best resources to transmit new ideas but with respect for old knowledge at the same time. This was successfully achieved in expressions such as bi-fold books and the chronicles described above. Architecture as a powerful form of expression also experienced the phenomenon of syncretism in the New World, and along with expression in other arts soon became an important tool for the ruling Spanish to convert people to new ideologies.

Syncretism in Mexico experienced Spanish influence during this period, bringing with it the additional cultural background of the Arabs as a result of over 700 years of occupation in the Spanish peninsula. This influence is clearly reflected in the Spanish architecture that was brought to Mexico, finding expression in *mudejar* (Spanish Muslim Arab) art and carpentry (Angulo & Hall, 1935). Syncretism therefore, has being extensively studied in official architecture, such as the religious buildings of the XVI century (Kubler, 1983), XVII and XVIII centuries (Bérchez, 1992), and, as mentioned, in *mudejar* art (Angulo & Hall, 1935; Baird, 1962; Edgerton & de Lara, 2001).

Despite the lack of official records, there are traces of other migrations, such as those of diverse ethnic groups from Asia (mostly the Philippines) and Africa (mostly the Yoruba people of the west coast) as a consequence of the same colonial rule. Groups from the Philippines mostly entered illegally but by their own will (Bruman, 1945; Cook & Borah, 1971) and Africans mostly came as slaves (Cook & Borah, 1971; Pi-Sunyer, 1957; Vasquez, 2010). Although there are few records of this phenomenon, some authors state that Mexico held a large immigrant population that was widespread in the country but that this was highly denied (Banks, 2005, pp. 202-203; Ben III, 2000; Hernández, 2004, p. 1539). Consequently, there is scant documentation of these events and such migrations melted or passed almost unnoticed. Moreover, they were

even deemed as irrelevant to history (Vaughn, 2005, p. 118). Today the regions that contain the largest populations of Asiatic and African races are the West Coast from Nayarit to Oaxaca.

However, what is relevant for this research is the syncretism of vernacular architecture. Although this was not deliberate it evolved a more subtle and unnoticed syncretism of building ideas in the vernacular, suitable for the local environment and materials (Edwards, 1983, p. 181). These are all important for the present research as such migrations as discussed above mostly became adapted to the rural environment (Fuller, 2003, p. 4). Moreover, looking at this type of syncretism in the research it is possible to trace adaptability to change in the diverse context of the vernacular. In terms of the focus of this research, the differences between case studies, particularly related to rural or urban/suburban building expressions, can be seen as a result of syncretism, as the vernacular adapted to new settings or materials. The pros and cons of the changes brought about by such syncretic responses may be measured in the case studies related to their environmental impact assessment to reveal whether the effect of such responses has been positive or negative overall.

Since colonial chronicles are huge, the following information is organized not as a formal chronology, nor by region or ethnic group, but rather focuses on passages, drawings, descriptions, and other historical records that help to fill gaps in historical knowledge about thatched buildings, the technologies and the materials and the cultures engaged in such traditions.

3.3.2.1 Ethnographic Information about Thatched Buildings in the Areas of Research during the Colonial Period

The city of Tututepec dominated an empire covering 20,000 km² in the foot hills of the Sierra Madre del Sur, 15 km inland from the southern pacific coast in Oaxaca, a region formerly dominated by the Mixtec Empire, and once the capital of one of the most powerful polities in Mexico (Joyce, 2009, p. 2). Pedro de Alvarado who went on to conquer what is known today as Guatemala passed Tututepec early in 1522 (Joyce et al., 2004).

In February of 1522, Alvarado arrived in Tututepec with 200 Spanish soldiers and an army of thousands of Zapotecs from Tehuantepec. In describing Alvarados's arrival in the coastal city, Díaz del Castillo stated that "they were taken to reside in the most populated part of the town, where the ruler had his altars and his largest houses, and where the houses were very close together and made of thatch..." (Joyce, 2009, p. 3)

The vast majority of Mixtecs (*ñandahi*) and Zapotecs (*peniqueche*) at the time of the Spanish were commoners.

Commoners wore modest clothing, usually made of maguey fibre, and lived in houses made of thatch and wattle and daub, sometimes with stone or adobe foundations...The patio was the focal point of daily activities where family socialized, women wove textiles and prepared food, men returned after the day in the fields, and children played. (Joyce, 2009, p. 49)

The sixteenth-century *Relaciones Geográficas* also describes the dwellings found in the Zapotec region near the villages of Atlatlauca and Tecuicuilco, not far from Mitla and close to modern Oaxaca city (Acuña, 1984 [1580] in González Licón et al., 2004, p. 100).

Houses of the common people are very small, with one or two ground-level rooms where two or three Indians used to live with their wives and children. Houses of principals and chiefs are larger because they have more rooms and larger patios. Some of them have two and three patios and other rooms around them, with no doors, were used as antechambers...all materials needed to build the houses such as wood, limestone and thatch for the roofs are nearby. (González Licón et al., 2004, p. 100)

In contrast official buildings and palaces in Oaxaca seem to have had flat solid roofs (González Licón et al., 2004). As in other regions, interesting architectural features are stated in colonial descriptions about the palace of Nezahualpilli, the prince of the Mexican capital Tenochtitlan, today Mexico City (Torquemada (1975-83 [1615]) in Evans, 2004, p. 27).

They said that he was a great astrologer and valued much understanding the movements of the celestial bodies...and at night he would go up to the flat roofs of his palace and from there watched the stars...At least I know to have

seen a place in his houses, on top of the flat roofs for four walls no higher or wider than a vara, with enough room for one man lying down and in each corner there was a hole where one put a pole from which was draped a canopy. And asking ‘What was this for?’ one of his grandchildren (who was showing me through the house) told me that it was from the king Nezahualpilli for when at night he was with his astrologers and watched the heaven and the stars, from where I inferred to be true that which people said of him; and I think that raising the walls a vara off the surface and adding a ceiling of cotton or silk [awnings]...offered a better way of observing the sky. (Torquemada (1975-83 [1615]) in Evans, 2004, p. 27)

The difference in status between official and ordinary buildings, and between rural and urban clusters in Mesoamerican societies, is clear regarding monumental buildings, such as the pyramids. Technologies were selected because of being the best solution for the building purpose (effectiveness, availability, durability). In that sense thatch must have fitted with all scenarios, as there are insights into its use in diverse spaces and for distinct purposes. Of relevance here are the “*cuezcomates or cuexcomates*” (above ground granaries) in the chronicles about Nezahualpilli’s palaces and his humanitarian personality.

He had made an observatory in his palace, covered with lattices so that one could see and not be seen, and from there he used to watch the people who came to the markets and on seeing some poorly dressed woman with children he would confer with his servants to learn about her and her needs and would clothe her and her children and feed them from the granaries for a year; this was very common for him. (Torquemada 1:261 in Evans, 2004, p. 28)

Alva Ixtlilxóchitl (1600–1640) also wrote about the same granaries and palaces when referring to the humbleness of Nezahualpilli (Evans, 2004).

For the part that falls to the north of those houses and near the kitchens, were granaries of admirable size, in which the king had a considerable quantity of maize and other grains in order to use in famine years [such as 1505 and 1506, when Nezahualpilli opened the granaries for his subjects]. Each granary held four or five thousand fanegas, and all was in such good order and well-ventilated that the grain lasted many years. On the south side were the gardens and mazes,

that with the height and size of the palace were guarded from cold winds from the north, and on the east side there was a pond with an aviary. (Evans, 2004, pp. 27-28)

A fanega means a sack (from the Arabic Faca) (Thomas & Sayahi, 2005, p. 38) and is a traditional Spanish and Portuguese unit of either volume or weight introduced into the New World during the XVI century (Custardoy et al., 2010, p. 161; María, 2013, p. 61). A fanega can be translated as 12 almudes or 48 cuartillos (Denson, 1975, p. 259) however, it is also related to a land unit (area), meaning the land area that can be planted with a fanega of seeds (for instance 'x' hectares per one fanega of maize seeds). Therefore, the unit varied widely according to purpose, time and region. For instance, in Coahuila in 1786 a fanega (volume) of 12 almudes amounted to 55.5 litres (4.625 litres one almud) (Corona Pérez, 2011, p. 131), while a fanega of wheat was rated between 150 pounds and even 30% less, or approximately 2.5 bushels in Alta California by 1846 (Gerber, 1993, p. 46). Furthermore, around the same time (1850s) in San Luis Potosi a fanega of maize was stated as being equal to 1 sack or ½ carga or 12 almudes, where 1 almud is 7.6 litres, making a fanega equal to 91 litres (Bazant, 1974, pp. 94-95). On the other hand, a vara (stick or pole) of Iberian origin is a unit of distance also introduced into the New World in the XVI century. It also varied widely, for instance while the Portuguese vara was stated to be 110 centimetres, the Spanish vara was defined as 83.6 centimetres (Castro, 2013, pp. 1137-1138). These units were implanted in the Spanish empires as far as the Philippines where such linear units as vara, braza, caballeria, pie and linea were also introduced in weekday marketplaces called tianguis (Quiason, 1985, p. 30).

In the Colonial Codice Florentino (Florentine Codex) (de Sahagún & de la Nación, 1979) there are illustrations of houses which give an idea of the roofs used. Some models were certainly pre-Columbian and survived the Colonial times (see Figure 3.12)

Figure 3-12: Houses in the Florentine codex after Rubio (1982). Drawings Jaime Rios C.

3.3.2.2 *Syncretism of Thatched Building Technologies in Colonial Mexico*

Another source of syncretism occurs in languages and certainly within vernacular languages, such as the African influence on the Mexican-Spanish language (Althoff, 1994; Beltrán, 1994). There are also some words that can be traced to an Asiatic origin. Today words such as palapa are widely used in Mexico to describe a woven thatched roof. However, the word palapa is vernacular to the Malayo language of the Philippines, where it also means a banana, or a pulpy leaf with fibrous veins, thus referring to the leaves of both bananas and palms (Gómez-Azpetia, 2006, pp. 3-4; Manuel, 1958, pp. 74-91).

In fact the Philippine migration into Mexico is important for the present research as it can be traced back to the first commercial route, which was achieved in 1566 (Schurz, 1917, p. 111) and established during the 16th, 17th and 18th centuries between Manila and Acapulco, in the search for new routes of commerce between East Asia and Western Europe via Mexico (Bruman, 1945, p. 214; Schurz, 1918, p. 18). What is truly interesting is that syncretism happened both ways. Food is a good example of this, since dishes of both sides were highly enriched by new plants and ingredients, leading

to some fruits being wrongly attributed to one continent or the other. The most intriguing case is the coconut *Cocos nucifera* L. which has interested scholars because of the early presence of the plant in the Americas. New information coming to light reinforces older findings and clearly points to the Philippines as its point of introduction into the Americas (Bruman, 1945, pp. 214-215; Clement et al., 2013, p. 344). Despite such discussions, what is certain is that of the two varieties, one is from Africa and the other from Asian and Polynesian origins (Clement et al., 2013; Zizumbo-Villarreal & Colunga-GarcíaMarín, 2008). Whether or not the plant did enter the country previous to the Spanish conquest, what is true is that people from the Philippines brought a whole background with them about palm uses.

In later years the Philippine people were brought to Mexico in numbers, mostly as sailors and slaves who jumped out of the boat in the ports of Salagua and Navidad to avoid immigration in the port of Acapulco (Gómez-Azpetia, 2006, p. 3). Such migrations brought many features of their native culture, such as the coconut culture and with it the palm tradition. For instance, a coconut beverage called tuba, extracted from the flowering stalk of a range of palms, is widely popular in Colima (Bruman, 1944; Corona Páez, 2011; Gómez-Azpetia, 2006; Zizumbo-Villarreal & Colunga-GarcíaMarín, 2008), and is very like drinks in both the Philippines and Polynesia (Brady & McGrath, 2010; Chandrasekhar et al., 2012; Marshall & Marshall, 1975; Solieri & Giudici, 2009).

In relationship to vernacular buildings and languages it is also striking that the Polynesian types of building are a good match for their Mexican counterparts. They are made out of triangular framing with roping and binding as a flexible technique more suitable for areas exposed to hurricanes and earthquakes than the rigid framing of the Spanish. Thus eventually the word palapa stopped meaning the leaf itself and became a synonym for thatch, replacing the former words of cayaco in the coast and xacalli in the inland country, both of Nahuatl origin (Gómez-Azpetia, 2006, p. 3).

As a conclusion it can be said that the relevance of language and architecture is clear as a cultural bridge, while for the case of the use of natural materials it becomes even more relevant. Endemic names of plants can enhance a better knowledge of both the properties of the plants and the characteristics of the place, and therefore provides useful information for the use of certain materials in buildings. This endemic,

vernacular, or aboriginal meaning is in many cases preserved by the continuity of the vernacular tradition. In many cases the vernacular language would allow a better understanding of the building, for instance the name of certain houses called *xacalli* means that they are made of materials such as straw (Simeón, 1988). This connection between the place, the language and the building is something that will be of relevance in the following investigation of both the buildings and the plants of which they are formed.

The key findings of this chapter for the thesis are based on archaeological, ethnographical and historical material. The different sources reveal that vernacular buildings in the areas of the research have a very long tradition with very little change for over a thousand years. It would be interesting to determine if this continuity (or the lack of it) is found in some of the case studies and, if so, what are the reasons for it?

Regarding the building examples it can be stated that thatch as a roofing technology is probably more difficult to prove from the archaeological material because of the nature of the fibrous material which decomposes quickly over time, but it is clearly visible in the house models from tombs and is shown to be clearly established in the Colonial codex examples. These show a wide variety of roof forms and types, suggesting that by this time thatch was a mature and widely used technology.

One of the main focuses of the following chapters of this thesis is then to find out the modern situation of both the buildings and the materials in diverse contexts, such as rural and its urban/suburban counterpart. The fieldwork is also intended to give useful data that has been missing in the architectural literature of vernacular thatched houses of Mexico, and its relation to the proper identification of species that will lead in turn to avoiding the need to make assumptions when carrying out the environmental assessment.

SECTION TWO

CHAPTER 4

FIELDWORK ON THREE THATCHING PALM SPECIES ALONG THE TRANS-MEXICAN VOLCANIC BELT

Traditional agricultural lifeways [sic] are on the defensive, with the many instruments of official policy favouring a maximization of productivity and profits in key, target areas and a more incremental transformation elsewhere. The basic issue for debate is long-term sustainability of yields, given the constraints of available capital, market conditions, and social and institutional structures. In those limited areas with good soils, level land, and sufficient water, high potential yields attract persistent capital investment. Elsewhere, soils are indifferent or erodible, and water localized or unreliable, so that capital assistance is sporadic and inconsistent, just enough to stimulate change but inadequate to deal with its consequences. It is here that traditional agroecology and its effectiveness over time assume critical importance...(Butzer, 1991, p. 139)

In this chapter the focus is on particular species of palms (Aracaceae) as an agro-building material for thatching. In terms of the introductory quotation, the importance of regarding thatching palms as productive agro-materials for the communities that work with them is crucial, since one aspect of debate is the productivity of land, its yield factors, and the system or systems of non-edible plants (Butzer, 1991). It is these that give rise to vernacular traditions, such as the ones being examined here. The investigation of the palm types in the fieldwork described in this chapter is based on observation, surveys of palm plantations and thatched buildings and structured interviews with those involved in growing and using the materials. The fieldwork takes place in regions selected through the historic enquiry into vernacular thatch building traditions. Although the main material investigated is palm, other complementary agro-building materials such as grasses or reed stalks, branches from trees and bushes, vines and fibrous plants for binding, cording and lashing, and hardwood materials for

structures are also part of the traditions being investigated. These are considered important but secondary given the present scope of the field work, however, where possible, surveys of these related building materials are also offered in a summarized form.

Throughout, the information presented for each plant is based on the fieldwork supported by other biological, geographical, and anthropological studies. These break down into paleo-ecological (Piperno et al., 2007, pp. 11877-11879), paleo-ethnobotanical (Berrío et al, 2006; Merlin, 2003, p. 298), ethno-ecological (Joyal, 1996a), biogeographic (Morrone, 2006, p. 467), maps, charts and studies of place names (toponimia) (Alavez Chávez, 1988; Smith & Boone, 2005), studies on archaeological and cultural anthropology (Plunket & Uruñuela, 2005), and studies of cultural ecology and traditional agro-ecology (Butzer, 1991).

As an example, paleoethnobotany as a subfield of ethnobotany is useful for elucidating the past relationships between humans and plants through the study of plant remains from an archaeological viewpoint (Pearsall 1989 found in Merlin, 2003, pp. 297-298). In the context of Mexico, the study and re-construction of these paleo-environments enable a better understanding of the dynamic character of natural environments and adaptation and the success of pre-Columbian cultures and societies, for instance in Mesoamerica (Berrío et al., 2006). It is also relevant to undertake ethnobotanical fieldwork along with ethnographical studies as a framework for investigating diverse fields related to indigenous knowledge (Heinrich et al., 1998, pp. 1861-1870), as well acknowledging the importance of ethnobotanical research for its relative cultural value (Hoffman & Gallaher, 2008, p. 201). This also suggests the importance of relying on more scientific quantitative methodologies in the fieldwork. Although quantitative approaches were once not current within ethnobotany, they have been followed more recently because of an increasing need to recognize the relevance of ethnobotanical investigation for global strategies for biodiversity conservation. A quantitative approach is important when addressing issues such as threat and loss of species, pressure over natural environments, and impacts of the use of plants (de Albuquerque & Hanazaki, 2009, p. 654).

Complementing the importance of these theoretical frameworks for the present chapter, there is also a need to establish a better categorization of the vernacular plants

and traditions under investigation. The chapter sections are, therefore, divided into the general ecology of the palms, followed by a study of the three main endemic palm species and their main geographical regions, with a particular emphasis on the localities where palm is an endemic material for thatching. The chapter ends with consideration of thatched granaries as an example of vernacular building, where these are found and the plants used in their construction.

The four regions under consideration fall within the macro geographical region of the Trans Mexican Volcanic Belt (TMVB). Two are in the westernmost area along the shoreline of the states of Jalisco and Colima. The focus in here is on two regions; one is the Bahía de Banderas region, in the municipality of Cabo Corrientes, Jalisco, and the second is in the municipality of Manzanillo, Colima and its neighboring municipality of Cihuatlán, Jalisco. The other two regions related to the investigation fall within the boundaries of the TMVB and the Balsas River Basin on its east side. The third is in the Mixteca Baja region, in the municipality of San Diego La Mesa, in Puebla State, and finally, although of secondary importance in the study, the fourth region surveyed was the locality of Chalcatzingo in the municipality of Jantetelco in the state of Morelos (see figures 4-1, 4-2).

Figure 4-1: Map of areas of study by state and regions

Figure 4-2: Contour map of Mexico after Wilson, 1897 and cross section of the Trans Mexican Volcanic Belt (this research)

The importance of researching in these particular areas is based on three key points:

- 1) An environmental setting that provides a place where palm species develop endemically;
- 2) A clear, long running and un-interrupted cultural tradition of using palm for thatching;
- 3) The relevance of such environments to vernacular dwelling because of the contemporary work using locally grown materials in the selected areas.

Each area selected is also different from the others in terms of their environmental settings and cultural background, and the fact that for each case very little research has been undertaken. For instance, for the prehistory of the Puebla region in the middle west of Mesoamerica (Plunket & Uruñuela, 2005) issues range from a lack of ethnographical records documenting migrations to the problem of data collection, calibration and categorization of societies (Callaghan, 2003, pp. 351-365). There is also a lack of ethnobotanical information on plants and their importance for sustainable management in the selected environments (Benz et al., 2000, p. 185; B. Benz et al., 1996, pp. 1-16; Callaghan, 2003, pp. 797-798). Even more important for the present investigation, there is a lack of architectural research about palm as a thatching material, either in the selected regions or elsewhere (Joyal, 1996a, pp. 429-444; Lopez-Toledo et al., 2011, pp. 1902-1904; McKillop, 1996, pp. 278-294; Pulido et al., 2007, pp. 139-148). In fact, very little work has been done from the architectural viewpoint on thatching technologies and their related materials worldwide, whether of palm or other agro-forestry building materials (Fearn, 2004; C. Flores & Ashton, 2000, pp. 267-276; Kimura, 1994, pp. 900-907; Martínez-Ballesté et al., 2006; Yates, 2006).

This investigation consisted of three levels of fieldwork enquiry:

- 1) For the first level of the fieldwork a survey in the selected regions was undertaken to narrow the list of potential places of study and associated participants, and to identify the species being investigated. A general mapping and classifying of building typologies was made to help understand the technologies, processes, management and materials related to the use of each identified palm and to determine the selection of building units and case studies (see sections 5.1, 5.2 and 5.3).

2) The second level of the fieldwork was to carry out structured interviews with selected participants, and to document the collection, processing and use of each particular palm and other agro-building materials related to the palm thatching technology.

3) Finally, the third level was the survey and inventory of the selected buildings as case studies (chapter 5), which complete the information needed for the environmental analysis (chapter 6).

As a result of the first two levels of fieldwork, the present chapter offers summarized tables of the general features and productive cycles, weights and sizes, harvest units and yield factors, related agro-forestry materials as well as the means and load capacities of the transportation related to each palm species in the case studies.

Several trips were made in each selected area of study to gather the information needed for the environmental assessment. Two fieldtrips for *A. guacuyule* in the West Coast, Jalisco were undertaken in June 2011 and November 2012 (section 4.2). For the case of *Brahea d.* the first fieldtrip was in May 2011 and the second during November 2012 in the Mixteca Baja region of the state of Puebla (section 4.3). For the third palm *Sabal r.* another field trip was undertaken between June–July 2011 in West Coast Colima (section 4.4), Finally a fieldtrip was made to Chalcatzingo Morelos in October 2012 to asses thatched granaries but this information remains secondary as it is not used in the environmental impact assessment. It has been left here for interest as it is a very rare building type (section 4.5)

For all case studies interviews with local experts were made. All the participants gave their consent under the ethics approval parameters administered through the Victoria University of Wellington Human Ethics Committee under the code RM#19463, and examples of full interviews are available in the thesis (Attachment 1).

Material samples were collected for each palm under study and their parts were recorded to aid in identifying the species. This collection was stored and later sent to the department of Biology of the National Autonomous University of Mexico (UNAM) to the expert on Mexican palms, Dr. Hermilo Jorge Quero Rico.

It is also important to clarify the botanical classification and referencing format of any particular species used in the following discussion. For instance; when naming a palm, say the palm *Attalea guacuyule*, it is written as *Attalea guacuyule* (Liebm. ex Mart.)

Zona: which can be understood as: *Attalea* (written always in italics) meaning the genus and *guacuyule* (also in italics and with no capital), meaning the specie. This is then followed by the author; person or group of people who validly published a botanical name, i.e. who first published the name while fulfilling the formal requirements as specified by the International Code of Nomenclature for algae, fungi, and plants (McNeill, 2012). In cases where a species is no longer in its original generic placement (i.e. a new combination of genus and specific epithet), both the author(s) of the original genus placement and those of the new combination are given (the former in parentheses); therefore for *Attalea guacuyule* (Liebm. ex Mart.) Zona; therefore, Liebm. stands for Liebmann, Frederik Michael; 'ex' for ex author (when there is a change of classification as here), Mart. for Martius, Karl Friedrich Philipp von, and Zona for Zona, Scott. Finally it is common that once the full reference has been stated, it is acceptable to abbreviate the name, for instance: *A. guacuyule*.

However, before dealing with the particular case study environments, and since the research focus is on palm as a vernacular material, it is necessary to undertake a basic study of palms.

4.1 General Ecology of Palms and their Relevance to Humans

A review of the general ecology of palms is undertaken as the basic framework for the fieldwork about endemic thatching palms in selected areas of Mexico. As a general statement, palms are among the plant families that have very large and wide applications and uses, and can be seen as one of the most beneficial plants for human development. On the other hand, most of the species worldwide are considered to be wild and suffering from over-exploitation (O'Brien & Kinnaird, 2002; Pavón et al., 2006; Ugent, 2000). Palms (Arecaceae or Palmae) are a family of flowering plants comprising about 2400 species distributed among the tropical and subtropical regions of the world (Govaerts and Dransfield, 2005 found in Baker et al., 2009, p. 240). Palms are still of huge economic relevance, as they have been in the past, as seen in the modern international trade in, for example, oil palm, date palm, coconut, and rattan. With most production happening at the subsistence level, palm has played a major role in many communities in the world (Baker et al., 2009, p. 240).

There has been an increase of interest in ethnobotany and economic botany related to researching useful native plants around the world, which has stimulated research into many plant groups (Balick & Beck, 1990, p. 1). Many of these investigations have been carried out in tropical regions, recognising palm as one of the major groups of useful plants within the tropical and subtropical regions (Balick & Beck, 1990, p. 1).

Because the great morphological diversity of palms is paralleled by a wide range of ecological adaptations and behaviour, it is difficult to make wide generalizations about their ecology, and many aspects such as nutrient cycling, light requirement, soil preferences, and interspecies competition have yet to be investigated in detail (Uhl & Dransfield, 1987, p. 45).

In terms of their general ecology, palms are important components of many types of vegetation in the tropics and subtropics. Some occur in vast stands fully dominating the vegetation, with *Nypa fruticans* in the eastern tropics serving as a remarkable example of palm dominated communities. *Nypa* often forms dense colonies on estuarine muds to the exclusion of dicotyledonous mangrove species which can mingle with the palm in other situations (Uhl & Dransfield, 1987, p. 45). Pure stands of *Nypa* may cover several hundred hectares in parts of Borneo and Sumatra. Such *Nypa* palm forests are of great importance to humans, not only for the plant's many commercial values, but as a mud stabilizer and gas exchanger (Uhl & Dransfield, 1987, p. 45).

Many other examples of huge extensions of palm dominated communities exist in diverse areas of the tropics, outstanding examples being in west Malaysia (*Oncosperma tigillarium* and *Calamus erinaceus*) (Uhl & Dransfield, 1987, p. 45), and the *Raphia taedigera* that grows in great abundance in the landward fringe of the mangroves in the Amazon estuaries (Bouillenne 1930 found in Uhl & Dransfield, 1987, p. 45). *Copernicia alba* forms huge stands on periodic flood lands in adjoining parts of Paraguay, Brazil, Argentina and Bolivia. In Africa *Borassus aethiopum* grows abundantly along rivers and coast lines.

In some cases, human activities and intervention have favoured palm propagation and domination. Examples are the case of *Metroxylon sagu* in New Guinea, or *Hyphaene compressa* in Africa (Uhl & Dransfield, 1987, p. 45). The human factor has also distributed introduced species that have eventually come to dominate some habitats,

for instance, the same *M. Sagu* was introduced into Malaysia and now dominates some wetland habitats (Uhl & Dransfield, 1987, p. 45).

4.1.1 Palm Habitats

Although some palms are found as large stands of single species, the most recurrent form of their ecology occurs as components of mixed tropical and subtropical forests (Uhl & Dransfield, 1987, p. 45). The lowland rain forests of the Sunda shelf (Southeast Asia) and of South and Central America are the richest in palm species. Little work has been carried out on the diversity of species within these forest communities, although some areas are remarkable in this sense. For example, Malaysian Borneo and the Choco region of Colombia can be singled out as extraordinarily rich in palm flora. In the former some 111 species in 20 genera have been reported in a little less than 53,000 hectares, though not in the form of single species dominated communities (Dransfield 1984b found in Uhl & Dransfield, 1987, p. 45), and in central Amazonia a survey plotting palms within 1.2 hectares showed 32 species and 12 genera, and overall 2122 palms per hectare in three distinct soils (Kahn & Castro, 1985, pp. 210-216).

For the present investigation the above examples form a useful background to the general ecology of palms in similar climatic conditions, as most palms in Mexico occur in tropical and subtropical forests. However there are palms found around the world that are adapted to unusual soil types and habitats. These habitats can be ultrabasic rocks like serpentine, with soils rich in heavy metals such as iron, copper, chromium or manganese, which are usually restricted in palm flora, although with rare exceptions (Uhl & Dransfield, 1987, p. 46). For instance, in Palawang Island in the Philippines ultrabasic soils support habitats for a peculiar assemblage of rattans (Uhl & Dransfield, 1987, p. 46). Some other unusual examples of palms have been recorded in poor soils, such as in the “kerangas” of Borneo (tropical rain forests that have developed on white sands). These “kerangas” are not a prime soil for palms, and yet they carry a varied and important palm flora (Uhl & Dransfield, 1987, p. 46).

More important for this research is the case of limestone soil palms as these are usually found in certain areas within the research study area boundaries where palm use has been reported. This type of soil is another unusual habitat for palms in the eastern

tropics, supporting some rare examples such as *Maxburrieta* (Uhl & Dransfield, 1987, p. 46). However, in the Americas a greater diversity of palms occur on limestone, like *Brahea*, *Gaussia*, *Pseudophoenix*, and species of *Thrinax* and *Coccothrinax*, where drier climates look to be related to a wider abundance of calcareous palms (Uhl & Dransfield, 1987, p. 46).

Finally another group of palms are found in the very different tropical altitude climate conditions. South America is a region with a greater diversity of altitude palms. The two genera *Dictyocarium* and *Ceroxylon* are confined to the mountain forests of the Andes, where *Ceroxylon utile* is the highest palm recorded in the world at above 4,000 m in Colombia (Uhl & Dransfield, 1987, p. 47).

4.1.2 Palm Taxonomy and Fossil Records

“Palms are among the first families of angiosperms that are definitely recognizable in the fossil record” (Moore & Uhl, 1982, p. 4). Although palm biogeography is still considered a discipline in its initial stage, and further research in different areas is needed to provide a clearer understanding of relationships and biogeographical patterns (Uhl & Dransfield, 1987, p. 57), fossil records of palms, although limited, are relevant in suggesting how palms may have originated and distributed. So far data collected have provided an outline of palm evolution from the Cretaceous through to the Neogene (Pan et al., 2006, p. 69), and pollen attributed to palms has been reported as far back as the Apian era (125-112 million years ago) (Pan et al., 2006, p. 69). There is unequivocal evidence in Africa that after the Campanian era (83.5-70.6 million years ago) palms then diversified, becoming widespread. Even though most of the records come from West Africa, many taxa were shared between Africa and the northern parts of South America at that time.

The fossil records have linked the spread of palms to early continental drift. “This [palm] occurrence is early enough that the present geographic distribution of the family must have been considerably influenced by the break-up of the ancient continents of Laurasia and Gondwanaland and the subsequent drifting of their fragments” (Uhl & Dransfield, 1987, p. 57). The current distribution of living endemic palms supports this hypothesis, as high endemism is shown at all taxonomic levels, with some subfamilies, tribes, subtribes, or genera having very restricted distributions

(Uhl & Dransfield, 1987, p. 57). However, there is still much work needed to confirm these theories. “Until recently palms have not been available for study, consequently their diversity has not been widely recognized...many taxonomic studies are still needed and the structuring of a formal hierarchy is not yet complete” (Moore & Uhl, 1982, p. 4).

4.1.3 Current Situation of Palms

In many cases the effect of human activity has caused loss of habitat and over exploitation of palm species. As a result, there are still major threats to the survival of many, with some being highly endangered, and some nearly extinct, or already extinct (Uhl & Dransfield, 1987, p. 51). Endangered palm species were first widely discussed by Lucas and Sygne (1978) in the *IUCN Plant Red Data Book*. Though governments rarely include statistics about it, production of palms is the basis of survival for whole human communities making the palm family of great economic relevance, and “the prospect of extinction should be thus of great concern” (Uhl & Dransfield, 1987, p. 51).

However, unlike most woody tropical plants, palms lend themselves to demographic studies because of their well-organized form of growth, discrete method of flowering, and easily determined age (Sarukhan 1978 found in Joyal, 1996a, p. 447). Wild populations of many species are harvested by traditional peoples for local use and a few species are harvested from the wild as a major source of cash (Balée, 1988; Balick 1988; Fox 1997; Hetch et al. found in Joyal, 1996a, p. 447). However, “despite the cultural and economic importance of palm leaves and their potential for sustainable extraction, little is known about the effects of leaf harvest on palm demography or population dynamics” (Endress et al., 2004, p. 1139).

4.1.4 Geography of Mexican Palms

While modern palm diversity in Africa consists of about 65 species in 14 genera, in the New World within the tropics the flora of palms account for about 550 species in 67 genera, while the Old World excluding Africa has around 1400 species in 100

(Govaerts & Dransfield, 2005 in Henderson, 1997; Pan et al., 2006, p. 69; Uhl & Dransfield, 1987).

According to Uhl and Dransfield (1987) there are six subfamilies around the world, of which three occur in Mexico (Quero, 1992, p. 203): the *Coryphoideae* subfamily, the *Ceroxyloideae*, and the *Arecoideae*. In Mexico, twenty-two genera of native palms have been recorded, although an accurate estimate of the number of species is still not established. Some genera where nomenclatural and taxonomic problems need to be sorted out are still under revision, however around 100 species can be suggested (Quero, 1992, p. 203).

The distribution of palm genera can be grouped in general bands according to the predominant geographical region of each. For instance, in Mexico some genera are typically Mexican as all or most of the species are present in that country, as is the case for *Brahea ssp.* (Quero, 1992, p. 203) (see figure 4-3).

Figure 4-3: Map of *Brahea ssp.* Based on Uhl & Dransfield (1987)

Some other genera such as *Attalea* or *Orbignya* belong to South America with Mexico as their northernmost limit, and thus with a much reduced number of species in Mexico (Quero, 1992, p. 203) (see figure 4-4).

Figure 4-4: Map of Attalea ssp. Based on Uhl & Dransfield (1987)

Also present in Mexico are genera that are mostly Central American such as *Cryosophila* and *Synechanthus*, while some others are typically Antillean (i.e. from the

Antilles), such as *Pseudophoenix*, *Coccothrinax*, *Thrinax*, *Roystonea*, and *Acoelorrhaphe*. Lastly, a few genera such as *Chamaedorea* have a wide distribution in the tropical Americas (Quero, 1992, p. 203), while *Sabal* is mostly a Caribbean genus (Uhl & Dransfield, 1987, p. 213) (see figure 4-5).

Figure 4-5: Map of *Sabal* ssp. Based on Uhl & Dransfield (1987)

4.2 Fieldwork on *A. guacuyule* Palm as a Thatching Material in the West Coast, Jalisco

This section focuses on *A. guacuyule* palm or coyul, cayaco or coquito palm to give its local traditional name in the region of the fieldwork undertaken along the Jalisco west coast.

The selection of the localities of study was based on two key aspects. The first was the relevance of palm as a building material in a specific environment, thus linking it to a human population, and the second was a record of a long tradition of its use. However, this was not an easy task, and although knowing the country's geography and culture, the location of true vernacular examples to be used as case studies only emerged as a result of the first stage of the investigation.

The focus here was on the west coast of the TMVB and in particular the localities south of Puerto Vallarta Jalisco. Although the survey covered all the shoreline of Jalisco, and the neighbouring areas of the shores of Nayarit and Colima, it centred its attention on the southernmost part of the Bahía de Bandera in the localities of Quimixto and Pizota in the municipality of Tomatlán, making this a study of a rural place with no motor way access. Also the survey focused in the southernmost shore of Jalisco in the municipality of Cihuatlán for tis abundance of *A. guacuyule* palm (figure 4-6).

Figure 4-6: Map of area of study of *A. guacuyule* palm in Jalisco, background map from INEGI

The palm *A. guacuyule* used to cover the whole shore of Colima state, in the area of Punta Tehuالمixtle and around Puerto Vallarta, Jalisco, up to San Blas and Chacala in Nayarit (Pennnigton & Sarukhán, 1968; McVaugh, 1993 in Tejero-Díez et al., 2008, p. 68). However, by the 1960s its distribution had clearly been interrupted and its population is now sporadic, and mostly along the bays and coves, in spots no greater than 10km long and 5km wide (Rzedowski & McVaugh, 1966). Although it was once considered a productive plant of high value as it was mostly exploited for oil, it was gradually substituted for by coconut groves, and lately has also suffered impact from developers and planners, mostly as a result of tourism and urban development (Tejero-Díez et al., 2008, p. 68). This has happened despite it being considered a protected plant species by the SEMARNAT (from its Spanish name Secretaria del Medio Ambiente y Recursos Naturales meaning Secretariat of Environment and Natural Resources) under the norm NOM-059-SEMARNAT-2001 (SEMARNAT, 2002, pp. 64-65: Segunda Sección), which establishes the criteria and proceedings for the proper use transport, storage and management of palm leaves.

As a result of this general survey and mapping, diverse palm groves were identified along the west coast in the state of Jalisco (centre), Nayarit (north) and Colima (south) (figure 4-6). Also first contacts were made to identify potential interviewees. As a result the Coyul or Coquito (*Attalea ssp.*) palm groves were established to be the most prominent along the Jalisco shorelines (figure 4-7). The leaves of this are used for thatching. Although Palma Real (*Sabal ssp.*) groves are less abundant it is also a popular palm for thatching, despite the fact that it is sometimes imported from the southern regions of Jalisco, Colima and Michoacán states. Therefore, *Sabal ssp.* palm is covered in the next section, regarding thatching in Colima (4.3), and *Attalea* palm remains the species under focus in this section.

Figure 4-7: Mature A. guacuyule palm grove mixed with endemic forest in the southern shore of Bahía de Banderas

4.2.1 Recognition of *A. guacuyule* Palm Species

For correct identification of the palm species material collections and photographic records of the plants under scrutiny were made on site. The samples collected were leaf, seeds, and flowering stalk when available.

The recognition of *A. guacuyule* palm species was not an easy task due to the poor understanding of the taxonomy of the genus, which is sometimes referred to as *Orbignya guacuyule* or *Orbignya cohune* and also as *Attalea cohune* or *Attalea guacuyule* (Pintaud, 2008, p. 53; Zona 2002).

A further question about this group is whether *Attalea guacuyule* from Mexico is distinct or not from *Attalea cohune* from Guatemala, Belize, Honduras and Nicaragua. Galeano and Bernal (2002) confirmed the presence of typical *Attalea cohune* in the Magdalena valley of Colombia, separated by about 1300 km from the previously known Central American populations (Pintaud, 2008, p. 58).

In the other hand *Orbignya* itself is represented in Mexico by two species, *Orbignya cohune* (Martius) Dahlgren ex Standley in the easternmost states of Tabasco, Chiapas, and Quintana Roo and *Orbignya guacuyule* (Liebmann ex Martius) Hernandez- X. on the westernmost Pacific slopes of Chiapas to Nayarit. There is almost no difference

between the two, with only small differences in the flowers (Quero, 1992, p. 212). Currently this division has happened because *Attalea* is considered a variant from Central America, whereas *Orbignya* is considered South American. Moreover the differences between the variants of the specie *Attalea* are still unclear.

In fact the species under discussion belongs to the *Attalea cohune* complex and was initially named *Orbignya guacuyule*, although afterwards it was catalogued as *Orbignya cohune* and thereafter the genus was separated to *Attalea* and more recently recognized as *Attalea guacuyule* (data corroborated by Dr. Hermilo Quero Rico, Mexican palm expert from the National Autonomous University of Mexico UNAM).

The palm under investigation in this research was confirmed as *Attalea guacuyule* (Liebm. ex Mart.) Zona, and the information corroborated with data from the Missouri Botanical Garden (2014) and Zona (2002).

Monograph of *Attalea guacuyule* (Liebm. ex Mart.) Zona, “Coyul or Cayaco palm”
Bahia de Banderas, Municipality of Cabo Corrientes, Quimixto, Jalisco, Mexico.

Attalea guacuyule. A) general appearance of a young palm; B) detail of the top of the leaf; C) bundle of seeds; D) young shoot; E) penducular bract; F) general appearance of mature palm; G) fruit; H) rachilla with small fruits; I) cross section and basal part of petiole; J) fruit in layers and cross section of the fruit and the seed.

Figure 4-8: Monograph of *A. guacuyule*, Jalisco Mexico

The following information belongs to the second level of the fieldwork and is a summary of the relevant information extracted from the structured interviews and surveys. The information is organized as follows: general aspects of the thatching technology and building typologies; management of the palm and the harvesting process; yield factors and carrying capacities; survey of related materials; and transportation means, loads, weights and units.

4.2.2 General Aspects of *A. guacuyule* Thatching Technology and Building Typologies

It is clear that the use of *A. guacuyule* leaves gives rise to a particular building tradition and related technology due to its particularly large leaves. Therefore, the *A. guacuyule* thatching technique does not need a secondary timber grid on which to fix the palm leaves as each leaf is tied horizontally by its long hard vein or stalk. The vein is tied directly to the main tijera (tie structure), and the leaves are woven overlapped so they make a more waterproof layer (see figure 4-9).

Figure 4-9: Thatching technique of *A. guacuyule*: note that the stalk is used as battens.

This type of thatch can last up to 20 years without maintenance, but sometimes less according to the angle of the roof structure and how tightly it was thatched. It can certainly last an average of 15 years before maintenance, and forms a longer lasting roof than other palm technologies in the region. To avoid paying for the whole work of

re-thatching sometimes patching is done to extend the life of the covering layer and the building structure. It is possible to continue to patch a roof so it will never need complete renewal. However, if the thatch is left without maintenance and the leaves start to go rotten and mouldy, then it is important to re-thatch the whole roof if the structure is to be preserved.

To make a commonly found *A. guacuyule* thatched roof of 6m by 4m or 7m x 5m (the most common sizes) with a pitch of 45 degrees requires about 300-360 palm leaves (25-30 dozen). Fresh-cut leaves are split with a machete along the rachis [spine] so one leaf makes two thatching items, and these items can be as long as 8m, and as short as 2.5m, but on average they are 3.5m long.

