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Review

SE Asian Palms for Agroforestry and Home Gardens

Anders S. Barfod [1,*], Manju Balhara [1], John Dransfield [2] and Henrik Balslev [1]

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1 Department of Bioscience, Aarhus University, Ny Munkegade 116, DK-8000 Aarhus C, Denmark; manjubalhara007@gmail.com (M.B.); henrik.balslev@bios.au.dk (H.B.)
2 Royal Botanic Gardens, Kew, Richmond, Surrey TW9 3AB, UK; j.dransfield@kew.org
* Correspondence: anders.barfod@bios.au.dk; Tel.: +45-8715-6572; Fax: +45-8715-4326

Abstract: Throughout SE Asia, palms are important in agroforestry systems and homegardens. Most species are used for multiple purposes based on both physical and nutritional properties of the palms. Except for a few commodities of worldwide importance such as palm oil and coconut, many palm products either do not figure in trade statistics, or they are merged with other products in a way, which makes it difficult to assess their importance. Here we focus on these products that are not prominent in national trade statistics and we review their sustainability and economic importance in SE Asia. We rank the most important palms according to their versatility, which is an extremely important property, especially for smallholders who practice subsistence agriculture. We conclude by listing a number of recommendations for future research directions based on experiences from the recently completed EU 7th Framework project (EU-PALMS 2009-2013).

Keywords: multi-purpose use; minor palm products; palm versatility

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1. Introduction

The palm family (Arecaceae; Palmae) comprises around 2440 species according to recent estimates [1,2]. The family has a pantropical distribution with the highest concentration of species in tropical rain forest, probably as a result of slow accumulation of lineages over evolutionary time [1,3]. Palms constitute one of the most important plant families throughout rural areas in the humid tropical zone [4–6]. In worldwide economic importance they are only superseded by grasses and legumes. Some palms such as the date palm (*Phoenix dactylifera* L.) and the coconut palm (*Cocos nucifera* L.) constitute iconic species because they have supported human life since the beginning of civilization [7,8]. Colonist smallholders as well as indigenous peoples across the tropics depend heavily on palms for food and construction material [4,5,9,10]. Most palm products are inadequately captured, or not captured at all in trade statistics at the local and regional economic levels [11]. Hence there is very little attention on their potential in home-gardens and agroforestry cultivation systems. Many palm species are underexploited and the products they deliver are often extracted in a way that is both inefficient and unsustainable [12]. Detailed studies conducted in north-western South America have shown that resource depletion due to lack of proper management has led to rising prices on local and regional markets [11]. Furthermore, sustainability and marketing potential of palm products are negatively affected by the low income obtained by primary producers, which often represents no more than 0.01%–3% of the retail value [11]. Poor governance, insecurity of land tenure and unequal sharing of profits endanger a sustainable long-term development of these valuable resources [13].

In SE Asia the pressure on palm resources has been tremendous. As a result of overharvesting in the wild, numerous species are now threatened or they have already become commercially extinct such as several species of rattans [6]. Palms constitute a ubiquitous element in homegardens and agroforestry systems throughout the region [14,15]. The most common ones are domesticated species such as coconut palm (*Cocos nucifera*), African oil palm (*Elaeis guineensis* Jacq.), betel nut palm (*Areca catechu* L.) and palmyra palm (*Borassus flabellifer* L.). Yet, studies of the potential of palms in agroforestry and homegardens are rare in the scientific literature. At the World Congress of Agroforestry held in New Delhi, India in 2014, palms were clearly underrepresented in the several hundred talks and posters presented. The aim of this review is to remedy the lack of attention on palms from the forestry community.

2. Study Region and Methodological Approaches

We have restricted the scope to the SE Asian region where the tradition for cultivating palms is particularly old. We have adopted a wide definition of the region, which comprises the following countries in alphabetic order: Brunei, Cambodia, Christmas Island, Indonesia, Laos, Malaysia, Papua New Guinea, Philippines, Singapore, Thailand and Vietnam. Our combined field experience covers all these countries except for the Christmas Island and Cambodia.

We have chosen to focus on nine palms that we estimate render most services to rural dwellers in the SE Asia. The choice of these species was informed by the authors' field experience in the region, which span more than 50 years. In cases where palm species or specific uses are widespread, we will refer to studies and personal observations conducted outside the SE Asian region.

