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Palm Harvest Impacts in North-Western South America

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Abstract Tropical forests harbor thousands of useful plants that are harvested and used in subsistence economies or traded in local, regional or international markets. The effect on the ecosystem is little known, and the forests resilience is badly understood. Palms are the most useful group of plants in tropical American forests. This paper introduces a cross-disciplinary study of the effects of harvesting palm products from the tropical forests in north-western South America. The size of the resource is estimated through palm community studies in the different forest formations that determines the number of species and individuals of all palm species. The genetic structure of useful palm species is studied to determine how much harvesting of the species contributes to genetic erosion of its populations, and whether extraction can be made without harm. Almost all palm species are used in rural communities for subsistence purposes Quantitative ethno-botanical research in different forest types have identified thousands of different ways of using palms for food, construction, tool-making, etc. Although most palms are used by the person harvesting them, many are sold on local markets as fruits, fiber, tools, construction materials etc., and a few have reached larger markets, including international markets. Palm populations are managed in various ways of which some are sustainable and others are destructive. National level mechanisms that governs extraction, trade and commercialization of palm products, are used to identify positive and negative policies in relation to resilience of ecosystems.

Resumen Los bosques tropicales albergan miles de plantas útiles usadas en economías de subsistencia o comercializadas en mercados locales, regionales e internacionales. El efecto de la cosecha de estos productos sobre el ecosistema y la adaptabilidad del mismo son poco conocidos. En los bosques tropicales americanos, las palmas forman el grupo de plantas con más usos. Este artículo presenta un estudio interdisciplinario de los efectos de la cosecha de productos derivados de palmas en los bosques tropicales noroccidentales de América del Sur. Se estima el tamaño del recurso a través de estudios de la comunidades de palmas para determinar el número de especies e individuos de palmas en las diferentes formaciones forestales. Se estudia la estructura genética de palmas útiles para cuantificar el impacto la cosecha en la erosión genética de sus poblaciones y para

determinar si se puede cosechar sin detrimento de las mismas. Estudios etnobotánicos cuantitativos en diferentes tipos de bosques han identificado, literalmente, miles de usos diferentes de palmas como alimento, para construcción, elaboración de herramientas, etc. La mayoría de las palmas son usadas por la misma persona que las cosecha. Sin embargo, muchos productos de palmas (frutos, fibras, herramientas, y materiales para construcción) son comercializados en mercados locales y regionales. Algunos productos como el palmito y el marfil vegetal llegan a mercados nacionales y internacionales. El manejo de las poblaciones de palmas útiles varía desde manejo sostenible hasta sistemas que involucran la destrucción de la palma. Se utilizan los mecanismos legales que gobiernan la extracción y comercialización de productos derivados de palmas en los países estudiados, paraidentificar las políticas con impacto positivo o negativo sobre la adaptabilidad del ecosistema.

Keywords Arecaceae · NTFP · Palm management · Palm trade · Palm uses · Ecosystem services

Palabras Clave Palmas · Productos forestales no-maderables · manejo de palmas · comercialización de palmas · usos de palmas · servicos de ecosistemas

Introduction

This volume of *The Botanical Review* includes seven papers that deal with different aspects of how harvesting of palm resources impacts tropical forests in north-western South America. The papers are derived from a consortium of researchers who together, in a project with the acronym PALMS (www.fp7-palms.org), attempt to understand how extraction of palm products impacts the ecosystem. To do this we use a variety of approaches from various research fields, including population genetics, community ecology, ethno-botany, economic botany, agro-ecology, socio-economy, and political science.

All over the world and particularly in developing countries human populations depend on a daily basis on natural resources provided by native plants and animals, for food, energy, construction, medicine, and these resources also provide a safety net during emergencies and food stress. Many forest products are sold locally and regionally and increasingly also on national or international markets. Apart from the direct use of these products selling them may provide cash incomes and reduce poverty. Human societies also depend on a variety of indirect services provided by ecosystems such as water catchment, erosion control, etc.

The use of and trade in natural resources impact the composition and services provided by ecosystems. In the papers included in this volume we attempt to evaluate how palm resource extraction have impacts on: 1) The biodiversity of ecosystems, 2) The resilience and limits of natural ecosystem functioning, 3) Local people's use of ecosystem goods and services, 4) Goods and services at regional, national or international levels, 5) The sustainability of the ecosystems, and finally we evaluate 6) Political-administrative measures that regulate the extraction, use and trade with non-timber forest products.