Figure 4-10: A common thatched roof of 7 by 5m with 45° pitch roof in Quimixto

The rigidity of the rachis means rounded corners cannot be formed. *A. guacuyule* thatched homes are of a distinctive A-frame construction. Since the thatching

technology uses the large leaves horizontally, and due to the roughness of the leaves only single pitch gable roofs can be produced, and hipped roof are practically impossible to make. Therefore the typology of *A. guacuyule* buildings falls within these main characteristic (see figure 4.11). Also it is possible to find these types of buildings with or without walls, as many times only posts are left uncovered to allow cross ventilation, notwithstanding that diverse materials for cladding such as wattle, bricks, or even palm leaves are also common. The following figure (4.11) shows the main typologies of *A. guacuyule* thatched dwellings found along the west coast of Jalisco.

Figure 4-11: Building typologies chart of *A. guacuyule*

4.2.3 Management of *A. guacuyule* Palm and Harvest Process

It seems that *A. guacuyule*, like many other palms, are valued for building because the palms are highly resistant to fire, whether man or nature made, in their natural environment (Tejero-Díez et al., 2008, pp. 88-89).

Economically speaking the palm is mainly valuable because of its products, these being the fruits for oil and food, and leaves for thatching. “Harvest of cohune [*Attalea*] leaves rarely if ever kills the palm, since only the largest of the arched, erect leaves are cut...some of which may reach to 18m” (Morris, 1988 found in McSweeney, 1995, p. 165). However, during the field survey such large leaves were never found, the largest being 8 to 10 metres (figure 4-12).

Figure 4-12: *A. guacuyule* young palmetto with human scale. Photo by Adriana Leiva

During the survey of palm groves it was found that *A. guacuyule* palm is very frequent around the localities of Quimixto and Pizota at the southernmost part of Bahía de Banderas, but sometimes to find a dense population of these groves it is necessary to take an hour's walk uphill or go to neighbouring shores, meaning to reach these palm groves it is necessary to get off the track and go into the wild.

The lifespan of this palm is long compared to other palms. As an example, a coconut palm *C. nucifera* can live only 10-12 years or 15 at most, whereas the *A. guacuyule* palm can live for 100 years. According to an interviewee from Pizota, there is a grove of these palms around this locality that was planted by a man when he was young, The interviewee stated that this man died 5 years ago aged 95, and the palms are still there and in good shape, so it can be reckoned that these palms are about 80 years old.

These palms can be up to 20m tall, and occur as an upper canopy palm of the lowlands (below 600m above sea level) with distribution in high-density stands within more species-rich forest (Furley 1975; Horwich & Lyon 1990; Johannessen 1957; Wright et al., 1959 in McSweeney, 1995, p. 163).

The job of harvesting the leaves can be sometimes dangerous as there are rattlesnakes in the bushes and also the palms are very tall when mature, and not everyone is willing to do this job.

There is no particular season when it is better to harvest the *A. guacuyule* palm, and palms can be harvested at a very early stage of the plant life. Even at seven years old the young palms, called 'palmetos', can be pruned and these even preferred because of the easy access to the leaves. Mature and old palms are also harvested, although old palms can get so tall that harvesting is more difficult. Tall palms have a rough bark, and the trunks tend to rot when old if there is excess water. Sometimes a long pruning tool is used to avoid climbing the whole trunk and risk its sudden collapse.

The job of harvesting can be done by a single person but is more commonly done by two persons. In general the process is as follow: after clearing the working area with a machete, the old dead leaves are cut away and disposed of as they are dry and therefore useless. Essentially the dry leaves of the palms are pruned in order to reach the mature and larger but still green leaves.

This task needs a sharp blade as the *A. guacuyule* palm leaf has a strong fibrous stalk, and a whetstone is an essential tool for constant sharpening of the blade during rest breaks. After harvesting the palms are usually carried to the closest point where they could be loaded into the means of transportation to the building site if this is further away.

Subsequently, to dry the leaves properly for thatching, they can either be left in situ on the ground piled in dozens under the pressure of a stone to avoid the leaf shrinking and losing the shape desired for thatching or, for a better drying process, the split leaves are tied and hung in bundles with the stalk horizontal and the leaves pointing downwards (see figure 4-13) and left in this position for five days. This last technique is preferred among the thatchers around Bahía de Banderas, for achieving a thatch that has better water resistance.

Figure 4-13: Detail of drying process of A. guacuyule leaves

The following table (4-1) summarizes general information related to the *A. guacuyule* palm concerning to its harvest season, life expectancy, minimum age of harvest and main products.

General features of <i>A. guacuyule</i> and productivity cycle	
Harvest season	Any
Minimum age for leaf harvest	7 years
Maximum life expectancy of the palm	100 years
Average height of the palm	12-15m
Maximum height of the palm	20m
Economic products	Leaves for thatching seeds for oil and food
Leaf harvest cycle	every 3 years
Average lifespan of leaves as thatching material	17 years

Table 4-1: General features and productive cycle of A. guacuyule palm

The table (4-2) shows the minimum, maximum and average weight and size of *A. guacuyule* palm leaves from the survey samples. It is worth noting that the leaves are almost double in weight when wet. Although this was calculated based on freshly cut leaves (4kg/3.5m of dry leaf on average and 7.6kg/3.5m of wet leaf on average), it raises the question of extra loading on the roof structure if water is absorbed under humid and rainy conditions. This suggests that the steeper the pitch of the roof the better the durability of the cover and thus the structure, by avoiding the leaves turning mouldy and rotten.

<i>A. guacuyule</i> leaves weights and sizes	
Minimum leaf size	2.5m
Average leaf size	3.5m
Maximum leaf size	8m
Minimum weight of leaf (dry)	3.6kg per (3.5m leaf)
Average weight of leaf (dry)	4kg per (3.5m leaf)
Maximum weight of leaf (dry)	4.4kg per (3.5m leaf)
Minimum weight of leaf (wet)	6.2 kg per (3.5m leaf)
Average weight of leaf (wet)	7.6kg per (3.5m leaf)
Maximum weight of leaf (wet)	8 kg per (3.5m leaf)
1 leaf (split)	2 thatching items

Table 4-2: Sizes and weights of A. guacuyule palm leaves

Finally, there is no local regulation over harvesting these palm leaves, although in order to export the palm items to more distant places a permit from SEMARNAT is needed.

4.2.4 Yield Factors and Carrying Capacity of *A. guacuyule* Palm Plots

The carrying capacity in ecological terms can be defined as the productivity of a particular crop that can be achieved without environmental degradation. This means the yield factor is related to the productive cycle of the plant. For a palm this means knowing the limits of what can be taken from the plant without affecting its ability to recover.

The *A. guacuyule* palm groves can be divided by whether they are a managed plantation, or endemic forest. In both cases it is important to note that the palm can exist alongside other species and thus be recognized as secondary plots or groves, which are areas where palm is not the main plant in the plot (see figure 4-14). Finally there are also endemic forests of just *A. guacuyule* palms, although these are very rare and never huge in extent. These endemic groves are in decline due to the increase in human activities such as land use change, agriculture and deforestation. More commonly, *A. guacuyule* is found in varying densities over deep, well-drained soils (McSweeney, 1995, p. 163).

Figure 4-14: Secondary palm groves of *A. guacuyule* near Cihuatlán, Jalisco

A study of an endemic forest with *A. guacuyule* palms in the neighbouring state of Nayarit by Tejero-Díez et al. (2008), about 10km north of Bahía de Banderas, estimated the average height and relative density of *Attalea ssp.* (see table 4-3).

<i>Species surveyed</i>	Height average (m)	Relative density % plants in plot	Perimeter at chest height cm
<i>Attalea ssp.</i>	9.4	20.83	23.05
<i>Brusera ovalifolia</i>	13.4	12.5	11.53
<i>Brosimum alicastrum</i>	17.7	8.33	12.89
<i>Ficus ssp</i>	19.3	4.17	16.39
<i>Eugenia fragans</i>	11.5	8.33	10.07
<i>other (11 species surveyed)</i>	10.7 - 6	4.17	8.59 - 1

Table 4-3: Results of survey of A. guacuyule in an endemic forest in south Nayarit; taken from (Tejero-Díez et al., 2008, p. 81)

The thatchers in their structured interviews stated that when harvesting *A. guacuyule* leaves about 12 leaves can be extracted on average per palm (young to adult), and as units for thatching a bundle is made out of 12 whole leaves (24 thatching items). Usually when sold, the palm comes in bundles of 12 leaves.

Once the leaves have been harvested it takes about three years for the palm to recover, but since the palm plots of this species can be extremely crowded the thatchers feel this is not an issue.

In the wild within secondary groves a rough density of 100 specimens can be found in an area of 400m². However, the palm tends to be grouped in small areas or random plots, sometimes also found as solitary palms, but rarely as sole specie endemic forests, thus on average around 200 to 300 palms are commonly found within a hectare of groves (see figure 4.15).

As part of the fieldwork, two 400m² (20m by 20m; 16m by 25m) areas and one of 16m² (4m by 4m) of *Á. Guacuyule* secondary grove plots were surveyed in the southern municipality of Cihuatlán, Jalisco, between Cuastecomate and La Manzanilla. In the survey densities of palms and leave production were quantified to estimate the minimum, average and maximum annual yield of similar *A. guacuyule* palm plots. The

results were translated to annual yield, for instance an average 12 leaves/palm/cycle (3years) equals 4 leaves/palm/year (see table 4-4).

Figure 4-15: Plan of surveyed plots of *A. guacuyule* secondary groves

Estimated yield factor of <i>A. guacuyule</i> leaves	
Harvest cycle	3 years
Minimum leaves harvested per palm	2 leaves/year
Average leaves harvested per palm	4 leaves/year
Maximum leaves harvested per palm	6 leaves/year
Low density of palms per 100m ²	30 palms
Average density of palms per 100m ²	115 palms
High density of palms per 100m ²	200 palms
Minimum yield factor	60 leaves/year/100m ²
Average yield factor	460 leaves/year/100m ²
Maximum yield factor	1200 leaves/year/100 m ²
Average number of leaves/hectare	46000 leaves/year/Ha

Table 4-4: Estimated yield factors of *A. guacuyule* palm leaves for thatching

In a similar study (McSweeney, 1995), there were an average 216.4 *Attalea ssp.* palms in six high density 100m² plots within an undisturbed forest in the northwest of Belize (McSweeney, 1995, p. 163), which is consistent with this survey.

4.2.5 Other Materials Used for Building *A. guacuyule* Thatched Structures

Palm is the material used as roof covering and sometimes for cladding. However, this is only the final envelope and needs a structure of other materials. In the past these structures were solely of wood, and only recently have imports of other building materials occurred in some of these rural localities. Equally, the export of endemic materials to modern cities had only happened in recent decades. Nowadays, thatched building structures can be made in combination with modern materials such as concrete, metal or a combination of both, and sometimes these are combined with wood. However for the purpose of this research the focus is on the use of agro forestry materials such as hardwoods, softwoods and fibrous materials, therefore the scope is narrowed for the present investigation to these building materials.

When it comes to wood for structures of *A. guacuyule* palm roofs Guayabillo, Verdecillo and Granadillo are all abundant and common in the municipality of Cabo Corrientes where Quimixto and Pizota are located. They are all good to bury in the

ground and are commonly used because they are resistant to rot and easily last over half century. They are also preferred as they are usually straight in shape and uniform in size. These woods can be used from 5 to 7 years old using a coppicing technique, but for posts to be buried, older poles are recommended, from trees aged 15-20 years.

Other common hardwoods used in the area are Habillo or Habilla, Tampizirán, Palo de Brasil, and Palo Fierro which are slow growing in comparison to other timbers but are also very reliable as posts to be buried. As a reference a Habillo tree with a diameter measured 1.5m from ground level of a brazada (a measurement of the two arms extended = 1,600-1,800mm) can be said to be over 50 years, although there are trees with trunks up to two to three brazadas in diameter. However, all these trees can be productive at the age of 10-12 years, although they are better after 20 years.

All the woods mentioned above can last the life expectancy of the building when buried (50 years) and some timbers last over a century depending on the type of timber, age of wood, and method of harvesting, maintenance and building technique. If well protected from contact with sun and water these timbers can last many centuries although the exact lifespan of such materials is difficult to establish as there is no valid data about old well preserved thatched building structures.

Lechozo is the name of another timber which is used for structural elements, except for posts to be buried. It is very large, straight and hard when used as a building element, and therefore reliable. However, as its name Lechozo (milky) suggests it secretes a white liquid when cut and if this liquid makes even minimum contact with the face, even after hands are washed, it can produce an allergic skin reaction. This tree mostly grows around Quimixto. Other less common woods not recommended for posts but also used for making rafters and beams are commonly called Comengalo, Chinillo and Tintilagua, although the botanical species were not identified for these last three timbers (see table 4.5). All these woods also grow fast and are productive after 7 years. The most common method of logging is by coppicing.

Table 4.5 below shows details of the principal timbers employed for structures in the Jalisco area in order to clarify the exact species used. In some cases the timbers could not be identified precisely.

CASE STUDIES OF THREE PALM SPECIES AND RELATED TECHNOLOGY ALONG THE TRANS-MEXICAN VOLCANIC BELT

HARDWOOD SPECIES USED IN WEST COAST REGION JALISCO			
COMMON NAMES	SCIENTIFIC NAME	AUTHOR	PUBLISHED
Guayabillo	<i>Psidium sartorianum</i> (O. Berg) Nied.	Niedenzu, Franz Josef	Die Natürlichen Pflanzenfamilien 3(7): 69. 1893.
Guayabillo borcelano	<i>Piranhea mexicana</i> (Standl.) Radcl.-Sm.	Radcliffe-Smith, Alan	Kew Bulletin 51: 546. 1996.
Granadillo	<i>Dalbergia retusa</i> Hemsl.	Hemsley, William Botting	Diagnoses Plantarum Novarum ... Mexicanarum 1: 8. 1878. (Jul 1878)
Granadillo; Sangualican	<i>Dalbergia granadillo</i> Pittier	Pittier, Henri Francois	Journal of the Washington Academy of Sciences 12(3): 62–63. 1922.
Verdecillo; Amapa amarilla	<i>Tabebuia chrysantha</i> (Jacq.) G. Nicholson	Nicholson, George	The Illustrated Dictionary of Gardening, . . . 4: 1. 1887.
Amapa rosa; Amapa morada	<i>Tabebuia impetiginosa</i> (Mart. ex DC.) Standl.	Standley, Paul Carpenter	Publications of the Field Museum of Natural History, Botanical Series 11(5): 176. 1936.
Habillo; Habilla; Jabillo	<i>Hura crepitans</i> L.	Linnaeus, Carl von	Species Plantarum 2: 1008. 1753. (1 May 1753)
Palo Fierro	<i>Olneya tesota</i> A. Gray	Gray, Asa	Plantae Novae Thurberianae 328. 1854.
Tampisiran	<i>Dalbergia granadillo</i> Pittier	Pittier, Henri Francois	Journal of the Washington Academy of Sciences 12(3): 62–63. 1922.
Lechozo	* <i>Brosimum alicastrum</i> Sw.	Swartz, Olof (Peter)	Nova Genera et Species Plantarum seu Prodomus 12. 1788.
	* <i>Vatairea lundellii</i> (Standl.) Killip ex Record	Killip, Ellsworth Paine	Tropical Woods 63: 5. 1940.
Palo de Brasil	<i>Haematoxylum brasiletto</i> H. Karst.	Karsten, Gustav Karl Wilhelm Hermann	Florae Columbiae terraumque adjacentium specimina selecta in peregrinatione duodecim annorum observata delineavit et descripsit 2: 27–28, pl. 114. 1862.
Coconut Palm	<i>Cocos nucifera</i> L.	Linnaeus, Carl von	Species Plantarum 2: 1188. 1753. (1 May 1753)
Tintilagua	Species not recognized		
Comengalo	Species not recognized		
Chinillo	Species not recognized		
SOFTWOOD SPECIES USED IN WEST COAST REGION JALISCO			
Otate	<i>Otatea aztecorum</i> (McClure & E.W. Sm.) C.E. Calderón & Soderstr.	Calderón, Cléofe E. Soderstrom, Thomas Robert	Smithsonian Contributions to Botany 44: 21. 1980.
Bamboo	<i>Bambusa</i> Schreb.	Schreber, Johann Christian Daniel von	Genera Plantarum 1: 236. 1789.
SPECIES USED AS BINDING MATERIALS IN WEST COAST REGION JALISCO			

<i>Sisal</i>	<i>Agave sisalana</i> Perrine ex Engelm.	Perrine, Henry ex author Engelmann, Georg (George)	Transactions of the Academy of Science of St. Louis 3: 305, 316, pl. 2– 4. 1875.
<i>Raphia</i>	<i>Raphia nicaraguensis</i> Oerst.	Oersted, Anders Sandoe	Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening i Kjøbenhavn 1858(1–4): 52. 1859.
<i>Cuichi or garrobo</i>	Species not recognized		
References: [a] http://www.tropicos.org/Name * possible species			

Table 4-5: List of timbers and other materials used for thatched structures in Jalisco

There is also a local vine that is used for joining and binding the structural frame. Its traditional name is Cuichi or Garrobo (a common name for the genus of male iguanas), and it is called this because the plant has a shape like the claws of this animal (see figure 4-16). This vine is very weather resistant and has a long lifespan, easily over 20 years and it can last the life of the structure if well protected from water and sun. Bamboo is sometimes used but never as a post element. An issue with bamboo is that it is difficult to make it last a long time. For instance, it rots in direct contact with water and it cracks and split with exposure to direct sunlight. It also needs to be very mature and properly harvested and treated to last, and people are not very used to using it and therefore do not have this knowledge.

Another grass for thatching that was used in the past is called cola de zorra or cola de zorro (fox tail) (specie unidentified). Apparently it was possible to see roofs thatched with this grass no longer than 50 years ago, however they no longer exist. This grass is considered wild and comes from high places. It is also long and resistant to rot, making it suitable for thatching. However, it is not considered further in this research.

Figure 4-16: Cuichi or Garrobo vine in Pizota, Bahía de Banderas, Jalisco. Photo by Fernando Castillo

4.2.6 Transportation of Materials and Load Capacities

The type of transportation depends on the accessibility of the palm field. For groves difficult or impossible to access by motorized vehicles, animals are used such as donkeys, mules or horses. The load capacity highly depends on the animal's health and the ability of the person wrapping and manoeuvring the palm bundles called brazas.

Since there are no motor roads in some rural localities such as Quimixto or Pizota, animals such as donkeys, mules or horses are mostly used as transport. The best way to transport the leaves is to tie the palms in bundles of a dozen, then rope them to the animal, so the animal either drags them to the site or carries them tied to its body. However, dragging them, although sometimes necessary, is less preferred because the leaves get dirty and messy from animal manure, sand and loam along the narrow tracks around Qumixto and Pizota (see figure 4-17).

Figure 4-17: Track in Quimixto. Photo by Adriana Leiva

If there is road nearby, as for the survey done in Cihuatlán in the southernmost part of Jalisco, different forms of motorized vehicles can be used, such as pickup trucks, or even bigger trucks. Where the groves are near the shore a panga boat is also a mean of transportation.

It can be estimated from the survey samples and the structured interviews that a dozen *A. guacuyule* palm leaves (wet) weigh roughly 90kg and 48kg dry on average. From information extracted from interviews and compared with data derived from the samples, a person can carry half dozen when wet and up to a dozen when dry, a mule

on average can carry 2 to 3 wet dozens and drag up to 4 dozen, but when dry can carry 5 and drag 6 dozens. Finally a pickup of 3.5 tonnes capacity can carry up to 20 dozen (wet or dry), and a panga of 3 tonnes carrying capacity can transport up to 18 dozen (wet or dry) if carrying nothing else (table 4.6).

It is important to state that whether wet or dry leaves are to be transported highly depends on the control of the plot and its inspection to see that the leaves are drying properly before thatching, and the distance to the site. However, in general, *A. guacuyule* leaves are transported wet as the thatcher prefers drying the leaves at the building site in order to avoid damaging them if they are transported some distance to the site.

Transportation means and load capacities		
Mean of Transportation	Defined unit	Total weight
Average weight of <i>A. guacuyule</i> wet palm leaf	3.5m	7.6kg
Average weight of <i>A. guacuyule</i> dry palm leaf	3.5m	4kg
Average weight of <i>A. guacuyule</i> wet palm dozen (average size)	12 leaves	91.2kg
Average weight of <i>A. guacuyule</i> wet palm dozen (average size)	12 leaves	48kg
Maximum load per person (wet leaves)	half a dozen	45.6kg
Maximum load per person (dry leaves)	12 leaves	48kg
Maximum load of a horse mule or donkey (wet leaves)	2 to 3 dozens	180-270kg
Maximum load of a horse mule or donkey (dry leaves)	5 dozens	240kg
Maximum load of a horse mule or donkey (dragging wet leaves)	4 dozens	360kg
Maximum load of a horse mule or donkey (dragging dry leaves)	6 dozens	288kg
Maximum load of a 3.5 tonnes pick-up truck (wet or dry)	20 dozens	1824 kg
Maximum load of a 3 tonnes panga boat (wet or dry)	18 dozens	1641.6 kg

Table 4-6: Transport means and load capacities related to *A. guacuyule* palm

4.3 Fieldwork on *B. dulcis* as Thatching Material in the Mixteca Baja, Puebla

A general area for the survey was established in two main cultural and geographical areas located between the basin of Mexico and the Mixteca of Puebla, which have also received very little attention in surveys of Mesoamerican prehistory (Plunket & Uruñuela, 2005, p. 89). The central valleys of Puebla and Matamoros-Chiautla (Plunket & Uruñuela, 2005, p. 90) are of particular interest with attention paid to the boundaries of these two areas, the southeast-southern region of the Valsequillo lake complex.

Figure 4-18: Map of area of study of *B. dulcis* in Puebla, background map from INEGI

Subsequently, a first exploratory field trip was undertaken in the localities of San Diego la Meza Tochimiltzingo, San Jeronimo Caleras, and San Fransisco Jalapexco,

20 kms east from the city of Atlixco, Puebla, Mexico, to establish palm plots and examples palm thatched buildings. From this first level of enquiry a number of owners, builders and experts were introduced to the research in order to establish potential participants for structured interviews about their knowledge of the vernacular techniques and materials.

4.3.1 Recognition and Survey of *Brahea d. Palm*

The next step was to collect samples of leaves, stalks, shoots, seeds and flowering stems, where available, in order to identify the palm species in use. Once samples were collected and confirmed by local experts, they were stored and sent in the form of media material (photos and videos) to Dr. Hermilo Jorge Quero Rico at the department of biology of the National Autonomous University of Mexico (UNAM). The palm in use was confirmed as *Brahea dulcis* (Kunth) Mart. (see figure 4-19).

Figure 4-19: Samples of *B. dulcis* palm (left: leaf, right: flower stalk)

Brahea dulcis (Kunth) Mart. is today widely used in central Mexico for a range of by-products from a diversity of arts and crafts products, to utensils such as baskets, and to roof coverings (Ugent, 2000). It mainly prefers limestone soil and is found in semi-desert colonies. It is found from North Veracruz State, to San Luis Potosi, and to Guatemala (Quero, 1994).

Monograph of *Brahea dulcis* (Kunth.) Mart. "Palma de sombrero"
San Diego la Meza Tochimiltzingo, Puebla, Mexico

Brahea dulcis. A) general appearance of mature palm with flowering stalk; B) detail of the leaf; C) basal part of the petiole from both sides; D) rachilla with mature and young fruits; E) young rachilla; F) fruit in different stages of its life; G) general appearance of mature palm and young clusters of palms

Figure 4-20: Monograph of *Brahea dulcis*

The following relates to the second level of the fieldwork and is a summary of the relevant information extracted from the structured interviews and surveys. The information is again organized as: general aspects of the thatching technology and building typologies; management of the palm and harvesting process; yield factors and carrying capacities; survey of related materials; and transportation means, loads, weights, and units.

4.3.2 General Aspects of the *B. dulcis* Thatching Technology and Building Typologies

When using *B. dulcis* palm pitched roofs of 45° are also desired for a longer lifespan of the cover and structure. Since the palm leaf is fan shaped and on average 60-80mm and no larger than 120mm across, for thatching the leaves are used vertically with the leaflets pointing downwards so the basal part of the petiole [stalk] is tied into a horizontal grid. A particular feature of this palm is that it is used in pairs to better waterproof the building (see figure 4-21)

Figure 4-21: Thatching method of *B. dulcis* palm

An initial survey of thatched buildings was carried out in the cities of Puebla, Cholula, and Atlixco, as well as in the localities of San Diego la Meza Tochimiltzingo, San Jeronimo Caleras, and San Fransisco Jalapexco all in the state of Puebla, to generate a typological chart of thatching techniques. In the case of *B. dulcis* there was a noticeably different typology for rural (see figure 4-22) and urban buildings (see figure 4-23). This first level of enquiry determined the selection of rural and urban case studies (sections 5.5 and 5.6).

Figure 4-22: Rural thatched building typologies of *Brahea dulcis* palm

Figure 4-23: Urban thatched building typologies of *Brahea dulcis* palm

4.3.3 Management of the *B. dulcis* Palm and Harvest Process

Plant management among the Mixtec shows its enhancement from the wild.

The management of the palm *Brahea dulcis* (H.B.K.) Mart. by the Mixtec is an example of enhancement of wild plants. In this case, fruits (called "capulines") and "palmeto" are edible, although the main use of the plant is the manufacturing of handicrafts such as hats and traditional mats called "petates." This palm has a vegetative reproductive system and its young ramets are resistant to fire. People use these characteristics to increase the numbers of this palm. They fell trees and shrubs and burn the area in order to eliminate competitors. A similar form of management is practiced to create artificial grasslands in order to increase the availability of some species used as forage for animals. (Casas et al., 1996, p. 463)

Enhancement consists of different strategies directed to increase the density of population of useful plants. This type of management includes the sowing of seeds or the intentional propagation of vegetative structures in the same places occupied by populations of wild or weedy plants. (Casas et al., 1996, p. 454)

The management of palm plots in the municipality of San Diego la Meza Tochimiltzingo, belongs to the comuneros (local community group of around 64 people) and between them they manage 9,000 hectares where plots of palms are abundant. This community group looks after the localities of Caleras, San Francisco, San Bartolo, Soledad and San Diego. There are other villages close by, for instance Rosario and la Huerta, but there is no palm there. Only the localities mentioned above have the palm resource in this region.

From an interview with a local thatcher, *B. dulcis* palm is commonly called Palma Silvestre, and from this palm many by-products can be made; for instance, diverse types of baskets such as chiquihuites, which are a two piece cylindrical covered basket traditionally used to store tortillas, a wide range of handcrafts and objects for festivities, and different sizes of mats called petates (see figure 4-24).

Figure 4-24: Diversity of products of *B. dulcis* palm

Another interview with a mat weaver who also works as a palm collector established it takes roughly 2000 shoots to weave a petate doble (double size mat) of 140 by 170cm.

In the past palm household goods were common, including a diversity of baskets, nets, sleeping mats (sometimes several layers to acquire enough softness and comfort), rain capes, and other items. For all these items the young palm shoots of *B. dulcis* are collected and used. Mature leaves are used for thatching buildings. This practice impacts the palm growth making it different from just harvesting the mature leaves at the end of their life. For thatching the old but still green leaves are harvested, which means the dead leaves are also cut away, allowing the palm to grow better and faster as energy no longer goes to this part of the plant but rather into the new shoots. If only the young shoots are harvested more energy is needed to regenerate new shoots, while the palm still has to put energy into the old and dying leaves.

Some people in this locality work in the rural charcoal industry which includes chopping wood, burning it for charcoal and transporting it. This is one of the main economic activities in this locality. Others work as masons, gardeners or labourers outside their locality. Yet thatching has also become an increasingly important economic activity.

Thatching is a skill that provides benefits to the community, through local construction and by bringing in money through the export of both the materials and skilled labour. Therefore, being able to use palm for thatching has always been important. In the past this was for providing shelter, and in the present as a means of bringing money into the local economy, as work is very scarce here and the land is not very productive.

In order to collect, cut and, most importantly, dry the leaves properly, specialized skill is needed, as a proper selection and drying process must be followed carefully. However, not many people in this area work on this as a profitable job, as it is considered rough work, although through the interviews it appeared that women are often subcontracted to collect palm for thatching and sometimes also act as palm lashers (a specific part of the weaving process within the building system).

The process of harvesting starts at the palm plots, and it takes into consideration the season and the technique needed to dry the leaf in an open fan shape.

The palm can be pruned in cycles of seven months and the preferred time for harvesting is during the luna tierna (new moon). From the moment the shoot sprouts to when it becomes a fan shaped leaf takes about a month, so that in the seven month cycle the palm will easily produce on average from seven to ten new proper leaves.

However the productivity of these lands is clearly linked with the natural cycles, and the most productive season is during the five drier months from November to March. In the other seven months, because of the rainy season, there is very little work related to harvest of palm and thus thatching.

If pruning is not done, as discussed above the palm productivity is greatly diminished, as the presence of old leaves tends to stop new shoots growing. So the more the palm is pruned the more productive the plant becomes. The people and the communities that have palm consider it to be a gift from nature as for them it represents a wealth and a blessing. The palm field does not have to be looked after as these palms are local, strong, and resistant to drought. The palm grows and reproduces naturally.

It is important that the leaves do not shrink during drying as this is crucial for the good performance of a thatched roof using this palm. This is achieved by cutting and piling the leaves in situ on opposite sides in pairs, one above the other and pressing them with stones. It takes 20 days to dry the leaves by exposing them to the sun. As a result when completely dry the fan will preserve its open shape as desired.

Table 4-7 is generated from the information collected from the structured interviews and fieldwork survey. It summarizes relevant information related to the season of harvest, the productive age, height and cycles of leaf harvest, as well as the different economic products.

General features of <i>B. dulcis</i> and productive cycle	
Harvest season	November to March
Minimum age for leaf harvest	3-5 years
Cycle of harvest	7 months
Maximum life expectancy of the palm	20-25 years
Average height of the palm	3m
Maximum height of the palm	5m
Economic products of the palm	seeds for food young palmettos for food mats diverse baskets art and craft objects
Leaf harvest cycle	every 7 months

*Table 4-7: General features and productive cycle of *B. dulcis* palm*

Table 4-8 summarizes the average weights of several leaf samples in order to define the *B. dulcis* palm units for thatching.

<i>B. dulcis</i> leaves weights and sizes	
Minimum leaf size	0.6m
Average leaf size	1.2m
Maximum leaf size	1.8m
Minimum weight of leaf (1.2m) dry	180g
Average weight of leaf (1.2m) dry	200g
Maximum weight of leaf (1.2 m) dry	210g
Minimum weight of leaf (1.2m) wet	267g
Average weight of leaf (1.2m) wet	278g
Maximum weight of leaf (1.2 m) wet	290g
Two leaves (one on top of the other)	1 thatching item

*Table 4-8: Sizes and weights of *B. dulcis* palm leaves*

4.3.4 Yield Factors and Carrying Capacities of *B. dulcis* Palm Plots

The first step in thatching the roof is to sort out the palm, whether the builder has collected the palm or paid someone for it. Normally a full normal task (tarea) of 1400-1500 leaves (see description below) costs 500-700 Mexican pesos (as at March 2011).

The largest unit to be considered is a tarea (task) and the smallest a piedra (1 stone) which varies from 7 to 10 pairs of leaves (since one building item is two leaves). One tarea is the equivalent of 20 cargas (loads), and the equivalent of one load is calculated by piedras (stones), usually being five stones, although there can be loads of six stones for what is known as a big task. Finally a stone is seven pairs of properly dried open fan shape palm leaves (table 4-9).

<i>B. dulcis</i> palm harvest units		<i>Equivalents and total quantities</i>	
Normal task			
Spanish name	English best translation	Amounts	Total palm leaves
1 Tarea	1 Task	20 Cargas (Loads)	1400
1 Carga	1 Load	5 Piedras (Stones)	70
1 Piedra	1 Stone	7 Pares (Pairs)	14
1 Par	1 Pair	2 Palmas (Leaves)	2
Note: A double pitch roof (45°) 6m by 4m traditional house requires 7 normal tasks, equalling 9800 palm leaves. It will last 15 years			
Big task			
Spanish name	English best translation	Amounts	Total palm leaves
1 Tarea	1 Task	20 Cargas (Loads)	1680
1 Carga	1 Load	6 Piedras (Stones)	84
1 Piedra	1 Stone	7 Pares (Pairs)	14
1 Par	1 Pair	2 Palmas (Leaves)	2
Special task			
Spanish name	English best translation	Amounts	Total palm leaves
1 Tarea	1 Task	100 Montones (Bundles)	2000
1 Montón	1 Bundle	10 pairs of leaves	20

Table 4-9: *Brahea dulcis* palm Harvest units and quantities for thatching

A special task is measured in bundles (sometime called montones rather than piedras) of up to 20 leaves each, equaling 2000 leaves in total, however this is unusual. Therefore the difference between a normal task and a big task depends on how many stones are needed for a load (carga). For a “5 stone task” 1400 palm leaves are needed, a “6 stone task” needs 1680, while a “special task” needs 2000 leaves. However the most common is the normal task, and the others are done if required by the buyer needing more leaves than can be provided by a normal task. So when someone is about to build a house, tasks are calculated according to the size of the building. Roughly a 6m by 4m building is the common size and accounts for 7 tasks. Such a building can last up to 15 years.

From a good cluster of *Brahea d.* palms, also known as a familia or family of palms, it is possible to extract 30 “stones” (see table 4-9). A cluster can vary widely but a small cluster represents around 30-40 palm plants and a dense one about double this. From a dense cluster (60-70 palms) an average of 400-500 leaves can be extracted. Therefore the equivalent of 30 stones of 14 palm leaves, totalling 420 leaves (6 loads) can be achieved in such plots. There are some very dense areas where a hectare may contain around 200 such bushy clusters. However for an average cluster fewer palm leaves can be extracted from a sole palm (6-8 leaves rather than 10-12).

Figure 4-25 shows the plan of the *B. dulcis* palm plots surveyed for estimating the average for clusters and palms given a defined area (2500m²). The information is the species content in the area, the size of clusters, and the number of palms per cluster.

Figure 4-25: Plan of plot surveyed of *B. dulcis* palm forest

Table 4-10 summarizes the information related to the yield factor of *B. dulcis* palms. It is given in years for ease of use in the environmental impact assessment (the average leaf harvest is 7 leaves per palm every cycle (7 months), thus 12 leaves per palm/year). Table 4-10 also shows the minimum, average and maximum yields per cluster as average yield of leaves/year/Ha based on information derived from the plots surveyed (figure 4-25).

<i>Estimated yield factor of B. dulcis leaves</i>	
Harvest cycle	7 months
Minimum leaves harvested per palm/year	10 leaves/year
Average leaves harvested per palm/year	12 leaves/year
Maximum leaves harvested per palm/year	20 leaves/year
Low density of palms per cluster (family of palms)	20-30 palms
Average density palms per cluster (family of palms)	45 palms
Maximum density of palms per cluster (family of palms)	60-70 palms
Minimum yield factor	200 leaves/year/cluster
Average yield factor	540 leaves/year/cluster
Maximum yield factor	1400 /leaves/year/cluster
Number of clusters in 50m by 50m plot (0.25 hectare)	27 clusters
Average density of palms in 0.25 hectare	1215 palms
Average number of leaves in 0.25 hectare	14580 leaves/year
Average number of leaves in a hectare	58320 leaves/year/Ha

Table 4-10: Estimated yield factors of B. dulcis palm leaves for thatching

4.3.5 Other Materials Used for Building *B. dulcis* Thatched Structures

It seems from the interviews that all the resources for building are local and most represent an income for these communities. Because all are provided by nature, in exchange there are certain management considerations that form a type of communal control system. For instance, looking at the available areas of trees, there are sections that are used for extraction while others are preserved as part of the reforestation programmes that the community undertakes. When a hectare is used for timber extraction by the community, then it is rested and respected for another five years, so then the trees have time to recover. The most common technique for harvesting timber is by coppicing or clearing and planting controlled species. The most common woods used for building are Coatillo, Palo Dulce, Ahuacoxtle, Sabino and Encino and they come from a deciduous forest and Encino forest lands that also are shared with neighbouring communities.

The poles commonly used are 20 to 25cm diameter at the base and at least 7 to 10 years old. They easily last 50 years. If wood is older and can be considered heartwood it will easily last over 100 years. There are traditions around the taking of timber, for instance, for better performance of the timber the cutting needs to be done right after full moon, called luna dura (hard moon) and this means wood can only be cut on four days every lunar cycle. The same is also true of palm. If these traditions are not

followed, very often it is possible to see these timbers starting to be affected by bugs and rotting as quickly as six years after the structure is completed. In contrast there are examples of posts in houses made with the proper harvesting techniques that are 125 years old, and still in good shape.

Another important material is the *ixtle* fibre from agave plants. According to local informants there are plenty of these plants in the localities, but there is a lack of a suitable technology to develop this process, so it is still done in the old way. Leaf fibres can be extracted from the *maguey* plant by smashing the leaves with stones and pulling strips from the inside the bulk of the leaves with two wooden poles. Because of the lack of suitable tools and equipment, this cannot be done at a commercial level.

The distilling of mescal alcohol for personal use and for sale is another productive activity for these localities using agave. The production of mescal liquor makes use of both controlled plantations and wild specimens of local agave plants (*espadin*). However, the *maguey* has a long harvesting cycle, as it only can be distilled when mature (10 years). As a result, a harvest of wild specimens, which are sparse and might mature later at 15 years, is a less productive activity since the price of mescal from this source is more than the alcohol on the market, because of the long harvesting cycle and the fact the process is carried out by hand.

Fallen *Yucca* trunks are also employed as *soleras* (beams) in certain vernacular techniques. Carrizo reed and Otate bamboo are used in *jalapitas* (the palm houses in the Puebla Mixtec region) and in modern structures other bamboo species can be applied such as *Guadua*, although Otate was the endemic bamboo available in the past. Otate bamboo lasts much longer than the Carrizo reed, and is very strong and can even be bent to achieve circular structures, which is not the case for Carrizo. Both Carrizo and Otate are used to make the grid part of the structure to which the palm is laced. A single stem of Carrizo is on average 7m long, 5cm diameter at its base and weighs 400 to 500g per stalk (7m). This material is harvested near the streams or rivers where the reeds grow. It can be collected by those who own the land or bought from them, and is another product in the local economy.

CASE STUDIES OF THREE PALM SPECIES AND RELATED TECHNOLOGY ALONG THE TRANS-MEXICAN VOLCANIC BELT

HARDWOOD SPECIES USED IN MIXTECA BAJA REGION PUEBLA			
COMMON NAMES	SCIENTIFIC NAME	AUTHOR	PUBLISHED
<i>Sabino</i>	<i>Taxodium mucronatum</i> Ten.	Tenore, Michele	Annales des Sciences Naturelles; Botanique, sér. 3 19: 355. 1853.
<i>Yucca</i>	<i>Yucca aloifolia</i> L.	Linnaeus, Carl von	Species Plantarum 1: 319. 1753. (1 May 1753)
<i>Encino</i>	<i>Quercus alba</i> L.	Linnaeus, Carl von	Species Plantarum 1: 319. 1753. (1 May 1753)
<i>*Cuitlapil</i>	<i>Cestrum nocturnum</i> L.	Linnaeus, Carl von	Species Plantarum 1: 319. 1753. (1 May 1753)
<i>Temacate de petaca</i>	<i>Pithecoctenium crucigerum</i> (L.) A.H. Gentry	Gentry, Alwyn Howard	Taxon 24(1): 123. 1975. (Feb 1975)
<i>Cuilote</i>	<i>Montanoa grandiflora</i> DC.	Candolle, Augustin Pyramus de	Prodromus Systematis Naturalis Regni Vegetabilis 5: 565. 1836. (1-10 Oct 1836)
<i>Pino</i>	<i>Pinus montezumae</i> Lamb.	Lambert, Aylmer Bourke	A Description of the Genus Pinus, ed. 3 1: 39, t. 22. 1832. (1 May 1753)
SOFTWOOD SPECIES USED IN MIXTECA BAJA REGION PUEBLA			
<i>Otate</i>	<i>Otatea aztecorum</i> (McClure & E.W. Sm.) C.E. Calderón & Soderstr.	Calderón, Cléofe E. Soderstrom, Thomas Robert	Smithsonian Contributions to Botany 44: 21. 1980.
<i>Carrizo</i>	<i>Arundo donax</i> L.	Linnaeus, Carl von	Species Plantarum 1: 81. 1753. (1 May 1753)
<i>Guadua</i>	<i>Guadua aculeata</i> Rupr. ex E. Fourn.	Ruprecht, Franz Josef (Ivanovich)	Mexicanas Plantas 2: 130. 1886.
SPECIES USED AS BINDING MATERIALS IN MIXTECA BAJA REGION PUEBLA			
<i>Sisal</i>	<i>Agave sisalana</i> Perrine ex Engelm.	Perrine, Henry ex author Engelmann, Georg (George)	Transactions of the Academy of Science of St. Louis 3: 305, 316, pl. 2–4. 1875.
<i>Lechugilla</i>	<i>Agave lecheguilla</i> Torr.	Torrey, John	Report on the United States and Mexican Boundary . . . Botany 2(1): 213–214. 1859.
<i>Henequen</i>	<i>Agave fourcroydes</i> Lem.	Lemaire, (Antoine) Charles	L'illustration horticole 11: 66. 1864.
<i>Espadin</i>	<i>Agave angustifolia</i> Haw.	Haworth, Adrian Hardy	Synopsis plantarum succulentarum ... 72. 1812.
References: http://www.tropicos.org (search by scientific name)			
* possible species			

Table 4-11: Building materials related to Brahea palm thatch technology

4.3.6 Transportation of Materials and Load Capacities

For these communities the palm sources are close by, about 30 minutes to 1 hour average walking distance, or sometimes a bit further. The palm leaves are left for two

to three weeks to dry in situ, and are then transported to the site or, if they are to be purchased, to the selling point which is usually the harvesters' places of residence.