At the end we will make a number of recommendations, which elaborate on the findings of a recently completed EU 7th Framework project (EU-PALMS 2009–2013) on sustainable harvesting of palms in tropical South America (results published in [5,10–12]).

3. Palm Attributes

Table 1 summarizes some of the most important features that characterize palms (family Arecaceae) as a plant group and how these affect their agricultural potential. Palm species cultivated in homegardens and agroforestry systems typically develop a stem, which is naked or covered with old leaf sheath. They grow relatively fast and often tower high above other plants in mixed cropping systems. The exceptions are the acaulescent salak palm (*Salacca zalacca* (Gaertn.) Voss), the creeping nipa palm (*Nypa fruticans* Wurmb) and the scandent species of rattans. The crown of most palms is a terminal rosette, quite dense, but of limited extension. Despite their high productivity they only occupy limited above-ground space and compete little for light.

The fibrous root system is quite dense especially near the bole. In some species it extends deep into the soil and mobilizes water ressources that few other plants can reach. This applies to e.g., African oil palm in the western part of its natural range in Africa where it often grows as a phreatophyte in dry river beds and gallery forests [16].

Palms belong to the monocotyledoneous angiosperms that are characterized by having a primary stem with scattered vascular bundles (atactostele) and lack of secondary growth. All tissues are laid down by the apical meristem and cell age is exceptionally high, in some cases more than two hundred years [17]. As a consequence palms add quickly to their length, they are slender with essentially the same stem diameter from base to the top and structurally extremely resistant to gale force winds because of the rigid vascular bundles embedded in a softer matrix of ground tissue, much like fiberglass. Water conduction through the stem is somewhat constrained by the anatomy but some palms are at the same time known to have exceptionally long vessels, up to 3 m long [18,19]. Since they are unable to produce secondary xylem they are highly sensitive to cavitation as caused by drought or subfreezing temperatures. In some palms, however, the presence of paratracheal parenchyma closely associated with the vessel suggests that vessel refilling is possible after embolism [20].

Table 1. Palm traits that play an important role in agroforestry cultivating systems.

	Positive Effects	Negative Effects
PALMS IN GENERAL		
Overall architecture	overall architecture highly predictable, which renders planning of the spatial structure in homegardens and agroforestry systems easy	in tall-stemmed species harvesting can be quite labor intensive
Rosette trees with apical growth	take up little space, relative to their productivity	plant vulnerable to insects attacking the apical meristem
Fibrous root system	very efficient in preventing soil erosion	dense and impenetrable
Stem with scattered vascular bundles	stem resistant to gale winds	timber generally of low value
Stems without secondary growth	fast-growing in height	damaged stems with limited possibilities for regeneration, highly vulnerable to cavitation
Leaves large	minimizes labor when used for thatching	vulnerable to damage by gale winds
SPECIFIC PALM GUILDS		
Species that are hapaxanthic (massive flowering at the very end of stem growth)	massive production	investment horizon too long
Scandent species (rattans)	produce a cane of high economic value	difficult to cultivate
Species naturally occurring in habitats of marginal agricultural interest	not competing with other crops	difficult to access
Species that are clustering	shoots may be harvested e.g., for palm heart in a sustainable way	the plant may become difficult to control

The apical meristem represents a highly vulnerable part of the palm and it is well protected against desiccation and insect attacks inside the palm heart formed by the bases of the newly produced leaves. Some insects such as the red palm weevil (*Rhyncophorus ferrugineus* Olivier), nevertheless, are able as larvae, to burrow inside the palm heart, destroying the meristematic tissues and eventually killing the palm. The red palm weewil has developed into a major pest on palms in Europe and SE Asia.

Palms are normally characterized by their large leaves that in extreme cases, such as in *Raphia regalis* may reach up to 25 m in length [21]. They are produced at regular intervals, but between species, they vary in longevity so that the number of photosynthetically active leaves in the crown ranges from just a few ones in the betel palm (*Areca catechu*) to more than 100 in the Canary date palm *Phoenix canariensis*. The large leaves are resistant to rot and for that reason they are popular for thatching in traditional house construction.

Some palm attributes have limited distribution within the family. One such rare condition is hapaxanthy, which means that the stem of the palm, after a period of vegetative growth, flowers and the stem (ramet) dies. In economically important species such as the talipot palms (*Corypha* spp.), the sugar palms (*Arenga* spp.) and the sago palm (*Metroxylon sago* Rottb.) energy is stored in the stem as starch, enabling the palm to produce a finite number of infructescences after which it dies. The leaves subtending the inflorescences in these hapaxanthic palms are sometimes highly reduced whereby the inflorescences form a compound terminal system above the crown of dying leaves. This applies for example to the sago palm that delivers the sago starch, which is a major staple in Eastern Indonesia and Papua New Guinea.

