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A Literature and Interview Based Approach to Identify Less Known Understory Species for the Enrichment of Different Shade Stages of Agroforestry Systems in Panama

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Abstract - English

The increasing world population and rising living standards demand more agricultural areas for food and energy production, because existing agricultural areas are not sufficient anymore while at the same time land is degraded at an accelerating rate. The need to diminish climate change and secure biodiversity as well as the shift to renewable resources requires a reduction of deforestation and the facilitation of reforestation and restoration. Agroforestry systems can contribute to both aspects, as trees and understory plant species and/or livestock are grown simultaneously. Therefore it is suggested to be a promising and sustainable alternative to common and widespread agricultural monocultures. However, one obstacle which keeps small-scale farmers from implementing agroforestry systems on their fields is the fact that with an increasing canopy closure trees do not permit the growth of most staple food crops (e.g. Maize, Beans, Yucca or Rice), because they need full sun. Therefore they are only suitable for the first years of an agroforestry system in the tropics. The Institute of Silviculture of Technische Universität München has been conducting a research project in the Eastern part of Panama, where valuable native timber tree species have been combined with common local staple food crops like Maize, Beans, Yucca and Rice during the establishment phase of an agroforestry system. However, so far there are no systems which systematically include economically valuable shade tolerant plant species for later stages of the agroforestry system. For this reason local small-scale farmers in the tropics are usually not motivated to grow trees in a systematic way apart from fruit trees or shelter-trees for livestock which they include to a small extent. They are lacking financial returns from agricultural crops when trees produce shade.

A closed cycle of understory plant species for different shade conditions will enable local small-scale farmers to generate income at any time of the agroforestry system and thereby may encourage them to systematically include trees on their fields.

Given their number small-scale farmers bear a great potential for fostering reforestation and reducing deforestation. Therefore this study aims at identifying shade tolerant understory plant species known in Panama that might be suitable for different designed shade stages of an agroforestry system. It was meant to be a theoretical baseline study and thus excluded practical trials. A triangulation was chosen as the methodological approach which consists of literature research, elaboration and application of a criteria checklist to numerically assess plant species for their theoretical appropriateness, as well as expert interviews. It was suggested that the needed information could be found best in different, partly unpublished sources which were most successfully accessed by this methodological approach.

In order to allow a systematic search for suitable plant species four different shade stages of agroforestry systems in Panama were determined. These stages are

1) full sun, when tree species are only small seedlings which do not produce any shade,
2) 20 - 30% of shade when trees reach a height of about 2 - 3 meters,
3) 50 - 60% of shade with trees of about 7 m and
4) a closed canopy with hardly direct sunlight reaching the understory. This will be the case when the trees reach their final height and diameter of the canopy.

The literature review resulted in a pre-selection of six possibly suitable understory plant species. In order to include different kinds of experts in the investigation, 23 Panamanian and international experts were divided into four expert groups: local practitioners (mainly farmers), employees of Panamanian governmental institutions, scientists as well as non-local practitioners. They were interviewed for their feedback regarding the preselected plant species, as well as for recommendations of further plant species for the four designated shade stages.

In total 104 different plant species were analyzed for their potential suitability, out of which 100 were recommended in expert interviews. 86 had to be neglected due to different reasons, e.g. because they were exotic to Panama, invasive or toxic. 18 plant species were analyzed in more detail, because they were considered appropriate for Panama, which were: Noni (*Morinda citrifolia*), Arazá (*Eugenia stipitata* McVaugh), Borojó (*Borojoa patinoi* Cuatrec), Ginger (*Zingiber officinale*), Cananga (*Cananga odorata*), Cat's Claw (*Uncaria guianensis*), Aloe Vera (*Aloe Vera* Auth), Cayenne Pepper (*Capsicum frutescens*), Panama Hat Palm (*Carludovica palmata*), Ipecac (*Cephaelis ipecacuanha*), Abuta (*Cissampelos pareira* L.), Coriander (*Coriandrum sativum*), Caña Agria (*Costus scaber*), Lemon Grass (*Cymbopogon citratus*), Garlicvine (*Mansoa alliacea*), Bitter Melon (*Momordica charantia* L.), Orchids (*Orchidaceae* spp.), Guaraná (*Paullinia cupana*) and Vanilla (*Vanillia planifolia*).

According to the applied criteria checklist the best performing plant species were Ginger (*Zingiber officinale*), Cananga (*Cananga odorata*), Coriander (*Coriandrum sativum*), Garlicvine (*Mansoa alliacea*) and the Panama Hat Palm (*Carludovica palmata*).