The geographic focus of the study is north-western South America including Colombia, Ecuador, Peru and Bolivia. There, humid forest occur in the western Amazon basin, the Andean slopes and highlands, and the Pacific lowlands of Colombia and northern Ecuador. These forests are among the most diverse ecosystems in the world, both in numbers of co-existing species and in total species numbers and the mountain forests and the Pacific coast include several endangered bio-diversity hot-spots, while the western Amazon lowland constitute one of the major remaining tropical wilderness areas (Orme et al., 2005; Davies et al., 2006) but at the same time it has been populated, used and managed by Amerindian cultures for thousands of years (Roosevelt, 1999). The impacts of indigenous traditional resource management are not very obvious, but it is increasingly clear that the composition of even seemingly virgin forests has been influenced by previous human activities (Willis et al., 2004). Modern occupation is far more conspicuous and has resulted in large-scale conversion of forests to farmland and pastures, and illicit cultivation of coca aggravates the problems (Fjeldså et al., 2005). Less conspicuous is the gradual degradation by over-exploitation of forests ecosystems. These forests have the potential to provide timber, game, construction materials, edible fruits, etc., sustainably, but excessive extraction devastates their productive potential.

Ecosystem Services

There is a reciprocal relationship between ecosystems and human use. Ecosystems provide human beings with *ecosystem services*, ranging from products harvested from plants for food, construction materials, medicine, etc. and game and fish that themselves depend on the plants, to indirect economic values, and esthetic and ethical values (Ehrlich & Ehrlich, 1992). Human use has since pre-historic times impacted populations of the species they exploit and the ecosystems these species occur in, often but not always reducing or damaging ecosystem services (Burney & Flannery, 2005). When impacts are significant humans must adapt to, or remediate, the changing resource base by modifying behaviors and practices; a challenge that is more relevant than ever with burgeoning human populations and consumption.

Ecosystem services are the benefits that people obtain from nature. There has lately been much focus on the conditions of the earth ecosystems and the provisioning (food, water, fuel, etc.), cultural (spiritual, recreational, etc.), regulating (climate, water, disease, etc.) and supporting (photosynthesis, soil formation, etc.) services that ecosystems provide to human livelihood and society (Millenium Ecosystem Assessment, 2003). Over the next century the need for ecosystem services will rise dramatically, particularly in the developing world, at the same time exposing the earth ecosystems to enormous stress. Alternative scenarios for the development of the earth ecosystem services have been described (Carpenter et al., 2006), and the challenge is to avoid the most negative effects since consequences may be grim (Tilman et al., 2001). A society and its economy depend on the capacity of the environment to maintain conditions for human and societal development, and are as such embedded in economic-ecological (or socio-ecological) systems (Folke & Gunderson, 2006). Human activities are responsible

for a variation of direct and indirect drivers of ecosystem changes (Nelson et al., 2006), and the challenge is to manage the economic-ecological systems within the limits of their resilience (Walker et al., 2004). Negative feed-backs from ecosystem services may otherwise alter social and economic activities and dynamics in ways that may intensify ecosystem change. Until recently policies and projects regarding natural resources were based on the assumptions that ecosystem responses are linear, and that human and natural systems can be treated independently (Folke et al., 2002).

In the humid forests of north-western South America the principal direct drivers of ecosystem change have been deforestation and over-extraction of forest resources; particularly lumber but also non-timber forest products, and the impacts of fertilizers and pesticides, contamination and apparently climatic change are increasing (Walther et al., 2002). Forests degrade beyond recovery (regime shift) particularly after deforestation for pastures, and forest fragmentation may increase this trend by facilitating repeated wildfires. In the Brazilian Amazon an increasing fire-incidence limits forest recovery (Laurance et al., 2002).

From the early 1980' there has been a strong notion among conservationists and development practitioners that poverty reduction and environmental protection should and could go hand in hand (Kusters et al., 2006). Two decades have resulted in mixed experiences, and although critics (Shone & Caviglia-Harris, 2006) have questioned the potential of integrated natural resource management to reconcile conservation, development and poverty alleviation, others have identified factors and improvements decisive for success (Frost et al., 2006; Hagmann et al., 2002; Millenium Ecosystem Assessment, 2003).