The collective term rattan is used for palms with long slender stems (canes) that are unable to support themselves. Thanks to groups of recurved spines on whip like extensions of the leaves and sterile inflorescences they are able to hook on to the surrounding vegetation and benefit from the supportive tissues of other trees.

Finally, scattered throughout the palm family there are clustering species that are able to produce suckers from the base of the stem. This feature is important for the sustainability of palm heart harvest on a commercial basis as is done in South America. In SE Asia the sago palm has the ability to produce ramets after the main stem has been harvested and it therefore often forms large clones where it occurs naturally. It has been shown how up to 15 different clonal varieties are recognized and maintained locally at village level and that these can be distinguished genetically [22]. The habit of the nipa palm *Nypa fruticans* is unique within SE Asian palms in having a prostrate stem. At regular intervals the stem branches dichotomously. Older parts of the stem disintegrate and as a consequence the plant eventually divides into separate ramets. It has been shown that in mangrove ecosystems with a long history these clones of physically separated ramets can cover more than one hectare [23,24].

4. Environmental Sustainability of Palm Harvesting

Exploitation of products derived from palms spans almost all agricultural practices from extractivism to plantation monoculture (Figure 1). This implies that the environmental impact of palm harvest is highly variable. Harvesting techniques may be more or less sustainable depending on the product sought for, life form of the palm and harvest intensity. It should be noted that the environmental impact and sustainability of harvesting are not always linked. This applies for example to the harvest of the solitary rattan *Calamus manan* Miq. Although this species has been harvested in a highly unsustainable manner and is on the verge of commercial extinction [25], the consequences for the natural ecosystem are probably limited as compared to for example forest clearing.

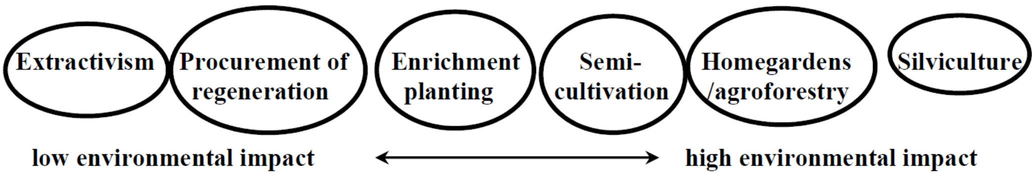

Figure 1. The transition from extractivism to silviculture.

In this context, distinction should also be made by environmental sustainability and economic sustainability. Plantation monocultures of, e.g., African oil palms that are managed in an economically sustainable way may still have a highly negative impact on the environment because of forest clearing and various pollution problems due to overzealous use of fertilizers and biocides. However, the African oil palm is still an interesting candidate for cultivation in agroforestry systems, especially in SE Asia where, unlike in tropical South America, there is little tradition for extracting oil from native palms.

There are tight links between economic importance and sustainability of harvesting (Figure 2). The ideal palm product would be one of global economic impact that can be harvested on a sustainable basis. However, it is a widespread and somehow logical assumption that a reverse relationship exists between economic importance of a plant product and sustainability of harvesting, at least if we restrict ourselves to environmental sustainability. In our two-dimensional economic importance by sustainability space, products like palm oil and rattan cane will appear at similar positions but for very different reasons as explained earlier. When rattan cane is considered at the species level it constitutes an unsustainable product because of overharvesting of the commercially most valuable species. However, when certain rattan species are no longer available, the production will soon shift to other rattan species of lesser quality that will replace the species most sought after. Many experimental plots with cultivation of rattan have been established often with limited success, but as the price of cane on the world market increases due to resource shortage, even low quality cane may have a future in homegardens and agroforestry systems.