When considering the different shade stages separately, the species that are suggested most appropriate are

for stage 1)
- Ginger (*Zingiber officinale*),
- Cananga (*Cananga odorata*) and
- Lemon Grass (*Cymbopogon citratus*),

for stage 2)
- Ginger (*Zingiber officinale*),
- Cananga (*Cananga odorata*) and
- Coriander (*Coriandrum sativum*),

for stage 3)
- Cananga (*Cananga odorata*),
- the Panama Hat Palm (*Carludovica palmata*) and
- Garlicvine (*Mansoa alliacea*),

and for stage 4)
- the Panama Hat Palm (*Carludovica palmata*),
- Caña Agria (*Costus scaber*) and
- Ipecac (*Cephaelis ipecacuanha*).

Further investigation in practical trials will be needed in order to assess the species' practical suitability for agroforestry systems in Panama, to determine best tree/understory combinations and densities, and especially in order to obtain economic data so that the profitability of the scenarios can be evaluated.

The chosen method appears to be appropriate for the set goal, but it did not allow for feedback by experts regarding those plant species which were recommended in the interviews. Therefore especially local practitioners shall be consulted once again and asked for their feedback regarding these plant species in question before conducting practical trials.

Abstracto - Español

La creciente población mundial y el incremento del nivel de vida de las personas exigen más áreas agrícolas para la alimentación y la producción de energía, pues los campos existentes ya no son suficientes y la tierra se degrada a un ritmo acelerado. La necesidad de reducir el cambio climático, asegurar la biodiversidad y el cambio hacia fuentes renovables de energía, requieren reducir la deforestación y facilitar la reforestación y la restauración. Los sistemas agroforestales pueden contribuir a ambos aspectos, pues árboles, plantas y animales del sotobosque crecen a la par. Por lo tanto, se sugiere que es una alternativa prometedora y sostenible frente a los monocultivos agrícolas comunes y generalizados. Sin embargo, un obstáculo que detiene a los pequeños agricultores en la implementación de sistemas agroforestales en sus campos es el hecho de que con un aumento de los árboles de cierre del dosel se impide el crecimiento de la mayoría de cultivos de alimentos básicos (por ejemplo, maíz, frijoles, yuca o arroz), ya que necesitan sol y, por tanto, sólo son aptos para los primeros años de un sistema agroforestal en el trópico. El Instituto de Silvicultura de la Technische Universität München ha estado llevando a cabo un proyecto de investigación en la parte oriental de Panamá, donde valiosas especies nativas de árboles maderables se han combinado con cultivos locales comunes de alimentos básicos como maíz, el frijol, yuca y arroz durante la fase de establecimiento del proyecto. Sin embargo, hasta ahora no hay ningún sistema que incluya sistemáticamente especies de plantas económicamente rentables tolerantes a la sombra para las etapas posteriores del sistema agroforestal. Por esta razón los pequeños agricultores locales de zonas tropicales no suelen motivarse por plantar árboles de manera sistemática aparte de árboles frutales o árboles de refugio para el ganado, que se incluyen en menor medida, debido a que se carece de rendimientos financieros de cultivos agrícolas cuando los árboles producen sombra.

Un ciclo cerrado de especies de plantas del sotobosque para diferentes condiciones de sombra permitirá a los pequeños agricultores locales generar ingresos en cualquier momento del sistema agroforestal y de ese modo puede animarlos a incluir sistemáticamente árboles en sus campos.

Debido a su número, los pequeños agricultores tienen un gran potencial para fomentar la reforestación y la reducción de la deforestación. Por lo tanto, este estudio tuvo como objetivo identificar las especies tolerantes a la sombra de plantas de sotobosque conocidas en Panamá que podrían ser adecuadas para el diseño de las diferentes etapas de sombra de un sistema

agroforestal. Se suponía que debía ser un estudio de base teórica y por lo tanto se excluyeron los ensayos prácticos. Como enfoque metodológico se eligió una triangulación que consiste en investigación en literatura, la elaboración y aplicación de una lista de verificación de criterios para evaluar numéricamente las especies de plantas para su adecuación teórica, así como entrevistas con expertos. Se sugirió que la información necesaria podía encontrarse en diferentes fuentes, en parte no publicadas, que se acceden con mayor éxito con este enfoque metodológico.

Se determinaron cuatro etapas de sombra diferentes de un sistema agroforestal en Panamá con el fin de permitir una búsqueda sistemática de especies vegetales adecuadas. Estas etapas fueron:

1) a pleno sol, pues como las especies de árboles son sólo pequeñas plántulas que no producen sombra,
2) 20 - 30% de sombra, cuando los árboles alcanzan una altura de entre 2 y 3 metros,
3) 50 - 60% de sombra con árboles de alrededor de 7 metros y
4) a dosel cerrado, con luz solar directa que apenas alcanza el sotobosque. Este último será el caso cuando los árboles alcancen su altura y el diámetro final de dosel.

