RESEARCH

Grischa Brokamp

Relevance and Sustainability of Wild Plant Collection in NW South America

Insights from the Plant Families Arecaceae and Krameriaceae

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Foreword by Prof. Dr. Maximilian Weigend and Prof. Dr. Hartmut H. Hilger

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„A loucura é breve, longo é o arrependimento.“

Brazilian saying

Supervisor´s Foreword

Nature's resources are being rapidly depleted as the need for space and resources of an ever growing number of humans increases. Plants, as primary producers, are the basis of nearly all natural productivity, but also the crucial biotic component in ecosystem services, such as carbon storage, and water and oxygen cycling. Man's impact on plant life – once limited and local – is now global and affects the entire biosphere. Hence, a growing number of scientists now state that we have entered a new geological epoch, the Anthropocene.

However, biotic resources are not unlimited and the ability to regenerate is often exceeded by the speed and extent of exploitation. It is in mankind's own vital interest to manage natural resources in a way that makes them last for future generations. This perspective of a "sustainability" depends greatly on various biological features and issues that can largely be captured by biological studies on growth, regeneration, productivity and recruitment. The associated social and economical facets are often less easily quantified and less predictable.

Palms are iconic for the tropics: beaches with coconut palms are the stereotype image of tropical paradise for people from the temperate zone. Extensive palm cultivation can have extremely negative side effects. Large-scale agricultural operations, though desirable, are among the ecologically most disruptive human activities. In respect to their effects on biodiversity, there are probably few agricultural developments that are as devastating as large-scale oil palm plantations in the tropics. On the other hand, palms are suitable for large-scale cultivation operations under relatively natural conditions, and they can provide a vast range of products even in natural densities under sustainable harvest regimes.

Grischa Brokamp participated in the project "PALMS: Palm Harvest Impacts in Tropical Forests" funded by the EU Seventh Framework Programme. As a student researcher within the project's Work Package "Small Industries and Trade Based on Palm Products" he conducted his research at the Institute of Biology, Freie Universität Berlin, from 2009 to 2011 and at the Nees Institute for Biodiversity of Plants, Rheinische Friedrich-Wilhelms-Universität, from 2012 to 2013.

In the present study, Grischa Brokamp reviewed and analyzed the current extent of palm use in northwestern South America, providing interesting insights into associated mechanisms, their limitations and perspectives. He successfully implemented the work package's tasks, learned Spanish and got acquainted with research tools commonly used in economics. One of the most challenging tasks was the collection of trade data by means of interviews with stakeholders along the value chains of the different major palm products that are commercialized in the study region. For this, he developed and stepwise modified a now well-established and standardized research protocol for the acquisition of detailed data on production and marketing networks of palm products, which he published in Spanish.

The study focuses on understanding the commercial relevance of palms and the relation to the current patterns of use and sustainability. There are conflicts between use and conservation. Current exploitation, trade, and utilization are not in line with industrial practices and needs in a world of perpetual human population growth. Administrative and policy failures can quickly thwart any progress made.

Conflicting uses are influenced by specific attributes of the value chains. Understanding the biology of any particular species can provide important insights into their possible sustainable management, as also demonstrated for the case of rathany (Krameria lappacea). With this dissertation, Grischa Brokamp presents valuable aspects of the usefulness, commercialization and possible sustainable use of different plant products from neotropical palms, as well as from a valuable Andean medicinal plant, based on a thorough understanding of the biological characteristics of the plants.

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Prof. Dr. Maximilian Weigend
Prof. Dr. Hartmut H. Hilger

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Berlin, June 2013 Grischa Brokamp

Contents

List of figures

List of tables

1 Introduction

1.1 Motivation and Research goals

People depend on natural resources supplied by wild plants, for food, construction, energy, and medicine all over the world and particularly in developing countries (Pimentel and Pimentel, 2008). Apart from the direct use or consumption of wild plant resources, the commercialization of plant raw materials or the sale of products manufactured from them provide cash income, reduces poverty, and represents a safety net during emergencies and times of food shortages. Furthermore, human societies also depend on a variety of indirect ecosystem services, such as water catchment, erosion control, carbon storage, etc. (Balslev, 2011), a major portion of which is provided by wild plants (Bastian, 2013).