The moving of the palm leaves once dry is done in bundles, previously tied up when the leaves were being dried under the stones. The palm loses weight once dry, and as a general calculation from the samples in the survey a fresh cut leaf weighs 278g average and a dry leaf an average 200g. The means of transport for moving the bundles from the palm fields to the first station is by person or animal, mainly donkeys and mules. Depending on the bundle size (here considered a load from a normal task as in table 4-9), one person can carry up to 3 loads or the equivalent of 210 palm leaves (42 kg). An animal can carry up to 350 to 420 palm leaves, about 5 to 6 loads (70-84 kg). Roughly two trips of two animals cover one tarea (normal to big task if 5 or 6 loads are considered as in table 4-9). A pick-up truck of 3.5 tonnes can transport up to three tasks (normal to big), meaning from 4200 to 5000 palm leaves (840-1000 kg). The capability of each transport mode depends to some extent more on volume than weight.

<i>Transportation means and load capacities related to B. dulcis</i>		
Mean of Transportation (dry leaves)	defined unit	total weight
Average weight of <i>B. dulcis</i> dry palm leaf	average leaf size (1.2m)	0.2kg
Average weight of <i>B. dulcis</i> dry palm of one load (normal task)	70 leaves	14kg
Maximum load capacity per person	210 leaves	42kg
Maximum load of a horse, mule or donkey	840 leaves	168kg
Maximum load of a 3.5 tonne pick-up truck	5000 leaves	1000kg

Table 4-12: Transport means and load capacities related to B. dulcis palm

4.4 Fieldwork on *S. rosei* as Thatching Material in Colima

This section describes another palm commonly known as Palma Real, Palma de Potrero or Palma de Palapa. It belongs to the genus *Sabal*. This genus belongs to the New World, being mostly found in the northern hemisphere within the Caribbean, Mexico and Central America (Uhl & Dransfield, 1987, p. 213). It can grow in many

areas of Mexico, and the species in focus here is endemic and found in limited environments along the shores of Nayarit, Jalisco, Colima and Michoacán. The localities where this palm is more abundant and easy to find in the region of Jalisco and Colima are Emiliano Zapata, Careyes, Cruz de Loreto for the state of Jalisco, and mainly around Camotlán in the state of Colima.

Figure 4-26: Map of area of study of *Sabal rosei* palm in Colima, background map from INEGI

Part of the relevance of researching in these areas is related to the traditional ceramic house models with their thatched roofs that belong to the shaft tomb cultures of Nayarit, Jalisco and Colima (chapter 3). Another aspect is the historic trade with Asia, and the Filipino influence and transfer of technology related to the imported culture of the coconut *C. nucifera* to Mexico during the 16th, 17th and 18th centuries. The areas investigated here are in Colima State which has a palm tradition, as well as being one of the best environments for certain palms. The localities where this field trip took place are shown in the map in figure 4.26

The culture of palm in Colima can be explain as arising from two main causes; one is an environment suitable for a wide range of palm species, and two is the historical and cultural background closely related to its colonial heritage and commercial relationship with Asia and in particular the Philippines and Southeast Asia. For instance the *Cocos nucifera* (coconut palm) was once propagated because of this Philippine influence, and groves are evident along the shore (see figure 4-6). Out of this coconut palm traditional beverages are prepared, as well as a variety of sweets and dishes. There is also a local traditional fermented beverage called tuba made from the sap of some coconut palms that is popular with the locals and is propagated around tourist spots, as is a coconut water drink with lime in Colima state.

Another productive palm in Colima is Palma de tepejilote and this is a palm of altitude found in the region of Minatitlan, Colima. The palm species is *Chamaedorea tepejilote* Liebm., which inhabits the shaded understory of Mexican tropical rain forests. It is a neotropical dioecious palm (Oyama, 1990, p. 649) and several products can be made out of its leaves, for instance brooms, baskets and hats, but it is also an edible plant. The *C. tepejilote* leaf harvest has shown no decreased leaf production in palm populations over time (Oyama and Mendoza, 1990 found in Ticktin & Johns, 2002, p. 188).

Colima has an exceptional climate suitable for palms, therefore palm groves of different species under cultivation can be seen, for instance Oil palm *A. guacuyule*, Coconut palm *Cocos nucifera*, and variants of dwarf coconut from domestic Southeast Asian origins such as the Malaysian dwarf, although “Another dwarf (the ‘Nui Leka’ of Fiji and Samoa)...has not been reported from Mexico” (Zizumbo Villarreal et al., 1993, p. 66). Some palms are also used as thatching materials in vernacular architecture as a wide variety of thatched roof typologies can be seen, many echoing Polynesian and Southeast Asian influences. Therefore Colima is considered important for the fieldwork underpinning the quest for knowledge about thatching.

4.4.1 Recognition and Survey of *Sabal rosei*

Sabalinae Martius in Endlicher is a sub-tribe that consists of a sole genus *Sabal* which occurs in the Caribbean islands and adjacent lands (Uhl & Dransfield, 1987, p. 213). “It is a genus with 16 species, seven occurring in Mexico...*S. pumos* (Kunth) Burret, in Michoacan; *S. rosei* (O.F. Cook) Beccari, in Guerrero, Jalisco, and Nayarit” (Quero,

1992, p. 209). The difference between the two is the length of the rachilla (flowering stalk), which is shorter than the leaf petioles in *S. pumos* as well as the leaves being more sparsely distributed than in *S. rosei* (information given personally by Dr. Hermilo Quero).

The first monograph on this genus was written by Beccari in 1907 containing 18 species inclusive of eight new taxa. In 1934 Bailey made a revision of the genus recognizing 22 species. Later, in 1944, Bailey published a further monograph on *Sabal* increasing the number up to 26. Finally, in 1990, Zona published the most recent monograph on the genus reducing the number to 15 (Quercellini, 2012, p. 8)

Sabal is one of the most economically important palm genus in Mexico, with many different uses from leaves for thatching to the making of different kinds of handicrafts. The trunks are also used for construction poles, and in some species like *S. mexicana* young palmettos are edible, and the fruits are used as supplementary food for pigs (Quero, 1992, p. 211).

Sabal ssp. Can occur in areas where it is the dominant species but can also be a secondary species in other types of forest. It can reach large sizes and constitute very dense secondary palm groves, when the forests are destroyed, mainly by fire in order to make grasslands for cattle (Quero, 1992, p. 214).

In secondary palm groves, most owing their existence to human disturbance, *Sabal* are palms are noteworthy in having increased their population in these (Quero, 1992, pp. 214-215). *Sabal ssp.* is rarely cultivated.

In the survey leaf and fruit samples were collected as well as making a photographic record and the species was confirmed as *Sabal rosei* (O.F. Cook) Beccari (figure 4-27).

Monograph of *Sabal rosei* (O.F. Cook) Beccari "Palapa Palm"
Camotlan, Colima, Mexico

Sabal rosei A) general appearance of a mature and young palm; B) detail of the leaf; C) rachilla with fruits; D) Leaf; E) basal part of petiole; F) bundle of seeds ; G) fruit; H) small fruit in stages and section; I) seed and cross section of the seed; J) cross section of the petiole.

Figure 4-27: Monograph of *Sabal rosei* palm

The following information belongs to the second level of the fieldwork and is a summary of the structured interviews and surveys. The information is organized as follows: general aspects of the thatching technology and building typologies; management of the palm and harvesting process; yield factors and carrying capacities; related materials; and transportation means, loads, weights, and units.

4.4.2 General Aspects of *S. rosei* Thatching Technology and Building Typologies

S. rosei thatched buildings have a range of features and technologies for thatching. As for other thatching techniques a steep roof is desired for better performance and longer lifespan of the thatch cover and roof structure. In general *S. rosei* thatched roofs can be achieved in various ways, from one or two pitched gabled roof, to a hip roof with four or more separate pitches. Such a building could be “L” shaped in plan view, or “T” shaped or a combination and walls can be on an angle, have rounded corners, or be oval or circular. Buildings are made with top roof windows or with clerestory openings.

S. rosei buildings are thatched in diverse ways, but always a horizontal grid is needed on which to lash or nail the palm leaves, which are laid vertically. The thatch can be tight or wide open to fit client needs, although the most popular thatching method is the “a hueso” (of bones), so named as it resembles the fingers of the hand closed tight one against the other (figure 4-28).

Figure 4-28: “A hueso” thatching technique

S. rosei thatch can easily last 10 years and up to 12 years if built with a roof pitch of 45 degrees or more. It may last 15 years and maybe a little longer, but it should really be re-thatched after 15 years. However if the structure is built with a pitch less than 45 degrees it will not last more than 10 years at maximum, and no thatched roof should have a pitch less than 35 degrees.

Expert builders can construct *S. rosei* thatched structures with a great span, say more than 20 m, but this depends on how the framing is done (figure 4-29). In the past, palapas (the common name) were roped, bound and lashed with *Sicua de guasima* (species unidentified), which is a vine from the locality that has very strong fibres. *Agave lecheguilla* was also used in the past, as it is now.

Figure 4-29: Inside view of a palapa roof structure with great span

Despite the many forms and sizes of *S. rosei* thatched roofs, a building of 6m x 4m with a double pitched roof of 45 degrees is a common size. Such a building costs about 50,000 Mexican pesos (12.7 pesos = 1 USD in March 2012) for the full job including materials and hand labour for both structure and thatch cover. The cost is 25,000

Mexican pesos for the palm thatch alone if the structure already exists and is going to be re-thatched.

Figure 4-30 is a typology chart showing the wide diversity of *S. rosei* thatch roofs. These thatched buildings can have open walls, or walls of wattle or bricks with windows, or any other material. Conventional building materials are found, sometimes combined with traditional materials, and many building forms are possible.

Figure 4-30: Building typologies of *S. rosei*

4.4.3 Management of *S. rosei* Palm and Harvest Process

Based on previous demographic models (A Martínez-Ballesté et al., 2002), it is known that xa'an palm (*Sabal ssp.*) in managed home garden populations is biologically sustainable among most culturally conservative Mayas in the Yucatan peninsula (Andrea Martínez-Ballesté et al., 2006, pp. 1-13).

The leaves of both palm species have been harvested since Pre-Columbian times for thatching purposes, and the form of use has remained practically unchanged until today. Thus, present-time Maya houses are still much like those that were built about 1000 B.C. (Martínez-Ballesté et al., 2006)

Among the modern Mayan traditional house gardens the xa'an palm density is high reaching some 900 palms/ha, whereas the householders who have shifted to less traditionally run Mayan house gardens have about 200 palms/ha. (Martínez-Ballesté et al., 2006)

In another study of other *Sabal* palm species by O'Hara (1999) harvesting the leaves of the palm *S. mauritiiformis* in Belize does not remove significant levels of limiting nutrients from harvest sites but could still affect ecosystems, making it important to discover what the palaperos (the thatchers) think about the sustainable yields of this palm.

S. mauritiiformis appears to contribute significant sources of phosphorus (P), potassium (K) and zinc (Zn) sources during certain seasons and that the magnitude of the contributions of *S. mauritiiformis* to total ecosystem cycling is much greater for dense populations than for sparse populations. These results suggest that although harvesting high-density of non timber forest products populations may be least damaging from a population perspective, it could be highly damaging from an ecosystem perspective if harvest results in the removal of important contributions to ecosystem cycling. (Ticktin, 2004, pp. 17-18)

S. rosei palm grows wild and plantations are enhanced but not nurtured. It is endemic in the west coast region. It is mainly found in Colima, Jalisco and Nayarit, although other *Sabal ssp.* is found in Sinaloa and Sonora, Michoacán and Guerrero.

It is a palm with a fan shape leaf but it has a spike-less vein. It is of mid-height and it has a small coconut seed similar to the coyul (a form of oil palm) but the difference is that this one is not edible.

The palms are suited to very specific climatic conditions as they are found in deciduous forests with coastal proximity but do not grow below 500m above sea level.

Currently a forestry permit is needed to cut and transport trunks of *S. rosei* palms, which are often used as structural elements such as posts. Such posts are desired for their appearance when vines are attached to the trunk (figure 4-31). Needing a permit also applies to other hardwoods and tropical timbers for posts, beams and rafters, as some are considered endangered and are protected, and some areas are widely deforested. Today the permit is authorized by PROFEPA (Federal Procurator for the Protection of the Environment) under the norm NOM-006-RECNAT-1997 (Norma Oficial Mexicana PROFEPA, 1997). However, there is still much clandestine logging of certain species and this also relates to palapa buildings.

Figure 4-31: Trunk of *S. rosei* palm with vine used as post

The palm found around Camotlán Colima is of lesser quality than that found in Tomatlán, Jalisco. Apparently this is because the Colima palm has a thicker vein (petiole), is rougher and more tough (referring to it being less flexible to work), and in consequence lasts a little less time. It can be said that these palms are the same plant species but with slight variations. Other plants share the field living in conviviality with the palm, such as a native wild coffee (not edible) or certain hardwood trees.

S. rosei secondary palm groves around Ciruelito and Ciruelito la Marina frequently occur with other land uses such as agriculture for growing cucumbers and maize or for grazing cattle (figure 4-32). These palms are kept because of the value of their leaves for thatching. Erosion is possible mainly due to disturbance from crop growing and farm animals.

Figure 4-32: Secondary Sabal rosei palm grove

Some fields of *S. rosei* palms seem to have adjusted to such pressures on land use, and one thing that is apparent is the high resistance of the palm species to fire, as some

fields have undergone slash and burn for agriculture. Although the palm leaves burn the trunks resist the fire and the leaves re grow again very quickly.

In such a scenario the palms are sparse and the productivity of such fields in terms of thatching materials can be considered low, being about 30 to 40% that of a fully populated palm field. The harvest from the whole plot of palms can be purchased and collected by a thatcher from the owner of the land, this being one way to obtain the material. Another is by purchasing the material already pruned in the equivalent merchant units of bundles and tasks (defined respectively as number of palms per bundle and bundles in total) (figure 4-33).

Figure 4-33: S. rosei palm leaves ready to be sold

Table 4-13 describes the general characteristics of *S. rosei* palm, summarizing the information from the structures interviews and plot surveys. As for the other case studies the focus is on the life of the plant, size, harvest cycle, products and harvest season.

General features of <i>S. rosei</i> and productive cycle	
Harvest season	All year round
Minimum age for leaf harvest	5 years
Maximum life expectancy of the palm	40 years
Average height of the palm	3m
Maximum height of the palm	5m
Economic products	Leaves for thatching
Leaf harvest cycle	every 4 months

Table 4-13: General features and products of *S. rosei* palm

In addition, table 4-14 focuses on the main features of *S. rosei* palm leaves. Data from field samples is summarized and general values relevant for the research established

<i>S. rosei</i> leaves weights and sizes	
Minimum leaf size	1.49m
Average leaf size	1.6m
Maximum leaf size	1.82m
Minimum weight of leaf (dry)	230g per (1.6m leaf)
Average weight of leaf (dry)	300g per (1.6m leaf)
Maximum weight of leaf (dry)	380g per (1.6m leaf)
Minimum weight of leaf (wet)	480g per (1.6m leaf)
Average weight of leaf (wet)	530g per (1.6m leaf)
Maximum weight of leaf (wet)	570g per (1.6m leaf)
One leaf equals	one thatching item

Table 4-14: *S. rosei* average size and weights of leaves

4.4.4 Yield Factors and Carrying Capacities of *S. rosei* Palm Plots

About *S. rosei* palm leaves productivity it can be said that the more the palm is pruned the more productive it becomes, as it reproduces its leaves faster. So pruning of old leaves allows new shoots to grow faster, meaning the plant is not wasting energy feeding leaves about to die. If pruning is not done the growth of the tree is arrested.

To estimate the yield factors and carrying capacities one *S. rosei* secondary palm grove of 50m by 50m as measured in the field was surveyed, and thereafter four random samples; two of 8m by 8m and two of 5m by 5m were surveyed thoroughly in the following way. The number of young, mature and adult palm specimens was counted. The perimeter at chest high of mature palms was measured. Numbers of dead leaves, mature leaves, shoots, flowering stalks and symbiotic vines were also counted. Thereafter a plan of the plot surveyed was developed with notes, and a photographic record of each part was also made for estimation of yields.

Figure 4-34: Plan of surveyed plot of Sabal rosei secondary palm grove

A 1 ha plot of palm can yield up to 10,000 leaves when harvested, and will reproduce these within four months (3 cycles a year). This means that a good plantation well looked after can yield three crops a year (1ha=30,000 leaves/year). If a plantation is not well looked after will only produce about 2000 leaves, but such land also produces other crops, for instance maize and cucumbers, and is also used as grazing for farm animals (see figure 4-35).

Figure 4-35: S. rosei palms in a secondary grove (plotted area)

Finally table 4-15 shows the yield factor of *S. rosei* palm leaves in years, using the data from the survey. For example, a low density plot surveyed has 44 palms in 0.25 hectares (see figure 4-35), and a low yield harvest is 6 leaves per cycle. Given that this palm has 3 harvest cycles a year, this is 18 leaves per palm multiplied by 44, giving 792 leaves per year in 2500m². A high density plot of 214 palms in 0.25 hectares with

a high yield of 14 leaves per palm per cycle produces 8988 leaves per year in 2500m². Finally an average yield and density resulted in 3870 leaves in 0.25 hectares or 15480 leaves per Ha per year.

<i>Estimated yield factor of S. rosei leaves</i>	
Harvest cycle (every 4 months)	0.33 year
Minimum leaves harvested per palm	18 leaves/year
Average leaves harvested per palm	30 leaves/year
Maximum leaves harvested per palm	42 leaves/year
Low density of palms per 2500m ²	44 palms
Average density of palms per 2500m ²	129 palms
High density of palms per 2500m ²	214 palms
Minimum yield factor	792 leaves/year/2500m ²
Average yield factor	3870 leaves/year/2500m ²
Maximum yield factor	8988 leaves/year/2500m ²
Average number of leaves in a hectare	15480 leaves/year/Ha

Table 4-15: Estimated yield factors of S. rosei palm leaves for thatching

4.4.5 Other Materials Used for Building *S. rosei* Thatched Structures

The vines that grow on the trunks of the *S. rosei* palm are not a good building material, and are considered parasites on the palm. However, because of their aesthetic value the vine covered trunks are usually desired as building posts, and despite the fact that the palm tree is protected (SEMARNAT, 2002) and its harvest as a wood (which is different from a non-wood forest product, for instance the leaf harvest) is controlled and regulated (Norma Oficial Mexicana PROFEPA, 1997), these trunks are sometimes illegally acquired.

Figure 4-36: Two different vines that kill the Sabal palm

The palm on the left of figure 4-36 has a Salate vine, and the one on the right a Tabachín. The vine grows in the manure of bats and grows downwards until reaching the ground when it roots, gets stronger and suddenly kills the palm. When this happens the trunks can be used for posts, since they are appreciated as an aesthetic element. From the interviews the palms in figure 4-32 might be 30 years old.

In a range of five kilometres between el Ciruelito and Camotlán plots of land of endemic forest were visited and surveyed, and some vines of Bejuco corralero (species unidentified) also collected. These vines are used in thatching structures as a binding material, and are said to be very resistant to weather exposure (sun and water) and have a long life. These vines were very common in the past and were used for fencing, roping, and binding as there were not many materials from the hinterlands available.

The process of harvest this vine is as follows. The big thick vine is the core plant. It will never be cut as it is quite old, and because it goes all the way to the top of the trees the vines that grow from it are the ones that are used. The thin ones are desired and will grow big and re-grow if cut. A six month old branch from the core vine is already good to use. During the trip when vines were collected it took about half an hour for each person to collect half a dozen 20m to 30m large vines.

The process consists in first identifying the vines that are more accessible, and then pulling them hard until there is enough length to be worth cutting and working with (10m at least). Sometime access is cleared with a machete as vegetation can be very dense. Then the vine is cut, pulled and carried into a clear area where all cut vines are gathered. Thereafter, each vine is cleaned with pruning scissors or with the machete, then each vine is split in half along its length to make two out of one. This makes the vines easier to work with as a binding element.

Vines have to be worked fresh. When they are stored and dry out they have to be soaked for one or two nights before working with them again. The vines shrink when dry, this is desirable to ensure tight joints when the vines are used for lashing components, but splitting must be done when the vine is freshly cut, otherwise this becomes very difficult. Sometimes the bark is removed, although this is only for aesthetic purposes, and this is also done when fresh otherwise it is almost impossible to do. The vines are then made into several hoops for ease of transportation and are ready to work with (figure 4-37).

Figure 4-37: Bejuco corralero vine samples and process

ENVIRONMENTAL IMPACT ASSESSMENT OF VERNACULAR THATCH BUILDING TRADITION IN MEXICO:

The field work looked at another area in the northern state of Jalisco (Cihuatlán) about 20km away from Manzanillo where there was a high diversity of useful hardwoods for building. This area is a strip along the shore from Cihuatlán Jalisco to Cruz de Loreto Jalisco. Again when available, leaf and flower photographic recording was undertaken to identify species. Table 4-16 summarizes this information.

HARDWOOD SPECIES USED IN WEST COAST REGION COLIMA			
COMMON NAMES	SCIENTIFIC NAME	AUTHOR	PUBLISHED
<i>Barcino</i>	<i>Cordia elaeagnoides</i> DC.	Candolle, Augustin Pyramus de	Prodromus Systematis Naturalis Regni Vegetabilis 9: 474. 1845. (1 Jan 1845)
<i>Botoncillo</i>	<i>Cordia alliodora</i> (Ruiz & Pav.) Oken	Oken, Lorenz	Allgemeine Naturgeschichte 3(2): 1098. 1841.
<i>Balsamo</i>	<i>Myroxylon balsamum</i> (L.) Harms	Harms, Hermann August Theodor	Notizblatt des Königlichen botanischen Gartens und Museums zu Berlin 5(43): 94. 1908. (1 Sept 1908)
<i>Guayabillo</i>	<i>Psidium sartorianum</i> (O. Berg) Nied.	Nieden zu, Franz Josef	Die Natürlichen Pflanzenfamilien 3(7): 69. 1893.
<i>Llora Sangre</i>	<i>Apoplanesia paniculata</i> C. Presl		Symbolae Botanicae, sive, Descriptiones et icones plantarum novarum aut minus cognitarum 1: 63, pl. 41. 1831. (Sept-Dec 1831)
<i>Verdecillo; Mapilla; Amapa Amarilla</i>	<i>Tabebuia chrysantha</i> (Jacq.) G. Nicholson	Nicholson, George	The Illustrated Dictionary of Gardening, . . . 4: 1. 1887.
<i>Granadillo; Sangualican</i>	<i>Dalbergia granadillo</i> Pittier	Pittier, Henri Francois	Journal of the Washington Academy of Sciences 12(3): 62–63. 1922.
<i>Rosa Morada</i>	<i>Tabebuia impetiginosa</i> (Mart. ex DC.) Standl.	Standley, Paul Carpenter	Publications of the Field Museum of Natural History, Botanical Series 11(5): 176. 1936.
<i>Tabachin</i>	<i>Caesalpinia mexicana</i> A. Gray	Gray, Asa	Proceedings of the American Academy of Arts and Sciences 5: 157. 1862.
<i>Habillo, Habilla, Jabillo</i>	<i>Hura crepitans</i> L.	Linnaeus, Carl von	Species Plantarum 2: 1008. 1753. (1 May 1753)
<i>Coconut</i>	<i>Cocos nucifera</i> L.	Linnaeus, Carl von	Species Plantarum 2: 1188. 1753.
SOFTWOODS SPECIES USED IN WEST COAST REGION COLIMA			
<i>Otate</i>	<i>Otatea aztecorum</i> (McClure & E.W. Sm.) C.E. Calderón & Soderstr.	Calderón, Cléofe E. Soderstrom, Thomas Robert	Smithsonian Contributions to Botany 44: 21. 1980.
<i>Bamboo</i>	<i>Bambusa</i> Schreb.	Schreber, Johann Christian Daniel von	Genera Plantarum 1: 236. 1789.
SPECIES USED AS BINDING MATERIALS IN MIXTECA BAJA REGION PUEBLA			

CASE STUDIES OF THREE PALM SPECIES AND RELATED TECHNOLOGY ALONG THE TRANS-MEXICAN VOLCANIC BELT

<i>*Bejuco Corralero</i>	<i>Hippocratea volubilis</i> L.	Linnaeus, Carl von	Species Plantarum 2: 1191. 1753. (1 May 1753) (Sp. Pl.)
<i>*Bejuco de Agua</i>	<i>Davilla nitida</i> (Vahl) Kubitzki	Kubitzki, Klaus	Mitteilungen der Botanischen Staatssammlung München 9: 95–99. 1971. (31 Aug 1971) (Mitt. Bot. Staatssamml. München)
<i>Sisal</i>	<i>Agave sisalana</i> Perrine ex Engelm.	Perrine, Henry	Transactions of the Academy of Science of St. Louis 3: 305, 316, pl. 2–4. 1875.
<i>Lechugilla</i>	<i>Agave lecheguilla</i> Torr.	Torrey, John	Report on the United States and Mexican Boundary . . . Botany 2(1): 213–214. 1859.
<i>Henequen</i>	<i>Agave fourcroydes</i> Lem.	Lemaire, (Antoine) Charles	L'illustration horticole 11: 66. 1864. (Ill. Hort.)
References: http://www.tropicos.org (search by scientific name)			
* possible species			

Table 4-16: List of other materials used related to *S. rosei* thatching in Colima

Figure 4-38: Brasil wood (*Haematoxylum brasiletto* H. Karst.) used for palapa structures, sometimes from illegal sources

The materials involved in the parts of the building are described in the following list:

- Vines: Bejuco de cerro corralero and Bejuco ojo de agua are the local names for the vines used for tying or binding joints, and there are many others less common.
- Vines: Bejuco Salate and the Tabachín vine strangle and kill the palm, and are not good for building. But an adult palm trunk with such vines is highly desired and controlled.
- Otate bamboo, is an endemic bamboo from altitude areas found in Minatitlan 500m above sea level and higher. This is the yellow one. There is also a black one that comes from the neighbouring southern state of Michoacán (figure 5-45). This is used as a secondary structural material and to provide a grid on which palm can be woven. It is most likely that the black specimen was treated with oil after peeling the outer skin of the bamboo stem, rather being a black endemic Otate species.
- Botoncillo, Barcino, Balsamo, Ilorra Sangre, Mapilla, Guayabillo, and Verdesillo are local names for the tropical timbers used for building the main structure of the triangular roof framing.
- Brasil, Barcino, Guayabillo, Bonetillo, Palo Liso, and Coconut palm trunks as well as Sabal palm trunks, are timbers used as main supports or posts for the building of a traditional palapa. These woods are the older ones and are considered to be madera de corazón (hardwoods with strong core). Most of these timbers can be used when 10 to 15 years old although some specimens can be older. Some are very resistant to water and rot when buried in the ground. They can last over a hundred years if well maintained and protected from the sun and rain, and the contrast when they are left uncovered, due to the natural forces on the material, is very noticeable.

4.4.6 Transportation of Materials and Load Capacities

Table 4-16 summarizes the information derived from the samples, surveyed plots and structured interviews. It is worth noting that the limits are related to volume and not to

weight. Human power is rarely used and animals, only when there is no access to the plots, as most in the Colima region have road access. However, for comparison estimation has being made of the different means of transport for both scenarios (wet and dry leaves) as for the other case studies. Basically there is no defined unit for this palm as it is sold by the plot harvested, so the defined unit has been made as dozens. The maximum load a pick-up truck can carry is 10000 leaves

<i>Transportation means and load capacities related to S. rosei</i>		
Mean of Transportation (wet/dry leaves)	Defined unit	Total weight
Average weight of <i>S. rosei</i> wet palm leaf	1.6 m	0.3kg
Average weight of <i>S. rosei</i> dry palm leaf	1.6 m	0.53kg
Average weight of <i>S. rosei</i> wet palm dozen (average size)	12 leaves	6.36kg
Average weight of <i>S. rosei</i> dry palm dozen (average size)	12 leaves	3.6kg
Maximum load per person (wet leaves)	6 dozens	38.2kg
Maximum load per person (dry leaves)	12 dozens	43.2kg
Maximum load of a horse mule or donkey (wet leaves)	33 dozens	210kg
Maximum load of a horse mule or donkey (dry leaves)	66 dozens	238kg
Maximum load of a 3.5 tonnes pick-up truck (dry)	830 dozens	2980kg

Table 4-17: Transport means and loads capacities related to S. rosei palm

When it comes to how many leaves are needed for a thatched roof a 6m x 4m 45° double pitch roof (a common unit) needs 6,000 palm leaves using the “a hueso” method. For the same example on average 120 Otates (bamboos) will be used for the grid (see sections 4.4.2 and 4.4.5). These might all come from a 5m x10m plot, as the bamboo grows densely and will regenerate in about 6 years. This means everything that is used is renewable in about 5-10 years, as even hardwoods coppiced on a 6 year rotation are good enough for building. The skill of the thatcher is key as if the work is not done properly it will not last 10 years, and will need patching after 5 years, but if good work is done it will easily last 10 years without maintenance.

4.5 Field work on Granaries in Chalcatzingo Morelos

Apart from the building case studies related to the three palms investigated in this thesis, an additional survey was carried out on a traditional granary in the locality of Chalcatzingo, Morelos. Though this is outside the initial scope of the research the preliminary results and some facts about this unique building tradition are presented here.

Since the present investigation is about palm traditions and technologies, this last survey was not taken into account for the assessments, as the granaries in Morelos are made with grass thatch, although it is important to say that these types of granary were once very common in central Mexico (figure 4-39) even if made out of different materials. In fact one granary similar in shape was spotted in the Mixteca region made out of palm, but unfortunately contact with the owner was not possible (see figure 4-40). Notwithstanding this, a survey was carried out in Morelos and the information is briefly discussed here because it formed part of the fieldwork, although the LCA assessment will be left for further research.

Figure 4-39: Traditional granary in Atlatlahualco, Mexico State. Image courtesy of National Geographic

Figure 4-40: Top opening of a granary with the plaited ring exposed

Figure 4-41: A contemporary granary in Chalcatzingo Morelos. Photo by Patricia Leiva

4.5.1 The Building, its Materials and their Preparation

Table 4-18 summaries the information collected on the granary in fig 4-40.

GRASSES AND REEDS SPECIES USED IN CHALCATZINGO MORELOS			
COMMON NAMES	SCIENTIFIC NAME	AUTHOR	PUBLISHED
<i>Zacate de campo</i>	<i>*Diectomis fastigiata</i> (Sw.) P. Beauv.	Palisot de Beauvois, Ambroise Marie François Joseph	Essai d'une Nouvelle Agrostographie 132, 160. 1812.
<i>Zacate silvestre</i>	<i>Andropogon fastigiatus</i> Sw.	Swartz, Olof (Peter)	Nova Genera et Species Plantarum seu Prodrum 26. 1788.
<i>Zacate para olla de cuezcomate</i>	<i>Bouteloua curtipendula</i> var. <i>tenuis</i> Gould & Kapadia	Gould, Frank Walton Kapadia, Zariri Jamasji	Brittonia 16(2): 201, f. 42. 1964.
<i>Zacate de reloj</i>	<i>Heteropogon contortus</i> (L.) P. Beauv. ex Roem. & Schult.	Palisot de Beauvois, Ambroise Marie François Joseph	Systema Vegetabilium 2: 836. 1817
<i>Otate</i>	<i>Otatea aztecorum</i> (McClure & E.W. Sm.) C.E. Calderón & Soderstr.	Calderón, Cléofe E. Soderstrom, Thomas Robert	Smithsonian Contributions to Botany 44: 21. 1980.
<i>Carrizo</i>	<i>Arundo donax</i> L.	Linnaeus, Carl von	Species Plantarum 1: 81. 1753. (1 May 1753)
WOOD SPECIES USED IN CHALCATZINGO MORELOS			
<i>Pino</i>	<i>Pinus montezumae</i> Lamb.	Lambert, Aylmer Bourke	A Description of the Genus Pinus, ed. 3 1: 39, t. 22. 1832.
<i>Cuilote</i>	<i>*Montanoa grandiflora</i> (DC.) Sch. Bip. ex K. Koch	Schultz, Carl (Karl) Heinrich "Bipontinus"	Wochenschrift des Vereines zur Beförderung des Gärtenbaues in den Königl. Preussischen Staaten für Gärtnerei und Pflanzenkunde 7: 408. 1864.
SPECIES USED AS WATTLE MATERIALS IN CHALCATZINGO MORELOS			
<i>Maguey</i>	<i>Agave angustifolia</i> Haw.	Haworth, Adrian Hardy	Synopsis plantarum succulentarum ... 72. 1812.
<i>Granjel</i>	<i>Randia echinocarpa</i> DC.	Candolle, Augustin Pyramus de	Prodromus Systematis Naturalis Regni Vegetabilis 4: 385. 1830.
<i>Bambú común</i>	<i>Bambusa vulgaris</i> Schrad. ex J.C. Wendl.	Schrader, Heinrich Adolph	Collectio Plantarum 2: 26, pl. 47. 1808.
<i>Temecata de Petaca</i>	<i>Pithecoctenium crucigerum</i> (L.) A.H. Gentry	Gentry, Alwyn Howard	Taxon 24(1): 123. 1975. (Feb 1975)
References: http://www.tropicos.org (search by scientific name)			
* possible species			

Table 4-18: Species used as building materials for a cuezcomate (granary) in Chalcatzingo, Morelos

In Morelos the granaries are commonly thatched with a diversity of grasses called zacate de campo (*Diectomis fastigiata* (Sw.) P. Beauv.). Zacate silvestre, also called zacate de campo (*Andropogon fastigiatum* (Sw.)) is also used. Zacate para olla (*Bouteloua curtipendula* var. *tenuis* Gould & Kapadia) is used in the form of fibres for reinforcing the cob (in situ adobe) to form the body of the building (Alpuche Garcés, 2008). Other materials used in the structure are granjel (*Randia echinocarpa* DC.) temecata de petate (*Pithecoctenium crucigerum* (L.) A.H. Gentry), cuilote (*Montanoa grandiflora* DC.), and pino (*Pinus montezumae* Lamb) (Alpuche Garcés, 2008). The first is used in the form of branches plaited into a ring beam that connects to the top edge of the bowl (la olla), the part of the granary made out of straw and clay cob that contains the grain, to secure the roof structure to the cob bowl. The others are mostly used as structural elements in the roof structure which is the part of the granary that is thatched. Finally agave espadin (*Agave angustifolia* Haw) is also used for the building structure, as the builders claim it lasts better than the other woods used and is very common in Chalcatzingo, although its availability will vary according to the region.

These granary forms can be traced back to pre-Columbian times without much change (section 3.3.1). They are very effective and long lasting buildings, and keep the crops fresh for more than three years. The building in the shape of a bowl like an inverted cone should last over 80 years without major maintenance apart from re-plastering the outside layer, although structures of over 100 years were reported in the interviews and visited as part of the fieldwork. The external plaster can last up to twenty years, and the roof thatch up to 40 years. The inverted cone shape makes it impossible for rats and mice to get at the stored grain, an early example of form following function.

4.6 Summary

This chapter has explained the background to the case studies and introduced the three palms used for thatching to be studied, these being *Attalea guacuyule*, *Brahea dulcis* and *Sabal rosei*. Typical thatched roofs buildings found in the areas of Mexico under investigation for each of these palms were presented. From these the six case study buildings were selected. These are investigated in detail in the next chapter, which will assess all the materials that have gone into their making for use in the environmental assessment in Chapter 6. This chapter ends with a brief look at a once very common

building type in the area, the thatched mud-walled granary, but this information is purely for interest as it does not form part of the environmental assessment.

CHAPTER 5

CASE STUDIES OF SELECTED PALM THATCHED BUILDINGS, TECHNOLOGIES AND RELATED MATERIALS

This chapter addresses the analyses of the complete buildings using thatch technologies rather than just the plants as in the previous chapter. It focuses on particular examples located in the areas of study to complete the main goal of this research—an environmental assessment of thatched buildings related to the use of palm. However, from an architectural viewpoint, the thatch is only the covering material (envelope) and thus implies a whole set of other materials (organic, inorganic and industrial) that need to be assessed to make a picture of the whole building. For instance, foundations may be of earth or stone and walls, structure and secondary structure of wood.

One of the findings from the previous chapters is that how each plant is used as a covering material can vary widely according to the technique used, and since there are different weaving techniques, there are also a wide variety of solutions to the supports for palm thatching. Sometimes battens are used but not always, while the distance between the battens and the material of the battens varies. Structures also vary in height, and in types of walls and foundations, so for each palm and its related technique other materials need to be considered.

Bearing this in mind, the present chapter addresses the case studies using the nomenclature defined on chapter one (section 1.8.3). Here the focus is on the quantification of materials and of the thatched building as a whole, taking into account the techniques related to each specific thatching material and the range of materials needed to support such techniques. However, to reduce the scope, the buildings considered are of similar size (called functional units) and thus of a domestic rather than commercial scale, although in two case studies (A-R2 section 5.3; and B-SU section 5.6) the structures are used by their owners to make an extra income, and are therefore commercial. Case study B-SU is bigger in size, but was included because of the detailed survey made during the construction of the building, this giving the

opportunity to record all data in detail. For a better comparative environmental assessment all results will be given as a final per m² value in chapters 6 and 7.

Finally, because within the residential category there can be a wide variety of building forms, sizes, structures and techniques (from the very modest to the very elaborate and expensive), the buildings analyzed here are restricted to the most common types based on the findings of the previous chapters covering the historical review (chapter 3) and field surveys of plants and typologies (chapter 4).

This chapter has three main sections, one for each palm and region, with two case studies for each. It follows the sequence of Chapter 4, starting with *Attalea guacuyule* in Jalisco (Cayaco building tradition) with two case studies A-R1 and A-R2 (both rural); it follows with *Brahea dulcis* (Jalapitas building tradition) with case studies B-R and B-SU (one rural and one suburban); and finishes with *Sabal rosei* (Palapa tradition) with one rural and one urban case studies (S-R and S-U).

5.1 Cayaco Thatch Buildings in Bahía de Banderas, Municipality of Tomatlán, Jalisco

Cayaco is a very common name among locals living along the shores of Jalisco and Colima for both the thatched building and the palm that provides the leaves for thatching (*A. guacuyule*). The palm has other local names such as Palma de Coquito, Palma de Coyul, Palma de Aceite (Oil palm) as well as Palma de Cayaco. However, Cayaco is mostly used if referring to the palm as a thatching material or to the building itself (for instance a Cayaco is building in the region means an *A. guacuyule* thatched structure, although a building cannot be made entirely out of this palm since the trunk is useless as it becomes rotten as it grows to an adult tree).

5.1.1 Cayaco Palm Building Typologies and Thatching Techniques

For all the thatching techniques using cayaco, the palm leaves are split along the stalk into two and dried for better performance (figure 4-13) and the stalks can be laced, nailed, or both to the rafters. In all cases the roof is thatched from bottom to top so the next thatch item overlaps, protects and weatherproofs the stalk and the binding

elements of the previous item. Since the palm leaves are long (6m minimum) and the petiole or stalk narrows from the base to the end along with the ‘fringes’ of the leaves, they are always woven counter-directional in layers, meaning that if the first row is oriented to one side the next row will be in the opposite direction for better weatherproofing (figure 4-9). As for all thatched buildings there is a relationship between the lifespan of the material and the pitch of the roof (for the water to run off easily), with a minimum pitch of 45 degrees required for the work to be guaranteed, although even more is usually desired, as the steeper the roof the longer the life of the thatch. Cayaco thatch buildings only have mono-pitched or double pitched gable roofs, as hip roofs and round structures are not built as the thickness and roughness of the leaves makes it impossible to bend or waterproof the hipped joint. The thatching technique does not vary widely as the possibilities of using the palm in a different way from that described above are, even if they exist, foreign to the local builders. The only variation is the weaving and the lashing technique, and the two most common techniques only differ in the distance between the thatching elements. In the close one, called ‘a hueso’ (‘of bone’, referring to the bones of the fingers when closed and how they touch one side by side), the thatch is very tightly woven and the stalks touch each other from the inside view (figure 5-1). The other technique is called ratonero (ratón is a mouse and the word means that the wider batten spacing allows mice to enter the roof) since a space of 3 to 5 fingers in width occurs between the thatched elements (figure 5-2). Another less common technique is called de tejido (woven) as each leaf is woven in a mat fashion, and this is sometimes used in combination with the ratonero technique, as this makes the roof more weather proof. The gable can also be thatched for cladding and is usually made using the tejido (woven) technique (figure 5-3).

Figure 5-1: “A hueso” thatching technique done with Attalea guacuyule

Figure 5-2: Process of splitting the leaves and detail of “ratonero” thatching technique

Figure 5-3: “Tejido” weaving technique of *A. guacuyule* palm as cladding

The tools are mostly human powered. An axe, machete, blade sharpeners, leather gloves, measuring tape, and a kind of angled handle to tighten the binding knots are essential. A hammer, saw, mallet, ropes, and planks or poles to be laid horizontally as scaffolding, and a knife, pliers, a penknife, a ruler and a plumb line are also among the primary tools. Finally screwdrivers, a hand powered drill, and a set of chisels are also important but not essential, and a hat and a hammock are also common for breaks.

Electrically powered tools can be used if the grid is nearby, and if not, petrol powered tools, such as a chain saw, might be used when big cuts are needed, although this will depend on the status of the thatcher. However these are not essential as everything can be achieved with non-powered tools.