La revisión de literatura dio lugar a una pre-selección de seis especies de plantas posiblemente adecuadas para el sotobosque. 23 expertos panameños e internacionales fueron agruparon en cuatro categorías de expertos, con el fin de incluir diferentes tipos de expertos en la investigación: profesionales locales (principalmente agricultores), empleados de instituciones gubernamentales panameñas, científicos y profesionales que no locales. Ellos fueron entrevistados para recoger su retroalimentación respecto a las especies de plantas preseleccionadas, así como para solicitarles sus recomendaciones sobre especies de plantas para las cuatro etapas designadas de sombra.

Un total de 104 especies diferentes de plantas se analizaron para determinar su potencial idoneidad, de las cuales 100 fueron recomendadas por los expertos. 86 tuvieron que ser descartadas debido a diferentes razones, por ejemplo, porque eran especies que no crecen en el sotobosque de árboles vecinos; porque eran especies exóticas en Panamá; porque las condiciones climáticas locales no eran adecuadas; porque pueden ser invasoras o tóxicas, entre otros. Las siguientes 18 especies de plantas se consideran con más detalle: Noni (*Morinda citrifolia*), Arazá (*Eugenia stipitata* McVaugh), Borojó (*Borojoa patinoi* Cuatrec), Jengibre (*Zingiber officinale*), Cananga (*Cananga odorata*), Uña de gato (*Uncaria guianensis*), Aloe Vera (*Aloe Vera* Auth), Cayenne Pepper (*Capsicum frutescens*), Palmera Jipijapa (*Carludovica palmata*), Ipecac (*Cephaelis ipecacuana*), Abuta (*Cissampelos pareira* L.), Cilantro (*Coriandrum sativum*), Caña Agria (*Costus scaber*), Hierba de limón (*Cymbopogon citratus*), Garlicvine (*Mansoa alliacea*), Melón amargo (*Momordica charantia* L.), Orquídeas (*Orchidaceae* spp.), Guaraná (*Paullinia cupana*) y Vainilla (*Vanillia planifolia*).

De acuerdo con la lista de verificación de criterios seleccionados, las especies de plantas con mejor desempeño son: Jengibre (*Zingiber officinale*), Cananga (*Cananga odorata*), Cilantro (*Coriandrum sativum*), Garlicvine (*Mansoa alliacea*) y la Palmera Jipijapa (*Carludovica palmata*).

Al considerar las diferentes etapas de sombra por separado, las especies que se sugieren más apropiadas fueron:

para la etapa 1)
- Jengibre (*Zingiber officinale*),
- Cananga (*Cananga odorata*),
- Hierba de limón (*Cymbopogon citratus*),

para la etapa 2)
- Jengibre (*Zingiber officinale*),
- Cananga (*Cananga odorata*),
- Cilantro (*Coriandrum sativum*),

para la etapa 3)
- Cananga (*Cananga odorata*),
- la Palmera Jipijapa (*Carludovica palmata*),
- Garlicvine (*Mansoa alliacea*),

para la etapa 4)
- la Palmera Jipijapa (*Carludovica palmata*),
- Caña Agria (*Costus scaber*),
- Ipecac (*Cephaelis ipecacuana*).

Más investigación y ensayos prácticos serán necesarios para evaluar la idoneidad práctica de las especies para sistemas agroforestales en Panamá, para determinar las mejores combinaciones y densidades de árboles / sotobosque, y especialmente para obtener datos económicos para evaluar la rentabilidad de los escenarios.

El método elegido parecía ser apropiado para el objetivo establecido, pero no permitió la retroalimentación de los expertos respecto a las especies de plantas que recomiendan en las entrevistas. Por lo tanto, los profesionales locales sobre todo, deben ser consultados nuevamente sobre este tema antes de la realizar ensayos prácticos.

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Abbreviations

A.D.	After Death
AF	Agroforestry
ANAM	Autoridad Nacional del Ambiente (National Environment Authority)
CHMP	Committee on Herbal Medicinal Products
CIRAD	Centre de cooperation internationale en recherché agronomique pour le développement; Agricultural research for development
CITA	Centro Nacional de Ciencia y Tecnología de Alimentos; Costa Rica's National Research Center on Food Science)
FAO	Food and Agricultural Organization of the United Nations
ha	Hectare
HDI	Human Development Index
Idiap	Instituto de Investigación Agropecuaria de Panamá (Institute of Agricultural Investigation of Panama)
ITTO	International Tropical Timber Organization
IUCN	International Union for Conservation of Nature
kg	Kilogramme
m	Meter
m.a.s.l.	Meters above sea level
MDG	Millennium Development Goal
MIDA	Ministerio de Desarrollo Agropecuario de Panama (Ministry of Agricultural Development of Panama)
Mio.	Million
NTFP	Non-Timber Forest Product
REDD	The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
t/ha/yr	Tons per hectare and year
TUM	Technische Universität München
UN	United Nations
UNDP	United Nations Development Programme
USDA	United States Department of Agriculture
WHO	World Health Organisation