However, currently and in the decades to come several challenges are looming that pose a threat to entire ecosystems and by that to numerous wild plant populations, and the ecosystem services they provide, consequently affecting the welfare and sustenance of mankind:

(I) A growing global population, heading for nine billion by 2040, has to ensure sufficient availability of food, water and energy to meet future needs. This will definitely have a disproportionately negative impact on the environment (Ehrlich & Holdren, 1971). Already by 2030, the world population will consume 50% more food and 45% more energy, as was estimated by the United Nations (2012) and plants will play a major role in satisfying the increased demand of both in the future (e.g., Berndes *et al.*, 2003).

(II) All over the world and especially in the tropics, natural ecosystems are subject to intensive human impact and the conservation of plant resources they provide is directly dependent upon active management (Altieri *et al.*, 1987). Particularly tropical forests are degraded by logging and the overexploitation of wild plant resources other than wood or – even worse – are completely destroyed by slash-and-burn agriculture (Rudel and Roper, 1997). Clearly, this affects local and global biodiversity and often results in permanent changes of land use (deforestation), which in turn has an effect as a driver in climate change (Tinker et al. 1996).

(III) Climate change is expected to be a major driving force for ecosystem change in the decades to come (IPCC, 2001, 2007). Associated changes in temperature, precipitation, and seasonal variation represent an profound threat to biodiversity (Bastian, 2013) and also constitute a major challenge for nature conservation (Svenning & Sandel, 2013). Already 30 years ago, a significant effect of global warming was discernible in wild plant populations (Root *et al.*, 2003) causing shifts in species distribution and abundance (Parmesan & Yohe, 2003), which, among other factors, lead to an increased extinction risk of species (Thomas *et al.*, 2004). Therefore, an increasing loss of biodiversity can be expected through the ef-

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fects of climate change alone, especially in regions with a high proportion of fragmented or isolated habitats (Rannow *et al.*, 2010) and species that are already threatened by changes in land use are particularly threatened (SMUL, 2008).

Overall, the impacts of both climate change and (increasingly) destructive human activities are closely connected and represent the most critical factors that creating new limits for our environment's resilience and ability to supply (Pasztor & Schroeder, 2012). Sadly, food shortage (or inappropriate distribution of produced food) and the resulting malnutrition as well as scarcity of drinking water already represent a huge problem for large parts of the world population, particularly in developing countries, which in 2010 resulted in around 925 million undernourished people worldwide (FAO, 2010).

NW South America represents a global hotspot of vascular plant biodiversity (Mutke & Barthlott, 2005) and hence there is an extremely high number of useful plant species to be found in the countries Bolivia, Colombia, Ecuador, and Peru, most of which are collected from the wild (De la Torre *et al.*, 2008; Reyes-García *et al.*, 2006; Aguirre *et al.*, 2002; Duivenvoorden *et al.*, 2001). However, legal and administrative frameworks that regulate the extraction and trade of non-timber forest products (NTFPs) in these countries are highly fragmented and inefficient; amounts of plant resources extracted from the wild are neither regularly controlled nor documented (De la Torre *et al.*, 2011).

These data are required and need to be assessed in order to understand the relative and absolute socio-economic importance of individual plant species and, thus, represent a crucial foundation to determine the value of corresponding ecosystems. "Lack of this understanding and failure of markets in reflecting the value of ecosystems mean that information conveyed to economic decision-makers at all levels remains incomplete. Typically, the full social and environmental benefit of these goods and services and the impact and full cost of their degradation are not translated in a way that will ensure optimal decisions for both the economy and the environment" (Newcome *et al.*, 2005). Welfare and sustenance of mankind in the decades to come therefore eminently depend on the success of establishing policies best suited to mitigate the combined impact of the main causal and intricately linked key factors for environmental degradation of ecosystems (i.e., increase of human population, climate change, and unsustainable management practices or destructive land use).