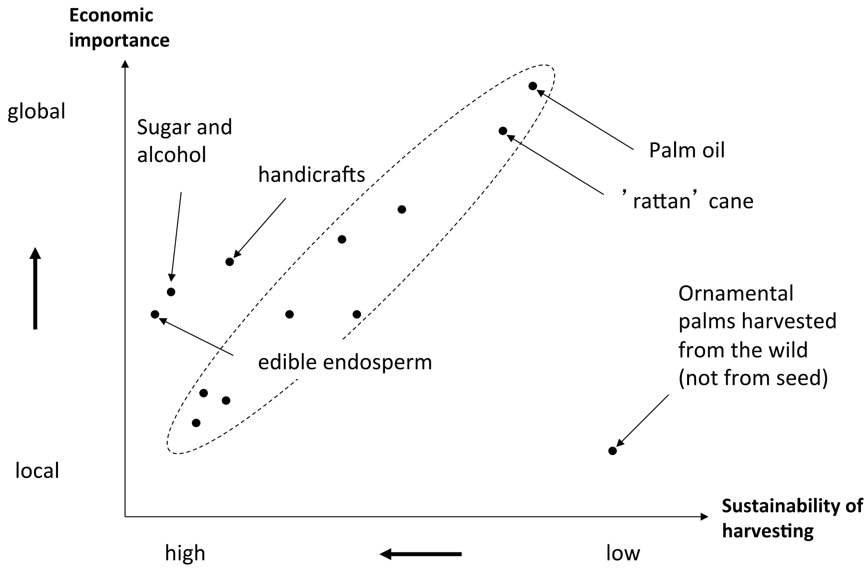

Figure 2. The theoretical relationship between economic importance and environmental sustainability of harvesting. The ellipsoid indicates the expected reverse relationship between sustainability and economic importance. The positions of selected palm products are plotted in the two-dimensional economic importance by sustainability space based on our expert opinion.

5. The Most Useful Palms for Agroforestry and Homegardens in SE Asia

Numerous palm species are exploited in SE Asia based on their structural and nutritional properties. Johnson [6] gives a comprehensive list of the scientific names, selected local names, overall distribution, products/uses as well as conservation status. In Table 2 we compare the uses of what we consider the nine most economically important species or species groups based on our combined field experience in the region and consensus among the authors. The species appears in order of estimated importance for livelihoods.

Coconut (*Cocos nucifera*) and African oil palm (*Elaeis guineensis*) appear on top of the list of the domesticated palms, not a surprise since they deliver major commodities of worldwide importance. Next to these follows a group of species collectively referred to as rattans that deliver cane for furniture making, which is a major export industry in the SE Asian countries. The ranking of the palms that follows is difficult since they are the subject of informal trade or often constitute an important element of subsistence farming. We put the betel palm (*Areca catechu*) on top because of its tremendous importance in parts of Indonesia and the Melanesian region where betel chewing is still widespread. In the same region, starch derived from the sago palm is a staple that in times of famine is vital for survival [26,27]. Next on the list of economically important palms in SE Asia is the palmyra palm, *Borassus flabellifer*. This domesticated species has a wide distribution and is used for multiple purposes. Sugar tapping is probably the most important one, despite the fact that it is labor intensive, especially in tall palms. In Peninsular Thailand the palmyra palm is often planted between rice paddies and it constitutes a characteristic element in the landscape (Figure 3c). In certain communities such as Sathing Phrae (Songkhla Prov.), the palmyra palm delivers raw material (sugar sap, leaves, wood *etc.*) to a large cottage industry (pers. obs.; [28]).

Table 2. The products delivered by the nine most important palms in SE Asian homegardens and agroforestry systems.

	Materials					Food				
	Ornamental	Wood	Leaf—handicraft and thatch	Bony endocarp	Cabbage (palm heart)	Edible endosperm	Sugar and alkohol	Starch	Edible mesocarp/ sarcotesta	Oil
* *Elaeis guineensis*	x			x	x		x			x
* *Cocos nucifera*	x	x	x	x	x	x	x			x
*** *Rattans*		x			x				x	
* *Areca catechu*	x					x				
* *Borassus flabellifer*	x	x	x		x	x	x		x	
Metroxylon sagu	x		x		x			x		
** *Arenga* spp.	x		x		x	x	x	x		
Salacca spp. (Salak)			x		x		x		x	
Nypa fruticans			x			x	x			

* species only known from cultivation. ** only the arborescent species *Arenga microcarpa*, *A. obtusifolia*, *A. pinnata*, *A. tremula*, *A. undulatifolia* and *A. westerhoutii*; *** representatives of the genera *Calamus*, *Calospatha*, *Daemonorops*, *Korthalsia*, *Myrialepis*, *Plectocomia* and *Plectocomiopsis*.