Harvest of Palms

Palms are one of the economically most important plant groups in the world. Due to their unique architecture and high productivity palms play a key role in providing a sustainable income to smallholders in some of the poorest parts of the world. Palms include nearly 500 species in north-western South America. Palm communities are diverse in local species richness and in number of stems (Montufar & Pintaud, 2006; Vormisto et al., 2004; Balslev et al., 2011); and palms are conspicuous and dominant in most tropical American ecosystems where they often are key functional components forming complex assemblages, comprising co-existing life forms and they occupy all layers of the forest (Kahn & Granville, 1992). Turn-over in palm species composition is high at all scales, from the microhabitat to the regional level, making palms suitable for testing the impact of human use through space and time. Extensive areas are dominated by large palms that grow under extremely limiting conditions (Kvist & Nebel, 2001; Macía & Svenning, 2005), and produce huge amounts of fruits and other valuable products (Peters & Hammond, 1990). Fruits from a few abundant and widely distributed palms are the main food source for the regions large game-species, such as peccaries, tapirs, brocket deer, etc. (Bodmer et al., 1999), and fish-populations feed on them during annual inundations of extensive palm-dominated areas (Goulding, 1980). Local people use palm products in numerous ways and most species are used locally for subsistence (Balslev et al.,

2008) Some species have major importance for food, fibers, construction, thatch, and medicine. Large amounts of these products are sold at regional markets (Peters & Hammond, 1990; Brokamp et al., 2011) and increasingly marketed on national and international markets

The importance of palms in the humid forests of north-western South America is evident both in villages and towns (Paniagua Zambrana et al., 2007; Macía et al., 2011). Palms are used everywhere and by everybody: round trunks serve as posts for houses and split trunks are used as planks for floors and walls, numerous houses are thatched with leaves; people eat fruits on a daily basis either crude or boiled, or fermented as nutritious drinks, and seeds and palm hearts are eaten; palm materials and particularly fibers serve for hammocks, bags, mats, kitchen utensils, fishing gear, etc., and some have medicinal uses (Sosnowska & Balslev, 2009). Sale of materials from palms provides cash too many low-income households, e.g., most handicrafts sold for tourists include palm materials (Brokamp et al., 2011).

Palms have been intensively used by local cultures since people first arrived to the region (Morcote-Ríos & Bernal, 2001). The distribution and abundance of palm communities including useful species found in seemingly virgin forests have for very long been subject to human impact and manipulation (Clement, 1999). Currently deforestation and habitat fragmentation reduce populations and ranges of many palms, but also facilitate the expansion of disturbance-resistant palms in secondary vegetation and cleared land. Palms therefore lend themselves well to modeling diversity under changing conditions created by human impacts. Furthermore the need for palm products may increase in the future, and changes in diversity and abundance patterns of palms will affect availability of these resources for millions of people. Diversity and abundance of palms therefore has important socio-economic implications, and should be taken in account when planning land-use and conservation.

Most palm genera and species found in north-western South America are reasonably well-delimited and their ranges known. The diversity of palm-communities and the factors determining it have been studied in the western Amazon (Kahn, 1987; Vormisto et al., 2004; Bjorholm et al., 2006; Montufar & Pintaud, 2006; Normand et al., 2006), and some studies describe palm regeneration in fragmented vegetation (Baez & Balslev, 2007). The genetic variation of a few species has been studied (e.g., Montufar et al., 2007) but much remains to understand how variation is correlated with factors as semi-domestication, fragmentation and population and ecosystem resilience. Considering the paramount importance of palms virtually all publications regarding useful plants in north-western South America also include information about palms (e.g., Boom, 1988). Several works describe marketing and processing of palm products and to some extent management (e.g., Hecht et al., 1988; Peters & Hammond, 1990; Borgtoft Pedersen & Balslev, 1992; Holm Jensen & Balslev, 1995; Flores & Ashton, 2000; Balslev et al., 2010). These cases are here being compared to evaluate factors related to sustainability.