The present work encompasses topics that range from basic botanical research through to the economic botany of plants that are subject to commercial exploitation in NW South America. The results here presented come from several studies that were conducted in order to contribute to a better understanding of the current situation of plant species that are regularly harvested from the wild and commercialized. Both biological baseline data and data on socio-economic importance, extent of trade, and economic value of plant raw materials are provided and may act as background data required for the design and implementation of programs that foster the conservation and sustainable exploitation of corresponding species.

1.2 Species

1.2.1 Arecaceae

The palm family (Arecaceae or Palmae) represents a large and diverse plant family of monocotyledonous flowering plants. According to the latest classification the family is divided into the 5 subfamilies Calamoideae, Nypoideae, Coryphoideae, Ceroxyloideae, and Arecoideae (Asmussen *et al.*, 2006), which comprise 28 tribes, 27 subtribes, and around 2,400 species in 183 genera (Dransfield *et al.*, 2008; Govaerts *et al.*, 2013). Palms are predominantly found in tropical and subtropical regions of the world and a major portion of palm species thrives in tropical rain forest habitats. Some seasonal and semi-arid habitats are also relatively palm rich, and a couple of species also even occur as a characteristic components of some desert floras (Boyer, 1992; Dransfield *et al.*, 2008).

South America has 457 palm species in 50 genera (Pintaud *et al.*, 2008), whereas numerous tribes of the subfamily Arecoideae dominate the palm flora here, with only 3 genera (*Chamaedorea*, *Geonoma* & *Bactris*) accounting for one third of all American palm species (Henderson *et al.*, 1995; Dransfield *et al.*, 2008). However, Ceroxyloideae and Calamoideae are also of importance in South America, the latter primarily because of the high abundance of individuals of just seven species (e.g., *Mauritia flexuosa*) from the tribe Lepidocaryeae (Dransfield *et al.*, 2008). Systematic affinities of palm genera and species dealt with in this thesis are presented in Table 1.1.

Although a typical palm builds a solitary stem – a shoot with a single apical meristem bearing a crown of leaves – many palms deviate from this bauplan and develop clustering stems or form shrubs, or even lianas (Dransfield *et al.*, 2008, Tomlinson, 2006). Notably, palm stems neither produce a bark nor do they consist of true wood with annual rings. This reflects their monocotyledonous character: In contrast to many other trees, palm stems contain vascular bundles scattered throughout a softer parenchymatous tissue, which are most densely packed in the outer part and decrease in number towards the center of the stem. This results in the fact that the fibrous palm timber is completely different to timber that comes from non-palm tree species and is the cause of the enormous flexibility and rigor of palm stems (Parthasarathy & Klotz, 1976; Dransfield *et al.*, 2008). Additionally, many palms are very well adapted to grow in seasonally flooded areas that are not suited for agriculture, where they often develop dense and monotypic stands (e.g., *aguajales* = dense stands of *Mauritia flexuosa*; *taguales* = dense stands of *Phytelephas aequatorialis*; e.g., Prance, 1979; Schlüter *et al.*, 1993).

Table 1.1 Systematic affinities of palm genera and species dealt with

Subfamily	Tribe	Subtribe	Genus
Calamoideae	Lepidocaryeae	Mauritiinae	*Lepidocaryum tenue*
			Mauritia flexuosa
Ceroxyloideae	Ceroxyleae		*Ceroxylon* spp.
	Phytelepheae		*Aphandra natalia*
			Phytelephas spp.
Arecoideae	Iriarteeae		*Iriartea deltoidea*
			Socratea exorrhiza
			Wettinia spp.
	Cocoseae	Attaleinae	*Attalea* spp.
		Bactridinae	*Astrocaryum* spp.
			Bactris spp.
		Elaeidinae	*Elaeis* spp.
	Euterpeae		*Euterpe* spp.
			Prestoea acuminata
			Oenocarpus bataua
	Geonomateae		*Geonoma* spp.
	Leopoldinieae		*Leopoldinia piassaba*