Figure 3. Examples of palm uses in the SE Asian region. (**a**) Sago swamp close to fields in Peninsular Thailand; (**b**) Sago mill constructed on site next to a group of sago palms ready for harvesting. Papua New Guinea; (**c**) A landscape dominated by rice paddies lined by palmyra palms in southern Thailand; (**d**) Experimental plot with rattan cultivated in old rubber plantation. Near Had Yai, Thailand; (**e**) Betel nut being prepared with lime and leaves of *Piper betle* L. for chewing. Market in Nepal; (**f**) Rattan canes stored after oil treatment. Furniture factory Hawai Thai, Bangkok, Thailand.

Here we treat species of *Arenga* used for sugar tapping collectively, since taxonomic research has revealed confusion over their identities in the past. Thus in Thailand *Arenga westerhoutii* Griff. has often been referred to as *Arenga pinnata* Merr. [29]. The latter species is only known from cultivation in a rather restricted area on the peninsula and must be considered domesticated in Thailand. *Arenga westerhoutii* is typically used for extraction of edible endosperm [30], whereas *Arenga pinnata* mainly delivers sugar tapped from the inflorescences. Nipa palms, palmyra palms and coconut palms are used in a similar way throughout SE Asia region and may in some area be more important from an economic point of view.

The salak palm (*Salacca zalacca*) delivers edible fruits that are consumed throughout SE Asia but especially in the Malay and Indonesian speaking parts where most of the breeding has taken place. The fleshy part of the fruit is produced by the outer fleshy seed coat (sarcotesta).

All over SE Asia natural stands of the nipa palm, *Nypa fruticans,* cover vast areas in estuaries, along rivers and behind mangrove forest. The importance of nipa palms for maintenance of coastal ecosystems and erosion control is well established [31]. The main product delivered by the nipa palmis leaves for thatching (atap). In the Phillipines and Malaysia, sugar is collected from the inflorescences to produce a local alcoholic beverage called tuba, hahal or tuak. In some areas, the endosperm is extracted for human consumption and other minor uses include dried leaflets as cigarette paper.

6. Versatility

As defined in its broadest sense, agriculture comprises all methods of production and management of livestock, crops, vegetation, and soil. One of the main reasons that palms form an integrated part of most farming systems throughout the tropics is their great versatility. A versatile crop is resilient to ever-changing boundary conditions of agriculture and delivers a number of services to the farming communities. They are particularly important in subsistence farming because they assure a minimum level of welfare.

The ideal palm in terms of versatility should be easy to handle, unarmed and not too tall. At the same time, it should be fast growing and deliver the main products as quickly as possible. A multi-stemmed (clustering) growth form may be an advantage in cases where the apical meristem is destroyed as a result of the harvest (e.g., palm heart, sago). When palms are exploited in vegetation surrounding the farmed land they should be locally common and easy to access.

One of the most desirable properties of palms is their ability to deliver a range of products. This applies to the fruits that may be used for human or animal consumption (e.g., mesocarp, sarcotesta, endosperm or cotyledon), oil extraction (e.g., mesocarp or kernel), fibers (e.g., sisal), handicrafts (endocarp, endosperm), charcoal, *etc.* Many palms have an edible palm cabbage or palm heart, which is tasty and highly nutritious. The stem of some palms deliver timber and cane. Whereas palm cane from rattans is marketed worldwide, most timbers are exploited locally for construction. The leaves are used for thatching locally but also processed into handicrafts.

Some palms grow on waterlogged soils, which is important since these are of marginal interest for agriculture. Lastly the ideal palm should be of ornamental value since this may add to the esthetic welfare of the farming communities.

To rank the potential of these nine most suitable palms in SE Asia for homegardens and agroforestry systems, we assigned a versatility score to each based on ten criteria: ornamental value, armature, accessibility, fruits used for multiple purposes, cabbage edible, growing on marginal soils, stems useful for timber, leaves useful for thatching, palm multi-stemmed, palm fast-growing. The versatility score is simply the sum of these criteria. Not surprisingly, the coconut palm appears as the most versatile palm of all (score 7). Four palms constitute a second layer of versatility: sago palm (*Metroxylon sagu*; score 6.5), palmyra palm (*Borassus flabellifer*; score 6), nipa palm (*Nypa fruticans*; score 6) and sugar palms (*Arenga* spp.; score 5). These species are exceptionally well adapted to homegardens and agroforestry systems but for different reasons. The sago palm receives a very high versatility score because it is growing on marginal soils, is accessible and locally common, multi-stemmed, fast growing and used for multiple purposes. The full potential of this palm is far from exploited and more knowledge is needed. Recent research has focused on the role of this species as well as *Nypa fruticans* and *Arenga pinnata* as potential energy crops [32–34].