1. Introduction

The problem of limited land area for conserving forest resources and increasing land pressure due to population growth and rising living standards is widely acknowledged. Degradation of fertile land puts even more pressure on forests, as additional land needs to be cleared because existing agricultural land is not sufficiently productive anymore due to exhausted soils and water scarcity. Climate change puts particularly developing countries at risk, being more vulnerable to and affected by negative impacts like droughts and floods which undermine food security (World Agroforestry Centre 2012; FAO 2008a). Additionally the FAO (2012a) states that production and availability of food has to be increased by 70% until 2050.

87% of global water use is dedicated to agriculture, much of it is lost to evaporation and runoff due to a lack of ground and canopy cover. This results in desertification, especially when perennial plants and trees are lost (World Agroforestry Centre 2012).

Pure timber plantations have certain benefits, as they recover degraded areas more rapidly than secondary forests and restore services that used to be provided by natural forests. At the same time they contribute to fulfil the growing demands for timber. However, they are not very attractive to small-scale farmers due to a high investment with late returns (Weber & Paul 2012), and because the land is lost to agricultural food production.

Combining trees and agricultural systems can meet production and conservation targets sustainably. Agroforestry is a way to intensify food production – as understory agricultural plant species and/or livestock are combined with trees – while maintaining environmental functions and thus ensuring the livelihoods of those depending on the landscapes. Agricultural crops bring early cash flows besides providing food, fodder, fibre, medicine, timber and energy. Thereby agroforestry systems support smallholder farmers while they maintain resilient ecosystems and hence long-term productivity through the incorporation of trees. These systems can contribute to the mitigation of climate change by storing more above- and below-ground carbon compared to pure agriculture. Agroforestry systems also help to regulate hydrological regimes (Weber & Paul 2012; World Agroforestry Centre 2012).

1.1 Background of the thesis / Problem statement

There are different approaches and designs of agroforestry systems. One example is growing annual agricultural crops along with forestry species during the first years of the forestry plantation (Nair 1993). This system originates from South-East Asia and is known under the name “Taungya”. It has been applied throughout the tropics but is restricted to the first 2-3 years of forest plantation establishment as long as enough light is available for light-demanding agricultural crops. Once the tree species expand their canopies, light conditions become unsuitable for most annual crops frequently used in this system such as Maize and Beans (Messerer 2011).

The Institute of Silviculture of Technische Universität München (TUM) has been conducting research on Taungya in Panama, respectively the combination of different tree species with staple food crops. The main objective of this project was to find agroforestry practices that enable early returns (within the first year) out of forest plantations in order to encourage local small-scale farmers to incorporate trees into commonly used agricultural production systems. This will have additional positive effects, as trees will diversify the production, which reduces the risk, because farmers do not depend on a single crop. Furthermore the input of land and labour can be used more efficiently. If planted and designed properly, trees can have positive impacts on the planted crops, microclimates, landscapes and the global climate (see chapter 1.2).

In most agroforestry concepts the agricultural production is given and becomes enriched by tree species. The project of the TUM proceeds the other way around: a timber plantation with valuable native Panamanian tree species was given and was combined with understory crops in order to determine the best combination of trees and crops, light regimes and planting distances (Weber & Paul 2010).

The study at hand is focusing on stages following the one of the project described above: all crop species investigated in the project require full sunlight and therefore can only be integrated into the agricultural system as long as the trees are very small. But in order to obtain a closed system with agricultural returns at all stages of different light conditions, valuable understory plant species tolerant to different percentages of shade needed to be included.

A lot of literature is available on common agroforestry systems which combine trees with Coffee, Cocoa or Banana, and also on the Taungya system (e.g. Abugre et al. 2010, Adegeye et al. 2010, Lin 2007; Oke & Odebiyi 2007;

Adekunle & Bakara 2004, Rolim & Chiarello 2004; Klein et al. 2002; Fassbender 1998; Beer et al. 1994, Teketay & Tegineh 1991; Bourke 1985, Aguirre 1963, Kennedy 1930). As prices of these cash crops vary a lot (see chapter 1.2) and small-scale farmers can hardly compete with large-scale producers of those cash crops, these plant species were not focused in this thesis. The focus was therefore put on economically valuable but less known local plant species.