Previous studies show strong correlation between genetic structure and geographic distance in *Oenocarpus bataua* (Montúfar, 2007), indicating a not homogeneous gene pool across large distances, despite absence of marked physical barrier to gene flow. The genetic structure of *Bactris gasipaes* var. *chichagui* is

strongly linked to steep humidity gradients in Ecuador, suggesting differential adaptation to humid and dry climate (Couvreur et al., 2006) over short distance. The effect of climatic gradients on the genetic structure of species with wide altitudinal range (*Oenocarpus bataua*, *Astrocaryum malybo*, *Bactris gasipaes* var. *chichagui*) are now being studied. The genetic structure of natural populations is also affected by anthropogenic activities such as selective logging and forest fragmentation (Lowe et al., 2005). Widespread alteration of habitat could have a highly detrimental effect on conservation of genetic diversity of useful palm species. The acquisition of precise landscape genetic data on six species in conjunction with documentation of population structure and dynamics under different degrees of human application is now being used to determine the boundary between potential resilience and irreversible alteration of populations, and ecosystems as an extrapolation.

Potential Impact

The PALMS project was prepared in response to a call by the European Commission's 7th framework program, soliciting research that would study the *use of natural resources and the impact on biodiversity, ecosystem goods and services*. More specifically the call solicited analyses of the *impact of use and trade in natural resources at ecosystem and the services they provide, and how to measure biodiversity, ecosystem resilience and the limits of it, and the sustainability of resource management*. Ecosystem services provided by sustainably managed ecosystems are the basis for human well-being, and were seen as major priority at all political levels (Millenium Ecosystem Assessment, 2003). The PALMS project responded to the call by proposing research that would improve the scientific basis for a sustainable management of ecological-economic systems in the forests of north-western South America. The multidisciplinary and co-ordinated approach of PALMS is innovative, representing a new way to evaluate ecosystem diversity and resilience, and define criteria and indicators for sustainable management. The project was designed so that its results and experiences could be of general interest for endeavors to manage species-rich tropical forests elsewhere in sustainable ways.

The PALMS project was implemented in the biologically richest part of the world; the humid forests of north-western South America, where flowering plants, birds, and others biological groups reach their maximum global diversity (Brooks et al., 2002). Many of these species are restricted to small areas threatened by expanding human populations particularly in the mountain and foothill forests (Cincotta et al., 2000), making it urgent to define and implement more sustainable uses of the region's ecosystems. The overwhelming diversity with many plants and animals being little known or even unknown to science complicates management and monitoring. The palm family was selected as study object in the hope that it can serve as a proxy for the regions biological diversity, and the impact of use and trade on its biodiversity and ecosystems. Palms are well suited for this purpose because local people and scientists alike know them well, and they are diverse and abundant, and palm products have major economic importance. The research focuses on ecological-economic systems that provide important palm products. Case-examples

that represent different ecological, socio-economic and ethnical conditions are being investigated across the humid forests of north-western South America.

A Collaborative Approach

Problems related to management of natural resources and their trade and commercialization have both local, national, and regional aspects. Nevertheless, the problems and their solutions do not follow national borders that in north-western South America do not, by any means, correspond to the delimitation of ecosystems or plant species distributions. All four countries involved (Colombia, Ecuador, Peru and Bolivia) have part of their territories in the western Amazon basin and other parts in the Andean Cordillera, and three of them (Colombia, Ecuador, Peru) have lowlands towards the Pacific Ocean. The Amazon ecosystems of the countries therefore have much more in common than each of them has with the same countries' Andean and Pacific ecosystems, etc. Still trade and commercialization tend to follow political rather than ecological frontiers. A regional international approach is therefore more sensible than a national or local approach. Latin American research laboratories' collaboration with foreign laboratories in the PALMS project improves the research quality and provides opportunities for increased exchange of experiences, access to sophisticated equipment and technical skills related to its use.

Combining Ecology, Socio-Economy and Policy

The project represented in the seven papers in this issue of *The Botanical Review* combine research on palms in the fields of population biology, community ecology, ethno-botany, economic botany, socio-economy, agro-ecology, and political sciences. These are divided in four components and nine work-packages (Fig. 1, Table 1). Four of them (WP1–4) undertake basic research on ecosystems, two of them undertake applied research in management and policy (WP5–6) and the remaining work-packages (WP7–9) are dedicated to the functioning of the project.

WP1 *Diversity and Abundance of Palm Resources,* compares the diversity, abundance and dynamic of palms in forests under different exposures and intensities of human disturbance, and evaluate the responses of the palm-communities, and their value as indicators of the state of the forests. This volume presents a review of the literature on tropical American palm communities, palm species richness, and palm growth forms (Balslev et al., 2011).

WP2 *Ecosystem Resilience and Limits of Functioning,* compares the functioning, productive potential, and diversity of forest remnants in different stages of fragmentation and degradation. A review of disturbance and resilience in tropical American palm populations and communities is included here (Montúfar et al., 2011).