Due to their high diversity, abundance and interactions, many palm species play key ecological roles and provide numerous ecosystem services (Johnson and the IUCN/SSC Palm Specialist Group, 1996). They are also of great cultural and economic significance (see, e.g., Endress *et al.*, 2013; Gilmore *et al.*, 2013; *Mauritia flexuosa* in lowland Peru), ranking third after grasses (Poaceae) and legumes (Fabaceae) in overall economic importance. According to Johnson (2011), palm products typically fall into three different general categories, which are (I) primary products, (II) secondary or by-products, and (III) salvage products. Primary products represent the chief commercial (or subsistence) product, secondary and salvage products refer to useful items or material directly generated by processing and harvesting of the primary product, respectively. Another categorization is based on the type and degree as well as on location and level of sophistication in the processing of palm products. (I) The majority of palm resources represent products for immediate use, which are extracted from the wild by means of an ax or machete and are exploited at subsistence levels only (palm heart for direct consumption, fruits, and fronds for thatch). (II) Production of goods that require a modest amount of processing, few tools, and which are produced in locations that are not exclusively designated for processing is refered to as cottage-level processing (traditional extraction of palm mesocarp oil, weaving of mats, manual carving of vegetable ivory). (III) Small-scale industrial processing implies the need for specialized equipment, a dedicated locality where processing takes place, and a number of skilled workers, that produce goods manually, semi-mechanized, or mechanized (Canning of palm hearts, distillation of palm wine). (IV) Large-scale industrial processing is distinguished from the preceding in terms of the greater physical size of the processing facility, a higher level of sophistication in the processing itself through more complicated mechanical devices and certain highly skilled workers to operate and maintain equipment (African palm oil factories, processing of most products with export quality; Johnson, 2011).

Palms (Arecaceae) stand out as a plant group of extraordinary usefulness and are of particular socio-economical importance on a daily basis for numerous rural communities in northwestern South America (e.g., Lévi-Strauss, 1952; Macía, 2004; Paniagua-Zambrana *et al.*, 2007; Macia et al. 2011). However, the bulk of utilized native palm species is harvested or managed in wild populations in various ways of which some are sustainable and others are destructive (Balslev, 2011) and *Bactris gasipaes* represents the only exception that is fully domesticated (Johnson, 2011). Consequently, palm species used for subsistence purposes are principally locally depleted close to villages, while commercialised species are generally more widely depleted (Kvist & Nebel, 2001; Iquitos, Peru). Overall only few (old world) palm species represent cultivated major crops, i.e., coconut, date, and oil palm (Johnson, 2011). Therefore, palms are perfectly suited to act as object of study in research on overall importance, trade extent, and the impact through harvest of wild plant raw materials in subsistence and cash economies in the midst of a global hotspot of biodiversity. A case study on the productivity and management of *Phytelephas aequatorialis* was performed in order to investigate the link between production rates of raw materials under different regimes of management and abiotic factors such as altitude and exposure to sun light. Detailed information on *P. aequatorialis* is presented in Chapter 4.1.

1.2.2 *Krameria lappacea*

Krameria lappacea, a slow-growing shrub that shows intriguing ecological characteristics and is found in an extreme environment of seasonal aridity. It is subject to destructive harvest from the wild for commercialization (Weigend & Dostert, 2005). However, scientific baseline data is scarce and a deeper understanding of the biological function of this commercially exploited plant species is non-existent. Data on abundance and productivity of *Krameria* are absent from the scientific literature. Its ecological role and relevance for the associated ecosystem remain poorly understood. Details on the systematic background of the family Krameriaceae as well as on ecological aspects and on commercial uses of *Krameria lappacea* are presented in Chapter 5.1 and 6.1.

1.3 Ecosystem goods and services

1.3.1 What are ecosystem goods and services?

Ecosystems and their biological diversity offer a wealth of goods and services, providing mankind with essential basic supplies and represent the foundation for economic prosperity and other aspects of welfare (Newcome *et al.*, 2005).

In a broad sense, the term ecosystem services refers to the range of characteristics and processes through which natural ecosystems, and the species that they contain, help sustain and fulfil human life (Daily, 1997). These services regulate the production of ecosystem goods, which refer to the natural products used by humans on a daily basis, such as wild fruit and nuts, forage, timber, game, natural fibres, spices, medicines and so on. Ecosystem goods thus represent the various products, i.e., the direct, economical value of an ecosystem and the associated biodiversity (Newcome *et al.*, 2005).