However, there is only so-called "grey literature"[1] available on agroforestry designs incorporating less common understory plant species. Knowledge generally exists in different (local) sources that are hardly linked with each other: institutions, universities and practitioners like farmers. There are also some criteria compilations available for the selection of plant species, e.g. provided by the FAO or the World Agroforestry Centre. But these are not comprehensive - they are superficial and often miss important criteria. The tool provided by the FAO deliberately consists of rather basic information on environmental crop requirements. The goal of this institution was to include a high number of (less known) species in this tool for which detailed information was not necessarily available (FAO Ecocrop 2007f). If only these reduced factors are taken into consideration, projects might fail. This in turn might bear the risk that scientists as well as farmers turn away from the idea of implementing agroforestry systems. Furthermore the market situation often remains unknown to farmers in rural areas. A linkage is missing between medium to small-scale producers and the market, or in other words between those who produce and those who sell and therefore know the market and possible trends in the country and on the world market.

In the wider perspective the Taungya system should be expanded by shade tolerant species to be planted in different shade stages of the system, so that economic returns can still be earned when commonly planted agricultural cash crops do not grow anymore. In this way the economic portfolio of existing practices should be enriched in order to improve the financial situation of local farmers. The concept of implementing shade tolerant plant species is meant to be applicable to agroforestry systems and forest plantations. It can be used especially by local farmers in Panama who already include trees on their farms, but only to a small extent. Up to now these are mainly fruit trees for personal consumption, but no valuable trees for timber production which would provide higher returns. Fruit trees often show bad stem forms which

[1] I.e. not officially published and available internationally but in institutions, ministries, organizations etc. (Hacker 2000).

lead to a reduced timber quality. Finally a recommendation is given on plant species that are considered worth to be investigated in practical trials in Panama as a follow-up project of the current studies.

In the narrower perspective this study aimed at two different objectives:

1. Systematically combine knowledge of different sources on plant species regarding their practical implementation in different shade stages of agroforestry systems in Panama.
2. Realistic assessment of ecological, social and economic aspects of possibly suitable plant species regarding their potential as understory crops in different shade stages of the overstory, in order to evaluate them for potential agroforestry systems. This shall be done by the application of an elaborated criteria checklist.

After these two objectives were reached the gained information was used to design a scenario regarding the combination of plant species in four different shade stages of an agroforestry system. The scenario could then be tested in practical trials for its real suitability.

1.2 State of the Art

Agroforestry systems can be found all over the world, in temperate as well as tropical regions. The systems' designs can be very different, e.g. systems that combine trees with crops or pasture, pastures with animal grazing, shelterbelts or home gardens (FAO 2011). It is not a new concept to integrate trees and livestock or crops on the same farm: According to Jose and Gordon (2008) it has been practiced for millennia, The World Bank (2004) states that throughout the world there are 1.2 billion rural farmers that apply agroforestry. Some scientists became interested in this concept in the early 20th century, but it took until the late 1970^{s} until scientific agroforestry became prominent (FAO 2011) when scientists recognized increasing destruction of tropical forests accompanied by soil degradation and loss of biodiversity as well as long-term failure and threat of agricultural and forestry monocultures, especially in tropical regions (Reid 2009; Kohli et al. 2008 and Gholz 1987). Since then a lot of research has been done on agroforestry by various authors in different parts of the world, e.g. by the FAO (2012, 2008), Nuberg et al. (2009a/b), Schroth and Harvey (2007), Schroth et al. (2004), Rao et al. (2000, 1998), Nair (1998, 1993, 1991), Gholz (1987).

Agroforestry systems can be a great contribution to tackle the crisis, but they can also have vast negative impacts if implemented in a wrong way with insufficient investigation, planning and design (Batish et al. 2008a). Scientists found out that agroforestry systems serve social, environmental and economic benefits, as they provide employment and therewith income which reduces out-migration and increases food security, health and education (Rojas-Briales & da Silva 2010; Batish et al. 2008a; Macqueen 2008b; Isaac et al. 2007; Ashley et al. 2006, Diemont et al. 2006; Garrity 2006 & 2004; Jama et al. 2006; Leakey et al. 2006; Current et al. 1995b). Economically it reduces the risks of farmers' investments, as these diversify their crop range and thereby the source of income (Lefroy 2009, Nuberg & Bennell 2009c): In case of a bad or lost harvest they can harvest timber or non-timber forest products (NTFP) to substitute their economic agricultural loss.