5.2 Case Study A-R1 (*A. guacuyule*, Rural) in the Locality of Quimixto

Quimixto is located at the south end of Puerto Vallarta, a half hour boat trip or four hours’ walk from the closest beach, Boca de Tomatlán. There is no road and electric light was only introduced into the main town of 400 people in the last 20 years. However, there are areas that still lack this service and thus this can be considered a

remote rural location. The first case study on this palm is located inland about 3 km northwest of the pier.

The site is enclosed by hills that shelter the place from strong winds, and is flanked by a cliff and a river that comes from the upper mountains of Tomatlán. The most attractive site in the town, a waterfall, is a 5 minute walk away. Visitors come to the town by boat from Vallarta for a day tour to the waterfall and to experience a jungle trail. The weather can be extremely warm and humid, therefore most cayaco thatch buildings are wide open with no walls, in order to allow cross ventilation.

This building (figure 5-4 to 5-12) is an example of a non-standard situation as it was built with fallen wood from hurricane Kenna that hit Bahía Banderas in 2002. This decision was made because after the hurricane hit the bay many rocks were brought down by the river that flanks one side of the site and many trees were blown down, some being valuable hardwoods.

Figure 5-4: Site of Quimixto, drawing of case study A-R1

5.2.1 The Building, its Materials and their Preparation

The only introduced materials for this project were some sacks of cement and burnt limestone, ropes, cords and a spade and a pick as tools, all these coming from Puerto Vallarta and brought on a 3 tonne capacity “panga” boat. A kit of other related tools was available from a local thatcher and a small shade was built to protect materials and labourers from weather conditions if needed.

Figure 5-5: Description of the building components CS: A-R1

The collection of all the materials, the preparation of the site and the gathering of tools was a slow process and took about two months. No permit is needed to build cayaco thatch buildings locally and no permit was needed to use the wood as the trees had

been felled by the hurricane. One tree was chopped down in situ to produce the floor boards of the mezzanine and permission from the local authorities was granted for this.

A detailed description of each material and the process of preparation is provided in the form of the following survey of building materials (5.2.1.1 and Tables 5-1 to 5-5) and detailed survey drawings have been produced as a guide for the tables.

Figure 5-6: Front view of the building (south), CS: A-R1

Figure 5-7: Side view of the building (east), CS: A-R1

Ground Floor

Figure 5-8: Ground floor plan of the building, CS: A-R1

Mezzanine floor

Figure 5-9: Mezzanine floor plan of the building, CS: A-R1

Structure un-thatched

Figure 5-10: Roof structure plan of the building, CS: A-R1

Elevation east structure

Figure 5-11: Elevation of the building (east), CS: A-R1

Elevation south structure

Figure 5-12: Front elevation of the building (south), CS: A-R1

Foundations

The building for this case study has a rock foundation that rises into a retaining wall 1.5m deep, 0.5m thick and 1m high (above the floor level) made of granite rocks to provide a barrier against flooding due to the closeness of the river and the potential for raised water levels. However, the building is 5m above the river bed and no flooding has occurred in the 10 years since the building was completed.

All the small rocks for the foundations and the sand used were carried by hand and with a wheelbarrow. All large rocks were moved by lever and rolling and nothing was brought further than 100 metres. Sometimes it took a full day to move a single rock into place. Digging was done with a single pick and a “coa”, which is a Nahuatl term for a long thin pole of hardwood, a tool used in the past that still can be seen in some areas today, mostly being used for agriculture.

The construction of this stage took about two months, with interrupted days from rain. In total 10 x 50kg sacks of cement and 20 x 25kg sacks of burnt limestone were used. These were imported in two different journeys from Puerto Vallarta, made by a panga boat of 3 tonne carrying capacity.

Structure and walls

Different types of wood can be used for cayaco buildings, but the species of hurricane felled timbers that were used to achieve the case study building, were Guayabillo, Granadillo, and Palo de Brasil (table 4.5). The most difficult of these fallen trees took two people up to two days to bring to site. Additionally one Verdecillo tree was cut in situ to provide the wood for decking the mezzanine. Bamboo was used as rafters and was brought from 10 minutes away by boat from the neighbour shores of Yelapa south of Quimixto. The building of the structure was achieved by two persons and took about three weeks.

Some walls were made out of coconut palm tree from off-cuts from another local building construction that used squared elements formed out of coconut *C. nucifera* trunks. Part of the verandah was made out of Otate *O. aztecorum* bamboo and the materials were brought on a mule a relatively short distance (a 1 hour walk).

The Thatch

From the beginning to the end the whole building work was achieved in a little under six months, with the difficult part being to organize all the materials, and the construction of the foundations due to weather conditions and the difficulties of the terrain. The collection of the thatch leaves took about two weeks, and the remaining tasks were relatively easy to execute. For instance, weaving the thatch (the whole roof covering of 63m²) took two men only two full days to complete. According to the owner of the building, these two days were difficult as there was heavy rain around and it was difficult to work. The very day after the thatch was finished a huge storm came, and according to the owner “it was so nice to be dry after such an odyssey, I have never been so comfortable before, not a single leak, not a single drop, and we were just sitting there watching the storm.”

5.2.2 Inventory and Inputs of Case Study A-R1 in Quimixto

The following information is presented in the form of tables and the same format is used for all six case studies. It is a summary of the materials, translated into quantities and volumes and the data in these tables will be used in chapter 6 for the environmental impact assessment. The information is grouped into two main categories: Organic and inorganic materials, and subdivided into hardwoods, softwoods and fibrous materials for the organic materials category, and into mineral and industrial materials for the inorganic materials one.

CASE STUDIES OF THREE PALM SPECIES AND RELATED TECHNOLOGY ALONG THE TRANS-MEXICAN VOLCANIC BELT

CS: A-R1 Case Study of <i>Attalea g.</i> (Rural) Input of Materials				
Organic Materials (Hardwoods)				
Classification of Materials		Volumes	Average Weight	Total Weight
by general group of materials and by species		per item	(a) air dried wood; 20% moisture	
Building part	Biological/Common name	units > m3	units > kg/m3	units > kg
posts	<i>Haematoxylum brasiletto</i> Palo de Brasil	0.24		
waste material (30%)		0.08	(b)	
Σ volumes per species >		0.32	900	288
posts	<i>Pirahnea Mexicana</i>	0.27		
beams	Guayabillo	0.25		
joists		0.96		
ridge pole		0.08		
wall plates		0.12		
eaves poles		0.12		
purlins		3.36		
ties		0.11		
inner struts		0.03		
waste material (30%)		1.62	(b)	
Σ volumes per species >		6.92	900	6228
claddings	<i>Cocos nucifera</i> Coconut palm	0.48		
waste material (30%)		0.15	(b)	
Σ volumes per species >		0.63	900	567
struts	<i>Dalbergia retusa</i>	0.44		
support posts	Granadillo	0.04		
waste material (30%)		0.15	(b)	
Σ volumes per species >		0.63	900	566
floor boards	<i>Tabebuia chrysantha</i> Verdecillo	1.50		
waste material (30%)		0.45	(b)	
Σ volumes per species >		1.95	925	1804
Σ total weight of hardwoods >				9453
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (b) (Atencia, 2003)				

Table 5-1: Input of hardwoods, case study A-R1

CS: A-R1 Case Study of <i>Attalea g.</i> (Rural) Input of Materials				
Organic Materials (Softwoods)				
Classification of Materials by general group of materials and by species		Volumes per item	Average Weight	Total Weight
Building part	Biological/Common name	units > m3	units > kg/m3	units > kg
rafters	<i>Bambusa vulgaris</i> Bamboo	0.60		
waste material (30%)		0.18	(c)	
Σ units per species >		0.78	55	43
veranda	<i>Otatea aztecorum</i> Oate bamboo	0.13		
waste material (30%)		0.04	(c)	
Σ units per species >		0.17	150	26
Σ total weight of softwoods >				68
References: (c) weighed by author				

Table 5-2: Input of softwoods, case study A-R1

CS: A-R1 Case Study of <i>Attalea g.</i> (Rural) Input of Materials				
Organic Materials (Fibrous materials)				
Classification of Materials by general group of materials and by species		Volumes per item	Average Weight	Total Weight
Building part	Biological/Common name	units > items	units > kg/item	units > kg
leaves for thatching	<i>Attalea guacuyule</i> Palma de coyul	360		
material waste		does not apply	(c)	
Σ volumes per species >		360	4	1440
skeins for roping	<i>Agave fourcroides</i> Henequen	5		
material waste		does not apply	(c)	
Σ volumes per species >		5	5	25
skeins for lacing	<i>Agave fourcroides</i> Henequen	4		
material waste		does not apply	(c)	
Σ volumes per species >		4	2	8
Σ total weight of fibrous materials >				1473
References: (c) weighed by author				

Table 5-3: Input of fibrous materials, case study A-R1

CS: A-R1 Case Study of <i>Attalea g.</i> (Rural) Input of Materials				
Inorganic Materials (Mineral materials)				
Classification of Materials by general group of materials and by type		Volume	Average Weight	Total Weight
Building part	Common name	units > m3	units > kg/m3	units > kg
retaining wall	<i>Igneous plutonic</i>	18		
	Granite rock			
waste material		does not apply	(d)	
Σ volume >		18	1600	28800
retaining wall	River sand	6		
waste material		does not apply	(d)	
Σ volume >		6	1400	8400
Σ total weight of mineral materials >				37200
References: (d) http://scribd.com/doc/2607520/Pesos-especificos-de-materiales-de-construccion				

Table 5-4: Input of mineral materials, case study A-R1

CS: A-R1 Case Study of <i>Attalea g.</i> (Rural) Input of Materials				
Inorganic Materials (Industrial materials)				
Classification of Materials by general group of materials and by type		Volume	Average Weight	Total Weight
Building part	Common name	units > items	units > kg/items	units > kg
retaining wall	Sacks of cement	50		
waste material		does not apply	(d)	
Σ quantity >		50	50	2500
retaining wall	Sacks of burnt lime	25		
waste material		does not apply	(d)	
Σ quantity >		25	25	625
nails for decking	Steel nails	10		
waste material	1kg bag	does not apply	(d)	
Σ quantity >		10	1	10
connectors (posts-beams)	Steel rebars	units > m3	units > kg/m3	units > kg
		0.006		
waste material		does not apply	(d)	
Σ quantity >		0.006	7850	47
Σ total weight of industrial materials >				3182
References: (d) http://scribd.com/doc/2607520/Pesos-especificos-de-materiales-de-construccion				

Table 5-5: Input of industrial materials, case study A-R1

5.3 Case Study A-R2 (*Attalea guacuyule*, Rural) in the Locality of Pizota

This case study is from the locality of Pizota near Quimixto. It lies towards the south of the bay about 15 minute by panga boat from Quimixto, or about a 45 minute boat trip from the city of Puerto Vallarta Jalisco, and is located south of the Bahía de Banderas just past the town of Yelapa. It is as remote as Quimixto, since it is located in the southern part of the Bay where the main services were only introduced just 20 years ago. Like Quimixto, there are many areas of the town that still lack basic services.

The place is surrounded by the same mountain system and enclosed by the Bahía de Banderas. It lacks roads and the only access is either by boat, animal or walking. The vegetation is sub-tropical and deciduous. It is a community of less than 1500 people, and thus falls within the rural classification. This case study is similar in form and size to other domestic buildings in the town and although it is part of a residential compound, due to its public location it serves as an occasional informal home-made food shack to the people who visit the town for the day from tours that come from Puerto Vallarta.

5.3.1 The Building, its Materials and their Preparation

The following building is slightly different from the first case study A-R1. The two main differences are that it was not built after the Kenna hurricane, therefore, in this building the process of obtaining each of the materials did not have the limitations of access to materials and the process is similar to any other *A. guacuyule* thatched job; the second difference is that this building is the common type of *A. guacuyule* thatched buildings as it does not have a mezzanine. However, it is on a slope therefore it used a big amount of rock, which in a different terrain situation could have being avoided.

The interview with the builder, who is a local thatcher made it possible to identify all the materials which were local and ready available. A visit was paid to the sources of some of the materials, to check distances, and species used (see also table 4.5).

The following section is presented in the form of survey drawings and tables.

Figure 5-13: Description of the building CS: A-R2

Figure 5-14: Side view of the building (west) CS: A-R2

Elevation south structure

Figure 5-15: Front view of the building (south) CS: A-R2

Floor structure

Figure 5-16: Floor plan of the building CS: A-R2

Roof structure

Figure 5-18: Roof structure of the building CS: A-R2

Foundations

The present case study has a granite rock foundation that is both foundation and a retaining wall that prevents the earth eroding as the building is along the shoreline on steep terrain. The retaining wall is 1.8m at its tallest and includes a stair to access the building from the beach, while at the back it rises 0.6m to prevent flooding and erosion from the land (figure 5.17 for cross section).

Although the volumes and the materials are similar to CS: A-R1, the design is slightly different because of the contour of the land and the purpose for which the building was made. While in Quimixto the building is raised to protect it from flooding from the river close by, in Pizota the design responds to the steep terrain, as well as to protect the building from the ocean tide, and to provide access from the beach.

The industrial materials such as cement and burnt lime were imported from Puerto Vallarta on two panga boat trips. This building is over 25 years old.

Structure

The structure is made from local hard and soft woods. It is made to last over 50 years, as species were used that can resist rain, damp and pests. The species used were: Palo Fierro (*Olneya tesota*), Tampizirán (*Dalbergia granadillo*), Tintilagua (*Ardisia compressa*), and Habbillo (*Hura crepitans*), (table 4.5) and they all are available within a 10-20 min walk. Most of the timber posts are over 15 years old and the rest of the structure elements are between 10 to 15 years on average. A structure like this case study is very common and can be achieved in a week or two by between two to four people if all the materials are ready at the site.

The Thatch

The building as stated is over 25 years, it has a good steep double pitch roof, and only two years ago was the thatch replaced. The palm *Attalea g.* grows in abundance in Pizota, and it took about 25 dozen palm leaves (300) leaves both to thatch it initially and to re-thatch it. The palm groves are within a 10 minute walk and the leaves are transported by animal such as mule or donkey and also by a person on foot.

5.3.2 Inventory and Inputs of Case Study: A-R2 in Pizota

CS: A-R2 Case Study of <i>Attalea g.</i> (Rural) Input of Materials				
Organic Materials (Hardwoods)				
Classification of Materials by general group of materials and by species		Volumes per item	Average Weight (a) air dried wood; 20% moisture	Total Weight
Building part	Biological/Common name	units > m3	units > kg/m3	units > kg
posts	<i>Olneya tesota</i> Palo Fierro	0.32		
waste material (30%)		0.10	(e)	
Σ volumes per species >		0.41	1230	509
pole beams	<i>Dalbergia granadillo</i>	0.18		
lower ties	Tampiziran	0.14		
struts		0.42		
waste material (30%)		0.22	(f)	
Σ volumes per species >		1.79	890	1593
Σ total weight of hardwoods >				2101
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (e) http://www.conafor.gob.mx/biblioteca/Consideraciones-tecnologicas-de-la-madera.pdf ; (f) http://www.cites.org/common/com/pc/19/S19i-03.pdf				

Table 5-6: Input of hardwoods, case study A-R2

CS: A-R2 Case Study of <i>Attalea g.</i> (Rural) Input of Materials				
Organic Materials (Softwoods)				
Classification of Materials by general group of materials and by species		Volumes per item	Average Weight	Total Weight
Building part	Biological/Common name	units > stalks	units > kg/m3	units > kg
ridge pole	<i>Ardisia compressa</i>	0.07		
eaves poles	Tintilagua	0.09		
purlins		0.09		
upper ties		0.08		
waste material (30%)		0.10	(b)	
Σ units per species >		0.44	760	331
inner struts	<i>Hura crepitans</i>	0.19		
rafters	Habillo	0.21		
waste material (30%)		0.12	(g)	
Σ units per species >		0.52	520	271
Σ total weight of softwoods >				601
(b) (Atencia, 2003); (g) http://orton.catie.ac.cr/repdoc/A0009S/A0009S129.PDF				

Table 5-7: Input of softwoods, case study A-R2

CS: A-R2 Case Study of <i>Attalea g.</i> (Rural) Input of Materials				
Organic Materials (Fibrous materials)				
Classification of Materials by general group of materials and by species Building part Biological/Common name		Volumes per item units > items	Average Weight units > kg/item	Total Weight units > kg
leaves for thatching	<i>Attalea guacuyule</i> Palma de coyul	240.00		
material waste		does nt apply	(c)	
Σ volumes per species >		240.00	4	960
skeins for roping	<i>Agave fourcroides</i> Henequen	4.00		
material waste		does not apply	(c)	
Σ volumes per species >		4.00	5	20
skeins for lacing	<i>Agave fourcroides</i> Henequen	4.00		
material waste		does not apply	(c)	
Σ volumes per species >		4.00	2	8
Σ total weight of fibrous materials >				988
References: (c) weighed by author				

Table 5-8: Input of fibrous materials, case study A-R2

CS: A-R2 Case Study of <i>Attalea g.</i> (Rural) Input of Materials				
Inorganic Materials (Mineral materials)				
Classification of Materials by general group of materials and by type Building part Common name		Volume units > m3	Average Weight units > kg/m3	Total Weight units > kg
retaining wall	<i>Igneous plutonic</i> Granite rock	18.00		
waste material		does not apply	(d)	
Σ volume >		18.00	1600	28800
retaining wall	River sand	6.00		
waste material		does not apply	(d)	
Σ volume >		6.00	1400	8400
Σ total weight of mineral materials >				37200
References:(d) http://scribd.com/doc/2607520/Pesos-especificos-de-materiales-de-construccion				

Table 5-9: Input of mineral materials, case study A-R2

CS: A-R2 Case Study of <i>Attalea g.</i> (Rural) Input of Materials				
Inorganic Materials (Industrial materials)				
Classification of Materials by general group of materials and by type		Volume	Average Weight	Total Weight
Building part	Common name	units > items	units > kg/items	units > Tonnes
retaining wall	Sacks of cement	60.00		
waste material		does not apply	(d)	
Σ quantity >		60.00	50.00	3000
retaining wall	Sacks of limestone	30.00		
waste material		does not apply	(d)	
Σ quantity >		30.00	25.00	750
Σ total weight of industrial materials >				3750
References:(d) http://scribd.com/doc/2607520/Pesos-especificos-de-materiales-de-construccion				

Table 5-10: Input of industrial materials, case study A-R2

5.4 Jalapita Thatch Building in the Mixteca Region, Municipality of San Diego la Mesa, Puebla

Like the cayaco thatch tradition (section 5.1) the jalapita building is highly interrelated with both the vernacular language and the local thatching traditions. The location of this part of the research is within the municipality of San Diego la Mesa Tochimiltzingo and within that municipality the town of San Francisco Jalapexco is highly specialized in thatching due to its proximity to endemic forests of palm fields of *B. dulcis*. This town gives its name of such *B. dulcis* thatched buildings called jalapitas. Localities that hold many examples of thatching are San Bartolo, San Francisco, and Caleras.

Figure 5-19: Jalapita house in San Fransisco Jalapexco

Originally most houses similar to jalapitas (figure 5.19), which are normally entirely thatched, were called in the region ‘xacalli’ nowadays ‘jacales’ from the Nahuatl xacatl (grass) and calli (house) (Siméon, 2004) making it the house of grass. This is still a popular name for these types of house in many parts of Mesoamerica. The name also makes clear that the thatched house, whether of grass or not, echoes a very early model (figure 3-2).

5.5 Case Study B-R (*B. dulcis*, Rural) in the Locality of San Fransisco Jalapexco

The following case study of a jalapita in Jalapexco is located in the Municipality of San Diego la Meza Tochimiltzingo, which belongs to the Mixteca baja (lower Mixteca). Although it is different from the Mixteca alta only in terms of altitude, it is still located in the central highlands of Puebla, about 1,800 m above sea level. The place is mostly on lime soil and it has much more extreme weather than the lowlands or shore areas of Mexico. It is also a dry climate and can suffer from seasons of drought. Its weather is harsh as it can get very cold during nights and winter. Therefore

it is very common to thatch the entire building, but different typologies with rock or adobe walls are also found. However, there is very little variation in size and shape as most rural dwellings are from 4m x 6m to 6m x 8m with a double pitched roof (figure 4.22).

The palm in use is *Brahea dulcis* (Kunth) Mart. It is also called Palma silvestre (wild palm or bush palm) and Palma de sombrero (hat palm). It grows in the wild and does not need any attention, either watering or other maintenance. It is very resistant to harsh conditions and to cold as well as hot weather. Additionally, a wide variety of by-products can be made out of this palm, for instance many types of basket, mats, hats and other ornamental objects, the latter mostly used nowadays in religious festivities often related to agriculture (such as corn plant figures). Once even rain coats were made out of this palm, a tradition now entirely lost. The fruit of the palm is also edible, hence its name *dulcis* (sweet) as it is said that the fruit is very sweet. However, during the 4 years of monitoring this plot during the present research very few of these palms flowered (typically 3 plants out of a plot containing hundreds) (figure 5-20). This may well be because young palms are preferred for harvesting as they grow in clusters and a single cluster can provide a good amount of leaves for thatching or shoots for weaving. The flowers do not appear until the plants are older.

Figure 5-20: *Brahea d.* palm with flowering stalk

The community is very poor and only in the last 10 years has the electricity grid for lighting arrived and a paved road been made. Most of the people are engaged in agriculture, growing maize, and extraction of coal, although recently people have become more and more engaged in other activities with an increased demand, such as the distilling of espadin agave (*Agave angustifolia* Haw.).

5.5.1 The Building, its Materials and their Preparation

Despite the increase in modern influences, thatched buildings are still very common in the rural communities around this region, and it is clear that such buildings have remained very similar in terms of materials, forms, sizes and techniques to those found 500 years or more ago (figure 5-21).

Figure 5-21: Comparison of jalapita building with images from the Codex Vaticanus B, Plate 71

It is also clear that the structure of the work has a fair degree of specialization. For instance, there are people in the working team dedicated to harvesting the palm and managing the plantations. This job is mostly done by women. There are also contracted weavers, again mostly women, although this may come about because men are more likely to do this job out of the region, maybe in response to the tradition of keeping women near the home for house duties. There are also people in charge of managing the forest to obtain the woods needed for the structure, and others who are called preparadores (the ones who prepare). These are in charge of cutting the palms and lacing them in pairs to be woven, and in piling and lashing them in proper bundles for the weavers to use. Finally are the people who manage the plots of reeds or bamboos to be used as battens or for the wattle structures. Other tasks include extracting fibres for lashing and tying from the different species of agave, and the builders of the jalapita structure. This level of stratification and specialization is another vestige of a very old system and tradition that is still current and that has seen very little change.

However, due to the arrival of modern progress, these systems and even the thatch tradition are beginning to decay as people shift to other more lasting materials, but with consequences for the building performance. For instance, the thermal insulation this thick palm envelope offers is much greater than that of a thin layer of corrugated steel roofing. According to the users, these traditional buildings are extremely comfortable, and indeed on personal visits the interior of the case study building was cool on a very hot day and warm during a cold night.

Figure 5-22: Description of the building parts CS: B-R

The following sets of drawing result from the survey inventory made at the site and were used in the calculation of volumes and weights of materials for the environmental analysis.

Figure 5-23: Front view of the building CS: B-R

Figure 5-24: Plan and elevation of CS: B-R in sequence of construction (a)

Figure 5-25: Plan and elevation of CS: B-R in sequence of construction (b)

Figure 5-26: Plan and elevation of CS: B-R in sequence of construction (c)

Figure 5-27: Plan and elevation of CS: B-R in sequence of construction (d)

Figure 5-28: Plan and elevation of CS: B-R in sequence of construction (e)

Figure 5-29: Detail drawing of roof structure of CS: B-R

Foundations

The whole building is made entirely of local natural materials, and a jalapita thatched roof can be achieved entirely out of natural materials. Some buildings will have a proper foundation or platform of rocks, and foundations can also be made out of adobe. However, a fair number of buildings are built without foundations and instead are built over a stabilized, compacted floor, made out of earth, clay, shards, sand, lime, and prickly pear juice, which seems to be the common, archaic way.

Walls and structure

The walls are commonly clad with palm, even the sides that are not pitched. Walls in this type of buildings are, if they occur, of medium height (1m on average). The triangular gable ends of the building can be made out of rock or adobe, but are most likely to be clad with thatch as well.

The main structure normally uses hardwoods such as Encino (*Quercus ssp.*) (Villaseñor, Delgadillo, & Ortiz, 2006). This structure will be in the form of a gabled roof with a secondary structure of battens to support the thatch envelope (figure 5-22). Roofs are double pitched in this area, but outside the region thatched buildings using the same palm can be made with a hipped roof of three, four or more sides according to the plan shape (figure 5-30). However, during the survey of typologies in this municipality no such structures were found, suggesting this is an external influence from clients outside the region (also see figure 4-22 and 4-23 of rural and urban building typologies of *B. dulcis*). Windows never exist, and doors can be found on any side of the building. Doors can be made out of wood or reeds, but wooden planks are preferred.

Figure 5-30: Hip roof made of *B. dulcis* palm thatch

The Thatch

Thatching with *B. dulcis* needs a horizontal grid no wider than 15cm to provide better rain proofing. Since the leaf is short and easily cracks it is woven in pairs (one leaf on the top of the other) with 10cm between paired items (figure 4-21). It needs a lashing material, which is sometimes the palm shoots of the same *B. dulcis*, and at others made out of *Agave ssp.* although more recently synthetic materials such as plastic cord are used.

In general the same thatching process is used with very little change, although from information given by interviewees very rarely a different method for lashing is applied to make the thatch roof last longer. In this technique a wooden or metal needle is used to interweave the palm items closer together.

Other building elements

Some building elements hint of the old former pre-Columbian tradition and social structure of keeping the family together around household, as it is still common to find a cluster of buildings within a shared land area. When this happens traditional buildings elements commonly accompany the extended household, such as pit ovens, sweat bath structures and granaries of various shapes (figure 5.31).

According to the informants, in the past one or more granaries were common within a household, and nowadays some households still have these, although people are shifting their traditions, and are replacing such building units with conventional fridges and relying on local convenience stores or even on distant supermarkets for acquiring their staples. Granaries, once so typical, should now be considered very rare and under extinction. They can be made in different forms and materials and once there would be one or more for each family within the household. Cultivation of land, if it still happens, is always close by. If it is not located on the land being cultivated the household is mostly found in the immediate neighborhood or in the communal hinterland, perhaps 5km distant.

From top left and clockwise: pottery inside the house, granary (cuezcomate), sweat lodge bath, platform granary unit on stilts, detail of cuezcomate (top opening) and cactus fence.

Figure 5-31: Diverse building elements of a traditional household

5.5.2 Inventory and Inputs of Case Study: B-R in San Diego la Mesa

CS: B-R Case Study of <i>Brahea d.</i> (Rural) Input of Materials				
Organic Materials (Hardwoods)				
Classification of Materials		Volumes	Average Weight	Total Weight
by general group of materials and by species		per item	(a) air dried wood; 20% moisture	
Building part	Biological/Common name	units > m3	units > kg/m3	units > kg
short posts	<i>Quercus alba</i>	0.58		
rafters	Encino	0.74		
ridge pole		0.18		
plinth		0.20		
purlins		0.18		
door post		0.03		
waste material (30%)		0.58	(b)	
Σ volumes per species >		2.49	590	1472
door boards	<i>Taxodium mucronatum</i>	minimal		
back tie	Sabino	0.03		
waste material (30%)		0.01	(b)	
Σ volumes per species >		0.03	590	19
Σ total weight of hardwoods >				1491
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (b) (Atencia, 2003)				

Table 5-11: Input of hardwoods, case study B-R

CS: B-R Case Study of <i>Brahea d.</i> (Rural) Input of Materials				
Organic Materials (Softwoods)				
Classification of Materials		Volumes	Average Weight	Total Weight
by general group of materials and by species		per item	(a) air dried wood; 20% moisture	
Building part	Biological/Common name	units > m3	units > kg/m3	units > kg
long gable posts	<i>Cestrum nocturnum</i>	0.25		
short gable posts	Cuitlapil	0.16		
batten supports		0.34		
waste material (30%)		0.23	(b)	
Σ volumes per species >		0.98	300	294
long eaves poles	<i>Yucca aloifolia</i>	0.39		
gable tie	Yucca	0.11		
waste material (30%)		0.16	(b)	
Σ volumes per species >		0.66	300	198
		units > stalks	units > kg/item	
long battens	<i>Arundo Donax</i>	61		
short battens	Carrizo	45		
waste material (10%)*		*10	(c)	
Σ units per species >		116.00	0.3	35
Σ total weight of softwoods >				527
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (b) (Atencia, 2003) (c) weighed by author				
*see assumptions (section 6.1.4)				

Table 5-12: Input of softwoods, case study B-R

CS: B-R Case Study of <i>Brahea d.</i> (Rural) Input of Materials				
Organic Materials (Fibrous materials)				
Classification of Materials by general group of materials and by species		Volumes	Average Weight	Total Weight
Building part	Biological/Common name	per item units > items	units > kg/item	units > kg
leaves for thatching	<i>Brahea dulcis</i> Palma de sombrero	2000.00		
waste material		does not apply	(c)	
Σ volumes per species >		2000.00	0.2	400
roping skeins	<i>Agave fourcroides</i> Henequen	5.00		
waste material		does not apply	(c)	
Σ volumes per species >		5.00	5	25
palm shoots for lacing	<i>Brahea dulcis</i> Palma de sombrero	2000.00		
waste material		does not apply	(c)	
Σ volumes per species >		2000.00	0.05	100
Σ total weight of fibrous materials >				525
References: (c) weighed by author				

Table 5-13: Input of hardwoods, case study B-R

CS: B-R Case Study of <i>Brahea d.</i> (Rural) Input of Materials				
Inorganic Materials (Mineral materials)				
Classification of Materials by general group of materials and by type		Volumes	Average Weight	Total Weight
Building part	Common name	units > m3	units > kg/m3	units > kg
floor	Compacted earth	3.60		
waste material		does not apply	(d)	
Σ volume>		3.60	1600.00	5760
Σ total weight of mineral materials >				5760
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (d) http://scribd.com/doc/2607520/Pesos-especificos-de-materiales-de-construccion				

Table 5-14: Input of hardwoods, case study B-R

5.6 Case Study B-SU (*B. dulcis* Suburban) in the Municipality of Atlixco, Puebla

The following case study differs from all the others for the reasons listed below:

- 1) the building size,
- 2) it is an informal commercial building sometimes hired for events,
- 3) it is located in an urban context and
- 4) parts of the building (walls) are made of baked bricks (from an earlier stage).

The relevance of including this case study building relies on the fact that it was found at the very start of its construction, during the fieldwork carried out in Atlixco, Puebla.

Another important aspect was the opportunity presented to take part in the whole construction process as a volunteer. Therefore, although the consent to use this information in the present research was granted from the contractor and the owner, there was no need to carry out interviews as all the information is from first hand.

5.6.1 The Building, its Materials and their Preparation

The palm had been already imported to the site and some work, such as drying the leaves properly, had been done (at the start of the volunteer work the last truck load of palm leaves was waiting to be unloaded). The timbers were also acquired from elsewhere, but in order to discover more a visit to this site was made after the building was finished.

The first task was to unload the 1.5 tonne pick-up truck that was full of the so called Sombrero palm. This took two men two hours. After a short break, the next task was to prepare the palms ready for the weavers. This palm leaf is fan shaped, short in length and with a large spiky stalk, so part of the process is making the palms into separate groups. Some labourers are in charge of random tasks such as piling the palm leaves to protect them from rain in a shed, others start carrying out the proper preparation of the materials. This involves selecting, chopping, and lacing the leaves to be tied in bundles, while others are dedicated to putting up the structure, or the roping.

However before describing the foundation, structure and walls, and thatching the set of survey drawing is presented below.

Figure 5-32: Front view of CS: B-SU

Figure 5-34: Front view of structure with battens of CS: B-SU

Figure 5-35: Plan of main structure without battens CS: B-SU

Figure 5-36: Side view of the building without roofing battens (north) CS: B-SU

Figure 5-37: Side view of the building with battens and un- thatched (north) CS: B-SU

Foundations

The construction had just started and the posts were already buried, but information about this process was collected to complete the survey. It took two working days to determine the best woods and cut them to proper size, excavate the holes that were 1m deep on average, or until hard soil [tepetate] (hardened volcanic ash layers) (Haulon, Werner, Flores-García, Vera-Reyes, & Felix-Henningsen, 2007, p. 498) was found.

Structure

Despite this, all of the processes that went into the construction of the building could be detailed. First the structure took one week to achieve, although the structure is different from the most common building typologies found in the locality. The fact the builder works as a contractor to commercialize thatch buildings means there are external influences, such as those found in coastal tropical buildings (section 5.7).

Some of the differences with the rural examples are the size of the building and the way of securing the beams to the posts and the struts and hip rafters to the beams. In this building some steel reinforcing bars were used for this purpose. The rest of the elements that go into the structure were bound with natural ropes of *Agave ssp.* as in the traditional vernacular way (figure 5-38). The construction of the whole structure was carried out carefully by the contractor and two helpers, whereas at other stages of the job the contractor was less conscientious about supervision since he knew his crew well and that they would achieve a good standard of building.

Figure 5-38: Roping system of battens of thatch buildings in Atlixco, Puebla

The roof is a hipped roof and has a system of inner angled struts in a pyramidal form to give more strength to the building (figure 5-39). All the wood used came from the Encino tree (*Quercus alba* L.), which is the most available in the region.

Figure 5-39: Hipped roof of structure view from the inside with inner angled struts in a pyramidal form

The secondary structure in the form of battens was entirely made of carrizo (*Arundo donax* L.). This was completed by a crew of four thatchers in three days and was all roped with ‘henequen’ rope made out of agave (*Agave fourcroydes* Lem.).

The Thatch

The thatching has different stages, the first being to prepare it ready to be woven. Since *B.dulcis* is a small fan-shaped leaf and is certainly more fragile than the other two palms in this investigation, each thatching item comes as a pair (figure 5-40). To

achieve this, first the stalk of the leaf is cut to a standard length of 10-15cm to allow it to be bound to the battens. The following pairing process is achieved by lacing the two palm leaves together with new shoots from the same palm to make one thatching item. Finally bundles of 40 pairs are piled and roped together in order to lift them with rope to the layer being woven on the roof, as the thatch is completed in layers from bottom to top and with overlaps on the sides as it is woven. The distance between pairs is one hand (100mm), and the distance between the battens is usually one to two hands (100-150mm).

This process took two weeks and used approximately four times the load of a pickup truck of 1.5 tonne carrying capacity.

Figure 5-40: Pairing items of Brahea dulcis

5.6.2 Inventory and Inputs of materials of Case Study B-SU in Atlixco

CS: B-SU Case Study of <i>Brahea d.</i> (Suburban) Input of Materials				
Organic Materials (Hardwoods)				
Classification of Materials		Volumes	Average Weight	Total Weight
by general group of materials and by species		per item	(a) air dried wood; 20% moisture	
Building part	Biological/Common name	units > m3	units > kg/m3	units > kg
posts	<i>Quercus alba</i>	2.26		
short beams	Encino	0.93		
medium beams		0.32		
long beams		0.25		
long hip rafters		0.69		
short hip rafters		0.25		
diagonal rafters		3.27		
rafters		1.12		
ridge poles		0.22		
purlins		0.31		
ties		0.05		
intermediate ties		0.09		
upper ties		0.01		
waste material (30%)		2.93	(b)	
Σ volumes per species >		12.68	590	7484
Σ total weight of hardwoods >				7484
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (b) (Atencia, 2003)				

Table 5-15: Input of hardwoods, case study B-SU

CS: B-SU Case Study of <i>Brahea d.</i> (Suburban) Input of Materials			
Organic Materials (Softwoods)			
Classification of Materials by general group of materials and by species		Volumes per item	Average Weight (a) air dried wood; 20% moisture
Building part	Biological/Common name	units > stalks	units > kg/m3
battens	<i>Arundo Donax</i> Carrizo	280	
waste material (10%)		*10	(c)
Σ units per species >		290.00	0.30
Σ total weight of softwoods >			87
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (b) (Atencia, 2003) (c) weighed by author *see assumption (section 6.1.4)			

Table 5-16: Input of softwoods, case study B-R

CS: B-SU Case Study of <i>Brahea d.</i> (Suburban) Input of Materials			
Organic Materials (Fibrous materials)			
Classification of Materials by general group of materials and by species		Volumes per item	Average Weight
Building part	Biological/Common name	units > items	units > kg/item
leaves for thatching	<i>Brahea dulcis</i> Palma de sombrero	15000.00	
waste material		does not apply	(c)
Σ volumes per species >		15000.00	0.20
roping skeins	<i>Agave fourcroides</i> Henequen	15.00	
waste material		does not apply	(c)
Σ volumes per species >		15.00	5
palm shoots for lacing	<i>Brahea dulcis</i> Palma de sombrero	5000.00	
waste material		does not apply	(c)
Σ volumes per species >		5000.00	0.05
Σ total weight of fibrous materials >			3325
References: (c) weighed by author			

Table 5-17: Input of fibrous materials, case study B-R

CS: B-SU Case Study of <i>Brahea d.</i> (Suburban) Input of Materials				
Inorganic Materials (Mineral materials)				
Classification of Materials by general group of materials and by type		Volume	Average Weight	Total Weight
Building part	Common name	units > m3	units > kg/m3	units > kg
floor	Compacted earth	11.17		
waste material		does not apply	(d)	
Σ volume >		11.17	1600	17872
Σ total weight of mineral materials >				17872
References:(d) http://scribd.com/doc/2607520/Pesos-especificos-de-materiales-de-construccion				

Table 5-18: Input of mineral materials, case study B-R

5.7 Palapa Thatch Building in the Municipality of Manzanillo, Colima

Palapa is the name given to buildings made out of the palm *Sabal rosei*. However, the traditional name for this palm is Palma de potrero (padlock palm), Palma de guano (dung palm), Palma de gorro (hat palm), or Palma de palapa, these last two names responding to the use of the material for thatching. Palapa is also the name of the thatched building itself. Also gorro de palapa is a local name to refer to a *S. rosei* palm thatch roof (figure 5-41).

Unlike the other two palms where the name has vernacular origins, the names of this palm are foreign. All those mentioned above are Spanish names, except for the last one that is of Malayo (tagalog) origin from the Phillipines This last suggests evidence of an imported technology, although the palm is native and the genus is truly accepted as a genus of the New World mostly related to the Caribbean plateau (section 4.1.4).

Despite their origins, the common names mentioned above highlight the features of the palm since the first name given (padlock palm) emphasizes the fact that this type of palm is very resistant to fire, and thus resistant to the so called slash and burn agricultural practice still common and well established in certain areas of rural Mexico. Since it is an economically productive forestry plant, farmers like to see it on agricultural land, to provide diversity in the economic productivity of the plot. It is

thus very common to have it in grass or cultivated fields. Regarding the second name, the fruit of this palm is very appealing to bats, and excretion of the seeds is an important part of the palm's reproductive cycle. The last two common names are related to a building technique since *Palma de gorro* meaning literally 'hat palm' is an echo of a roof, while *palapa* refers to the fibrous stalk or petiole of a palm, or a rattan (which is a palm), or a banana plant, all fibrous materials on stalks and with broad leaves that are good for thatching. Indeed these plants were often processed into many other utilitarian forms, as once the banana was precious not only for fruit but for its fibrous content for making cloth, as in the case of *Musa textilis* (Cafferty, 2005).

*Figure 5-41: Traditional thatch style “gorro de palapa” building near Ciruelito,
Colima*

The following section highlights how palapa technology in the middle west coast area of Mexico has evolved and improved over time through external influences and transfer of technology (local and foreign), even though purely architectural research

would regard it as a simple and traditional vernacular technology that only responds to local conditions and materials. This reveals an interesting point regarding the beginnings of globalization through vernacular expressions that has been going on for at least 500 years on the Mexican west coast, and that has resulted in a wide variety of building typologies (figure 4-30). This suggests the transfer of technology could have happened at any time and in any place, and that one culture could have adopted a foreign technology, adapted it to local resources and converted it to the point where it is considered to be native. Thus the vernacular can represent the place and the culture but only once a vernacular has been truly established. This is important for sustainability and the vernacular as it shows that globalization, which tends to increase the energy and resources going into buildings, happened long ago but at a very different rate from modern globalization. It may be that rate of change and exchange of ideas rather than just change itself is the issue for sustainability and the built environment.

5.7.1 Asian Influence and the Evolution of Palapa Technology in Mexico

Between the 16th to 18th centuries Mexico and the Philippines were closely connected through the trade route of the Manila-Acapulco galleons. This fact brought a large population from the Philippines to Mexico and vice versa. The Philippine people could have come with the deliberate intention to live on the Mexican coast due to social and tribal problems in their own lands. Mexico was then considered a very promising land and welcoming to indigenous groups as it is clear that Mexico already had a wide cultural diversity. It was at that time conformed as a confederation of nations with a very complex structure and with local autonomy, rather than a colony or a republic, or nation. Today, there is still a large population of mixed-races of Asian origins, mostly from the Philippines and Southeast Asia, although originally in Mexico they were named using the generic term of ‘Chinese’.

The Asian influx as stated in section 3.3.2 brought with it the cultures of their people, which is clearly reflected in many features in present Mexico and that can be traced on a map moving inland from the west coast. For instance there are china and pottery (Kuwayama, 1997; Slack Jr, 2009), the lacquer technique (Foster, 2014; Martinez Shaw & Mola, 2014), the tapa paper technology (Bell, 1985), the distillation process

(Bruman, 1945; Zizumbo-Villarreal & Colunga-GarcíaMarín, 2008), and of course the coconut and other related palm traditions and technologies (Brady, 2010; Marshall & Marshall, 1975) (section 4.4). Although there is discussion that some of these traditions were introduced prior to European contact, this is outside the scope of this research.