More importantly, ecosystem services support life through the regulation of essential processes, such as the purification of air and water, the pollination of crops, nutrient cycling, decomposition of wastes, and generation and renewal of soils, as well as by moderating environmental conditions by stabilising climate, reducing the risk of extreme weather events, mitigating droughts and floods, and protecting soils from erosion (MEA, 2005).

Ecosystem services thus represent the indirect value of an ecosystem and since the release of the Millenium Ecosystem Assessment (MEA, 2005) the number of studies on the evaluation of ecosystem services has grown, each of them defining and subcategorizing ecosystem services in slightly different ways (Ojea *et al.*, 2010). According to Newcome and collaborators (2005), ecosystem services can be grouped into the following six categories, which are broadly based on both their ecological and economic function: (I) Purification and Detoxification: filtration, purification and detoxification of air, water and soils; (II) Cycling Processes: nutrient cycling, nitrogen fixation, carbon sequestration, soil formation; (III) Regulation and Stabilisation: pest and disease control, climate regulation, mitigation of storms and floods, erosion control, regulation of rainfall and water supply; (IV) Habitat Provision: refuge for animals and plants, storehouse for genetic material; (V) Regeneration and Production: production of biomass providing raw materials and food, pollination and seed dispersal; and (VI) Information/Life-fulfilling: aesthetic, recreational, cultural and spiritual role, education and research. Clearly, plants are the crucial ecosystem component in the provision of the six categories mentioned above.

1.3.2 Importance and valuation of ecosystem goods and services

Establishing the link between a given ecosystem and its goods and services and how these are valued by individuals is the key to an understanding of the importance and value of ecosystems and their incorporation in economic and other policy decision-making (Newcome *et al.*, 2005). This topic gave rise to a novel subfield of economics (environmental economics), which undertakes studies of the economic effects of national or local environmental policies and includes concepts such as market failure (unfettered markets fail to allocate resources efficiently) and valuation of the environment (assessment of the economic value of ecosystems; Harris, 2006; Hanley *et al.*, 2007). A central concept of environmental economics represents the determination of total economic value (TEV), which primarily is composed of use values that involve some interaction with the resource, either directly or indirectly as explained in Chapter 1.3.1, but also takes non-use values into account. Non-use values are associated with benefits derived simply from the knowledge that the ecosystem is maintained and are, by definition, not associated with any use of the resource or tangible benefit derived from it. When goods and services are provided in actual markets, the price individuals pay is at least a lower-bound indicator of how much they are willing to pay for the benefits they derive from consuming that good or service. For environmental resources which are not traded in actual markets, such behavioural and market price data are missing. Regardless of whether all components of TEV can be expressed in monetary terms for a given ecosystem good or service, the concept is reported to be useful in gathering the necessary information for more sustainable decision-making (Harris, 2006; Hanley *et al.*, 2007; Newcome *et al.*, 2005).

According to Newcome and collaborators (2005) four factors need to be taken into account when the importance of ecosystem goods and services are incorporated in economic decisions: (I) Understanding of the ecological functions that produce ecosystem goods and services; (II) Interface ecology and economics, which involves identification of those goods and services that are directly supplied, indirectly provided or (positively or negatively) influenced by human activities; (III) Definition and quantification of the economic benefit provided by goods and services, taking account of the components of the total economic value that applies in each case; and (IV) Distribution of benefits that derive from ecosystem goods and services among different beneficiary groups (spatially defined at the very least) and time periods, i.e., identification of different stakeholders, which is also useful in understanding the distribution of the costs involved when ecosystems are degraded.

1.4 Ecosystem goods, legal extraction, and value chains

1.4.1 NTFPs and MAPs - Plant resources from nature

Before the 1980s, timber was perceived as the primary product obtained from forests and accordingly forest policy and formal management were focused on it, largely downplaying other available goods such as, e.g., mushrooms, resins, leaves, and fruit, while completely ignoring provided ecosystem services and conservation. These „other products“ or non-timber forest products (NTFPs) were defined as “all the biological material (other than industrial round wood and derived sawn timber, wood chips, wood-based panel and pulp) that may be extracted from natural ecosystems, managed plantations, etc. and be utilised within the household, be marketed, or have social, cultural or religious significance” (Wickens,