Additional future income streams might be the payment for the maintenance of ecosystem services such as biodiversity (Kohli et al. 2008; Marcar 2009; Nuberg et al. 2009c; Salt & Freudenberger 2009; McNeely & Schroth 2006; Vandermeer 2002; Olson et al. 2000; Michon & de Foresta 1996), carbon sequestration (Mutuo et al. 2005; Montagnini & Nair 2004), protection of soil quality (Ellis & van Dijk 2009; Harper et al. 2009; Baligar et al. 2008; Batish et al. 2008b; Kohli et al. 2008; Belnap et al. 2005; Giller 2001; Rao et al. 1998; Young 1997; Current et al. 1995b) and catchment water (Harper et al. 2009; Williams & Saunders 2002) as well as the provision of shade and shelter (Marcar 2009; Nuberg & Bennell 2009c; Nuberg et al. 2009b; Reid 2009; Liebman & Staver 2001; Binning et al. 2000), reduction of wind and thus of wind erosion and evaporation (Nuberg & Bennell 2009c). The German Federal Agency for Nature Conservation supports the idea of charging companies for ecosystem services (SusCon 2012). Trees have low maintenance costs after the first few years once they become big enough to fight weeds (Harper et al. 2009).

Agroforestry systems have always not only been about environmental benefits and economic incentives of timber extraction, but also about non-timber forest products (NTFP) like fruits, mushrooms, medicines, nuts, honey or spices. These have been primarily used for subsistence purposes, but the demand for some products increased at local and international markets, e.g. for the production of pharmaceuticals and cosmetics or the food industry. Many of these plant species require forest-like habitats in terms of shading or microclimate, e.g. Cocoa and Vanilla. Although 10-25% of the income of low-income farmers consists of selling NTFP, the export potential is still very limited. NTFP are considered minor forest resources, as volumes are generally small, quality standards low, conducting transactions is costly and maintaining competitiveness difficult (Rojas-Briales & da Silva 2010; Bellow et al.

2008; Scherr et al. 2002; Wunder 2001; Michon & de Foresta 1996). Domestication of natural or wild plant species takes decades until they reach high quality standards that make them marketable to be grown in bigger amounts. Michon and de Foresta (1996) doubt whether farmers and foresters have time to wait. They also question if smallholder farmers will be able to compete with bigger producers once NTFP have been domesticated and market prices fall which in turn might lead to the exclusion of smallholders from managing these forest resources. Nevertheless the two authors still consider NTFP to be "a promising alternative to timber extraction in natural forest management" (Michon and de Foresta 1996) due to economic (development of new markets), ecological (reducing the disturbance of forest ecosystems compared to the extraction of timber) and socio-political reasons (supporting the development of new opportunities for indigenous forest communities and fair trade of natural products). They further argue that only simple techniques, low energy input and local knowledge are needed for NTFP production.

Obviously there are also negative aspects connected to agroforestry, mainly if systems are not implemented properly. This includes a lack of sufficient information, education and technical knowledge. Growers are generally reluctant to invest in innovations unless related costs and benefits are clearly understood (Byrne et al. 2009; Nuberg & Bennell 2009; Binning et al. 2000). In addition trees in pasture or agricultural fields may impede grazing or harvesting due to roots, leaf litter and woody residues (Reid 2009). From an economic point of view agroforestry is more flexible compared to pure agriculture, as different crops of the system can be harvested throughout the year and trees can serve as additional income in case of a bad harvest. However, agroforestry can also be less flexible, as trees will occupy a certain land area for a much longer time period than agricultural crops do.

Environmentally spoken the biggest challenge of agroforestry is to minimize competition between trees and understory plants for light, nutrients and water, moisture and pollinators (Byrne et al. 2009; Reid 2009; Kohli et al. 2008; García-Barrios 2003). Further risks include invasiveness and genetic contamination (Harper et al. 2009; Kohli et al. 2008; Richardson et al. 2004; Williams & West 2000), pests and diseases (Schroth et al. 2000), and allelopathy (Batish et al. 2008b; Singh et al. 2003; Duke et al. 2002; Birkett et al. 2001; Coder 1999).

A lot of research has been done on agroforestry where trees were combined with highly priced plant/shrubby species like Coffee and Cocoa (e.g. Lin 2007; Oke & Odebiyi 2007; Somarriba 2007; Rolim & Chiarello 2004; Klein et al. 2002; Fassbender 1998; Teketay & Tegineh 1991; Beer et al. 1990; Bourke 1985). In these cases the approach is usually to select the understory cash crop and then look for suitable tree species (Elwers, personal communication 2011). Less common NTFP species that could potentially be included in the understory of agroforestry systems were so far seldom included in such analyses, thus there is a knowledge gap, as it was not investigated yet, if less known species could be an economic alternative for common cash crops in agroforestry systems as soon as light conditions are no longer suitable for commonly used cash crops. Prospects of timber prices are very stable and even increasing (e.g. ITTO 2010) compared to those of common cash crops in agroforestry like coffee and cocoa (e.g. Deutsche Börse 2012; International Cocoa Organization 2012). Therefore the economic importance of timber could increase so that farmers will consider planting more trees instead of cash crops. However, early returns cannot be expected from timber production, so that farmers will rely on some kind of cash crops in order to compensate the investments in trees.