Palms were not the only import as other productive plants were brought from the Asian and the Pacific areas, such as the litchi, tamarind, mango and banana, but of relevance for this work a whole set of technologies surrounding palm culture were also introduced. Of prime importance for this work are the thatching technologies that might well have been improved by contact with Asian and Pacific technology, and the long historical tradition of using the material in these countries.

It is known that palapa as a word, referring in the former language to the fibrous stalks of palms and other related plants, was adopted by locals, and became the term used to refer not only to the material for thatching but to the roof of the building and also to the whole structure. This word was initially popular in west coast Mexico, particularly in Colima (where large plots of coconut palms, tamarinds, bananas, and mangos can be found) but soon started moving through the rest of the country and now has even reached the United States, where palapa is a common word to refer to a thatched building or roof.

Palapa structures found now in west coast Mexico are far more complex in technique than other thatch technologies elsewhere. For instance the palapa building structures can be found as a mono or double pitched roof, or as hipped roofs of three, four or more pitches, with clerestories or without, and sometimes with multiple clerestories. Some also have upper storage space, roof windows, and one or more openings for cross ventilation.

They are also built on stilts or platforms or simply with poles, and can have wattle, or wattle and daub walls, as well as walls using mixed techniques (bricks, adobe, concrete posts with infill, or open walls). The plan can be rectangular or the roof can follow curved walls and curved roofs can be achieved (figure 5-42). This variety all comes from the weaving techniques and the use of *Sabal* palms (figure 5-43).

Figure 5-42: S. rosei thatched curved roof structure with multiple roofs

Colima has the best reputation for its thatchers around Mexico and these can sometimes be contracted to work in distant places. It is not unusual to see Colima thatchers anywhere in Mexico and even abroad. According to those interviewed, palapa builders from this area have built palapas in the United States, in Central America, in Caribbean countries and as far away as Saudi Arabia. It is not just the labourers who are exported but also the materials and the technology itself. It is also very likely that high quality, expert palm thatchers from elsewhere have been trained by Colima thatchers or by someone who had been trained by them.

Figure 5-43: S. rosei “a hueso” weaving techniques allows many possible shapes of thatching structures

The environment of Colima offers very similar conditions to those of Southeast Asia, which helps to explain not only the expertise of the builders, but the tradition of using the materials, as Colima and southern Jalisco are considered a centre for using natural materials and for thatching. This is of interest for this research as in accounting for the embodied energy of a building it is clearly accepted that the further a material travels the more transport energy it requires. Thus exporting the materials and traditions out of the local area may not be a sustainable action, even though the materials are natural.

Finally, it is clear that Asian knowledge about tropical buildings had a large influence despite their small population in comparison with other migrant groups in Mexico. It seems influential even compared to the Spanish who brought different building systems and backgrounds, such as that of the Arabs, to Mexico. These resulted in desert type buildings very suitable for the arid regions and climates of Mexico, with their central patios for collecting water and thick layers of thermally massive materials. However, these are not suitable for tropical climates, particularly those prone to hurricanes and earthquakes as is this coastal region.

However, the rapid and increasing population of palapa buildings is also a response to the technologies that were developed in Mexico prior to Asian contact. Similarities include triangular flexible framing, achieved with lashing techniques, and use of

suitable hard and soft woods, which are flexible and resistant to such conditions. Despite the earlier statements about the improvements to technologies due to the Asian influence during the colonial period (16th to 18th centuries) and despite the discussion of whether the contact happened before that of the Europeans, it is clear that the coast also had a relationship with other areas such as Ecuador and Colombia. It is evident from pre-Columbian evidence that more complex structures existed prior to any solid proof of Asian contact during the colonial period (figures 3-1; 3-7; 5-44).

Figure 5-44: Comparison of modern palapa thatch and early ceramic model. Drawing after von Wining 1998

Finally, those interviewed for this research suggested the evolution of complex structures (sometimes with a roof span greater than 40m with no intermediate posts) and of the weaving technique are more likely to have been caused by modern improvements and demands foreign to those related to the cultures above. These influences are from international and national tourism, and commercial and residential development in the region. A local thatcher native to Colima can trace back the origins of the most preferred and well-known thatching technique used now (*tejido a hueso*, (figure 5-43) to a line of masters and disciples. This is a method that does not need any lacing or lashing material to attach the palm to the battens. However this can only be

achieved with sabal palms, because this palm has a long strong stalk or petiole that extends far beyond the leaves (figure 4-28; 5-45).

Figure 5-45: Detail of 'a hueso' weaving technique done with Sabal palm showing the stalks visible from the interior

5.8 Case Study S-R (*Sabal rosei* Rural) in the Locality of Ciruelito la Marina, Colima

In the search for vernacular expression and particularly for buildings to assess for this research, many thatchers pointed to the region in the locality of Ciruelito la Marina located 600m above the sea level and about 45 km away from the shores of Manzanillo, Colima as the place to visit, as it has a long tradition of thatching. Ciruelito is one of three regions popular among builders when gathering materials to build palapa thatch buildings. These materials range from hardwoods for the primary structure, to fibrous materials for the secondary structure such as Otate bamboo, and

particularly the leaves of *Sabal r.* as thatching items. The other two popular regions for their high densities of *S. rosei* palm are in the northern neighbouring state of Jalisco in the localities of El Tigre near Cruz de Loreto and La Selva de Cuitzmala near the towns of Emiliano Zapata and Careyes, however these last two localities are culturally and regionally more engaged with Manzanillo as the closer municipality than any other in Jalisco.

Ciruelito la Marina is a small town of about 500 people, mostly engaged in agriculture through the cultivation of cucumbers and maize and grazing cattle. The other major economic activity is the harvesting of materials for buildings. However, despite its popularity amongst thatchers, locally called palaperos, the town is virtually unknown to outsiders and seldom visited by locals not interested in buildings. Also striking is that despite being considered as a ‘warehouse’ of natural materials, very few thatched buildings can be seen, as people have shifted to the use of modern conventional materials, such as hollow block, baked bricks and concrete frame houses with a concrete slab or steel sheet roof instead of thatch. This may be a function of more money coming into the area from the sale of these natural materials. Notwithstanding this, those palapas that do exist are very different from the more elaborate structures of thatched buildings found along the shores in resorts, residences and commercial buildings (figure 5-46)

Figure 5-46: S. rosei thatch palm commercial building

The following case study was of particular interest as the building had the particular characteristics proper to a higher altitude climate. It also resembled an old vernacular style rather than a modern thatched structure. It was also located in the middle of Ciruelito which is famous for its materials for thatching (figure 5-47).

Figure 5-47: S. rosei thatch palm building case study S-R in Ciruelito

5.8.1 The Building, its Materials and their Preparation

The building in this section is different from the ones found on the shore and this is due to the fact that the Ciruelito region is at a higher altitude. Rather than open walls and high posts, the case study building is enclosed, windowless and has a shallow roof. This form is in response to the colder weather of the nights. However, overall the building is still high in terms of the total height of the roof from ridge pole to floor, in order to make it comfortable during the warmer weather of the day. Its sides are low to protect from both wind and rain.

The building was spotted during the field trip to the plots as it is near the palm groves. The owner was then contacted in order to gain permission to survey the building as part of this investigation. Permission was granted for a photographic record, drawings and measurements in order to have enough information to produce the survey drawings and for the input analysis.

Figure 5-48: Description of the building components, CS: S-R

Figure 5-49: Thatch building in its site, CS: S-R

Elevation east structure

Figure 5-50: Front view of the building (east) CS: S-R

Roof structure

Figure 5-51: Roof structure plan, CS: S-R

Elevation south structure

Figure 5-52: Plan of roof structure, CS: S-R

Foundation

The building is constructed on an earth embankment, as since the building is small in size and weight it did not need a deep foundation. The earth embankment is of stable soil and thus the poles were buried to a depth of 1 metre. It has a concrete floor 70 mm thick.

Structure and walls

The building has a combination of materials and techniques, such as wattle walls and board walls. However, due to the fact the owner was not an expert, not all the materials could be traced back to a specific species. Consequently, some general assumptions will have to be made for the inventory of materials based on materials that seem similar to the ones used in this building. These assumptions came from the local expert

thatcher who identified the boards of the wall as Habilidad wood with Mangle branches for the wattle. The posts were identified as Balsamo wood and the rest of the structural elements were Verdecillo.

The Thatch

Worth noting is the way the leaves were thatched is unlike the usual techniques, though both the owner and the expert thatcher stated this type of building was like those found in the past. It used nails instead of rope or an interweaving technique to fasten the thatch to the battens (figure 5-53).

Figure 5-53: Detail of the thatching technique from inside, CS: R-S

5.8.2 Inventory and Inputs of Case Study: S-R in Ciruelito la Marina

CS: S-R Case Study of <i>Sabal r.</i> (Rural) Input of Materials				
Organic Materials (Hardwoods)				
Classification of Materials by general group of materials and by species		Volumes per item	Average Weight (a) air dried wood; 20% moisture	Total Weight
Building part	Biological/Common name	units > m3	units > kg/m3	units > kg
corner posts	<i>Myroxylon balsamus</i>	0.23		
wall posts	Balsamo	0.11		
door posts		0.11		
ridge pole		0.02		
wattle support posts		0.07		
door frame		0.04		
waste material (30%)		0.17	(b)	
Σ volumes per species >		0.75	950	713
long eaves poles	<i>Tabebuia chrysantha</i>	0.20		
short eaves pole	Verdecillo	0.14		
hip rafters		0.25		
rafters		0.24		
angled rafter		0.25		
short rafters		0.13		
roofing battens		0.25		
door fence		0.02		
waste material (30%)		0.44	(b)	
Σ volumes per species >		1.91	1032	1975
Σ total weight of hardwoods >				2688
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (b) (Atencia, 2003)				

Table 5-19: Input of hardwoods, case study S-R

CS: S-R Case Study of <i>Sabal r.</i> (Rural) Input of Materials				
Organic Materials (Softwoods)				
Classification of Materials by general group of materials and by species		Volumes per item	Average Weight (a) air dried wood; 20% moisture	Total Weight
Building part	Biological/Common name	units > m3	units > kg/m3	units > kg
wall boards	<i>Hura crepitans</i> Habillo	0.28		
waste material (30%)		0.08	(g)	
Σ volumes per species >		0.36	520	187
wattle	<i>Rhizophora mangle</i> Mangle	0.61		
waste material (30%)		0.18	(h)	
Σ volumes per species >		0.79	840	664
Σ total weight of softwoods >				851
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (g) http://orton.catie.ac.cr/repdoc/A0009S/A0009S129.PDF (h) http://orton.catie.ac.cr/repdoc/A0008S/A0008S48.PDF				

Table 5-20: Input of softwoods, case study S-R

CS: S-R Case Study of <i>Sabal r.</i> (Rural) Input of Materials				
Organic Materials (Fibrous materials)				
Classification of Materials by general group of materials and by species		Volumes per item	Average Weight	Total Weight
Building part	Biological/Common name	units > items	units > kg/item	units > kg
leaves for thatching	<i>Sabal rosei</i> Palma de palapa	3000.00		
waste material		does not apply	(c)	
Σ volumes per species >		3000.00	0.30	900
Σ total weight of fibrous materials >				900
References: (c) weighed by author				

Table 5-21: Input of fibrous materials, case study S-R

CS: S-R Case Study of <i>Sabal r.</i> (Rural) Input of Materials				
Inorganic Materials (Industrial materials)				
Classification of Materials by general group of materials and by type		Volumes	Specific Weight	Total Weight
Building part	Common name	units > m3	units > kg/m3	units > kg
Floor	Concrete floor	1.37		
waste material (10%)*		0.14	(d)	
Σ volume>		1.51	2300	3471
nails for thatching waste material	Iron nails	units > bags	units > kg	
		25.00		
		does not apply	(d)	
Σ volume>		25.00	1	25
Σ total weight of industrial materials >				3496
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (d) http://scribd.com/doc/2607520/Pesos-especificos-de-materiales-de-construccion *see assumptions (section 6.1.4)				

Table 5-22: Input of industrial materials, case study S-R

5.9 Case Study S-U (*Sabal rosei* Urban) in the City of Manzanillo, Colima

The last case study is located on the shore of the city of Manzanillo, in the state of Colima. This case study was built by a palapero and he was granted permission to provide data by the owner of the building. He was the expert on plant uses in the fieldwork carried out for the *S. rosei* palms.

The thatched building is used as an outdoor room for a residence, and is more luxurious than the other buildings surveyed.

5.9.1 The Building, its Materials and their Preparation

In this case study the building materials are more luxurious as they were paid for to be part of a terrace in a high class residential neighbourhood, therefore wider diameter posts and a more elaborate structure were employed.

The materials were transported over a 25km radius as they were brought from the region of Ciruelito which is about 25km away from the city of Manzanillo. The information about the loads and means of transportation was not always available so it

will be calculated based on appropriate assumptions. However, the survey of the building materials was carried out and additional information in the form of images of the stages of the process were accessed (figures 5-54 to 5-58).

Figure 5-54: The building components for CS: S-U

Figure 5-55: The structure under construction used hardwood such as Guayabillo and Otate bamboo as battens

Figure 5-56: The structure from inside un-thatched

Figure 5-57: Top view under final thatching

Figure 5-58: The roof thatched from the inside

Front elevation

Figure 5-59: Front view of the building, (south) CS: S-U

Side elevation

Figure 5-60: Side view of the building, (west) CS: S-U

Roof structure plan

Figure 5-61: Plan view of the building, CS: S-U

Floor plan

Figure 5-62: Plan view of the building structure, CS: S-U

The materials and features of the building parts and processes are described as follow:

Foundation

The foundation for this building is a common technique for *S. rosei* thatched structures, The posts are buried to a depth of 1m-1.20m or until stable soil is found and concreted in, with a concrete slab floor.

Structure

The poles are wider in diameter than found in more traditional buildings and this building has a clerestory roof and better quality finishes. It uses older pole woods, which are all Granadillo and Botoncillo local timber of 100mm to 250mm diameter. It also used vine as the binding material which is considered a higher quality specification. These materials can last up to 100 years or more if properly maintained.

Thatch

The thatching uses the “a hueso” method on a grid Otate bamboo. As it is a hipped roof it needs a more elaborate weave at the corners to protect the joints. It is a totally woven structure with no lashing or nails used.

5.9.2 Inventory and Inputs of Case Study: S-U in Manzanillo, Colima

CS: S-U1 Case Study of <i>Sabal r.</i> (Urban) Input of Materials				
Organic Materials (Hardwoods)				
Classification of Materials		Volumes	Specific Weight	Total Weight
by general group of materials and by species		per item	(a) air dried wood; 20% moisture	
Building part	Biological/Common name	units > m3	units > kg/m3	units > kg
posts	<i>Dalbergia retusa</i>	0.44		
long pole beams	Granadillo	0.41		
short pole beams		0.24		
bottom hip rafter		0.31		
clerestory corner posts		0.07		
long trimmer pole		0.19		
short trimmer pole		0.07		
top hip rafter		0.07		
ridge pole		0.14		
waste material (30%)		0.58	(b)	
Σ volumes per species >		2.51	950	2387
long rafters	<i>Cordia alliodora</i>	2.50		
medium rafters	Botoncillo	2.30		
short rafters		1.20		
waste material (30%)		1.80	(i)	
Σ volumes per species >		7.80	520	4056
Σ total weight of hardwoods >				6443
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (b) (Atencia, 2003); (i) http://www.fs.fed.us/global/iitf/Cordiaalliodora.pdf				

Table 5-23: Input of hardwoods, case study S-U

CS: S-U1 Case Study of <i>Sabal r.</i> (Urban) Input of Materials			
Organic Materials (Softwoods)			
Classification of Materials by general group of materials and by species		Volumes per item	Average Weight
Building part	Biological/Common name	units > m3	units > kg
battens	<i>Otatea aztecorum</i>	1.05	
	Otate bamboo		
waste material (30%)		0.31	(c)
Σ units per species >		1.36	150
Σ total weight of softwoods >			408
References: (c) weighed by author			

Table 5-24: Input of softwoods, case study S-U

CS: S-U1 Case Study of <i>Sabal r.</i> (Urban) Input of Materials			
Organic Materials (Fibrous materials)			
Classification of Materials by general group of materials and by species		Volumes per item	Total Weight
Building part	Biological/Common name	units > items	units > kg
leaves for thatching	<i>Sabal rosei</i>	7200	
	Palma de palapa		
waste material		does not apply	(c)
Σ volumes per species >		7200	0.30
Σ total weight of fibrous materials >			2160
References: (c) weighed by author			

Table 5-25: Input of fibrous materials, case study S-U

CS: S-U1 Case Study of <i>Sabal r.</i>(Urban) Input of Materials				
Inorganic Materials (Industrial materials)				
Classification of Materials by general group of materials and by type		Volumes	Specific Weight	Total Weight
Building part	Common name	units > m3	units > kg/m3	units > kg
floor slab	Concrete floor	3.22		
waste material (10%)*		0.32	(d)	
Σ volume>		3.54	2300	8135
Σ total weight of industrial materials >				8135
References: (d) http://scribd.com/doc/2607520/Pesos-especificos-de-materiales-de-construccion				
*see assumptions (section 6.1.4)				

Table 5-26: Input of industrial materials, case study S-U

5.10 Summary

This chapter has detailed the six case study buildings to show how they are constructed and the materials used. These materials have been measured by weight and volume and assumptions made about any wastage produced during the construction process. How the materials were brought to site is also stated where known. All information has been collected from site visits and structured interviews and in one case from working as part of the construction team. The information summarised in forms of tables will be used as the basis of the environmental impact assessment.

SECTION THREE

CHAPTER 6

ENVIRONMENTAL ASSESSMENT OF SELECTED VERNACULAR PALM THATCHING TECHNOLOGIES

The following section is the environmental impact assessment forming the final stage of the investigation. It uses a combination of the qualitative and quantitative results from the fieldwork analyses with the use of complementary data from bibliographical review such as conversion factors.

The results of the research investigation are presented in summary in the form of tables and graphs detailing species used and materials classified as volumes and weights, as well as the time taken, distance travelled and resulting 'energy' that goes into the thatching structure over its life. The aim is to highlight the areas where this type of vernacular architecture can be strong and weak in terms of building sustainability.

The findings are, therefore, in the form of inventories and matrixes of materials, embodied carbon, embodied energy, and the ecological footprint for each building, to better understand where the energy goes. These include the carbon, energy and ecological footprint of transporting materials to site, based on the types of transport, load capacity, number of trips, types of fuel, performance, and distances travelled when these occur. From these tables graphs are derived to show the separate breakdown of carbon, energy and ecological footprint in two ways; one as first constructed and the second over a 50 year expected life.

Finally a comparison is made of all the case studies to highlight differences. The results are reduced to a per m² basis for comparison with conventional building technologies used in the localities of the research. However, before the environmental impact assessment of the case studies, some assumptions must be made clear.

6.1 Assumptions for the Environmental Impact Assessment

6.1.1 The selection of case studies

The selection of case studies and functional units is based on the typological features of each palm species and the focus on small thatched residential buildings (some with minor commercial uses) rather than large commercial ones, to avoid the impact of large structural elements on the assessment, and to have a similar life expectancy.

6.1.2 Lifespan of the building and limits of the Life Cycle Analysis

The lifespan of the building was set at 50 years. Although the interviews highlighted the fact the life of vernacular thatch residential dwellings vary greatly, some lasting as little as a thatching cycle (12-20 years) and other over a century, the lifespan of the building was set at 50 years as an average found in the fieldwork and interviews, and based on other developed world research into the life cycle assessment of residential dwellings (see table 2.1), to allow a better comparison.

The limits of the life cycle analysis were reduced to the embodied energy that goes into the building and thus ignoring operational energy (section 19.3.3). The limits of the assessment are from the extraction of materials, their manufacture or processing and assumed maintenance or renovation over the 50 year building life. Not considered is the end of the building life, its demolition and disposal, the possible reuse or recycling of materials and components, and the integration of composted vegetative building materials to the soil.

6.1.3 Estimation of Carbon and Energy of Materials and Conversion Factors

The indirect or embodied energy of some materials in some cases had to be assumed. For instance, the embodied energy coefficient of mineral and industrial materials could not be properly calculated as their processing could widely vary. Therefore some assumptions were made about the carbon or encapsulated energy content of natural mineral materials, such as rocks or sand, some processed materials such as rope and cordage, and industrial materials such as iron, cement and limestone. These particular assumptions will be clarified for each case study within the inventory tables.

It is also important to note that all information was not always available, such as the weight of all the timbers involved in a building or the identification of certain species

due to the lack of related bibliographic or plant material to carry out this task. Therefore where necessary assumptions are drawn from the literature and use made of the closest acceptable value.

Some things, especially related to industrial were difficult to calculate and therefore also rely on assumptions. In the past the relevant vernacular technologies were successful without relying on industrial materials, but this is a reflection of the ever changing nature of things, including the vernacular process. However, the most complete information relates to the vegetative materials surveyed in the fieldwork, and particularly for the three palm species under investigation. Table.6.1 gives the factors used for materials other than the natural materials investigated in the fieldwork and the references. Without figures for Mexican production best guesses were made about the most appropriate sources.

Material	MJ/kg	gmC/kg (carbon)	kgC/kg	Reference
Granite	5.9	25.36	0.025	(Mackay, 2008) (MJ/kg) (Crishna et. al, 2010) (gmC/kg)
Sand	0.1	1.88	0.0019	(Alcorn, 2001)
Cement	6.2	271.06	0.271	(Alcorn, 2001)
Burnt limestone	1.2		0.386	(Gliessman, 1998) (MJ/kg) (de Lespinay, 2006) (kgC/kg)
Steel rebar	8.6	95.99	0.0599	(Alcorn, 2001)
Nails (steel)	12.3	3.35	0.0034	(Alcorn, 2001)
Bricks	6.7	1.83	0.0018	(Alcorn, 2001)
Concrete 1:3:6	0.77	26	0.026	(Hammond & Jones, 2008)

Table 6-1: Conversion factors of Materials

6.1.4 Wastage of Organic and Inorganic Building Materials

The figure for wastage for both organic and inorganic materials is based on observation building experience in the region. However because a proper calculation methodology for each species was out of the scope of the research assumptions were still made. For instance, in the case of hardwoods and softwoods, 30% waste materials

was considered a reasonable figure, representing the organic matter disposed in the preparation of the building element, as branches and leaves are cut and disposed of as well cutting the trunk to the required shape. Whether this waste material becomes firewood has not been considered. Some off-cuts are used in the same building as smaller building elements or kept for other works, but it is also true that many will never be used and will rot or be burnt.

For wastage there is a difference between industrialized and vernacular materials. For the former, building elements are made to standard measurements and industries thus tend to minimize their waste production. In the vernacular harvested elements like leaves are the shape to be used, and each shape informs a particular technique, so wastage is not an issue.

So for the materials considered in this research, such as bamboos (*Otatea ssp Guadua ssp* or *Bambusa ssp*) and wattle branches (*Rhizophora mangle*) the assumption applied is similar to that for hardwoods and softwoods. Any organic matter not useful is disposed of and there is shaping of elements in to the required size. Therefore, a wastage of 30% based on the specific weight of the materials is used.

For the particular case of ‘carrizo’ reeds (*Orundo donax*) the specific weight shown in tables (section 5.5.2 and 5.6.2) has being calculated based on the building unit instead of on the plant when harvested, therefore, although the figure of 30% waste seems odd, it takes into account the preparation of the plant to the required shape for building.

The three palm species are considered to be harvested and used without wastage, since the quantity used to calculate the total weight for the environmental analysis was derived from the average dry weight obtained from the fieldwork data from whole leaves when first harvested, rather than as a thatching unit shaped to size. The palm to be thatched needs to be properly prepared as explained in chapter 4. For instance the bulkiest part of the stalk (petiole) is cut-off to make the leaf into equal size thatching units

For inorganic materials such as rock and sand in cases studies A-R1 and A-R2 (sections 5.2.2 and 5.3.2), the assumption behind ignoring waste is based on the information from the fieldwork, since the rocks and the sand come from the building site.

Finally the waste figure for industrial materials are different for materials bought in standardized amounts such as nails, cement and limestone (sacks) from materials prepared in situ such as concrete. In the former the waste generated during production is already implicit in the embodied energy coefficients for the standardized volumes for the construction task. For concrete the estimated waste figure is based on experience and observation on building sites. For small buildings in developing countries such as Mexico more human labour and craft skills are used to achieve elements of conventional materials such as concrete, so the mixture is usually prepared on site instead of using ready mix. This means there is always a left over that is sometimes used for the next task, but is also sometimes impossible to save. Consequently a waste figure for concrete of 10% is considered reasonable.

6.1.5 Transportation

The food energy for the work done by humans and animals was not taken into account here, since for both daily exercise is part of rural life in Mexico. However, when it comes to motor transport, although the type of transport use for each process was investigated, and the general information such as type and model of vehicle, distances, load capacities and performance was known, for the 50 year life scenarios this information is not known. Here the transport is assumed to be the same as that of the most common scenario for the case study or region.

6.2 Results and Matrix Calculation of the Assessment Tables

To calculate the tables, useful information was derived from the two types of fieldwork. The qualitative data from the surveys was used to establish the plant species, sizes and weights and to note the types of energy involved in the process and the means of transport and distances when required. The surveys also provided quantitative data to establish the volumes used as accurately as possible.

The tables were thus obtained from this hybrid approach, and supplementing missing information from a bibliographical review of input-output analyses to obtain relevant conversion factors for carbon, energy and land footprint.

The information is provided in a matrix arrangement that has five main columns that are ordered from left to right as follows: classification of materials; total weight (obtained from previous analyses, chapter 5); total carbon content; total energy; and ecological footprint, all in consistent units. The matrix arrangement has a different number of rows depending on each case study. Particular matrixes are grouped as organic materials: hardwoods, softwoods and fibrous materials; and inorganic materials: mineral materials and industrial materials. This is done to better show the level of environmental impact related to each grouping. Additionally each group is sub-divided in specific materials or building elements summarizing the final sum of each group of materials or species derived from previous tables (chapter 5).

An additional row in the matrix besides the title for each group of materials shows the conversion factors for carbon, energy and ecological footprint for each particular species or material. The calculation is as follows: the total weight shown in the second column of each material is multiplied by the corresponding conversion factor to calculate, the total carbon content in the third column. again the total weight in the second column is multiplied by the corresponding conversion factor to show the total energy in the fourth column, and finally, the total energy in the fourth column is multiplied by the corresponding conversion factor to obtain the ecological footprint shown in the fifth column.

At the bottom of each matrix references are given for data not obtained from the fieldwork. Where convenient the data was rounded to two decimal places. These tables are first presented for each case individually and are then compared. The results are divided into the organic materials that go into the building, for instance hardwoods, softwoods, fibrous materials, the 'natural' inorganic materials, for instance sand and rock, and industrial ones such as cement or lime, and finally the fuel related to transporting the materials.

The energy content of the building is first assessed when it was first constructed. The transport energy to get the materials to the site is then presented separately. The final tables are based on a 50 year building life and include the embodied energy of maintenance.

6.3 Results of *Attelea guacuyule* Palm Technology

The life of palm thatch is assumed to be 17 years, based on an average life of 15-20 years according to the interviewees, meaning the roof is thatched three times in 50 years. The distances to bring the palm to site were considered to be the same for the 50 year life of the building.

6.3.1 Case Study A-R1; Building Elements

Tables 6.2 – 6.6 show the carbon, energy and ecological footprints of five classes of materials (hardwoods, softwoods, fibrous, mineral and industrial materials). The reference letters apply to all tables to show from where assumptions have been drawn.

By weight, in this case study mineral materials account for 72.3% of total due to the substantial rocks built into the thick and deep retaining wall to contain possible flood waters. The rest is distributed as 18.5% hardwoods, 6.2% mineral materials and only 2.8% fibrous material and 0.2% softwoods. Although this is one of the most remote case studies hidden in the endemic forest, the fact it uses so much rock and mineral materials makes it one of the buildings using fewer organic materials buildings among the case studies.

CS: A-R1		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/material)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(a)(om) Organic matter units> Tonnes	(a)(j) units> Tonnes (C)	(a) units> GJ	(k) units> Hectares/year
ORGANIC MATERIALS HARDWOODS	(a)(j) Conversion factor: 2g organic matter (om)=1gC			
	(a) Conversion factor: (15GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Haematoxylum brasiletto</i> Palo de Brasil	0.29	0.14	4.32	0.04
<i>Pirahnea Mexicana</i> Guayabillo	6.23	3.12	93.47	0.93
<i>Cocos nucifera</i> Coconut palm	0.57	0.28	8.51	0.09
<i>Dalbergia retusa</i> Granadillo	0.57	0.28	8.49	0.08
<i>Tabebuia chrysantha</i> Verdecillo	1.80	0.90	27.05	0.27
HARDWOODS	9.46	4.73	141.83	1.42
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j)(Brown & Lugo, 1982); (k)(Wackernagel & Rees, 1996)				

Table 6-2 Carbon, energy and ecological footprint of hardwoods at time of construction, case study A-R1

CS: A-R1		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/material)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(a)(om) Organic matter units > Tonnes	(a)(j) units > Tonnes (C)	(a) units > GJ	(k) units> Hectares/year
ORGANIC MATERIALS SOFTWOODS	(a)(j) Conversion factor: 2gom = 1gC			
	(a) Conversion factor: (15GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Bambusa vulgaris</i> Bamboo	0.043	0.019	0.644	0.006
<i>Otatea aztecorum</i> Oate bamboo	0.026	0.013	0.255	0.003
SOTFWOODS	0.068	0.032	0.899	0.009
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j)(Brown & Lugo, 1982); (k)(Wackernagel & Rees, 1996)				

Table 6-3 Carbon, energy and ecological footprint of softwoods at time of construction, case study A-R1

CS: A-R1		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/material)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(a)(om) Organic matter units > Tonnes	(a)(j) units > Tonnes (C)	(j) units > GJ	(k) units> Hectares/year
ORGANIC MATERIALS FIBROUS MATERIALS	(a)(j) Conversion factor: 2gom = 1gC			
	(j) Conversion factor: (10GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Attalea guacuyule</i> Palma de coyul	1.440	0.720	14.400	0.144
<i>Agave fourcroides</i> Henequen	0.033	0.017	0.330	0.003
FIBROUS MATERIALS	1.473	0.737	14.730	0.147
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j)(Brown & Lugo, 1982); (k)(Wackernagel & Rees, 1996)				

Table: 6-4 Carbon, energy and ecological footprint of fibrous materials at time of construction, case study A-R1

CS: A-R1		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/material)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	units > Tonnes	(I)(m) units > Tonnes (C)	(II)(m) units > GJ	(k) units> Hectares/year
INORGANIC MATERIALS MINERAL MATERIALS	(I) Conversion factor: 0.025kgC/kg Granite			
	(II)(m) Conversion factor: (II) 5.9GJ/T; (m) .1GJ/T			
	(k) Conversion factor: (100GJ/ha/yr)			
Igneous plutonic Granite rock (I)(II)	28.80	0.720	169.92	1.70
River sand (m)	8.40	0.017	0.84	0.01
MINERAL MATERIALS	37.20	0.74	170.76	1.71
References: (k)(Wackernagel & Rees, 1996); (I)(Crishna et al., 2010); (II) (Mackay, 2008); (m)(Alcorn & Wood, 1998);				

Table 6-5 Carbon, energy and ecological footprint of mineral materials at times of construction, case study A-R

CS: A-R1 EMBODIED ENERGY AS FIRST CONSTRUCTED				
Classification of Materials	Total weight (species/material)	T. Carbon content> (m1,2,3)(n)	Energy> (m4,5,6)(o)	Ecological Footprint (k)
Common name/species	units > Tonnes	units > Tonnes (C)	units > GJ	units> Hectares/year
INORGANIC MATERIALS INDUSTRIAL MATERIAL	(m1,2,3) Conversion factor: (m1)1T of cement=0.271 TC; (m2)1T of rebar= 0.06TC; (m3)1T nails= 0.0034 TC;			
	(n) 1T of burnt lime= 0.386 TC			
	(m4,5,6)Conversion factor: (m4) 6.2GJ/T; (m5) 8.6 GJ/T; (m6) 12.3GJ/T); (o) 1.2GJ/T			
	(k) Conversion factor: (100GJ/ha/yr)			
Sacks of cement (m1,4)	2.500	0.675	15.50	0.1550
Sacks of burnt lime (n)(o)	0.625	0.241	0.75	0.0075
Iron rebar (m2,5)	0.047	0.003	0.41	0.0041
Iron nails (m3,6)	0.010	0.00004	0.12	0.0012
INDUSTRIAL MATERIAL	3.182	0.919	16.78	0.17
References: (k)(Wackernagel & Rees, 1996); (m)(Alcorn & Wood, 1998); (n)(de Lespinay, 2006); (o)(Gliessman, 1998)				

Table 6-6 Carbon, energy and ecological footprint of industrial materials at time of construction, case study A-R1

6.3.2 Case Study A-R1; Transport

Table 6.7 sets out the energy involved in transporting the materials to site using fossil fuels. The animal and human transportation has not been accounted for as this are deemed to be carbon neutral. A further assumption made is that the limestone, skeins and nails were all transported to the site in one trip by boat.

ENVIRONMENTAL IMPACT ASSESSMENT OF VERNACULAR THATCH BUILDING TRADITION IN MEXICO:

CS: A-R1	TOTAL EMBODIED ENERGY OF TRANSPORTATION OF MATERIALS AS FIRST CONSTRUCTE									
Material transported	Trip type (capacity/hp/ fuel)	Load per trip	No. trips	total distance (total # of trips) (km)	Total litres Litres	Energy kWh	Total CO2 kg	Total C Tonnes	Total GJ GJ	Ecological Footprint Hectares
					CONVERSION FACTOR REFERENCES					
					(q)	(r1)	(r2)	(s)	(t)	(c)
Palm leaves (4kg each leaf)	Panga boat (3Tonnes/40 hPp/ marine diesel)	12 dozen	2	50	50	500	1300	0.355	1.800	0.018
Cement	Panga boat (3Tonnes/40 hPp/ marine diesel)	50 sacks (50kg)	1	36	18	180	468	0.128	0.684	0.00684
Burnt lime	Panga boat (3Tonnes/40 hPp/ marine diesel)	25 sacks (25kg)	1	36	18	180	468	0.128	0.684	0.00684
Skeins		7 skeins (29kg)								
Nails		10 kg in total								
TOTAL VALUES FOR TRANSPORTATION >>>				122	61	860	2236	0.61	3.17	0.032
(k):(Wackernagel & Rees, 2013, p. 158)							100GJ/Hectare/year			
(q):http://www.mercurymarine.com.au/media/469955/40-60hp_fourstroke_lowres_fa.pdf							(efficiency km/litre)= 2km/lit			
(r1):http://www.dccenergi.dk/sites/dpdccenergi.dev.dp.adapt.dk/files/ftp/pdf/marine/marine_gasoil_uk.pdf							(r1):10 km/l: Energy content > 1lt=10kw/l : 1litre marine diesel=10kw			
							(r2):CO2 emission, kg/l value=26 therefore 1litre m. diesel= 26kgCO2			
(s): http://www.carbontrust.com/resources/guides/carbon-footprinting-and-reporting/conversion-factors							carbon dioxide factors into carbon, multiply the figure by 12 and divide by 44 >therefore: 12/44=.2727			
(t):http://www.onlineconversion.com/energy.htm:							1 kilowatt hour = 0.0036 GJ			

Table 6-7 Carbon, energy and ecological footprint of transporting materials to the site of case study A-R1

Table 6.7 shows that bringing the cement to site accounted for 21% of the total transport energy even though this formed less than 7% of the building by weight.

Case Study A-R1 Transportation over 50 years life (every 17yrs)			
Total C Tonnes	Total GJ GJ	Ecological Footprint Hectares	Cycle of Re- Thatching (years)
0.35	1.8	0.018	17 years
0.35	1.8	0.018	34 years
0.70	3.6	0.036	

Table 6-8 Carbon, energy and ecological footprint of transporting materials to the site over 50 years for case study A-R1

Table 6.8 shows the energy that would be used over 50 years for re-thatching on the assumption the same type and energy is involved in transporting materials as when first built.

6.3.3 Case Study A-R1; Embodied Energy as First Constructed

The total carbon footprint of the building when first constructed is 7.77 tonnes and the breakdown of this is shown in Figure 6.1. The biggest carbon footprint comes from the hardwoods used in the building structure at 60.85% of total, with fibrous, mineral, industrial materials and transport nearly equal at 9.5% for fibrous and mineral, 11.8% for industrial and 7.9% for transport.

Figure 6-1 Breakdown of carbon footprint of A-R1 when first constructed

Looking at the energy in the building in terms of GJ gives a different distribution (Figure 6.2). The energy going into mineral materials is now the largest at 63% of total. The conversion factor was based on dressed stone leaving a quarry in Scotland. As this stone would have been cut and dressed with powered machinery this may be an over estimate for Mexcio, where more work in preparing stone for use could be done by hand. Because at this stage the ecological footprint is based on an energy to land conversion figure this unusual distribution is reflected in the ecological footprints of the building elements when first constructed (figure 6.3).

Figure 6-2 Breakdown of energy distribution in building A-R1 when first constructed

Figure 6-3 Breakdown of ecological footprint in building A-R1 when first constructed.

6.3.4 Case Study A-R1; Embodied Energy over 50 Years

Based on a 50 year building life and combining the embodied energy and the transportation energy for initial construction and building maintenance gives a new carbon footprint (Figure 6.4).

Figure 6-4 Breakdown of carbon footprint of building AR-1 over a 50 year life

No hardwoods, mineral materials or industrial materials are renewed in this time period. Fibrous materials (palm leaves) and transport increases in order to bring the palm to site for the re-thatching. Hardwoods are still the biggest component of the total carbon footprint but the palm for thatching now represents the second largest component.

The changes in the energy (GJ) and ecological footprint are shown in figures 6.5 and 6.6, noting that the mineral value may still be too high because of the reasons given above.

Figure 6-5 Breakdown of energy distribution over a 50 year life for case study A-R1

For all the 50 year comparisons the softwood component has tripled based on the assumption that otate and bamboo will be replaced at the time of re-thatching even though they account for a very small proportion when first constructed (figure 6-2).

Figure 6-6 Breakdown of ecological footprint over a 50 year life for case study A-R1

The high impact of hardwoods used in this building when first constructed and after 50 years needs noting. However, these were trees that fell as a result of a hurricane and would otherwise have rotten in the forest. Putting them in the building means the carbon remains locked up rather than adding to CO₂ emissions. A conventional LCA cannot account for this. The hardwoods will also last longer than the assumed 50 year lifespan. Issues about locking up carbon and the lifespan of such hardwoods will be discussed further in chapter 7.

6.3.5 Case Study A-R2; Building Elements

Tables 6.9 – 6.13 show the carbon, energy and ecological footprints of case study A-R2

In this case the comparison by weight is similar to the previous case study A-R1. Here, mineral materials account for a higher 83.6% although by total weight they are equal to A-R1 (37.2 tonnes of granite rock, sand and cement mortar). This is not because of any similarity in the technique employed. A-R1 could have avoided many mineral materials by constructing the building farther from the river, which was a possibility, thus making shallower foundations possible. In the case of A-R2 due to the location of the very steep site in from the shore the full amount of mineral materials were necessary to achieve a retaining wall plus foundation to level the building site.

Despite the fact that the roofs of AR-1 and AR-2 are very similar in typology the latter uses fewer hardwood timbers as it does not have a mezzanine or decking. It does, however, include more industrial materials because of having a concrete floor.

The distribution by weight of materials for AR-2 is 83.6% mineral, 8.4% industrial, 4.6% hardwoods, 2.1% fibrous materials and 1.3% softwoods. Like the other *Attalea* thatched building, despite being so remote it is the building with lowest proportion of organic vegetative materials of all the case studies.