WP3 *Products Provided by Palms to Local People* documents the diversity and abundance of palm uses, the importance and value of palm products in local communities, interchange and incipient trade in these products, and present

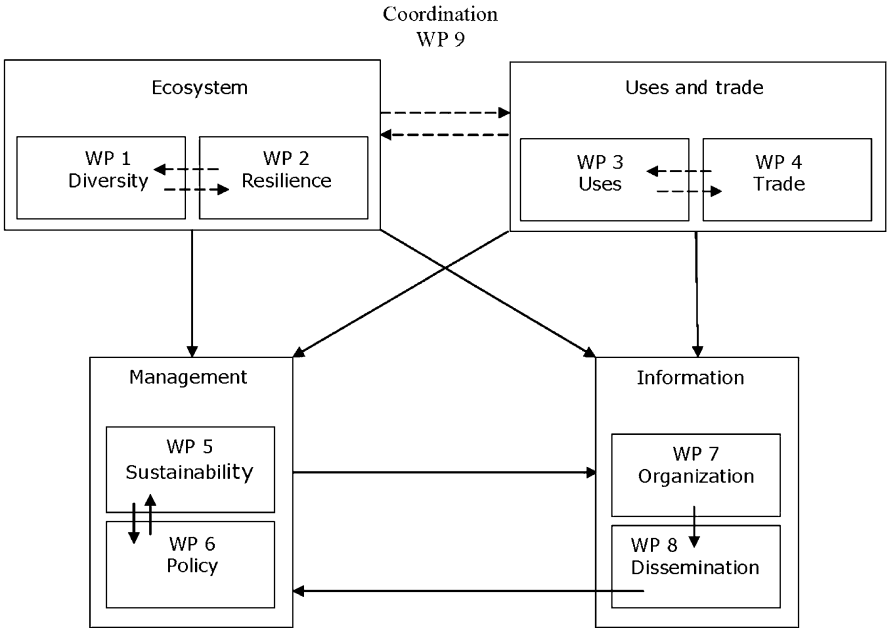

Fig. 1 Relationships of the four components and nine work-packagesof the PALMS project. The *dotted-line arrows* indicate that researchers from different packages undertake research at the same sites, in some cases supplementing each others work (an ecologist making a transect inventory may also gather data about the uses of palms and *vice versa*). The *un-broken arrows* illustrate predominant flow of analyzed data, conclusions, results and outputs

intensities of resource use. A quantitative review of the thousands of palm uses in north-western South America is presented by Macía et al. (2011).

WP4 *Small Industries and Trade Based on Palm Products* describes marketing and sale of palm products including "traditional" uses in regional towns as well as processed materials sold at national and international markets. This volume includes

Table 1 The nine work-packages (WP) of the PALMS project featured in this issue of The Botanical Review. Four work-packages (WP1–4) provide basic ecological research, two work-packages (WP5–6) provide applied research in socio-economy and policy, and three work-packages (WP7–9) relate to the functioning and coordination of the project

WP	Title
1	Diversity and abundance of palm resources
2	Ecosystem resilience and limits of functioning
3	Products provided by palms to local people
4	Small Industries and Trade Based on Palm Products
5	Sustainability and management of resources
6	Policies and sustainable use and management
7	Compilation and organization of information
8	Communication
9	Coordination

an account of local regional, national and international markets for palm products in north-western South America (Brokamp et al., 2011).

WP5 *Sustainability and Management of Resources* investigates and compares ecosystems managed for the provision of palm products to define indicators of sustainability and describe sustainable practices. Palm management in South America is revied in this volume (Bernal et al., 2011)

WP6 *Policies and sustainable use and management* analyzes policy and administrative practices related to use and trade of products from palms and other plants; and a sustainable management of the resource base. An account of the rules, regulations, and policies in Colombia, Ecuador, Peru and Bolivia that are relevant for trade and management of palms and other non-timber-forest-products is included in this volume (Torre et al., 2011).

The last three work-packages deliver support to the project and do not have independent research agendas, and therefore they have not contributed to this volume.

WP7 *Compilation and Organization of Information* gathers information about uses of palms and palm products and their management.

WP8 *Communication* informs stake-holders at all levels about the project results and other relevant information.

WP9 *Coordination* ensures effective project coordination.

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