The idea is that there might be plant species that are more suitable for the enrichment of agroforestry systems than common cash crops in case an increase of the stock density is envisioned so that potentially attractive timber production can be fostered.

Place & Dewees (1999) and Shah et al. (1996) point out several aspects that need to be fulfilled in order to encourage farmers' adoption of agroforestry systems: guaranteed benefits, property rights on land, access to credit, good quality planting material, technologies for production and processing, information, training and markets, awareness raising at all levels to value the projects. Cross-cultural communication problems, a missing link to usual agricultural activities of the farmers, as well as conflicts between the provision for human livelihoods, respect for cultural and social values and forest restoration can be further barriers of adoption and successful implementation of agroforestry systems (Vieira et al. 2009; Lamb et al. 2005; Peneireiro et al. 2005).

These aspects together with the discovered knowledge gap regarding the economic potential of less known understory plant species lead to the selection of the topic at hand.

Interviews with different – mainly local – expert groups are considered an important tool to obtain diverse information and to address the aspects described above. Especially the incorporation of local farmers, their knowledge, experience and needs is considered crucial. Being involved in investigations and the development of agroforestry systems might help in the long run to encourage the farmers' adoption of such systems. This distinct knowledge was not to be found in literature but in (local) people (see chapters 2.3 & 2.5).

2. Methodology

This chapter describes the methodological approach chosen to identify suitable plant species other than commonly grown staple food crops as an economically profitable understory for agroforestry systems in Panama.

2.1 Qualitative vs. Quantitative research approaches

First it needed to be decided, whether a qualitative or quantitative approach should be chosen for data collection. In natural sciences it is usually rather quantitative methods that have been applied for investigations. However, qualitative methods have become more and more popular in recent years in a variety of disciplines (Mayring 2002; Flick et al. 2000). The aim of qualitative research is to describe different perspectives of humans and hence contribute to a better understanding of social realities. Advocates of quantitative methods argue that qualitative research lacks representativity of selected research subjects and insufficient objectivity regarding data collection and analysis. However, researchers applying qualitative approaches state that there is no reference to the research object in quantitative research, which leads to irrelevant results (Kelle 2007).

While quantitative approaches are mainly about measurements and numerical presentations of empirical circumstances, qualitative methods focus on actions of humans and the rules by which they are determined (Raab-Steiner & Benesch 2009; Girtler 2001).

The study at hand was conducted with a qualitative approach, more precisely questionnaires, as it was the aim to get information regarding knowledge, experience and attitudes towards plant species which could not be obtained with quantitative methods. The goal to obtain detailed information connected to recommendations for possibly suitable plant species as well as the reasons for experts to recommend them were more important than a high number of recommendations without detailed information. Thus the quality of information was prioritized, and not the number of nominations. While information about physical needs and market opportunities of plant species needed to be obtained as well as recommendations of plant species suitable for agroforestry systems in Panama, it was not aimed to get numerical data, and therefore the desired information could not have been collected with a quantitative approach.

Expert interviews were considered the most suitable kind of interviews, because the topic was very specific and only those people who deal with it in a specialized way were assumed of being able to answer the questions. It was expected that experts on the topic of this study were limited, which also undermined the choice of a qualitative approach.

In social sciences expert interviews are very common, as very dense data can be obtained by asking people who have profound knowledge on the research topic. Furthermore an expert may recommend other colleagues to be interviewed, thus the number of interview partners may increase while conducting the interviews. However, expert interviews may include some risks, as for example the results and answers of these interviews could be overrated simply because the interviewees are considered experts and as a result are not analysed as critically as non-experts. Therefore this research approach generally has to be properly reflected regarding how much expertise experts indeed have and requires a preparation and theoretical foundation as profound as other techniques (Bogner & Menz 2005).

2.2 Triangulation as the method of choice

As mentioned earlier, there is hardly or insufficient literature available on suitable NTFP species as an economically profitable understory of agroforestry systems in the tropics. Existing information can only be found in different sources which are not interconnected. In order to obtain the needed information and to be able to evaluate the suitability of plant species for agroforestry systems, a systematic approach called “triangulation” (Kelle 2007, Flick 2004, Mayring 2002) was identified appropriate, as different methods are combined. This approach has already successfully been applied in many fields of research (cp. Gläser-Zikuda et al. 2012, Decrop 1999), including forest science (cp. Höllerl 2009).

Triangulation generally means that a research object is getting investigated from different perspectives using different approaches. The methods should be equally rated – as far as possible – and lead to an additional gain in knowledge compared to the application of only one perspective with one method (Flick 2004).