CS: A-R2		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(om) Organic matter units> Tonnes	(a)(j) units> Tonnes (C)	(a) units> GJ	(k) units> Hectares/year
ORGANIC MATERIALS HARDWOODS	(a)(j) Conversion factor: 2gom=1gC			
	(a) Conversion factor: (15GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Olneya tesota</i> Palo Fierro	0.51	0.25	7.64	0.08
<i>Dalbergia granadillo</i> Tampiziran	1.59	0.80	23.90	0.24
HARDWOODS	2.10	1.05	31.53	0.32
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table 6-9 Carbon, energy and ecological footprint of hardwoods at time of construction, case study A-R2

CS: A-R2		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(om) Organic matter units> Tonnes	(a)(j) units> Tonnes (C)	(a) units> GJ	(k) units> Hectares/year
ORGANIC MATERIALS SOFTWOODS	(a)(j) Conversion factor: 2gom = 1gC			
	(a) Conversion factor: (15GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Ardisia compressa</i> Tintilagua	0.331	0.149	4.965	0.050
<i>Hura crepitans</i> Habillo	0.271	0.122	4.065	0.041
SOTFWOODS	0.602	0.271	9.030	0.090
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table 6-10 Carbon, energy and ecological footprint of softwoods at time of construction, case study A-R2

CS: A-R2		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(om) Organic matter units> Tonnes	(a)(j) units> Tonnes (C)	(j) units > GJ	(k) units> Hectares/year
ORGANIC MATERIALS FIBROUS MATERIALS	(a)(j) Conversion factor: 2gom = 1gC			
	(j) Conversion factor: (10GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Attalea guacuyule</i> Palma de coyul	0.960	0.480	9.600	0.096
<i>Agave fourcroides</i> Henequen	0.028	0.014	0.280	0.003
FIBROUS MATERIALS	0.988	0.494	9.880	0.099
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table: 6-11 Carbon, energy and ecological footprint of fibrous materials at time of construction, case study A-R2

CS: A-R2		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	units> Tonnes	(a)(j) units> Tonnes (C)	(l)(m) units> GJ	(k) units> Hectares/year
INORGANIC MATERIALS MINERAL MATERIALS	(l) Conversion factor: 0.025kgC/kg Granite			
	(l)(m) Conversion factor: (l) 5.9GJ/T; (m) 0.1GJ/T			
	(k) Conversion factor: (100GJ/ha/yr)			
Igneous plutonic Granite rock (l)(ll)	28.80	0.720	169.92	1.70
River sand (m)	8.40	0.017	0.84	0.01
MINERAL MATERIALS	37.20	0.74	170.76	1.71
References: (k)(Wackernagel & Rees, 1996); (l)(Crishna et al., 2010); (ll) (Mackay, 2008); (m)(Alcorn & Wood, 1998);				

Table 6-12 Carbon, energy and ecological footprint of mineral materials at time of
construction, case study A-R2

CS: A-R2		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content> (m1)(n) units> Tonnes (C)	Energy> (m4)(o) units > GJ	Ecological Footprint (k) units> Hectares/year
Common name/species	units> Tonnes			
INORGANIC MATERIALS INDUSTRIAL MATERIAL	Conversion factor: (m1) 1T of cement= 0.271 TC; (n) 1T of burnt lime= 0.386TC			
	Conversion factor: (m4) 6.2GJ/T; (o) 1.2GJ/T			
	(k) Conversion factor: (100GJ/ha/yr)			
Sacks of cement (m1,4)	3.000	0.810	18.60	0.1860
Sacks of burnt lime (n)(o)	0.750	0.290	0.90	0.0090
Concrete floor (m2)	4.250	0.111	3.27	0.0327
INDUSTRIAL MATERIAL	3.750	1.100	19.50	0.23
References: (k) (Wackernagel & Rees, 1996); (m) (Alcorn & Wood, 1998); (n) (de Lespinay, 2006); (o) (Gliessman, 1998); (p) Hammond & Jones, 2008)				

Table 6-13 Carbon, energy and ecological footprint of industrial materials at time of construction, case study A-R2

6.3.6 Case Study A-R2; Transport

The transport of materials is assumed to be the same as for the first case study since water is the only access for motorized transport, so panga boats are the most common means of transportation to this shore. However, the transport applies only once as it was only for the industrial materials to achieve the retaining wall and concrete floor which will last over 50 years. Materials for re-thatching are assumed to be from local plots accessed by animal and human power as when first constructed. The distances represent a round trip to the Puerto Vallarta-Boca de Tomatlán area, the nearest place to buy industrial materials approximately 23 km away.

ENVIRONMENTAL IMPACT ASSESSMENT OF VERNACULAR THATCH BUILDING TRADITION IN MEXICO:

CS: A-R2	TOTAL EMBODIED ENERGY OF TRANPORTATION OF MATERIALS AS FIRST CONSTRUCTED									
Material transported	Trip type	Load per trip	No. trips	total distance	Total litres	Energy	Total CO2	Total C	Total GJ	Ecological Footprint
	(capacity/h p/fuel)			(km)	Litres	kw/l	kg	Tonnes	GJ	Hectares
					CONVERSION FACTORS REFERENCES					
					(q)	(r1)	(r2)	(s)	(t)	(k)
Cement (retaining wall)	Panga boat (3Tonnes/ 40hPp/ marine diesel)	50 sacks (50kg)	1	46	23	230	598	0.163	0.874	0.0087
limestone (retaining wall)	Panga boat (3Tonnes/ 40hPp/ marine diesel)	25 sacks (25kg)	1	46	23	230	598	0.163	0.874	0.0087
Cement (concrete 1:3:6)		10 sacks (50kg) for concret e								
TOTAL VALUES FOR TRANSPORTATION >>>				92	61	460	1196	0.33	1.75	0.017
(k):(Wackernagel & Rees, 2013, p. 158)							100GJ/Hectare/year			
(q):http://www.mercurymarine.com.au/media/469955/40-60hp_fourstroke_lowres_fa.pdf							(efficiency km/litre)= 2km/lt			
(r):http://www.dccenergi.dk/sites/dpdccenergi.dev.dp.adapt.dk/files/ftp/pdf/marine/marine_gasoil_uk.pdf							(q1):10 km/l: Energy content > 1lt=10kw/l : 1litre=10kw			
							(q2):CO2 emission, kg/l value=26 therefore 1litre = 26kgCO2			
(s): http://www.carbontrust.com/resources/guides/carbon-footprinting-and-reporting/conversion-factors							carbon dioxide factors into carbon, multiply the figure by 12 and divide by 44 >therefore: 12/44=.2727			
(t):http://www.onlineconversion.com/energy.htm:							1 kilowatt hour = 0.0036 GJ			

Table 6-14 Carbon, energy and ecological footprint of transporting materials to the site of case study A-R2

6.3.7 Case Study A-R2; Embodied Energy as First Constructed

Figure 6.7 show the breakdown of embodied carbon when first constructed, in this case the highest figure is for industrial materials, showing that although the total weight of industrial materials is only 8.5% of total, as more industrial materials are used the carbon increases, here accounting for 27.6% of total carbon footprint. The remaining carbon footprint is made up of 26.3% hardwoods, 18.6% mineral materials, 12.4% fibrous materials, 8.3% for transportation and 6.8 for softwoods.

Figure 6-7 Breakdown of carbon footprint in building when first constructed, case study A-R2

Figure 6.8 shows the embodied energy breakdown of case study A-R2. Like the previous case study A-R1 the largest figure is for mineral materials, potentially due to the use of a foreign conversion factor as none was found for Mexico, and thus this

might be an overestimate as more hand labour might be used for extraction and dressing of stone at the quarry. On average as first constructed mineral materials account for 70.4% of total embodied energy, which does correspond with their percentage of total weight (83.6%). The remaining embodied energy is distributed as 13.04% hardwoods, 8.04% industrial materials, 4.07% fibrous materials, 3.72% softwoods and only 0.72% for transportation.

Figure 6-8 Breakdown of energy distribution in building when first constructed, case study A-R2

The breakdown of the ecological footprint shown in figure 6.9, and is consistent with figure 6.8 of energy due to the energy to land conversion factor applied to all case studies.

Figure 6-9 Breakdown of ecological footprint of building when first constructed, case study A-R2

6.3.8 Case Study A-R2; Embodied Energy over 50 Years

Figure 6.10 shows the breakdown of carbon over the 50 year lifespan of the building. The figure for fibrous materials has escalated in proportion making it the largest. Industrial materials, hardwoods, mineral materials and transportation remain the same as first constructed. Softwoods also remain unchanged, unlike the first *Attalea* case study, as these softwoods are long lasting and part of the structure. It is worth noting that in *Attalea* technology softwoods are low due to the fact no battens are needed as the palm leaves are thatched by lacing horizontally along the leaf vein or petiole.

Figure 6-10 Breakdown of carbon footprint of building A-R2 over a 50 year life

In figures 6-10 and 6-11 the energy and ecological footprint breakdowns over the 50 year life are again consistent. The fibrous materials have increased in proportion, almost equalling hardwoods and surpassing industrial materials.

Figure 6-11 Breakdown of energy distribution of building A-R2 over a 50 year life

Figure 6-12 Breakdown of ecological footprint after 50 years for case study A-R2

6.4 Results of *Brahea dulcis* Palm Technology

Whereas the case study of the palapa thatched using *Attalea* used both mineral and industrial material that of *Brahea* uses mainly natural organic materials and this provides an insight into how vernacular traditions also had differing environmental impacts. The chosen *Brahea* rural case study (B-R) is representative of the buildings using this palm found during the fieldwork investigation. The assumptions as to building life and wastage are the same as for the *Attalea* case study (see Section 6.2.1).

There is no embodied energy for transport in this case study because all materials were carried to site by human and animal power, both of which are assumed to be carbon neutral and have no environmental impact.

6.4.1 Case Study B-R; Building Elements

Tables 6.15 – 6.18 show the carbon, energy and ecological footprints of the four classes of materials. Reference letters apply to all tables to show from where assumptions have been drawn. By weight the hardwoods account for 17.94% of the building, the softwoods 6.35% and the fibrous materials 6.33%, with the mineral materials in the compacted, stabilised earth floor accounting for 69.38%. However, by weight this building is essentially all natural materials.

CS: B-R		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(om) Organic matter units> Tonnes	(a)(j) units> Tonnes (C)	(a) units> GJ	(k) units> Hectares/year
ORGANIC MATERIALS HARDWOODS	(a)(j) Conversion factor: 2gom=1gC			
	(a) Conversion factor: (15GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Quercus alba</i> Encino	1.47	0.74	22.08	0.22
<i>Taxodium mucronatum</i> Sabino	0.02	0.01	0.30	0.003
HARDWOODS	1.49	0.75	22.38	0.22
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table 6-15 Carbon, energy and ecological footprints of hardwoods at time of construction, case study B-R

CS: B-R		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(om) Organic matter units> Tonnes	(a)(j) units> Tonnes (C)	(a) units> GJ	(k) units> Hectares/year
ORGANIC MATERIALS SOFTWOODS	(a)(j) Conversion factor: 2gom = 1gC			
	(a) Conversion factor: (15GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Cestrum nocturnum</i> Cuitlapil	0.294	0.132	4.410	0.044
<i>Yucca aloifolia</i> Yucca	0.198	0.089	2.970	0.030
<i>Arundo Donax</i> Carrizo	0.035	0.016	0.525	0.005
SOTFWOODS	0.527	0.237	7.905	0.079
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table 6-16 Carbon, energy and ecological footprints of softwoods at time of construction, case study B-R

CS: B-R		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(om) Organic matter units> Tonnes	(a)(j) units> Tonnes (C)	(j) units > GJ	(k) units> Hectares/year
ORGANIC MATERIALS FIBROUS MATERIALS	(a)(j) Conversion factor: 2gom = 1gC			
	(j) Conversion factor: (10GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Brahea dulcis</i> Palma de sombrero	0.500	0.250	5.000	0.050
<i>Agave fourcroides</i> Henequen	0.025	0.013	0.250	0.003
FIBROUS MATERIALS	0.525	0.263	5.250	0.053
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table 6-17 Carbon, energy and ecological footprints of fibrous materials at time of construction, case study B-R

CS: B-R		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	units> Tonnes	(p) units> Tonnes (C)	(p) units> GJ	(k) units> Hectares/year
INORGANIC MATERIALS MINERAL MATERIALS	(p) Conversion factor: 1T=0.023 Tonnes of Carbon			
	(p) Conversion factor: 0.45GJ/T			
	(k) Conversion factor: (100GJ/ha/yr)			
Compacted earth	5.76	0.132	2.59	0.026
MINERAL MATERIALS	5.76	0.13	2.59	0.03
References: (p) (Hammond & Jones, 2008); (k) (Wackernagel & Rees, 1996)				

Table 6-18 Carbon, energy and ecological footprints of mineral materials at time of construction, case study B-R

6.4.2 Case Study B-R; Embodied energy as First Constructed

The total carbon footprint of the building when first constructed is 1.38 tonnes and the breakdown of this is shown in Figure 6.13. All carbon is now from plant materials and that in the compacted earth floor, forms 9.42% of the total carbon footprint. The other natural materials are hardwoods at 54.35%, softwoods 17.17% and fibrous materials 19.06%.

Figure 6-13 Breakdown of carbon footprint in building B-R when first constructed

The energy breakdown, and consequently the ecological footprint follow a consistent pattern (Figures 6.8, 6.9). Hardwoods are slightly higher now at 58.71% of total energy (GJ), followed by softwoods at 20.73%, fibrous materials at 13.77%, and mineral materials 6.79%.

Figure 6-14 Breakdown of energy distribution in building B-R when first constructed

Figure 6-15 Breakdown of ecological footprint in building B-R when first constructed

6.4.3 Case Study B-R; Embodied Energy over 50 Years

Because no transport energy is involved the environmental impact is only related to regular maintenance. Figure 6.16 shows the carbon footprint after 50 years, with the

majority now accruing to the fibrous materials because of re-thatching. The assumption for the lifespan of the thatching material is 12.5 years (averaging 10 to 15 years), and thus 3 re-thatching cycles are included.

When analysing the carbon footprint over 50 years the highest figure is for fibrous materials, followed by softwoods which have also increased, as some need to be replaced every re-thatching cycle. These are cuitlapiles (*Cestrum nocturnum*) and carrizos (*Arundo donax*) which form the substructure and battens respectively and which account for 62% of total softwood materials as first constructed. However, Yucca (*Yucca aloifolia*) as a structural element is assumed to last over 50 years. These assumptions are based on fieldwork information. Finally hardwoods and minerals materials remain the same as first constructed.

Figure 6-16 Breakdown of carbon footprint of building B-R over 50 years

The embodied energy (Figure 6.17) and hence the ecological footprint (Figure 6.18) follow a similar pattern due to the land to energy conversion, however this time the biggest impact is from the softwood materials rather the fibrous ones. The proportion of softwoods replaced every 12.5 years remains consistent (62%) as in figure 6-16.

Figure 6-17 Breakdown of energy distribution of building B-R over 50 years

Figure 6-18 Breakdown of ecological footprint of building B-R over 50 years

6.4.4 Case Study B-SU; Building Elements

Tables 6.19 – 6.22 show the carbon, energy and ecological footprints of the four classes of materials. Here is important to highlight that the only industrial materials used were 11 3/8” diameter rebar from a demolition site. These were used to secure beams to posts therefore the assumption here is that no industrial materials were used. By weight the mineral material in the compacted, stabilised earth floor accounted for the highest proportion at 62.37% of total followed by hardwoods 26.11%, fibrous materials 10.91% and softwoods only 0.61%. Like the previous *Brahea* building this is essentially an all natural materials construction.

CS: B-SU		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(om) Organic matter units> Tonnes	(a)(j) units> Tonnes (C)	(a) units> GJ	(k) units> Hectares/year
ORGANIC MATERIALS HARDWOODS	(a)(j) Conversion factor: 2gom=1gC			
	(a) Conversion factor: (15GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Quercus Alba</i> Encino	7.48	3.74	112.26	1.12
HARDWOODS	7.48	3.74	112.26	1.12
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table 6-19 Carbon, energy and ecological footprints of hardwoods at time of construction, case study B-SU

CS: B-SU		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(om) Organic matter units> Tonnes	(a)(j) units> Tonnes (C)	(a) units> GJ	(k) units> Hectares/year
ORGANIC MATERIALS SOFTWOODS	(a)(j) Conversion factor: 2gom = 1gC			
	(a) Conversion factor: (15GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Arundo donax</i> Carrizo	0.174	0.078	2.610	0.026
SOTFWOODS	0.174	0.078	2.610	0.026
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table 6-20 Carbon, energy and ecological footprints of softwoods at time of construction, case study B-SU

CS: B-SU EMBODIED ENERGY AS FIRST CONSTRUCTED				
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(om) Organic matter units> Tonnes	(a)(j) units> Tonnes (C)	(j) units > GJ	(k) units> Hectares/year
ORGANIC MATERIALS FIBROUS MATERIALS	(a)(j) Conversion factor: 2gom = 1gC			
	(j) Conversion factor: (10GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Brahea dulcis</i> Palma de sombrero	3.000	1.500	30.000	0.300
<i>Agave fourcroides</i> Henequen	0.075	0.038	0.750	0.008
<i>Brahea dulcis</i> palma de sombrero	0.050	0.025	0.500	0.005
FIBROUS MATERIALS	3.125	1.563	31.250	0.313
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table 6-21 Carbon, energy and ecological footprints of fibrous materials at time of construction, case study B-SU

CS: B-SU EMBODIED ENERGY AS FIRST CONSTRUCTED				
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	units> Tonnes	(m) units> Tonnes (C)	(l)(m) units> GJ	(k) units> Hectares/year
INORGANIC MATERIALS MINERAL MATERIALS	(p) Conversion factor: 1T=0.023TC			
	(p) Conversion factor: 0.45GJ/T			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Compacted earth</i>	17.87	8.042	22.52	0.23
MINERAL MATERIALS	17.87	8.04	22.52	0.23
References: (p) (Hammond & Jones, 2008); (k) (Wackernagel & Rees, 1996)				

Table 6-22 Carbon, energy and ecological footprints of mineral materials at time of construction, case study B-SU

6.4.5 Case Study B-SU; Transport

Information about transporting materials for case study B-SU was known. A 3.5 tonne gasoline pick-up truck was used, and its consumption in km/l is based on information gathered in the fieldwork, along with distances travelled and total loads carried. Transportation accounts for less than 1% of the carbon footprint and 3.04% of the energy and ecological footprints as first constructed.

CS: B-SU TOTAL EMBODIED ENERGY OF TRANSPORTATION OF MATERIALS AS FIRST CONSTRUCTED								
Material transported	type of transport (capacity: km/l)	Load per trip kg	No. trips	total distance (km)	Total litres (total trips) Litres	Total C Tonnes	Total GJ GJ	Ecological Footprint Hectares
					CONVERSION FACTORS REFERENCES			
					(u)	(v)	(w)	(k)
hardwoods	Pick up 3.5 tonnes gasoline (8km/l)	3000	2	25	6.25	0.00406	2.1875	0.021875
reeds (softwoods)	Pick up 3.5 tonnes gasoline (8km/l)	250	1	20	2.5	0.00163	0.875	0.00875
(<i>B. dulcis</i>) palm	Pick up 3.5 tonnes gasoline (8km/l)	3000	2	25	6.25	0.00406	2.1875	0.021875
TOTAL VALUES FOR TRANSPORTATION >			5	70	15	0.01	5.25	0.053
(k):(Wackernagel & Rees, 2013, p. 158)						100GJ/Hectare/year		
(u): data from fieldwork						8km/litre		
(v): http://www.evworld.com/library/energy_number.pdf						0.65kgC/l of gasoline		
(w): http://www.epa.gov/cpd/pdf/brochure.pdf						0.35GJ/l of gasoline		

Table 6-23 Carbon, energy and ecological footprint of transporting materials to the site of case study B-SU

Table 6-24 shows the transportation over 50 years, assuming the same types of vehicle, distances and loads.

Case Study B-SU Transportation over 50 years life			
Total C Tonnes	Total GJ GJ	Ecological Footprint Hectares	Cycle of Re- Thatching (years)
0.006	3.06	0.031	12 years
0.006	3.06	0.031	24 years
0.006	3.06	0.031	36 years
0.02	9.18	0.093	

Table 6-24 Carbon, energy and ecological footprint of transporting materials to the site over 50 years for case study B-SU

6.4.6 Case Study B-SU; Embodied energy as First Constructed

Figure 6-19 shows the breakdown of the carbon footprint of B-SU as first constructed. Mineral materials account the highest proportion at 59.86%, although it is important to note that the earth in the floor comes from excavating for the posts at the site, and so this figure should be treated with discretion as it might be an over estimate. The rest of the carbon footprint is 27.85% hardwoods, 11.64% fibrous materials and almost nothing for softwoods and transport 0.58% and 0.07% respectively.

Figure 6-19 Breakdown of carbon footprint for building B-SU when first constructed

The energy breakdown of B-SU as first constructed is shown in figure 6-20. The hardwoods are now the biggest proportion accounting to 64.56% although only 26.11% of the building by weight. The remaining breakdown is 17.97% fibrous

materials, 12.95% mineral materials and 1.5% softwood materials. Transport this time accounts for 3.02%.

Figure 6-20 Breakdown of energy distribution in building B-SU when first constructed

Finally, as before, the ecological footprint is consistent with the energy breakdown.

Figure 6-21 Breakdown of ecological footprint in building B-SU when first constructed

6.4.7 Case Study B-SU; Embodied Energy over 50 Years

The results over a 50 year life remain similar in proportion to those for the building as first constructed except for fibrous material, which increase by a factor of four, making these the largest component of the energy and ecological footprints (figures 6-23 and 6-24) and the second largest in carbon footprint (figure 6-22). Softwoods and transport grow by a very small amount and still remain a very little proportion of the total. The assumption of 12.5 year life for the thatch palm is the same as for building B-R.

Figure 6-22 Breakdown of carbon footprint of building B-SU over 50 years

Figure 6-23 Breakdown of energy distribution of building B-SU over 50 years

Figure 6-24 Breakdown of ecological footprint of building B-SU over 50 years

6.5 Results of *Sabal rosei* Palm Technology

The chosen *Sabal* case studies are one rural and one urban example both of similar size. The assumptions as to building life and wastage are the same as for the other case studies and the life of the thatch cover is 12.5 years, as for *Brahea*.

6.5.1 Case Study S-R; Building Elements

Tables 6.25 to 6-28 show the carbon, energy and ecological footprints of the four classes of material used (hardwoods, softwoods, and fibrous and industrial materials). By weight the hardwoods account for 32.77% of total, the second highest value. The heaviest element is the concrete floor at 45.89% of total. Softwoods are 10.37% and fibrous materials 10.97% of total respectively.

CASE STUDIES OF THREE PALM SPECIES AND RELATED TECHNOLOGY ALONG THE TRANS-MEXICAN VOLCANIC BELT

CS: S-R		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(om) Organic matter units> Tonnes	(a)(j) units> Tonnes (C)	(a) units> GJ	(k) units> Hectares/year
ORGANIC MATERIALS HARDWOODS	(a)(j) Conversion factor: 2om=1gC			
	(a) Conversion factor: (15GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Myroxylon balsamus</i> Balsamo	0.71	0.36	10.70	0.11
<i>Tabebuia chrysantha</i> Verdecillo	1.98	0.99	29.63	0.30
HARDWOODS	2.69	1.34	40.32	0.40
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table 6-25 Carbon, energy and ecological footprints of hardwoods at time of construction, case study S-R

CS: S-R		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(om) Organic matter units> Tonnes	(a)(j) units> Tonnes (C)	(a) units> GJ	(k) units> Hectares/year
ORGANIC MATERIALS SOFTWOODS	(a)(j) Conversion factor: 2gom = 1gC			
	(a) Conversion factor: (15GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Hura crepitans</i> Habillo	0.187	0.084	2.805	0.028
<i>Rhizophora mangle</i> Mangle	0.664	0.332	9.960	0.100
SOTFWOODS	0.851	0.416	12.765	0.128
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table 6-26 Carbon, energy and ecological footprints of softwoods at time of construction, case study S-R

CS: S-R		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	(om) Organic matter units> Tonnes	(a)(j) units> Tonnes (C)	(j) units > GJ	(k) units> Hectares/year
ORGANIC MATERIALS FIBROUS MATERIALS	(a)(j) Conversion factor: 2gom = 1gC			
	(j) Conversion factor: (10GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Sabal rosei</i> Palma de palapa	0.900	0.450	9.000	0.090
FIBROUS MATERIALS	0.900	0.450	9.000	0.090
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table 6-27 Carbon, energy and ecological footprints of fibrous materials at time of construction, case study S-R

CS: S-R		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	units> Tonnes	(m3)(p) units> Tonnes (C)	(m6)(p) units > GJ	(k) units> Hectares/year
INORGANIC MATERIALS INDUSTRIAL MATERIAL	Conversion factor: (m3) 1T nails= 0.0034 TC; (p) 0.026TC/T			
	Conversion factor: (m6) 12.3GJ/T (p)0.77GJ/T			
	(k) Conversion factor: (100GJ/ha/yr)			
Concrete floor (p)	3.742	0.097	2.88	0.0288
Iron nails (m3,6)	0.0250	0.00009	0.31	0.0031
INDUSTRIAL MATERIAL	3.767	0.097	3.19	0.03
References: (k) (Wackernagel & Rees, 1996); (m) (Alcorn & Wood, 1998); (n) (de Lespinay, 2006); (o) (Gliessman, 1998); (p) (Hammond & Jones, 2008)				

Table 6-28 Carbon, energy and ecological footprints of industrial materials at time of construction, case study S-R

6.5.2 Case Study S-R; Transport

Transportation means were not known but were assumed to be the same as B-SU as these are common in rural Mexican. However, the transportation of industrial materials for S-R is assumed to happen only once as these materials will last over 50 years.

TOTAL EMBODIED ENERGY OF TRANSPORTATION OF MATERIALS AS FIRST CONSTRUCTED								
CS: B-SU								
Material transported	type of transport (capacity: km/l)	Load per trip kg	No. trips	total distance (km)	Total litres (total trips) Litres	Total C Tonnes	Total GJ GJ	Ecological Footprint Hectares
					CONVERSION FACTORS REFERENCES			
					(u)	(v)	(w)	(k)
i. materials (concrete)	Pick up 3.5 tonnes gasoline (8km/l)	3500	1	30	3.75	0.00244	1.3125	0.013125
TOTAL VALUES FOR TRANSPORTATION >			1	30	3.75	0.002	1.31	0.013
(k):(Wackernagel & Rees, 2013, p. 158)						100GJ/Hectare/year		
(u): data from fieldwork						8km/litre		
(v): http://www.evworld.com/library/energy_number.pdf						0.65kgC/l of gasoline		
(w): http://www.epa.gov/cpd/pdf/brochure.pdf						0.35GJ/l of gasoline		

Table 6-29 Carbon, energy and ecological footprint of transporting materials to the site of case study S-R

Apart from the concrete slab all other materials were moved to the site using people and animals. The impact of bringing the industrial materials to site is minimal (table 6.29) when compared with the rest of the embodied carbon, energy and the ecological footprint of the materials in the building. However, the ecological footprint, and hence the energy distribution, show a slightly different pattern.

6.5.3 Case Study S-R; Embodied energy as First Constructed

The carbon footprint of the palapa when first constructed is 2.3 tonnes (Figure 6.25), of which the hardwoods account for the largest proportion at 58.19%, softwoods and

fibrous materials are 18.06% and 19.54% respectively, while inorganic materials are only 4.21% despite being the highest in weight (45.89% of total by weight). The total locked up carbon at the start of the building life is, therefore, 58.19% of total, the other being in emissions attributable to the other materials. The floor slab did not need to be in concrete and replacing this with fibrous materials could reduce the impact of the floor. There is an additional (almost zero) carbon component of 0.02% related to bringing the materials for the concrete slab to site.

Figure 6-25 Breakdown of carbon footprint in building S-R when first constructed

When it comes to the breakdown of the energy and ecological footprints as first constructed (figures 6-26 and 6-27) the proportions remain similar to those of the carbon footprint, with hardwoods at 61%, softwoods 19%, fibrous materials 13.5% and inorganic materials 4% of total, with transport at 2.5%.

Figure 6-26 Breakdown of energy distribution in building S-R when first constructed

Figure 6-27 Breakdown of ecological footprint in building S-R when first constructed

6.5.4 Case Study S-R; Embodied energy over 50 Years

The only significant value to increase over 50 years is for the fibrous materials due to re-thatching, making it the highest value in terms of carbon content (figure 6-28) and the second highest in energy (figure 6-29) and ecological footprint (figure 6-30). The other materials last the full 50 years because here the battens are of long lasting hardwood. Softwoods are for walling using the boards and wattle technique and are thus well protected and not considered necessary to be changed.

Figure 6-28 Breakdown of carbon footprint of building S-R over 50 years

Figure 6-29 Breakdown of energy distribution of building S-R over 50 years

Figure 6-30 Breakdown of ecological footprint of building S-R over 50 years

6.5.5 Case Study S-U; Building Elements

Tables 6.30 to 6-33 show the carbon, energy and ecological footprints of the four classes of material used (hardwoods, softwoods, and fibrous and industrial materials) in the S-U (urban) case study. By weight the hardwoods account for 36.02% of total, the second highest value. The heaviest element is the concrete floor at 49% of total. Fibrous materials are 13% and softwoods the smallest at 2.44% of total respectively.

CS: S-U EMBODIED ENERGY AS FIRST CONSTRUCTED				
Classification of Materials	Total weight (species/materials) (om) Organic matter	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	units> Tonnes	(a)(j) units> Tonnes (C)	(a) units> GJ	(k) units> Hectares/year
ORGANIC MATERIALS HARDWOODS	(a)(j) Conversion factor: 2gom=1gC			
	(a) Conversion factor: (15GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Dalbergia retusa</i> Granadillo	2.39	1.19	35.81	0.36
<i>Cordia alliodora</i> Botoncillo	3.59	1.79	53.82	0.54
HARDWOODS	5.98	2.99	89.63	0.90
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table 6-30 Carbon, energy and ecological footprints of hardwoods at time of construction, case study S-U

CS: S-U EMBODIED ENERGY AS FIRST CONSTRUCTED				
Classification of Materials	Total weight (species/materials) (om) Organic matter	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	units> Tonnes	(a)(j) units> Tonnes (C)	(a) units> GJ	(k) units> Hectares/year
ORGANIC MATERIALS SOFTWOODS	(a)(j) Conversion factor: 2gom = 1gC			
	(a) Conversion factor: (15GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Otatea aztecorum</i> Otate bamboo	0.408	0.204	6.120	0.061
SOTFWOODS	0.408	0.204	6.120	0.061
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table 6-31 Carbon, energy and ecological footprints of softwoods at time of construction, case study S-U

CS: S-U		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials) (om) Organic matter	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	units> Tonnes	(a)(j) units> Tonnes (C)	(j) units > GJ	(k) units> Hectares/year
ORGANIC MATERIALS FIBROUS MATERIALS	(a)(j) Conversion factor: 2gom = 1gC			
	(j) Conversion factor: (10GJ/T)			
	(k) Conversion factor: (100GJ/ha/yr)			
<i>Sabal rosei</i> Palma de palapa	2.160	1.080	21.600	0.216
FIBROUS MATERIALS	2.160	1.080	21.600	0.216
References: (a) https://bioenergy.ornl.gov/papers/misc/energy_conv.html ; (j) (Brown & Lugo, 1982); (k) (Wackernagel & Rees, 1996)				

Table 6-32 Carbon, energy and ecological footprints of fibrous materials at time of construction, case study S-U

CS: S-U		EMBODIED ENERGY AS FIRST CONSTRUCTED		
Classification of Materials	Total weight (species/materials)	T. Carbon content>	Energy>	Ecological Footprint
Common name/species	units> Tonnes	(p) units> Tonnes (C)	(p) units > GJ	(k) units> Hectares/year
INORGANIC MATERIALS INDUSTRIAL MATERIAL	Conversion factor: (p) 0.026TC/T			
	Conversion factor: (p) 0.77GJ/T			
	(k) Conversion factor: (100GJ/ha/yr)			
Concrete floor 1:3:6, proportion	8.1350	0.21151	6.26	0.0626
INDUSTRIAL MATERIAL	8.135	0.212	6.26	0.06
References: (k) (Wackernagel & Rees, 1996); (p) (Hammond & Jones, 2008)				

Table 6-33 Carbon, energy and ecological footprints of industrial materials at time of construction, case study S-U

6.5.6 Case Study S-U; Transport

Transportation assumptions are the same as for the other *Sabal* case study. However, here transportation is more significant due to the moving not only of the industrial materials to site but because of all the organic material from the rural context.

CS: B-SU		TOTAL EMBODIED ENERGY OF TRANSPORTATION OF MATERIALS AS FIRST CONSTRUCTED						
Material transported	type of transport (capacity: km/l)	Load per trip kg	No. trips	total distance (km)	Total litres (total trips) Litres	Total C Tonnes	Total GJ GJ	Ecological Footprint Hectares
					CONVERSION FACTORS REFERENCES			
					(u)	(v)	(w)	(k)
hardwoods	Pick up 3.5 tonnes gasoline (8km/l)	3250	2	30	7.5	0.00488	2.625	0.02625
reeds (softwoods)	Pick up 3.5 tonnes gasoline (8km/l)	408	1	30	3.75	0.00244	1.3125	0.013125
(<i>S. rosei</i>) palm	Pick up 3.5 tonnes gasoline (8km/l)	2106	2	30	7.5	0.00488	2.625	0.02625
i. materials (concrete)	Pick up 3.5 tonnes gasoline (8km/l)	2700	3	5	3.125	0.00203	1.09375	0.0109375
TOTAL VALUES FOR TRANSPORTATION >			8	95	21.875	0.014	7.66	0.077
(k):(Wackernagel & Rees, 2013, p. 158)						100GJ/Hectare/year		
(u): data from fieldwork						8km/litre		
(v): http://www.evworld.com/library/energy_number.pdf						0.65kgC/l of gasoline		
(w): http://www.epa.gov/cpd/pdf/brochure.pdf						0.35GJ/l of gasoline		

Table 6-34 Carbon, energy and ecological footprint of transporting materials to the site, case study S-R

It is assumed transport assumptions for re-thatching will be similar to those for first construction, being a 3.5 tonnes gasoline pick-up truck, a common means of transport in the region and elsewhere in Mexico. However, based on such a premise transport becomes much more significant due to moving materials from the rural to the urban context to satisfy the needs of re-thatching.

Case Study S-U Transportation over 50 years life (every 17yrs)			
Total C Tonnes	Total GJ GJ	Ecological Footprint Hectares	Cycle of Re-Thatching (years)
0.007	3.94	0.039	12 years
0.007	3.94	0.039	24 years
0.007	3.94	0.039	36 years
0.02	11.82	0.117	

Table 6-35 Carbon, energy and ecological footprint of transporting materials to the site over 50 years for case study S-U

6.5.7 Case Study S-U; Embodied energy as First Constructed

The carbon breakdown of S-U shown in figure 6-31 shows a high content of carbon in hardwoods at 66.47% of the total. This is followed by fibrous materials at 24.01% and industrial and softwood almost equal at 4.71% and 4.5% respectively, and a building total of 16.59 tonnes.

Figure 6-31 Breakdown of carbon footprint in building when first constructed, case study S-U

The energy footprint (figure 6-32) and ecological footprint (figure 6-33) are not only proportionally consistent due to the same energy to land conversion factor used in all case studies but also proportionally similar to the carbon footprint (figure 6-31). The

breakdown of the energy and ecological footprints as first constructed is 68.3%. 16.5% 5.8%, 4.8% and 4.6%, for hardwoods, fibrous materials, transport, industrial materials, and softwoods respectively, with a building total of 131.27 GJ and 1.31 Ha/year.

Figure 6-32 Breakdown of energy distribution in building S-U when first constructed

Figure 6-33 Breakdown of ecological footprint in building S-U when first constructed

6.5.8 Case Study S-U; Embodied energy over 50 Years

Over a 50 year life fibrous materials increase dramatically in a way similar to building S-R. However softwoods also show a significant proportional increase in the carbon, energy and ecological footprints. Transport also increases significantly as a part of the energy and ecological footprints.

In figure 6-34 fibrous materials are the largest value, followed by hardwoods, softwoods, industrial materials and transportation, while in figure 6-36 for energy and figure 6-37 for ecological footprints hardwoods are slightly bigger.

Figure 6-34 Breakdown of carbon footprint of building S-U over 50 years

Figure 6-35 Breakdown of energy distribution of building S-U over 50 years

Figure 6-36 Breakdown of ecological footprint of building S-U over 50 years life of case study S-U

6.6 Comparison of palm thatch case study results

When all case studies are compared it seems that not all vernacular building are equally sustainable

Table 6.36 compares the ecological footprints of the six case studies, by material group and as a total.

Surprisingly, the *Attalea* palm case studies had higher ecological footprints than the other four case studies, even though they were in the middle of forest lands. This shows that some building methods have to be used carefully. Here the imported industrial materials and the extensive use of rock to create retaining walls and, for A-R1, a modern-style deck, makes a higher environmental impact that the rural vernacular uses of *Brahea* and *Sabal* which seem to adhere to a more traditional way of building that has remained little changed for centuries. In some sense this shows that traditional vernacular architecture is more sustainable than the current idea of what vernacular architecture is, especially when it is imported into the urban scenario as for *Brahea* B-SU and *Sabal* S-U.

ECOLOGICAL FOOTPRINT COMPARISON OF THE 6 CASE STUDIES AS FIRST CONSTRUCTED							TOTAL
CASE STUDY	HARDWOODS	SOFTWOODS	FIBROUS MATERIALS	MINERAL MATERIALS	INDUSTRIAL MATERIALS	TRANSPORT	ECOLOGICAL FOOTPRINT
A-R1	1.42	0.009	0.147	1.71	0.17	0.032	3.488
A-R1	0.32	0.09	0.099	1.71	0.23	0.017	2.466
B-R	0.22	0.079	0.053	0.03	0	0	0.382
B-SU	1.12	0.026	0.313	0.23	0	0.053	1.742
S-R	0.4	0.128	0.09	0	0.03	0.013	0.661
S-U	0.9	0.061	0.216	0	0.06	0.077	1.314

Table 6-36: Total ecological footprints of the six case studies as first constructed

Finally table 6-37 shows the total breakdown of the carbon, energy and ecological footprints of all the six case studies per m^2 to allow for small differences in the sizes of the six buildings.

COMPARISON OF THE 6 CASE STUDIES AS FIRST CONSTRUCTED PER M2						
	CS-A-R1	CS-A-R2	CS-B-R	CS-B-SU	CS-S-R	CS-S-U
CARBON FOOTPRINT (CT)	0.23	0.152	0.076	0.195	0.115	0.195
EMBODIED ENERGY (GJ)	11.079	10.029	2.093	2.453	3.256	5.365
ECOLOGICAL FOOTPRINT (Ha/Year)	0.11	0.102	0.021	0.025	0.033	0.054

Table 6-37: Breakdown comparison of carbon, energy and ecological footprints per m^2 of the six case studies as first constructed

Figures 6-37 to 6-39 show the breakdown graphically. In figure 6-37 of total carbon tonnes embodied per m^2 the highest values were for A-*Attalea* R1 and the suburban and urban case studies of *Brahea* and *Sabal* respectively, followed by *Attalea* R-2. The two smallest carbon footprints were for the *Brahea* rural and *Sabal* rural buildings, which used all natural materials with earth instead of concrete floors. However, for the latter buildings all the carbon is locked up in the materials, whereas the carbon in buildings with industrial materials comes from CO₂ emissions, which are adding

carbon into the carbon cycle through the use of fossil fuels. This will be discussed further in chapter 7.

Figure 6-37: Carbon footprint comparison of the six case studies (TC/m²)

Figures 6-38 and 6-39 are proportionally the same. These again show that the modern fashion-following *Attalea* rural examples have the highest impact followed by the suburban and urban examples of *Brahea* and *Sabal* respectively, with again the most sustainable being the *Brahea* rural example

Figure 6-38: Embodied energy comparison of the six case studies (GJ/ m²)

Figure 6-39: Annual ecological footprint comparison of the six case studies (Ha/ m²)

6.7 Summary

The data described in chapter 5 has been used to calculate the environmental impact of the six case study buildings in terms of carbon footprint, energy footprint, both as constructed and after 50 years to take account of maintenance, and ecological footprint. When the results for the six cases study buildings are compared although the rural *Brahea* thatched building of all natural materials has the lowest impact, as might be expected, other rural buildings have a higher impact than those in suburban and urban settings, even when taking account the impact of transporting materials. This is because of the way they have been constructed. It thus seems that just using vernacular techniques is not a short cut to making sustainable buildings. This is discussed further in chapter 7.

CHAPTER 7

DISCUSSION AND CONCLUSIONS

This chapter addresses issues related to the research findings. It answers the research question and also draws conclusions about the contribution to knowledge and the potential for further research emanating from this investigation.

7.1 Discussion

The research question at the beginning of the thesis was devised in response to evidence that within sustainable architecture literature, vernacular architecture tends to be seen as being sustainable per se. However in most cases there is no solid evidence to support this view.

First a distinction needs to be made as to what counts as vernacular architecture, given the huge legacy of building technologies based on local resources that have developed within a wide variety of climates. Unlike modernism which attempted to devise ideals that could be applied universally to buildings, for example Le Corbusier's Five Point of Architecture, the very diversity of vernacular buildings make these hard to treat as a single discipline. This research, with its focus on just three palm thatching techniques, exemplifies this diversity even within a relatively restricted area of Mexico.

As discussed in the case studies the use of palm thatch needs to be analyzed carefully, as a wide variety of materials and techniques can be used, and the thatched roof sits on a building, the structure and envelope of which will influence the environmental impact of the whole building. This means there is no simple answer to the research question: **Are vernacular thatch building traditions sustainable in the trans-Mexican volcanic belt?**

Even within this geographical location different building and thatching traditions occur. More importantly vernacular traditions have also been influenced by modern design and building requirements. Although the six case studies were selected to be similar in size and function their detailed examination revealed significant differences, such as in the foundations that had a significant effect on the overall environmental impact.

7.1.1 Are Vernacular Thatch Building Tradition Sustainable in the Trans-Mexican Volcanic Belt?

As highlighted above, the answer to this question is, **not always**.

This research and its findings shows how vernacular buildings can be either sustainable or not. The variables that affect this result are:

- 1) Using inorganic and industrial materials such as rocks, or concrete, as shown in case studies A-R1, A-R2, and S-U, which all had a higher impact per m² that in the rural and more traditional examples of B-R and S-R.
- 2) The form of transport used and distances travelled to acquire and use both natural (as for B-SU, and S-U) and man-made materials (as for A-R1, A-R2 and S-R).
- 3) The use of excessive hardwoods for elaborated structures (A-R1, B-SU as S-U) showing a higher impact.
- 5) The purpose of the building, as shown in B-SU, which was bigger to suit its informal commercial purpose.
- 4) The lifespan of not just the building but the building components, as although a 50 year life was investigated some components like hardwood posts might last 100 years or more.

As shown by the case studies, vernacular building traditions should be classified clearly in order to better understand them. For traditional buildings it is possible to do this but where tradition becomes mixed with modern design aims this becomes more difficult.

Another aspect that should improve building sustainability is the use of local materials. What this research has shown is that low environmental impact occurs where this local materials and traditional buildings forms and techniques are used, as for the case of B-R. However, the opposite occurs where local materials are used in remote areas combined with modern materials, as in the case of A-R1 and A-R2.