Table 3. Estimated versatility based on the criteria explained in the text.

	Ornamental Value	Unarmed	Easy Accessible	Multi-Purpose Fruits	Edible Cabbage	On Marginal Soils	Stems Useful	Leaves Useful	Multi-Stemmed	Fast Growing	
* *Elaeis guineensis*	x	x		x						x	4
* *Cocos nucifera*	x	x		x	x	x	x	x			7
*** *Rattans*					x		x		(x)	x	3.5
* *Areca catechu*	x	x								x	2
** *Arenga* spp.	x	x	x		x			x			5
* *Borassus flabellifer*	x	x		x	x		x	x			6
Metroxylon sagu	x	(x)	x			x		x	x	x	6.5
Salacca spp.					x				x	x	3
Nypa		x	x			x		x	x	x	6

* species only known from cultivation. ** only the arborescent species *Arenga microcarpa* Becc., *A. obtusifolia* Mart., *A. tremula* Becc., *A undulatifolia* Becc. and *A. westerhoutii*; *** representatives of the genera *Calamus*, *Calospatha*, *Daemonorops*, *Korthalsia*, *Myrialepis*, Plectocomia and *Plectocomiopsis*.

The full potential of the palmyra palm is already realized in many areas but innovation is needed in sugar tapping techniques. During the last two decades, timber derived from the heavily sclerified peripheral layers of the stem is increasingly being used for production of handicrafts in Thailand. Although beautifully crafted, the utilitarian value is often low due to the anatomical structure. It can be distinguished from coconut "wood" that is used in a similar way by having thicker vascular bundles.

The sugar palms are highly versatile species first of all thanks to the many products that they deliver: leaves for thatch, endosperm, starch, palm cabbage, sugar sap, leaf sheath fibers for torches *etc.* They are rarely included as a component in homegardens and agroforestry systems probably because they do not fruit until the end of their life cycle, which last approx. 35 years [30]. Martini *et al.* [35] reported on an interesting case of domestication of *Arenga pinnata* in agroforestry systems from Sumatra, which reveals the potential of this species, not only for human livelihoods, but also for biodiversity conservation. More research is needed to unfold their full potential in mixed cropping systems and successive planting should be considered to make continuous harvest possible. The possibility of using carbon credits to remedy the lack of income from establishment to flowering of the palms should be explored further [36]. Amongst the most versatile palms, the nipa palm probably has the least developed potential for homegardens and agroforestry systems. It will thrive on waterlogged soils inland, which are not suitable for other types of agriculture. Due to its clonal growth form it can form dense stands that can be exploited for many purposes, the most important ones being sugar, edible endosperms and thatch. The nipa palm possesses a great competitive strength in its preferred habitats and is considered an invasive species outside its natural range e.g., in the Niger delta in Africa, where it threatens to replace the native mangrove vegetation [37].

7. Conclusion and Recommendations for Future Research

The palm family delivers several keystone species in SE Asian homegardens and agroforestry systems. On this background it is surprising that besides the cash crops coconut and African oil palm most species have an underexploited potential. Furthermore, the markets for many of the products delivered by these lesser-known palms species are quickly gaining in importance such as edible endosperms, palm wine and handicrafts made of palm timber. Based on experiences from a recently completed EU 7th Framework project (EU-PALMS 2009–2013), we suggest a number of directions for future research for SE Asian palms:

- Mapping of genetic variation of wild populations and selection of elite material for plant breeding;

- Better insight and improvement of harvesting techniques to assure that these are efficient and sustainable;
- Thorough understanding of value chains for palm products, which is crucial for the development of future markets;
- Research on integration of lesser known palm species and possibilities for exchange of agricultural practices between regions;
- Research on alternative uses of palms that already play an important role in homegardens and agroforestry systems across the SE Asian region;
- Innovation and technology transfer to make the processing of palm products more efficient;
- Better insight in distribution and marketing of palm products to promote the cash income of smallholders;
- Research on sustainability and carbon sequestration potential of palm cultivation.

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