7.1.2 Sustainability and Vernacular Palm Thatch Building Traditions

One of the findings of this research is that vernacular palm thatch building traditions, although currently considered primitive, simple and unpretentiously functional in the literature, are none of these things. Although at first sight they look simple in shape with little variation, their whole procurement is extremely complex and implies great knowledge of traditional forestry management, particularly regarding species, and their uses and by-products.

Therefore in regard to land management and extraction of materials the western way of addressing life-cycle assessment by looking at each material separately also needs to be approached in a different way for vernacular buildings. None of the palm plots visited were entirely devoted to the production of leaves for thatching, as most plots yielded a variety of products, such as edible seeds and palmetto shoots for *Brahea dulcis* and *Attalea guacuyule* seeds are also edible and a rich source of oil. The leaves, of *Brahea dulcis*, particularly young shoots, can be used for many by-products in the form of crafts such as mats and hats. Finally, *Sabal rosei* trunks are used as building elements (posts). This complexity makes it very hard to extract accurate yield factors for thatching palms. It is also important to highlight the problem of sustainable palm production since yield factors of can be diminished or increased, according to natural competition with other species, approaches to land management and methods of procurement related to final use of the palm products. Rather than the developed world non-cultural approach to agriculture the issue of vernacular building materials procurement appears much more related to the permaculture approach in agriculture, where the same land has many different yields. This made it difficult to undertake ecological footprint calculations based on the land required to produce the palm leaves for thatching as measured in the fieldwork. This led to the less satisfactory use of an energy/land conversion factor when establishing the ecological footprint. Understanding multiple yields from the same land is an area for further research.

The findings from the present research suggests the conventional model of assessing embodied energy in the western way is not always valid as most of the materials have not being studied and can vary widely within a same family of plants. For instance not all hardwoods will have the same biomass, the same rate of growth and replacement, the same age when harvested, and the same durability. The western model currently

assumes all materials reach a standard performance based on standard, tested, parameters. Natural materials, however, will not all be the same, so that building skills for vernacular buildings are different from those of the developed world, where many small buildings are no more than assembly on site of factory produced materials and components. Any move to preserve vernacular building traditions must include preserving the traditional building skills. The interviews in the fieldwork demonstrated how skilled the thatchers were in building and materials management. That said, these same vernacular traditions will also benefit from information for better decision making particular regarding conservation of natural environments. Therefore, applying the same type of LCA analysis to vernacular buildings and natural materials has proven problematic in this research as these materials are not standardized in a formal way, and knowledge about them is not written down but is rather passed on by oral tradition. Another problem was the enforced use of assumed coefficients for embodied energy that might not be appropriate to the rural context where much more work is done by hand. This is another area for further research.

The vernacular building experience is different. What can be built relies on what is immediately available, and as the experience after hurricane Kenna showed, experience and wisdom allow for adjustments in the harvesting process, so fewer palm leaves were harvested because of the damage the palms had received. At the same time fallen hardwoods were collected and used, not only for the case study building but also within the community for many other uses. Thus what materials are used may change according to availability. The high carbon footprint from the use of these hardwoods also ignored the lock-up of the carbon for the life of the building, thus delaying the process of decay and production of greenhouse gas emissions. What is more important in the carbon footprint is the carbon from industrial materials, so the LCA needs to be re-considered to separate these two types of carbon. The hardwoods in the case studies should last over 100 years, and even then not all will left to rot but the good parts will be salvaged and recycled into new buildings. The thatch also locks up carbon for its 17 year life, after which the normal process of rotting and returning the nutrients in the thatch to the soil takes place. This again is not reflected in the standard LCA accounting, and there is need to develop a more holistic methodology adapted to vernacular building traditions. This, again, is an area for further research.

Findings from this research highlight the relevance of in depth in situ studies that bring together quantitative and quantitative research, since the contribution of interviewees complements the statistical and quantitative information. Many interviewees knew exactly what was needed in terms of choice of materials and roof form for the longest life and the longest interval between thatching and re-thatching. The sub-text in the interviews was that not following these best practices would lead to inferior structures and that the building owners would come to regret this, Thus the vernacular is not about the building immediately after construction or even after a normal six months defect period, but the builder is always considering the future life of the building, thus echoing definitions of sustainability that ask society to think not just about now but about future generations.

This future thinking may be a reflection of owners and builders living in the same community. It is much easier to be caring in a small local community and much harder to do this in a globalised society where there is an absence of communities where everyone knows everyone.

7.2 Conclusions

This research has shown that vernacular buildings are complex constructions that are hard to analyze using the LCA tools designed for buildings in developed countries made of standardized man-made materials. It is also clear that those involved in making these buildings in Mexico today have a sound understanding of how to manage their resources, both at the time of harvesting and when they are in the building, so as to achieve a sustainable use of these resources.

This study has also pinpointed the relevance of a hybrid methodology, through using in depth structural interviews for qualitative results that add value to quantitative results from the surveys. This route allows for the emergence of differences and similarities, thus highlighting the consistency or lack of it within variables and from there decisions can be made about improving the models.

7.2.1 The Future of Thatching Traditions: a Non Western Approach

One important point to be noted is that the attention paid to vernacular buildings, forms, materials and techniques by architects is mostly to borrow these for their own

modern practices when searching for identity and cultural value. This means they ignore the knowledge needs for the creation of true vernacular buildings, such as knowledge of non-exploitative landscape and forestry management practices. Additionally, architects and practitioners have given very little attention to finding out what vernacular building traditions really involve.

To make the above statement clearer, it is very unlikely that someone will survey and analyze a vernacular tradition in order to preserve it through making new buildings in the same way. Analysis often has the reverse effect. For instance fire issues and fire protection are current within policy making, with the ‘solution’ of banning thatch traditions because of their risk, and the wiping out of much thatched building in western societies. Often where thatched building traditions remain these have been condemned to museums, as their only value is historical. What is needed is undertaking programs of research to improve both education towards the use of natural materials and their design considerations; for instance the use of fire detectors on the thatch can alleviate the fire risk.

Architects tend to borrow elements from the vernacular just for their aesthetics and seldom consider the whole system within the vernacular that leads to making such buildings. This is also true of natural materials, which are seen as more sustainable because of their lower impact. However, as this research has shown if these materials are used in a modern design context their ‘sustainability’ comes into question.

7.2.2 Further Research

The main goal for this research was to establish a model to account for the embodied energy inherent in vernacular palm thatch building traditions in Mexico. This led to establishing an inventory of the materials that go into the construction of the case study buildings, leaving outside the scope of the research the operational energy in use and disposal energy in order to establish a full life-cycle analysis for each technique. This is an area for further research.

Additionally there is room for further research into the thermal mass that diverse thatching materials have, since this will affect the energy that goes into the building during its lifespan, whether for air conditioning or heating, when compared to other

conventional building materials and technologies. This in turn can affect in comfort issues related to energy and how the thatched roof can or cannot provide an advantage.

Also further research can be highlighted in relation to a more thorough evaluation of the materials involved and biological studies to provide not only the impact of the building, but the impact on the land, through proper quantification of carbon sequestration and the biomass these types of vegetation contain, as thatch is mostly related to forestry materials.

Finally interdisciplinary studies can be made to establish the whole population of a particular species and palm used in each region in order to estimate the potential limits of sustainable harvest and the relationship of this with the number of houses that can be produced in a time-land relationship.

Additionally issues related to the social value and relevance of these buildings should also be approached in an inter-disciplinary way by taking into account the social, psychological and anthropological aspects of making them if a sustainable approach is desired.

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APPENDICES

Fieldwork on *A. guacuyule* Palm in Jalisco

Translated and abridged from the Spanish by the author

Part one

25th June 2011

Today I am starting my fieldwork at Puerto Vallarta, Jalisco, Mexico and for the following two weeks I will be driving along the coast to the southern state of Colima. For various reasons this coast line is the main area of concern for this research. One of the most important is its geographical condition, along with its vernacular tradition, and its history of evolution of vernacular traditions, especially the palm weaving techniques developed here in the last 500 years. Puerto Vallarta is located on the west coast of Mexico 20°40' North and 105° 20' West. According to the 2010 census it has a population of 255,725. It is located at the middle of Bahia the Banderas on the Pacific coast. Two main rivers have been of importance for the development of this location, the *Cuale* River to the south of Puerto Vallarta Downtown and *Ameca* River to the north. The vegetation is a deciduous forest of a semi-tropical type, which has a majestic diversity and beauty.

The best months of the year to appreciate nature are October and November just after the rainy season and before the dry season is established in winter, the driest months being March and April. Humidity levels start to rise as summer approaches. Now is the middle of the year and the weather is very hot with high humidity levels, as it is the rainy season and has rained for a couple of nights. Puerto Vallarta is located in a very peculiar and clear geographical position. The town is limited in its growth and is sheltered by the mountains of the *Sierra Madre Occidental* ranges on the south and east belt of the town. It gets flat towards the northern part of the bay towards the northern neighbouring state of Nayarit where shallow mangroves are much more in evidence than on the coastal slopes to the south of the bay. In this environment (the northern area of Nuevo Vallarta, state of Nayarit) because of its easy access, over the last two decades developers have affected it dramatically, transforming the natural

mangrove environment into a skyscraper 'Las Vegas' type resort, with huge environmental harm and continuing environmental threat.

With these geographical changes three different types of development can be appreciated:

A) An uncontrolled one of very fast growth and with the worst environmental impact effects;

B) A slow development that has built the historic city (over the last 150 years as it was founded as a city around 1850) and that has developed and preserved a typology in resonance with its environment and;

C) A vernacular one completely blended with nature, which has sometimes disappeared, sometimes been lost in the wild, and sometimes adapted itself to the new lifestyle.

Tomorrow's task is to find and document the third type of development.

26th June 2011

Today we undertook fieldwork in the locality of Quimixto in the southern part of the bay. Here you can drive to the farthest point before the road diverts from the shore and follows the path to the mountains. This last locality is Boca de Tomatlán. It is a fishing town where at present people only make part of their living by fishing as they also make some income from the increasing tourist flow, especially during the holidays and winter months from tourists from Canada and the United States who come here to settle, and also from a considerable number of national tourists. The town has a pier for small boats called *pangas*. These *pangas* are mainly owned by locals and used for fishing in the early morning before the sun rises and for tourist transport during commercial hours (9 a.m. to 6 p.m.) so they can visit the neighbouring localities of the south bay which lack of road access. Along with these uses, the inhabitants of these localities use the *pangas* to transport their goods, part of their food and groceries, to bring pasture crops for animals from nearby and often to carry building materials. To reach Quimixto by *panga* takes about 20 minutes including stops. Once on the boat the landscape changes and suddenly all the modern buildings are less obvious and nature manifests its beauty.

Along the shore vernacular buildings start to dominate the landscape and it can be appreciated how these *palapas* (palm thatch buildings) melt with the surroundings making them difficult to spot. Sporadically other types of houses of adobe and tile-roof structures can be seen in a sort of conviviality with nature and, sadly, increasingly as the value of this place increases, modern interventions with a more interruptive and intrusive typologies are starting to invade this shore. The first stop is made at the beach of Las Animas a favourite place for tourism as it offers great seafood and beautiful sandy beaches for swimming. These localities that have until now been kept safe from uncontrolled development are increasing in popularity and many eco resorts and spas have arisen offering a different tourist experience; one that is closer to nature.

As the boat moves away from the village large areas of untouched nature can be appreciated. In these shores many modern water sports like diving and yachting are common. Ocean life is very diverse and during a *panga* trip manta rays, whales, and dolphins are often seen (on one such trip I once saw a walrus sunning itself on a rock). The best season to spot wild is during the winter migration.

If the swell is good as it is today the trip can be very pleasant. The next stop is Majahuitas another village popular for its nice sandy beach and great sea food. The restaurants here are nearly all built with huge palm thatched roofs. Some can be of fine design and vast areas are covered. Here because there is no pier many people jump off the boat as it gets close to the beach and then it moves back and continues its trip. Now there are fewer people in the boat as most of the passengers have stayed in *Las Animas* and Majahuitas. Quimixto is the next stop. Although Quimixto is a popular destination for tourism, tourists do not often reach the village by *panga*, as more often they want an organized tour that includes a more expensive but comfortable trip in a catamaran. Often as you leave Majahuitas village the people who remain in the *panga* know each other and because I have made this trip many times as I have been working with the local community on ecotourism development, I recognize some familiar faces.

As the *panga* approaches the beach it makes a turn to drop anchor. As we all get off the boat we pay the boat man and disperse to our final destinations. I stop on the beach and look around. At the far end I can see two men waving and I recognize one of them as I get closer.

Hello Avelino I say! We shake hands followed by a hug and then he says: don't you remember *Gustavo* as I shake hands with the other guy. His face looks familiar I said. Yes he has grown replies Avelino; he lives at the little grocery store where you used to buy your local ice cream called '*bolis*' remember those made out of *nanche* (local fruit).

Avelino: So it is a long time since your last visit how long is it, 2 years? What news have you brought us? I reply and chat about the most relevant and recent news and update them about my new family. He updates me about his family. Avelino is an important person for the fieldwork on the *palapa* as he is one of the community leaders, a fisherman, a representative of the tourist horse riding cooperative, and a person committed to the environmental problems of his locality, especially rubbish collection and disposal as burning and burying problems increase. Tourism and the increasingly modern life style have shifted some of the villagers' habits, and this has carried with it problems of consumerism that are the major causes of disposable products arriving but not leaving. With Avelino and Oliver Fernandez we have created a guardianship of land agreement for ecotourism and permaculture development of which I am part, and environmental education about these issues has been carried out, especially with young people.

I apprise him of the research topic. "Avelino, this time my visit is short so I would like to ask you few things about the work I am doing." As I explain to him my intention for the present fieldwork, he agrees to contribute and he accepts for his name to be mentioned and shown in this fieldwork report.

We decide to have an interview at his place as the rain was approaching fast. Suddenly as usual here in the rainy season the skies open. Fortunately we reach the house before this happens where we agreed to talk about the building technology. He also says he will look for other local builders of *palapas* to gather more information, and suggests making contact with Pedro Gutierrez as he is one of the most experienced local thatchers.

Me: Is Pedro the guy who lives by the river going to our site Avelino?

Avelino: Yes '*El peludo*' or '*pichichi*' (his pet names) remember him, he built the *bungalow* (as he was referring to the *palapa* we built at the site around 10 years ago).

Me: Yes, I remember he use to bring the leaves carried by mules, with Agustin '*El Tilin*'

Avelino: Yes, well *Tilin* is still around, you know? After that last time you were here, he was very sick and lived here with me for a while. (Agustin '*el Tilin*' used to live in the wild with no urban contact at all for huge periods of times, sometimes for two years in a row, consuming local fruits, local seafood and food from the streams, and with absolutely no consumption of products from outside of the village). Now he is back at the site, although sometimes he goes to Tomatlán to look for mason's jobs but I don't like this, as he sometimes ends by drinking with other labourers. Agustin '*El Tilin*' has great knowledge of the local environment and forest management, edible and medicinal herbs, plants and even which roots to use to get fresh water.

Me: So can you tell me about the palm that is used?

Avelino: Yes, The '*cayaco*' palm, the one with the '*coquito de aceite*' (small oil nut), is the one abundant here.

Me: I know it.

Avelino: the other one used is the so called '*palma real*' (as it is commonly known among *palaperos*). It is much more expensive to build with here as it needs to be brought from hinterlands, although rich people pay for it as it is more aesthetic and they prefer it. The problem is that it implies more effort and cost especially for transport, which is why it is only commonly used on the retreat homes of rich people. It has to be brought out from the village, therefore has to be carried by truck or pickup to the pier in Bahia de Tomatlán and moved here by boat, then by animals to the site. In some ways this is good for the locals because it needs more people to load and unload and to transport palm to the site, so they sometimes earn a little extra money through these occasional opportunities.

Me: Back to the '*cayaco*' palm, how far from here is this palm harvested and collected?

Avelino: They are everywhere but for a dense population you will find them about a half an hour's walk towards the waterfall or neighbouring shores. Some other plots may be as far as an hour away, but for that you have to get off the track and into the

wild. Sometimes it is dangerous as there are more *cascabeles* (rattle snakes) and not everyone is willing to do this job.

Me: And do you remember how many leaves of this palm it takes to cover a square metre?

Avelino: Roughly about 40 to 50 halves to cover 1 m² that is about 25 leaves, but that can cover up to 3.5-4 m of length depending on the size of the leaf, taking into account a 1 or 1.5m overlap (therefore about 8-10 palms per m² average).

Me: How it is woven?

Avelino: Well it doesn't need a grid [secondary structure] as it is tied horizontally by its long hard vein or stalk. The vein is tied directly to the *tijera* (main structure), and you overlap the leaves so they can make a better weather proof layer.

Me: For the transport how many leaves can a mule or donkey carry?

Avelino: Well that depends on the accessibility to the palm fields, as the *palapero* has to open a track with his *machete* (blade). It also depends on the animal's health and the carrying capacity of the animal and the ability of who is wrapping the *brazas* (bundles), but let's say on average they can carry over 4 bundles of twelve palm leaves on each journey.

Me: Right, about 50 leaves:

And, what is the average life for these roofs, what is the longest they can last?

Avelino: This type of thatch can last up to 20 years without maintenance, but sometimes less according to the angle of the roof structure and how it was thatched, but for sure over 12 to 15 years before maintenance. They definitely last longer than the Palma Real ones. But when you pay attention to your house, and patch the thatch where the roof starts to present leakage problems, then your *palapa* can last longer.

Me: So it can be patched instead of re-covered?

Avelino: Yes sometimes to avoid paying for the whole work of thatching some additional patches are made to extend the life of the building. You can continuously patch your roof so you will never have to completely renew it, unless it is left without maintenance and the leaves start to go rotten and mouldy, then it is important to re-thatch if the structure is to be preserved.

Me: What materials are used for the structure?

Avelino: Basically the resistant woods, *Guayabillo*, and *Granadillo* are common here, also *Verdecillo* is found, and they are good to bury. There are other tropical timbers but these are not suitable for the *palapa* structure. These trees are common because they are rot resistant and straight in shape and uniform in size.

Me: How old are these woods before they are used for a *palapa* structure?

Avelino: They can be used starting from 5 to 7 years, but definitely for posts to bury older trees are recommended, around 15-20 years.

The rain has ceased and we decide to walk to the land that we have guardianship for where we built a *Palapa* 12 years ago to document it and to see if we could find the experienced thatcher Pedro. Unfortunately we couldn't find him, so we continue to the site, where we found the building in perfect condition. Another little structure has been built for an outdoor kitchen and so I took photos of the place and the building. After a while we return to the village as it was getting late and is important to reach the pier before sunset and before the tide is high again if intending to return to Boca de Tomatlán by *panga*. On the way back we decide to stop for the *bolis* (ice creams) mentioned earlier.

We talked about keeping in touch by telephone (as today some villagers have mobile phones) for the purpose of gathering more information, and he agreed. Then we walked back to the shore in search for a *panga* to transport us back to Boca de Tomatlán. After a half an hour of waiting a *panga* left the village, and we say our farewells. The rest of the trip back I was reviewing the places of interest to be visited in the coming days, and decide to make a list back in Vallarta before getting organized for the trip to Colima.

Part two

The following fieldwork was done by phone in November 2012, as another trip would have been impossible to repeat. However, this part of the interview was done with Oliver Fernan, chosen for its specific setting and conditions, building techniques and tools used, and approach to use of the local materials.

This interview was carried out while in New Zealand and made via skype. The importance of interviewing Oliver is because he organized and was fully part of the building process.

Oliver has consented to this information and his details being included and familiar with this research.

The information presented here is related specifically to the case study of *Attalea guacuyule* palm on a remote site near Quimixto village municipality of Cabo Corrientes, state of Jalisco Mexico.

Oliver talks about the palm technique:

The palms used were from oil palm *Attalea guacuyule* split in halves and woven in the way called ‘tejido ratonero’ (mouse thatch), which is different from the one called ‘tejido a hueso’ (bone thatch). Both are woven with split leaves of palm horizontally overlapped and pointing in counter directions. The difference between the ‘ratonero’ and the ‘a hueso’ thatch is that in the former a space equivalent to two to three fingers is allowed to save palm material –this is why it is called the ‘mouse thatch’ as there is enough space for the small rodent to get through, which can often be the case, while in the latter, the ‘bone thatch’, no space is allowed and the thatch is done by placing one stalk as tight as possible to the next one, with the final appearance of the fingers of the hand closed – this is why is called ‘a hueso’ (bone thatch)

Since there is very little difference in performance (rain and shade protection) and it was possible to prevent rodents getting into the roof covering the decision was made to use the ‘tejido ratonero’ thatch method to use less palm to save energy, as transport and access to the site and sources were the main issue.

Me: Where were these palm leaves collected? Avelino mentioned from the bushes towards the waterfalls (about 5 km away.)

Oliver: Some but not all. Two thirds of the palms were collected on the neighbouring shore around 10 minutes away on a *panga* boat trip from Quimixto pier and heading towards Yelapa (the next southern village in the Bay).

Me: How were they transported?

Oliver: By *panga* boat, as we decided this was the best way; one because it was a very crowded spot of oil palms, and they were young, so easy to harvest.

Me: Can you describe this process?

Oliver: Yes, two of us went there, then with a *machete*, the old dead leaves are cut away as they are useless, so you can say you prune them in order to reach the older and bigger but yet green leaves. On average 6 leaves are cut from each palm plant as this allows the palm to recover. This part I enjoyed as a single strike to achieve a clean cut needs to be performed with a machete so is quite an exercise. This sometimes requires you to sharpen the blade as it is a strong fibrous stalk, so we carry with us a limestone and sometimes spend time sharpening the blade during our breaks. Then the palms were carried to the piling station closest to the boat. Then we load the boat and head back. There we require mules as they are the strongest animals to transport the leaves to the site. We usually work with two mules if available, as this saves time in coming and going.

Me: So how many palm leaves of Attalea palm can a *panga* boat carry? And how did you transport them to the site?

Oliver: Up to 6 dozen leaves ($6 \times 12 = 72$ leaves) if well packed, so we did 4 boat trips, and a mule can carry an average of 3 to 4 dozen, and we did journeys of 3 dozen. So the best way we found was to tie the palms in bundles of a dozen, then rope them to the animal, and the animal will drag them to the site. This is unusual and people do not like this way because the leaves get all dirty and messy from horse manure, sand and loam, so people pack the leaves on the back of the animal instead of pulling and dragging them. But because access to the site is very far, windy and hilly, dragging them was a better method for us, so as to manoeuvre the animal. This of course implied an extra task, cleaning the leaves once in the site, so we shake them into a rocky place close by the river and water them, and then they are ready to split.

Me: How long does the process you are describing take?

Oliver: One full day to cut, pack, and carry the equivalent of one *panga* boat trip and carrying them into the site. So it took us 4 days to sort out the material we used from this source to the site.

Me: How did you acquire the other palm leaves?

Oliver: They were carried by land using animals from about 5 km away. This was done by mules as well, and was performed by '*el Pichichi*'. 6 dozen were brought from this

other source in two mule trips. I paid him two journals (1 journal=one day's wage=\$300 Mexican pesos=\$26.5USD; approx. \$1USD=\$11.3 MXP in 2003).

Me: So how many dozens were used to thatch your building (roof area= 7m x 4.5m x 2 pitches =63 m²)

Oliver: We used around 30 dozen= 360 leaves= 720 halves.

Me: I know there were special considerations for this building as it was built with fallen wood from Hurricane Kenna that hit Bahia Banderas back in 2003. Can you explain more about this?

Oliver: Yes, I actually decided to build this dwelling after the hurricane. In the days after the hurricane hit the bay I came to the site (which is divided by the river that comes from up the mountains from el Tuito village and, more specifically, from far above) and I saw so many rocks brought by the river, and saw many trees blown down, some precious hardwoods. I put aside a couple of potential posts that day as I found them in the river. The task was not easy; some were quite difficult to get out. A lot of people took advantage of this situation and therefore I needed to do it promptly. I knew that there was plenty but some trees were already taken, and so only the more difficult or less accessible still remained. Yet I found enough material and found I had the time to confront the challenge.

Since that moment I asked Agustin '*el Tilin*' if he knew how to build as I knew he did work as a mason before. He told me that the only thing that I had to bring him was some sacks of cement, some of burnt limestone, and a spade and a pick. So I went back to Puerto Vallarta and sorted out the tools he asked for plus a good *machete* blade. The next weekend I headed to Quimixto with enough goods to stay at the site for a month.

Me: What sort of goods?

Oliver: Beans, lots of beans, potatoes, onions, garlic, salt, and rice. The rest was always around, fruits, limes, fish, and seafood, so I was more concerned about staple foods. Also a couple of bowls and a cooking pan and a boiling pan with some cutlery.

We set up camp there, but we often slept at Avelino's place 20 minutes walk away.

Me: So were materials like cement and burnt limestone used for foundations? Can you explain how this was done?

Oliver: Yes the first task was to excavate and to carry rocks from the river. This task was heavy; sometimes the rain did not allow us to work full days, and we spent lots of time on this stage. All was carried by hand, by lever and by rolling, nothing was brought further than 100 metres but big rocks were moved and sometimes it took a full day to move a single rock into place. Digging was a problem two; I actually regret not having better tools and better planning. We used the pick but only had one. We used a 'coa', which is a long thin pole of hardwood, being the tool used in the past and still seen today, and the name is Nahuatl. Today it is mainly used in agriculture, but was very handy and useful to have around. It is like what you know today as a crowbar.

Me: How long did this stage of the building take?

Oliver: About 2 months, but in hours around 20 hours a week each for two men.

Me: And how much material was used?

Oliver: Of rocks I have no idea, but we used 10 x 50kg sacks of cement and 20 x 25kg of burnt limestone, brought in two journeys, both from Puerto Vallarta.

Me: Do you know what species of wood were used and how they were acquired?

Oliver: That varied a lot. As I said I used different types of wood to achieve the building. We used whatever was available and blown down by the hurricane; as far as I remember most of the woods were 'Guayabillo', 'Chinillo', and 'Palo de Brasil'.

It is difficult to say because this was done in many different ways, but I can tell you everything started via voice. I let people know about my intention, so mostly all of the elements we used were brought from different sources. When somebody spotted a fallen trunk or good branch they let me know; then we organized the day to collect them. We brought with us the tools needed to clean and clear, mainly *machete* and hand saw. In a general way I can tell you that the most difficult ones took up to two days to bring them here, one in cleaning and clearing and another in working their way here. They were all moved by men in pairs, always me and someone else. Sometimes this was 'Tilin', sometimes Avelino, and sometimes 'el Pichichi' or 'el Oaxaco' or whoever was willing to do this job, mainly for free. Most of the people I mentioned, you know we have helped them every time that we could, so they did not do it for money.

Bamboo was also used; honestly I do not know what type, but it was brought from around Yelapa. One occasion I was there, the thick bamboo I mean, we brought a dozen good thick stems and we carried them by *panga* and they were transported by me from the pier of Quimixto to the site. Also Otate bamboo was used but was brought from a higher place, heading to el Tuito following the waterfalls. Around 50 stalks were used for fences and some was left for another building that we built a couple of years later. The Otate bamboo I paid *el Pichichi* to harvest and it was carried in 2 journeys with mules from about 10km uphill.

Me: So as an estimate, how many man hours did this whole process take?

Oliver: Difficult to calculate as I did not keep track of it, but I will say very roughly about two weeks all day, two labourers, so about 160 hours.

Me: And for building the structure?

Oliver: That was done in 5 days by *Tilin* and me.

Me: What materials were used for binding and how did you do this?

Oliver: Well I bought 5 skeins of 5kg of sisal cord, some recycled burnt steel wire was also used, and two skeins of Raphia cord of 2 kg, about 8m of recycled reinforcing steel bars were used (1 m for each post joint with the beams) and some 2.5 inches (67 mm) steel nails were used, about 1 kg not much, only to secure certain joints.

Me: And the thatching?

Oliver: That was the easy part: from the beginning to the end the whole work was achieved in six months, the difficult part was to organize all the materials, executing the construction was relatively easy. Actually the thatch itself took us two days. The whole roof cover (63m²) was done by *Tilin* and me. It was quite a story, because during those days rain was around. Actually one day we struggled very much and we ended by covering ourselves with banana leaves. That day starting the fire was a big issue, as there was no more dry wood left, and it was good to be with *Tilin*. He is the only person I have ever known to start a fire with wet wood in the rain, it was quite amazing. I did so much enjoy the fire and the food that day when the rain was gone. Anyway back to the thatch, the story is that just after we finished a huge storm came, and it was so nice to be dry after such an odyssey. I have never been so comfortable

before, not a single leak, not a single drop, and we were just sitting there watching the spectacle.

Me: I remember you mentioned something about chopping a tree?

Oliver: Yes, this was the only tree that was cut on the site. *Pichichi* did that work and he used a petrol chain saw with a long blade, I think it was a Husqvarna, not sure about the engine but it was a long blade. What I know is that he spent 4 days on such a work, from chopping down the tree, to dressing it.

Me: What type of tree?

Oliver: I do not know but I can find out.

Me: That will be very useful, thanks.

Me: And fuel, how much fuel was used?

Oliver: I think it was two 20 litre containers.

Me: And how many boards did he achieve?

Oliver: We used over 40 boards 2.5 m long, 25 cm wide and 3/4" (1.9cm) thick for the decking, but I think he shaped about 60 as some were used as a dividing wall on the bottom floor.

I also used coconut palm tree off-cuts that I acquired in the town of Quimixto when someone was dressing some elements from a coconut palm trunk.

Me: Did you pay for these?

Oliver: No as they were done by Avelino and the client did not want them, so I asked to him and he was happy for me to have them.

Me: Thank you very much for the information, for letting me use your building as a case study, and me or my supervisor might contact you further for any queries or further information if needed, if that is okay.

Oliver: Yes no worries and let me know.

End of Interview

Fieldwork on *Brahea dulcis* Palm in Puebla

Translated and abridged from the Spanish by the author

Interview carried out for this research by Ana Paula Martinez Lanz in San Francisco Jalapexco village, municipality of Atlixco, Puebla State, Mexico

26 November 2012

Participant

Name: Felix Ponce Valdez
Locality: San Francisco Jalapexco
Age: 34 years
Work: A palm crafts person (14 years of professional activity)

Ana: Would you like to introduce yourself and your work? (Personal information given as above)

Felix: I have worked with palm products for 14 to 15 years. I understand this is an old tradition passed on by our ancestors and I work in this in art to preserve and promote a skill that is a heritage that was passed through family members.

Working the palm is very pleasant work that is not only to do with buildings. From this palm a lot of by-products can be made. To give an example all the arrangements that people put in their house (like a symbolic woven four petal flower) for Easter festivities are made of this palm and this is one of the many economic products for this region.

I would like that this craft to be brought to life and not become extinct. I would be very pleased to see that this work or similar can provide benefits for this community of Jalapexco, to bring work to lots of people here as work is very scarce. So with the system that I have, I employ lots of people. For instance when working on thatched roofs, I contract 6 to 8 local people for full weeks (between 2 to 3 weeks average per building) to collect, cut and most importantly to dry the leaves properly, as this is something that needs care. It needs a constant eye to dry the leaf open (the leaf in a fan shape) and see it does not shrink as this is crucial for the good performance of the thatch roof. This is done by piling the leaves and pressing them with stones. For this stage the process takes 20 days to dry them by exposing the leaves to the sun; then as a result when it is completely dry the fan will preserve its open shape as desired.

The process of selecting the material, cutting and drying is performed on the site of the source. Then after drying the bundles are carried by animals from about 30 min to 1 hour distance, where they are compiled in the yards as a first step, and then organized for transporting to the next point, which can vary according to where the building is going to be.

Ana: Do many people work here as you do?

Felix: No, here only three persons including myself do it as a profitable profession. And you can see my hands are all rough and cut by the spikes of the palm stalk we use. Young people do not like this; they prefer other work -sometimes even more intense- but less damaging.

Ana: So what else do these people do?

Felix: They work in the charcoal rural industry; this includes chopping wood, burning it for charcoal and transporting it, as this one of the main economic activities in this locality. As I said work is very difficult and scarce and the people try to engage in whatever allows them to bring in some income for their families. Some work as masons' labourers, and they go and look for work outside the village; some they stay here and work in the charcoal activity.

So for me palm is an opportunity, and it is something that I hope will not vanish but stay here. I want to promote it and this is why I am happy to carry out this interview, to let this technique be known and bring us benefits back.

Ana: And how did you learn this skill?

Felix: It is something I learnt from my parents. They also knew the tradition, and they also learned it very young in the same way as the skill was passed to them by their parents. Today this pattern is shifting as now I see it as not only reproducing the tradition but also providing work and income for the family and for others and their families, in a more commercial way. That is my true intention.

I can see in the palm building tradition a whole system that involves different people in different stages; for instance I have explained the labour for collecting the material. Myself on the other hand, I dedicate most of my time to being in charge of a bigger organizational pyramid, talking with the owners, or the *patrones* (masters, referring to other architects, engineers, or dealers in the modern building industry). I attend

meetings, make budgets, and organize the crews. Others for instance they dedicate themselves to the collecting of other materials such as the *Carrizo* reed. Some others gather and collect the wood for the structure, and some other the fibres of *ixtle* (Agave fibres).

We have plenty of *ixtle* in the localities, but we do not have a proper technology to develop this process well, so we still do it in the old way. From Maguey plant leaves we extract the fibres by smashing the leaves with stones and pulling strips from the inside of the bulk of the leaves with two wooden poles. Because of the lack of good tools and equipment we cannot do this commercially, and end up buying the yarns from other providers, but it is an activity that I am sure we can set going in these communities as a productive one.

Equipment, tools and impetus is what we need. For instance the palm we use can be pruned at an average of 7 leaves per cycle, and it takes 7 months for the palm to bring back new shoots (say another 7 leaves will be in good shape after 7 months from pruning). But if you do not do that then the palm stops its productivity, tends to dry faster and its productivity is greatly diminished. So the more it is pruned the more productive the plant becomes. For us this is considered a gift from nature and represents a wealth that we have here, like a blessing, as we do not have to care for them, we do not even water them, as these palms are local, strong and resistant to drought. The palm grows and reproduces naturally. We just have to collect the leaves (prune it) and manage it. Seven months for me is not a very big cycle as in seven months I can come and have more, for me this is beneficial.

Ana: How do you get the palm? Do you have your own fields or plantation?

Felix: No, I buy the palm from other local people. This saves me money and provides an income for the families collecting and managing the palms, but I want to state that 64 people belong to the *comuneros* (communities group conformation), and among us we manage 9,000 hectares, and all this land is crowded with palms so there is plenty. This community group accounts for the localities of San Jerónimo Caleras, San Francisco Jalapexco, San Bartolo, Soledad and San Diego. There are other villages close by for instance Rosario and la Huerta, these two localities are close by but there is no palm over there. It is only this area that has the palm resource in this region.

Ana: What is the name of the palm?

Felix: We know it as *Palma Silvestre*

Ana: And do you know the scientific name?

Felix: No honestly I do not.

Ana: And do you know how many palms a hectare will have?

Felix: Lots, not sure but for instance, from a bush (cluster of palms) we extract 30 *montones* 'bunches' (meaning bundles of leaves). Roughly a dense cluster of about 60 to 70 plants, around 500 - 600 leaves per *matorrales* bush. (Here a bush is considered a whole family of palms).

Ana: And how many *matorrales* per hectare? Could you estimate this?

Felix: As a rough estimate up to 2000

Ana: What age is the palm productive?

Felix: Not sure but the palm from young can be pruned in a cycle of 7 months, as I mentioned. For instance when the new shoot starts to sprout in a month it already has the shape of a palm leaf, so in that 7 month cycle it will easily produce on average from 7 to 10 new proper leaves.

Ana: Going back to the palm roof, how big is the demand and who are your main clients?

Felix: Mainly architects, but every now and then we work directly with people who want to build for themselves without an architect or engineer.

Ana: And how frequent is the demand?

Felix: Well it depends how big the work is. The demand can be ongoing, but mainly the biggest demand is during the 5 months from November to March. Because of the rainy season there is very little work related to thatching in the other 7 months. This is because the palm is very difficult to dry. What happens during the wet season is that instead of drying the leaves tend to become mouldy and rotten. So within five months we do as much as possible. We would like to perform the job all year round but we have to adapt to the natural cycle.

Ana: Are there any other negative factors (like the rainy season) or positive ones that you can comment on when using this traditional skill?

Felix: Positive is the materials are all local and represent an income for us, all is provided by nature. Looking at the wood, there are sections that are used for extraction while others that are preserved for reforestation programs that the community undertakes, as it is a source of income for many we tend to care about such things.

When we use a hectare for extraction by the community for a cycle, then it is rested and respected for another 5 years, so then the trees have time to recover.

A negative thing about harvesting the palm is that there are scorpions, wasps, snakes, and you have to be careful as these animals live in the palm bushes. Sometimes we all have to stop and run for protection, especially if a wasps' nest is disturbed.

Ana: And in the roof itself?

Felix: Well this is not often the case, as today often people fumigate their roofs.

Ana: What do you fumigate the roofs with?

Felix: Well with conventional killers, *Raid* or *Foley*.

Ana: And is this work carried out by you?

Felix: No by others

Ana: What is the cost of a 6 x 4 m area double pitched roof (34 m²) structure of around 6 - 8 posts?

Felix: Material and labour around \$20,000 pesos (\$1 USD= \$ 13.2 MXP–Mexican pesos, November 2012)

Ana: And just the structure?

Felix: From \$9,000 MXP

Ana: And just the woven palm?

Felix: From \$6,000 MXP

Ana: And how many labourers for this example?

Felix: 6 people.

Ana: How long will it take?

Felix: Two to three weeks: split in two groups 3 working here in the gathering of materials, and another 3 on the site executing the building.

Ana: Do you know how to build as in the past and what materials were employed then?

Felix: Mainly the same, *ixtle* and palm shoots would have been used for ties and knots; the rest remains mainly the same.

Ana: And what types of wood are used?

Felix: Sabino and Encino

Ana: Do you know the scientific names?

Felix: No sorry

Ana: And are they local or regional?

Felix: Yes all are local.

Ana: And how much do they cost, for say an item?

Felix: Varies from \$150 to \$200 pesos each item, depending on the thickness and length but a standard 3m long undressed tree trunk costs around \$150 MXP

Ana: Do you collect these materials?

Felix: No I subcontract people.

Ana: Is there any program that controls, regulates or promotes management of these forests?

Felix: Not really, there is some regulation by SAGARPA and other governmental institutions that are becoming federal, but locally all management is carried out by the local communities, as I explained talking about the cycles of the forests. The community is very aware of this concern because as a local economic resource we need to care for it.

The woods that are used for building are not used for charcoal; that wood is a different type and it requires different systems. This last one I don't really know about.

Ana: Would you be able to estimate an amount of trees per hectare for these woods for buildings?

Felix: Not really

Ana: And how old are these timbers? Or what diameter are the poles?

Felix: 8 to 10 inches (20 to 25 cm) at the base

Ana: How long do these structures last and are they maintained?

Felix: They easily last over 40 years. The structure is very strong and does not get affected by bugs. The wood is cut in special stages; for instance wood for a better performance needs to be cut right after the full moon *Luna dura*, and wood can be cut every lunar cycle only on 4 days, the same with the palm.

Harvesting is a very important stage of the whole process. If this is not done following the consideration I just mentioned, very often it is possible to see these timbers starting to be affected by bugs and rotting as fast as 6 years old, but doing it properly can make a big difference. As an example, as far as I remember my great grandfather built a house. My father is now 56 years, and so I believe some of those timbers which are still in perfect conditions will be over 100 years, maybe 120 years old. But they did have great deal of consideration for this forest management. My father and my grandfather taught me the seasons of harvesting for these buildings. This is something passed down through generations and is part of our traditions, and I follow such a heritage.

Ana: How do you get the palm in terms of quantities?

Felix: We called them *tareas* (homework), each *tarea* is 100 bundles, and each bundle is 20 leaves. (Therefore 1 *tarea* = 2,000 leaves)

Ana: Is there any program of protection or regulation for the palm?

Felix: The palm has no regulation at all, it is 'free'. The tree is used for different purposes, for instance while craft people use green shoots for building, we use the old leaves for thatching, so I use what they do not.

Ana: Double checking about the negative and positive aspects of this material.

Felix: Mainly it is very rough work; the palm is very fragile, and slippery (in the sense of securing the bundles) so it is a skill that requires certain knowledge. Also the spikes are like a saw and they can hurt a lot. Birds should be mentioned as enemies of these buildings as sometimes they like to nest in these structures, so they can affect the thatch.

The benefits are that the thatch is very good thermal insulation. You can see we are here inside this house and it is very hot outside but very comfortable inside. Even when it is very cold as happens at night or during certain periods of the year the place is warm enough to be comfortable.

Ana: So this structure that we are in now is called the same as the other ones which are fully thatched from palms (walls and roof cover)?

Felix: No those are called *jalapitas* or *jalapas*, the first as a pet name. Those are proper dwellings, whereas the one you are in now is a more modern type that not always has such a function. The *jalapitas* are the old tradition that still survives. I still live in a *jalapita* and my brother who lives not so far away also dwells in a *jalapita*.

Ana: And a Jalapita how much will it cost for the same size example of 6 x4 m and a double pitched roof?

Felix: A bit more expensive, because it requires more material and labor to cover the walls, but the price does not increase much, let's say roughly from 22,000 MXP.

Ana: And the floor?

Felix: The floor is made of earth, but to last longer the earth is mixed with prickly pear juice and burnt limestone. It is compacted and binds together, so it lasts much longer than if it is just made with beaten earth.

Ana: Do you know how to make the floors you are describing?

Felix: Yes

Ana: So about transport?

Felix: The trip depends on the volume; my truck which is a little pick up can only carry three *tareas*.

Ana: Would you know how much a leaf weighs?

Felix: Very roughly up to 2kg.

Ana: And do you know how many palm leaves a person can carry?

Felix: Probably 3 to 4 bundles (60 to 80 leaves)

Ana: And an animal?

Felix: A donkey can carry about from 12 to up to 18 bundles. From the source field to here (or the first station) the material is all carried by animals, as there is no car access to the source; once here it can be carried by trucks.

Ana: And what types of truck are usually used?

Felix: Mainly $\frac{3}{4}$ or 1 tonne pickups; here there are no 3.5 tonne trucks available.

Ana: And how many palm leaves does 1 m² need?

Felix: 100 leaves

Ana: Assuming a house is brand new, how long before it starts to need maintenance?

Felix: After 8 years, up to 10 at the most.

Ana: What type of deterioration occurs?

Felix: The palm deteriorates because of the sun, rain, wind.

Ana: Do you patch it?

Felix: More likely the whole palm cover is changed, as you usually damage the palm by trying to patch it. You can do this but it is more cost effective for both the client and the thatcher to replace the thatch layer.

Ana: You mentioned *Carrizo* reeds but what other materials do you use?

Felix: We use bamboo, *Carrizo* reed and *Otate* bamboo. For instance *Otate* bamboo lasts much longer than the reed, and is very strong and you can even roll it. Both *Carrizo* and *Otate* are used as the grid for the structure to which the palm is laced.

Ana: Other materials like steel?

Felix: Yes, steel can be used, but we can build with 100% natural materials

Ana: What is the most common other material used today, commercially speaking?

Felix: Steel wire nails are usually included for commercial purposes as it takes less time, is still cost effective and needs less maintenance. Some want *ixtle* binding but not all, and in such a case the binding is only aesthetic to cover the metal wire.

Ana: How long does the *ixtle* last?

Felix: Not sure exactly but at least more than 10 years

Ana: What amounts of materials would be used for the the 6 x4 m example with two pitched roofs?

Felix: 6 posts are better as the beams are easier and shorter, because if you only use 4 posts you need 6m long beams, so we usually use 6 posts. For the *morillos* which are the rafters you use 18 elements; 6 beams; 120 *Carrizos* of Otates; 4 to 5 *tareas* of palms; and for roping around 90m of ixtle rope. There are 600 palms in a small *tarea* although there are big *tareas* of 2000.

Ana: How much does a *Carrizo* weigh?

Felix: Very little, say a half kg up to 1 kg, and this material is harvested near the streams or rivers where they grow. We usually buy them from the owners of those lands as it is an economic product for them.

Ana: How long does a bamboo stalk last and is any treatment used for this material?

Felix: If it is not treated it does not last long, say 6 to 10 years when insect infestation can be seen. To treat it you will drill into each section of the stalk and soak it on water with herbicide/pesticide, then it last longer, but I cannot tell an average life for it.

Ana: How fast do these bamboos or reeds regenerate?

Felix: The *Carrizo* completely regenerates every year

Ana: Is there anything else you want to add to this interview.

Felix: I would like to see this interview having a positive outcome. I would like the content to be well promoted, as I would like to see more people in the community engaged in this tradition as a better economic opportunity for the community. This will represent growth and work for many, not only for people like me but for all the people that need to be involved in the process. I am older now but I think I have enough experience to share that I didn't achieve in school. I was not able to go to school as I did not have the money or the time so I decided on this path but I think work and effort on both sides are needed for a better future for all the people involved. By re-evaluating and recovering this tradition people will see it not just as a skill for the poor, and this is something I would like to work on. I have come across good architects that are amazed about my knowledge, and they ask me where I learnt this skill and I always answer in the school of life, through experience and I do not want this way of learning to be lost. But today I am aware we need support from external agents.

Ana: I want to extend my gratitude and on behalf of my colleague Jaime as well. If you need any further information or have any doubts about this interview please feel free to contact me, my colleague or his supervisor on the contacts found in the form.

Felix: Thanks as well and I am looking forward to seeing the results of the work.

Fieldwork on *Sabal rosei* palm in Colima

Translated and abridged from the Spanish by the author

28 June 2011

Arriving in Manzanillo Colima, Mexico, I go to the house of Luis Covarrubias, as I have previously made contact with him. He is a good friend and colleague and 7 years ago we were in charge of developing the ecotourism project, Natura Camp. Luis Covarrubias is grandson of the great Mexican artist, cartoonist and painter Miguel Covarrubias†. Some of the pictures and videos collected for this part of the fieldwork were taken by him and some by me and so sources will be stated.

29 June 2011

Today we went searching for *palapas* and *palaperos*, and were pointed to a palm thatcher, Francisco Figueroa in Domicilio calle de Pipila s/n Santiago, Manzanillo, Colima, Mexico. I introduced myself and asked for an interview about palm thatching technique. After a brief talk he gave permission for this interview and agreed to use of his name and information in this research. He was a little uncertain of our purpose so he decided to give me a general overview with not too much detail and refused to talk more.

The so called *Palma real* is endemic in the west coast region called the occident of Mexico. It is mainly found in Colima, Jalisco and Nayarit, although apparently it is also found in Sinaloa and Sonora, Michoacán and Guerrero. He mentioned the localities where this palm is more abundant and easy to find as follows: Emiliano Zapata, Careyes, Cruz de Loreto in the state of Jalisco, and mainly in Camotlán in the state of Colima. It is a palm with a fan shape leaf but it has a spike-less vein, is of mid-height and it has a small coconut seed similar to *Coyul* (form of oil palm) the difference being that this one is not edible.

He mentioned that *Barcino*, *Guayabillo*, *Bonetillo*, *Palo Liso* are woods used for structures and the trees can be found from north Manzanillo to Cruz the Loreto (south Bahia de Banderas). He highlighted that you need a forestry permit to transport and move these trees as they are tropical hard woods and some areas are widely deforested. Today that permit is authorized by PROFEPA (Federal Procuration of Environment). He added that there are still many clandestine activities around taking these species.

This was all the information I could gather as he was going out on another job. After asking if it would be possible to come back another day, he refused as he said he was happy to help but very busy. He pointed us in the direction of another thatcher (*palapero*), so I thanked him for his time and information but we could not find the other *palapero* so went home and structured a plan for the coming days. Luis and I talked about an old college friend Oscar, who comes from a family of thatchers, so Luis found his contact and we called him and established an appointment for the next day.

30 June 2011

We start our search for *palaperos* at 8:00 in the morning by driving around the city of Manzanillo. We had contacted Oscar Gerardo Enciso Sanchez, who used to work as a tourist guide at the Natura Camp project. He comes from a family of *palaperos* and we called him and arranged an appointment for that same afternoon. After talking with Oscar Enciso we found via him one of the most experienced and well known *palaperos*, Jose Luis Soto Rosales and his Brother Juan Soto Rosales. We then went in search of their place with a stop for a cold coconut water drink from *Cocos nucifera* prepared as a typical beverage through all Colima. There are two ways to have this precious water, one is directly from the coconut shell, and after drinking the liquid, the *coquero* (person who manages the coconut palm plantation for its various products) uses his *machete* (a primary tool in this traditional skill) to cut the coconut in half. Sometimes another tool called *cuchara* (spoon) made of steel or from a slice of the outer skin of the coconut cut in the form of a spoon is produced and the ‘fleshy meat’ on the inside wall of the coconut shell extracted. This is prepared by adding lime and *chile* (Capsicum) powder to make a typical snack. Finally we continue with our and find Jose Luis Soto Rosales at #158 Emiliano Zapata Street, Colonia San Martin in the locality of Salagua municipality of Manzanillo Colima, Mexico.

Jose Luis and Juan Soto Rosales were given a brief introductory explanation and a formal appointment to explain the project was established for the morning of the next day. So we shake hands as a typical gratitude gesture or indication of a mutual agreement or deal. We then drove back to Luis Covarrubias’ place, and reviewed the information collected.

1st July 2011

The working day started very early and we leave the house at 7 am. On the way to our meeting with the *palapero* Jose Luis Soto Rosales we stop at a grocery store to buy some groceries and beverages where we come across a *comerciante* (merchant) driving his pickup truck full of palm brooms. I wanted to talk to him about these and decided to purchase a broom but he was doubtful about selling it to me as he sells them as a bundle of twelve to stores in town, and it was therefore a problem to just sell one. I insist on purchasing just one at a higher cost to cover the loss, as I explained what I was doing there and that I was not interested in making profits out of that trade, just interested in acquiring one of his products as a record of this research. Finally he agreed to sell me one item while giving me very limited information as he was doubtful of our true intention. Finally he gave the name of the palm used for the manufacture of these brooms. He said it is *Palma de Tepejilote* and he adds that this palm is a palm of altitude found in the region of Minatitlan, Colima, Mexico. That was the only information that I gather from him after purchasing the item.

We arrived at Jose Luis Soto Rosales' place at half past eight. That day I decided to explain the research thoroughly in the hope he would agree to share his knowledge. He went and asked his brother Juan Soto Rosales to join us in this to have his approval as well as they mostly work in partnership. Jose Luis explained that sometimes they accept different jobs if there is enough demand, in which case they make their own profit.

I explained that this was an academic research project and the collected data was for statistical purposes as a basis for doing an environmental assessment of the palm building technique and tradition in Colima Mexico, that all related information is intended to be used in the publication of such work, that their names could remain anonymous or could be used if they agreed to this. They agreed to all this as they liked the idea. Jose Luis commented that he felt it is very important as there are no works about the content of the project. If you want to know about earth building you can go to libraries and find lots of relevant information, but if you want to know about our work you find almost nothing about *palapa* buildings. He added that he was happy for me to use his name as it could give him further publicity.

The rest of the day we spent in defining the building itself. He explained to me the parts and materials of a *palapa* (see list below), and we made a drawing of it.

- *Bejuco de cerro corralero, bejuco ojo de agua* (local names applied to the vines used for tying or binding joints, and there are many others less common.
- *Salate bejuco* (vine) that strangles and kills the palm, also the *Tabachín* vine one
- *Otate bamboo*, an endemic bamboo from altitude range areas found in Minatitlán 500 m A.S.L. and higher. This is the yellow one. He mentioned a black one that comes from the neighbouring southern state of Michoacán. This is used as a secondary structure material and to provide a grid on which the palm can be woven.
- *Botoncillo, Barcino, Balsamo, Lloro Sangre, Mapilla, Guayabillo, and Verdecillo* are local names of tropical timbers used for the building of the main structure of the roof triangular framing.
- *Barcino, Guayabillo, and Palmas*, are timbers used as main supports or posts for the building of a traditional *palapa*. These woods are the older ones and are considered to be *Madera de Corazon* (timber of strong core ‘heart’ or centre). Most of these timbers are 10 to 15 years old and some are very resistant to water and rot when buried in the ground. They can last over hundred years if well maintained and protected from the sun and rain, and the contrast where the material is left uncovered is very noticeable.

We talked briefly about the durability of the thatch.

Me: How much does it cost in today’s market to thatch a roof?

JL: For a building of 6m x 4m, the most common one, and with a double pitch roof of 45 degrees, it costs 50,000 Mexican pesos (12.7 pesos = 1 USD up to March 2011) for the full job of materials and hand labour, including both structure and thatch cover, and 25,000 Mexican pesos for the palm thatch cover only if the structure already exists and is going to be re-thatched.

Me: How long does the palm thatch last?

JL: If properly thatched and designed (he emphasised the pitch being no less than 35 degrees), a *palapa* made of *Palma Real* or *de palapa* can last up to ten years. If it is built with a 45 degree pitch roof it will definitely last between 10-12 years. If thatched with *Cayaco palm* (Coyul) it could easily outlast 12 years, maybe 15, maybe a bit more if properly thatched and designed, but really must be re-thatched after 20 years.

We wrap up the day by organizing a schedule for the fieldwork in the coming days. We agreed to meet the next day in the morning. He told me that he will look for some work on at the moment with other *palaperos* and ask if we could visit the site to see the technique and process. I happily agreed to his proposal and we left his place at 1pm.

2 July 2011

I arrived in his place in the morning and after a brief talk while he finishes his coffee we get into the car. I drove for about 23 km towards the locality of Camotlán. The environment suddenly started changing as we were going up the hill. We finally reached the area and then we stopped in the road and walked into a field of palm. He said that these palms are not planted as they grow naturally in this field (apparently they have very specific climatic conditions as they are found in deciduous forests with coastal proximity but they definitively do not grow below 500m above sea level .

Interview with Jose Luis Soto thatcher (palapero) from Manzanillo, Colima

JL: I was saying that this palm lasts a little less well than the one found in Tomatlán (Jalisco). The palm found here in Colima is of less quality apparently because of the stalk, as the Colima palm .has a thicker vein (stalk), is rougher, and tough (making it less flexible to work).

Me: So are they different species?

JL: They are the same plant but with slight variations.

As we were walking into the field of palm he shows me another plant.

JL: This is like a native wild coffee and you can see here it is together with this baby palm sprout (he points out how this palm lives in conviviality with other plants in the wild). This palm can grow really fast—up to three metres—and this is what we use to thatch the *palapa*.

Me: Are those beans edible?

JL: No, they look like coffee but they aren't edible

JL: You see this land is very sparsely populated and on this land nobody cares for the palm plantation, but you can see it is used for mixed agriculture as well as to harvest the palm leaves for *palapas*.

Me: So what else is planted on these lands?

JL: Cucumber primarily, although cattle are common.

I noticed how damaged these fields were because of their use by farm animals, and this is the main reason why the palm population has drastically decreased.

We found two examples of palm with vine in symbiosis, and he explains the differences between the two cases

JL: The left is a palm with *Salate* vine, and the right is *Tabachín*.

Me: Does the vine come from bird manure and grow downwards?

JL: Yes they grow downwards both of them, until they hit the ground and then get stronger and will suddenly kill the palm. They grow out of bats' manure not birds'.

Me: And those trunks can be used for posts?

JL: Yes because they are very nice (aesthetic) and people like their appearance.

Me: And these palm trunks how old are they, maybe 40 years?

JL: No, those ones might be 30 years old.

We then left the site, and drove to the town of el Ciruelito.

We arrive in the locality of Ciruelito la Marina and we spot a *palapa* building that to my eyes looked similar to the ones drawn in pre Columbian codex 500 years ago, so I decide to stop and get information as I had never seen an example like this in the west coast area of Colima before.

As we approach I introduce myself to the house owner and explained my purpose of this visit to this locality. Jose Luis Soto the thatcher also introduced himself in order to reinforce what I had said. After explaining our purpose I asked her if we could take pictures and video clips of her place, and make a little interview with her. She accepted and therefore we carried on.

Me: Would you like to introduce yourself?

Woman: Yes my name is Maria Guadalupe Chavez.

Me: Would you agree your address to be known?

Maria: Yes; *address known, Ciruelito de la Marina municipality of Manzanillo Colima

*(this is a usual address when localities are small enough in population and size where the address refers to the person instead of the physical place (domicilio conocido 'Address known')

Me: So, can you say something about your house, a description or any information?

Maria: This is called *gorro de palapa* (palapa hat-meaning a thatch cover or roof) because there are different types of *palapas*. For instance in Cancun (Quintana Roo state at the south east peninsula of Mexico) there are different ones or in Cabos (at the south Baja California, Mexico) they also vary, but I can tell you that from here they export material to those places. This is because here is where they gather the materials. A lot of people come from many different places to obtain their materials, for instance they come from Guadalajara, and so there are people like my husband who actually buy the 'plot of land' or ha if you want to say it like that, but only for the leaves.

They can prune the leaves of the palms because they have a permit. They need a permit from the forestry authorities otherwise they can get fined. So for those who actually export palm from here they need the forestry 'guide' permit so if they get stopped by the federal police they do not get into trouble.

This also applies to wood. For instance to chop the palm trunk needs a permit. Because there are palms that have a vine that looks plaited and these are regulated, so although the vine ends by killing the plant it cannot be chopped too young. They usually do not allow you to carry a large number of those trunks (no more than four), but I do not know whether a normal coconut palm trunk would fall into that category.

Me: And are there still houses like yours around that we can go and see?

Maria: Well no, honestly not many are left here there is just this one. The neighbour has another but it is different, and there is one more at the back of the church, but it is also different and is very high, and they use it for public events or you can hire it for a celebration.

JL: In the past these houses were very common, but not anymore.

Maria: Yes that is true but here there are only three.

Me: Can you talk about living in your house? Is it cool to live in?

Maria: Yes it is very cool, too much I will say, as on some days of the year when the temperature drops I can say that I get cold. Most likely during the day it is very comfortable, But during the night less so.

Me: Is there anything else you want to say about this type of buildings?

Maria: Well this is still like the old ones, and this is made of Palma real, because there are different palms used, like the coconut palm or the oil ones. Today palapas are built differently, they are higher in their structure and they sometimes have 'another little house on the top' (referring to the more elaborate structures of open roof windows and mezzanine floors). This one was built by my husband, and feel free to take a look inside, but please don't mind the mess.

Me: Thanks a lot, yes, and no worries.

As I approach to the house I took video another clip, trying to get as much detail as possible without disturbing her privacy.

I leave the house and offer her the equivalent of \$50 NZD for her time which she accepted. Unfortunately she did not have a phone for possible further contact but I told her that I would be pleased to come back and show her the results of the study and offer her a copy if she wanted, which she accepted.

We then went to see the other palapa building at the back of the church. We also spotted some other palms and stocks of palm leaves for sale, but we could not find the owners so we could not take this further.

We drove to the next village, el Ciruelito, which is different from Ciruelito la Marina. We passed the place and drove for another 5 km until we stop beside the highway. This time we were after vines that that are said are very resistant to sun and rain and last a long time. These vines were very common in the past as there were not many materials available in the hinterlands, and these were used for fencing, roping, and binding.

As we approach the plant Jose Luis explains the physiology of the plant to me.

JL: That one over there, the big thick one, is the core plant. You will never cut that one and it can be quite old, because is like the mother. You can see it goes all the way to the top of the trees, so the vines that grow from it are the ones that we use.

Me: Is that plaited one over there the same vine (*bejuco corralero*)?

JL: No you need to know how to tell the difference as there are many different vines around.

This little one that you see here is like the baby of the plant, this will grow big and will grow again if cut.

Me: Would you cut a sample?

JL: There you go (as he gave it to me).

Me: Can you take a cutting of this vine, would it succeed?

JL: It will if there is water (a creek) close by.

Me: How long does it take a 'useful' vine to grow?

JL: At six months branches from the core are already good.

Jose Luis took advantage of us being there and cut some for his job, so we helped him to learn the skill. It took us about half an hour to collect half a dozen 20 to 30 m large vines.

The process is as follows. First comes identifying those that are more accessible. Then you pull these hard until you have pulled enough length worth cutting and working (10m at least). Sometimes access is cleared with a machete as vegetation can be very dense. Then it is cut, pulled and carried aside to a clear area where all cut vines (branches) are also placed. Each vine is cleaned with pruning shears. Then each vine is split in half along its length to make two out of one, as these are easier to bind.

JL: This one has to be worked fresh. If you store it and it dries you need to soak it for one or two nights before working it again. It stretches when dry so this is something desired, but what you must do when it is freshly cut is to split it, otherwise this job becomes very difficult. When splitting if you get to a difficult knot is better to cut across, discard the knot and start splitting the new section again. Sometimes the bark is

removed, although this only for aesthetic purposes, and this is also done when freshly cut otherwise the task is pretty much impossible.

We collect the vines that we harvest, made several hoops for ease of transportation and return to Manzanillo. We drop Jose Luis at his place and set an appointment for the next day to make a review of the information and to gather some examples of his work that he has very kindly offered.

July 3rd 2011

Today I left Luis' place alone as he was busy with his own work. Jose Luis and I have decided to review all the information gathered and collected from him to double check for any mistakes made during the fieldwork or interviews. He decides to take me to another area where hardwoods are available and plenty of examples can be seen, so this time we drove towards the northern state of Jalisco to the locality of Cihuatlán about 20km away. As we take ourselves there we review the information, as set out below.

6000 palm leaves cover a 6 x 4m building, with 45 degree double pitch roof.

A 3 tonne truck can carry 10,000 palm leaves

JL: Is important to say that the more you prune the palm the more productive it becomes, as it reproduces its leaves faster. As old leaves are cut new shoots will grow faster. The plant is not wasting energy feeding dead leaves or leaves about to die. If pruning is not done its growth gets stuck.

A 1 ha plot of palm can yield up to 10,000 leaves when harvested, and it will reproduce these in three to four months. This means that a good plantation well looked after can yield three crops a year (1ha=30,000 leaves/year).

JL: A plantation like the one we visited is not well looked after and you can only get about 2000 leaves, but have to take into account that such land is also productive in other things, for instance growing maize and cucumbers and also as grazing for farm animals.

Me: In the 6x4, double pitch 45° example how much Otate bamboo will be used?

JL: 120 Otates on average

Me: How many Otates per m²?

JL: Bamboo can be very crowded, maybe you can get all that in a 5x10m plot and it will regenerate in about 6 years.

JL: So everything that is used can be said to be renewable in about 5-10 years as even the hardwoods that are coppiced in a 6 year+ rotation are good enough for building.

Me: What were you saying about durability?

JL: If the work is not done properly it will not last 10 years, and you will start patching after 5 years, but if good work is done it will easily last 10 years without maintenance.

For instance this one you can see does not have good pitch (he points out an example) this one will not last, and the reason is simple. Because it retains more water it rots faster.

It will be good to go and look at some examples of building now underway. I know a thatcher called Jorge Mendoza. He learned from his brother Samuel, and he is doing one of the finest jobs around. Samuel is one of the oldest thatchers around and he has taught plenty of thatchers, he taught me for instance.

There is an older man who is still alive, but he is ill and most likely not available. His name is Donato Ochoa. As far as my memory goes he was the main promoter of thatch buildings around although he used to work the other palm, the oil palm called cayaco that was the traditional one around here, being cheaper and more available. But then Samuel Mendoza came onto the scene and started propagating this technique.

JL: This technique of Palma Real is now very common and people like it very much. For instance one day an Arab Sultan came and he fell in love with the comfort and appearance of the building. He contracted an engineer Javier Renteria, I know where he lives. He lives in Tomatlán and has worked a lot in Careyes. He went twice to Saudi Arabia I think, to build palapas. He has been in Guatemala, in Cuba, and in many places, and everything has been transported from here, the wood and the palms. I recommend you go and talk to him.

Big palapas can be made with a great span, say more than 20 m, but you have to be an expert in the structure, it is all about how you frame it, to achieve it.

Me: But in the past to your knowledge, palapas like the one we saw in Ciruelito, how they were made and bound?

JL: With sicua de guasima

Me: What is that?

JL: Is a tree from around, it has very strong vines and was used as binding. Lechuguilla (agave spp.) was also used in the past as it is in the present because of their strong fibres, and vines like the ones I showed you.

We stop by a few examples and take pictures to build a typology of palapa buildings of the region.

We found a palapa roof beautifully woven. The owner was outside so we decided to approach her. After a brief introduction she agreed and consented to us recording her place but she decided that her identity should remain anonymous but not the address. The place was at Aguila real street colonia San Ignacio, Cihuatlán, Jalisco. She gave us some brief general information as she was busy and off to work. The information gathered was as follows:

This palapa, I decided to build it as the second floor as my house is of conventional materials as you can see. It is made out of blocks, and cement plaster and has a concrete slab roof. 'This is hell over the day as it gets too hot almost all year round' she says. This is in the first reason why I decided to build a Palapa roof on the top. After a local thatcher built it (she just named him 'Pancho' as short for Francisco) 7 years ago, the house became much more fresh and comfortable. I decided to make it a second floor building, not only to protect the house from insolation, but to have an open place where we could rest and cool when there is a nice breeze, and this is why it is fully open. But one day my girl fell down as she was playing with a kite and did not notice the edge of the building, 'fortunately nothing major happened to her' she adds. This is the reason why I have contracted another person to put a verandah around, which was made at a different stage, as sometimes you cannot afford the full job at once.

I asked for permission to take some pictures just from the outside and she agreed. After that I expressed my gratitude for her time and information and we continued our journey.

We finally reach our destination, a local place that sells hardwoods from a controlled management forest. I made contact I explained why we were there. I had known this place before, so we did not spend much time there. They agreed their information could be used as long as it did not prejudice their business, so at this stage the contacts and names will remain anonymous.

Finally we decided to return, and we stop to have lunch as my reward for all his kindness, time, effort and information. Then we returned to his place where we met with his brother Juan and they shared with me some of the pictures from their portfolio for me to use. I offered the equivalent of 100 NZD as a symbolic trade. At first they did not accept as they were pleased to give their time, but I insisted and finally convinced them to have it. I gathered contacts and phone numbers for further information about this research. We finally said good bye and I directed myself to Luis' place to review all information.

Fieldwork on Cuezcomates in Chalcatzingo

(Example of a structured interview)

Translated and abridged from the Spanish by the author

Fieldwork in Chalcatzingo Morelos on Thatched granaries

Case study: Cuezcomate (granary) at Chalcatzingo, municipality of Jantetelco, State of Morelos, Mexico

October 2012

Name: Alberto Pavón Carrales

Address: Calle Paraiso Escondido #5 Community of Chalcatzingo, Jantetelco, Morelos

Age: 37

Occupation: Craft person, and primary school teacher

And

Name: Lorenza Ramos Romero

Address: Manuel Doblado # 1 Chalcatzingo Jantetelco, Morelos, Mexico

Occupation: Housewife

Alberto: I have 20 years of experience in this technology, as I first started building scale models as a crafts person, then I started building 1-1.5 m high versions, and now I build full size structures.

Ana: Who taught you?

Alberto: At the beginning my great grandparents, later my father reinforced my knowledge. Certainly it is a family tradition when it comes to cuezcomates.

Here we are in front of a cuezcomate from around 1908-1910, 7 m tall. It is the granary for storing maize and is therefore a very important element for the community.

Materials:

Bottom part: quarry stone is used and today it is bonded with cement mortar, although in the past it was bonded with the same clay.

Middle part: This is the bowl part and is the grain container. It has an inverse conical shape. It is built with local clay soils (a material or mixture is called *Atocle*) and this clay is mixed with grass bundles., and when mixed are called *piloles* or *iguanas*

(Alpuche, G. 2008, p 107) (a sort of cob). The bowl part is shaped in ring forms working on a spiral, binding each *pilole* to the previous one and widening the rings with each new layer. At the mid-point of the bowl the work starts to narrow to achieve the inverse conical shape.

Ana: What would be the benefits and the negative aspects of this tradition?

Alberto: I can see many advantages, especially from the materials point of view. It is to store maize grain and the main advantage is that this type of building preserves the grain very well, especially in terms of humidity, temperature and protection from rodents and birds. Inside it is fully protected.

Lorenza: For instance some of the grain in this granary is five years old, and we still use it for consumption and feeding animals.

Ana: What is the cost of such a building today?

Alberto: Well it is expensive today around 80,000 pesos (13 pesos= 1 USD –by 2012). It is a specialized craft and requires well trained people.

Ana: How big is the demand?

Alberto: Today it is very small, almost all works required will be for museums or public gardens, more like an art or a tourist object.

Ana: So you think tradition is in decay?

Alberto: Yes, unfortunately it is a tradition that is disappearing, as people have lost the agricultural practice so less grain is obtained and storage is no longer needed. You can even see that previous granaries are sometimes destroyed or dismantled. These small craft enterprises are the only way to regain and restore tradition. Sadly it is now a memory or a souvenir of the pre-Columbian culture.

Ana: Can you estimate how much it would cost just for the roof cover thatch?

Alberto: Around \$30.000 pesos

Ana: Can you explain the whole process of the building from the beginning?

Alberto: First the site is selected, and this building has a special orientation to the four cardinal points. Once this has been established, the circular base is drawn and set. These four sections are called (*gajos*) and are the base for the foundations. The

materials have been commented on before, so today the foundation work is usually done in the modern way (cement mortar).

Once the foundations are established, materials are gathered for the bowl. This is *zacate de campo o colorado* and is mixed with a clay mix called *atocle*. This clay is gathered from fields and from lakes or water collection points where sedimentation happens.

Long bundles of straw daubed with clay are created, (in Alpuche (2008) this is described as chopped grass mixed with the clay), then they are bonded in line to shape a ring form, which progressively widens as it grows up to create the bowl shape (inverse cone). At the middle point, the rings are progressively narrowed as the levels of rings grow up, to create this time a cone shape.

Once the bowl or mid part has been built, the bundles of *zacate de cerro*, *zacate colorado* are bonded into the bowl, by plastering with the same clay at one extreme of the bundles. Three lines of bundles are placed with the purpose of protecting the bowl from water and air erosion.

The structure of the roof starts with a vine (*bejuco de temecate*) plaited hoop, so it can support rafters and the roof.

The wood could be of pine but the traditional rafter material would be the *quiote*, the flowering stalk of the maguey plant. This has the quality of being very light and resistant when dry. This is because of the fibres it contains.

It is first shaped into a conical shape and approximately 18 *quiotes* or rafters are used. Once the triangle structure is formed, a flexible branch called *cuilote*, will create the grid to support the bundles of grass that form the thatch. These are thinner than a bamboo and flexible and resistant.

Finally the grass bundles are thatched from the bottom to the top in layers. The first row is called *el trencillo*, and this first layer is usually thicker as it will support the other layers and has a double tie.

For the edges to be aligned a piece of wood is used called *chompancle*. The bundles are hit with this wood in order to keep them aligned.

Finally the top layer which is also called *trencillo* is installed and it has a double lash to secure it.

At the top a clay vessel called *apaxtle* is placed, which is said to have the purpose of protecting the grass, although it also has a ritual function.

Ana: What meaning does it have?

As stated in the book *El cuezcomate de Morelos, Simbolismo de una troje tradicional* by Dr. Óscar Alpuche Garcés (2008), it represents the sky dome of the universe and is considered to symbolize *Ehecatl*, the nahua deity of the wind.

Ana: And once it is finished does a celebration happen?

Alberto: I think that part can be answered by (*Lorencita*) Lorenza

Lorenza: Food is prepared for all the people involved who work there, this is in the sense of thanksgiving, and for this one here we didn't see the celebration, as it is the oldest one. It dates back over 100 years. Because this one was made by *Chucho* your Great great grandfather, Lorenza says to Alberto.

This one is the first he made, and he died 50 years ago.

So the celebration also has the purpose of blessing the crops and the seed, so it can last, this is why a food and drink offering is made.

Ana: On average how many people are employed to build a *cuezcomate*?

Lorenza: Not a lot, around six people, but the celebration includes their families too, so it becomes bigger.

Ana: Is this work done only by males?

Lorenza: Yes men only, today women work on the small souvenirs as well but the full scale ones are carried out by men. But the food is prepared only by women.

About the food *tamales* are prepared; *quequexate* is made out of toasted maize grains, and is made in the form of a fermented beverage.

Once it has been finished the cross is placed on the top and this is symbolic as well but marks the finish.

The *quequexate* is prepared with anise, cinnamon and molasses. In the past it was done with honey. This tradition is also changing and some things have been lost unfortunately,

Since there is no longer a demand for *cuezcomates* they are almost considered something from the past.

Ana: So there are no new *cuezcomates*?

Alberto: They built one on the archaeological site but for tourism; it is higher and it is used as a view point for the archaeological site.

Ana: So it does not have the same purpose (storing grain). What are the flowers that are placed for?

Lorenza: This flower is called *Pericón* and is placed for a specific festivity san Miguel on September 9th, and it is placed in order to have a proper blessing.

Alberto: Just as a point of interest *Doña Lorenza* worked directly with the author of the book Mr. Alpuche. Some of the information in the book comes from Lorenza. I was actually called for the presentation of the book. They came and picked me up to take me to *Cuernavaca*.

Ana: Back to materials, what wood types are used?

Alberto: It does not involve a lot of wood, as wood is just for the roof structure. It is more straw and earth.

Ana: How do you get the wood?

Alberto: You need to go and cut it in the field. The wood used is already dry, and it takes a whole day, so you start in the morning. For instance the *quiote* has to be cut in the hills. You cut 18 stalks and then carry these to the first station to be loaded and transported.

The *chompancle* is collected from a fallen branch of the *chompancle* tree and then the board is cut.

The *cuilote* has to be done in the bush as well. It is a medium size shrub and you have to search for the toughest branches, approximately 300 branches are used for a *cuezcomate*.

All the materials are local materials from around the community

Ana: How are these materials transported.

Alberto: With animals, mainly donkey or mules.

Ana: And how much can a donkey carry (in weight)?

Alberto: Around 120 kg

Today wood is still carried by animals but sometimes pick-up trucks are used. For example I have the opportunity to repair the *cuezcomate* of Palacio de Cortez in Cuernavaca and I had to sort the materials in another village called *Cetepexco*. We used one trip in a 3 tonne truck.

Ana: How much wood can a 3 tonne carry?

Alberto: Well not that much wood is needed.

Ana: Is there is any management program to protect these species, say from the Ministry of Forests?

Albert: No, you can see there is a lot of clandestine cutting of trees and there is no control of that.

Ana: What age are these woods?

Alberto: For instance to be tough the Agave stalk should be over 5 years old.

Lorenza: I have agaves in my plot, and those agaves have good flowering stalks, and they are cut when the stalk is well matured to ensure its strength. This 'wood' is very tough and does not get termites or bugs (polilla). It is left to dry and it becomes very

resistant and is very fibrous. It takes a while to change this into rafters. Once it is in place only its appearance changes when it is dry but it does not get bugs. It only attracts *moyotes* a kind of beetle but *moyotes* just like to be around the wood and do not drill holes.

Ana: And roughly how long does it last?

Lorenza: It is long lasting. The ones used here have not been changed from the moment we moved here. It took 35 years before we asked for a repair as it was starting to leak at the top. A plastic sheet was put in place while the repair was agreed.

Ana: About the other two woods, do you know how old they are when cut?

Lorenza: No I don't

Alberto: The *cuilote* should be about three years.

Lorenza: But the pine, which is a modern application, does not last as it is very attractive to bugs. Usually when pine and *quiote* are used the pine has already deteriorated but the *quiote* is still in good shape.

Alberto: The *chompancle* is used from an old tree of around 80 years, but it is very little used as said, and is extracted from fallen branches. It is not a material that goes into the building. It is part of our tools.

Lorenza: For instance when this one was repaired, I bought 3 poles of pine. This is usually done because is easier to obtain today as the *quiote* needs to be cut in the mountain and this is why people are shifting to pine wood. The pine used here you can see is in the frame of the roof opening, the rest was *quiote*. I had to look for a labourer to go and cut it and carry it for me. I used around 6 *quiotes* (maguey flowering stalks).

Ana: So the bottom part plaited is *quiote*?

Alberto: No that is *Temecate*, the branches are flexible branches, called *cuilotes*.

Ana: And to bind and lash what material is used?

Alberto: What we call *mixiote* is the fibre of the maguey plant

Lorenza: These I have too.

Alberto: This is extracted from the leaves. Leaves are cut and strips of fibre are extracted. Then they are left to dry in the sun. Then when they are going to be applied to the building they are soaked, and they become flexible.

Ana: Can you tell me what grasses are used?

Alberto: Yes *zacate Colorado* or *zacate the cerro* (red grass or wild grass).

Ana: Another material that can be used for these building structures is palm.

Alberto: Well because this is not a region suitable for palms they are not employed. It is more endemic materials from the community that are used. I want to comment that there is another variety of grass; both are red but this other one has a leaf. What is the name of that one Lorenza?

Lorenza: *tlacolole*

Alberto: I didn't know this name

Ana: But this grass is not employed in this one?

Lorenza: It has both, and as it was difficult to collect all at once, it was carried from diverse places, and they brought some from Tepaltzingo and Atotonilco.

Alberto: Both grasses are very suitable for protecting the structures.

Ana: This grass, did you buy it, grow it or cut it from the wild?

Alberto: Well 10 years ago it was very easy to find and cut from plots of land and there was still plenty. But today they sell it and it is very expensive, precisely because people have noticed that it is a precious material for crafts and building, especially because they know today that it is applied to buildings as museum pieces.

Lorenza: For instance for this grass I paid \$40 pesos for each bundle and I used 400 so \$16,000.

Alberto: Plus hand labour. This is why I mentioned these buildings have become expensive.

Ana: Is there any protection plan for the grass as for the wood?

Alberto: Unfortunately no, especially the *quiotte* which has vastly diminished in the region as people are no longer engaged in using it. Obviously there are remote places where it is abundant, but it is not cost effective as it becomes very expensive.

Ana: Any negative factors for this building?

Alberto: Well fire is the most common danger, although we have never heard of burning a *cuezcomate*. For this reason we have to be careful, especially at festivity times as fireworks are common so more caution is needed around this structure.

Lorenza: Well scorpions are sometimes an issue, but we are aware of them and therefore they are not a big problem. Birds are the bigger problem as they take grass for nesting and this is why the cover is more affected.

Alberto: Scorpions are an issue because they like to live in the grass, so we take precautions and use gloves when changing the grass.

Ana: Do you know how many bundles of grass can be extracted from a cultivated plot of a hectare?

Albert: My uncle plants some and he grows around half a hectare and they collect around 350 bundles.

Ana: When you say 'bundle' how much grass do you mean?

Alberto: Around 6 kg or about 5 shoots or plants of grasses altogether account for a bundle.

Ana: And the transport?

Alberto: The same vehicles are used today but some people still use animals.

Ana: How much grass can a 3 tonne pick-up carry?

Alberto: About 500 bundles.

Ana: You mentioned that for this *cuezcomate* 400 bundles were used?

Lorenza: About 25 bundles were left over, so it used 375 bundles for the roof cover.

Ana: And how long does it take to grow this grass?

Alberto: It is planted in July and cut in December, so 5 months.

Ana: How long will this roof cover last?

Alberto: The *cuezcomate* roof that I repaired in Palacio de Cortez was 40 years old without maintenance.

Lorenza: This one was 45 years old before it was fully replaced, but at the time of dismantling you could tell that all the bundles were pretty rotten (from the outside), although the inside was still okay.

Ana: Any other materials you could mention?

Lorenza: Well rocks and cement, but this one does not have cement as it was glued with *atocle* clay mix. And my husband built the floor surrounding it as it was prone to erosion in the rainy season from the running water.

Ana: Positive and negative aspects in general?

Alberto: Positives, they are available, and they have excellent thermal properties. They used to be cheap but this is changing. Negatives are that the roof is prone to fire and insect attack.

Lorenza: And the children as they play around them need to have constant supervision.

Ana: But this is about the roof and the bottom part.

Alberto: Pretty much there is nothing inconvenient

Ana: As an estimate would you know the quantity of the materials used?

Alberto: In cubic metres, or weight?

In stones it comes to around 200 kg; this one does not have any cement but say one sack for each of the four stages if it did, so 4 sacks.

About 3m³ of clay is needed

Lorenza: For grass about 375 bundles were used for this roof; the bowl has not being repaired since it was first built.

Ana: But an idea of the amount needed for the bowl?

Alberto: Roughly 450 bundles.

Ana: In the case of building a new one, how would you transport all these materials?

Alberto: Well if from far away definitely with a 3.5 tonne pick-up, but two trips are needed. The first trip will carry stone and clay soil and the second would be for collecting grasses and wood.

Ana: Any regulation of these materials?

Albert: Until today no, you just go and chop them.

Ana: Finally the last part of this interview is about the capacity of the granary.

Lorenza: This one can hold up to six and a half tons of grain.

Ana: There are smaller and bigger ones as well.

Lorenza: Some of the grain that is in here is over 5 years old. Sometimes when the price is good we can sell some, and there is still plenty for the pigs, turkeys, and young cows. We grind the grain to feed them.

Ana: And you buy this maize?

Lorenza: No, we still harvest our own maize. After collection, we take the grain out of the husk and then store it.

Ana: So there are still maize crops around here?

Lorenza: Yes, but not all people grow maize as some have shifted to growing *sorgo* (sorghum) which can also be stored here as food for animals.

Ana: What else can be stored here?

Lorenza: Well depending on your crop, some will harvest peanuts, beans, maize, and sorgo. I once stored pumpkin seed as we had a very successful crop. I stored it and it lasted very well. When people came and bought it from me, I did not enter the granary but my grandsons did, and they use to tell me how much was remaining. One day they told me there was no more. Later when I finally went inside the structure to clean it, and I found there were still a couple of pumpkin seed sacks remaining, over two years old but the seed was in perfect condition, just as it was collected, not rotten or deteriorated. It lasted long because it is very cool inside so food is well preserved there.

Ana: How are these grains or food commonly transported?

Alberto: Before they were all carried by animals and some still are. We use animals for small amounts but a big truck is preferred. The grain is collected and piled in the field and then it is carried here and threshed and stored.

Ana: Well thanks very much. Is there is anything else that you would like to add to this interview?

Alberto: Since the recovery program of this technology started with an arts and craft project interest has arisen, especially about the materials of these buildings, and even today some have asked for the technology to be used for a room unit or habitation space with slightly modified features. For sure, one of the aspects people like about these structures is the comfort that can be achieved.

Ana: Is there is any other place where this technology still exists.

Alberto: Yes, there is a town nearby called *San Marcos Acteopan*. Here there still are several granary structures in use. In the municipality of *Jantetelco* I think this is the only town that still preserves this technology. *Jonacatepec* used to have some but I haven't spotted any lately. *San Marcos* is about 10 km away from here. In *Cetepexco* I have seen some, yes, and it is also about 10 km away.

Lorenza: But those in *Tepexco* are made with branches, using a wattle and daub technique, so they are slightly different.

Ana: Well thanks again very much. I extend gratitude also on behalf of my colleague Jaime Rios and we appreciate your information very much.