In this case the triangulation consists of a literature review, a compilation of a comprehensive criteria checklist, and expert interviews (Fig. 1). The literature review and development of the criteria checklist took place simultaneously, thus influencing each other, as new criteria were found while reviewing literature which in turn led to more concrete literature research to foster the criteria. The literature review in combination with the application of the criteria checklist resulted in a pre-selection of possible plant species which should be commented on by experts in interviews in a following step. These were conducted to get suggestions for possibly suitable plant species on the one hand and feedback as well as additional information on the pre-selected species on the other hand. The interviews in turn lead to further literature research on those plant species recommended by experts. The criteria checklist, however, was not modified after interviewing the participants. For this reason the arrow “criteria checklist” to “expert interview” is only one-sided, whereas all other arrows are double-sided.

The approach of triangulation finally led to the result of recommending plant species for further investigation in practical trials based on ecological, economic and social criteria.

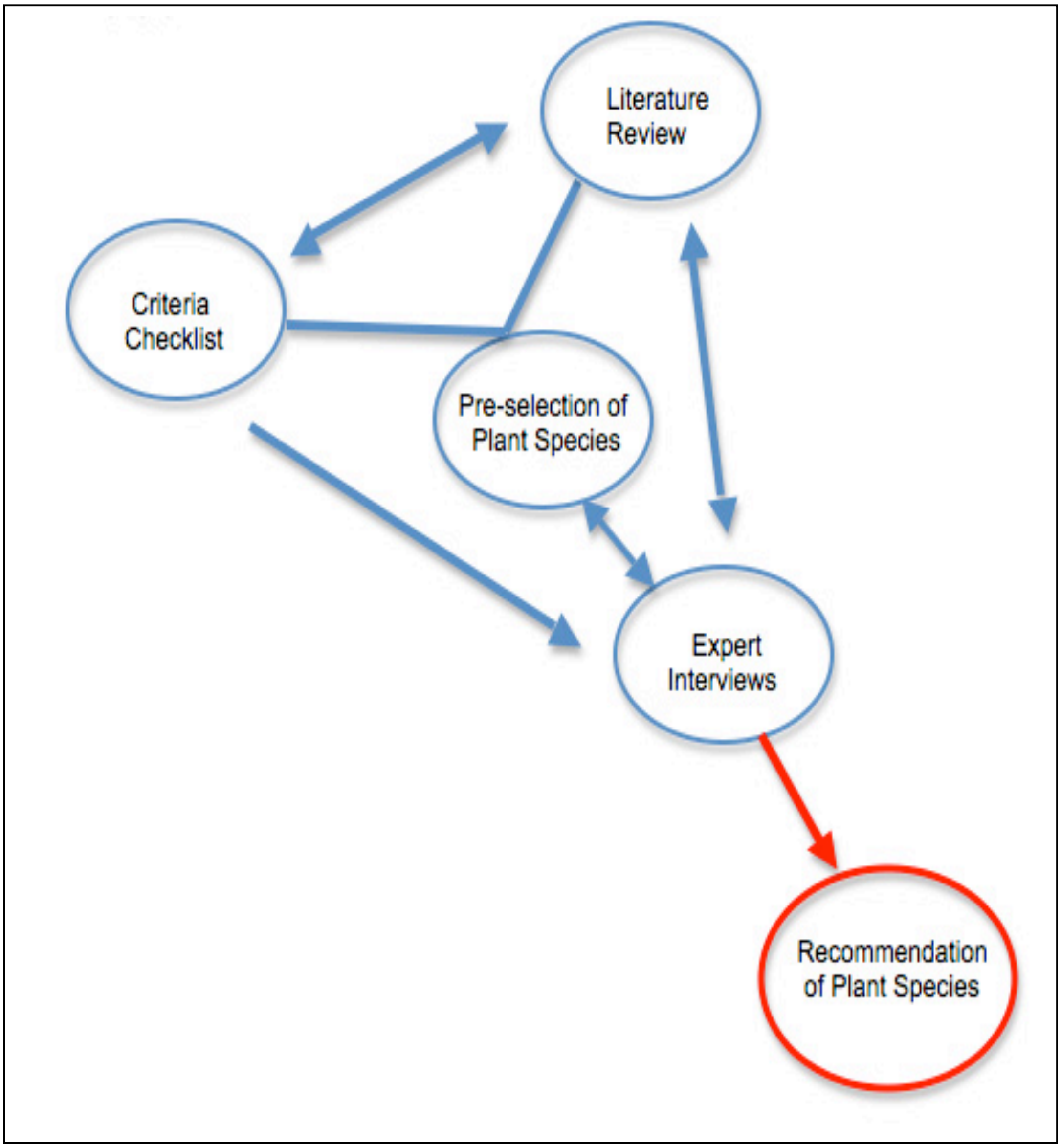


Fig. 1. Triangulation between literature review, composition of a criteria checklist and expert interviews. (Own illustration)

The different steps of the approach will be described below in more detail.

2.3 Literature review

The first step of the methodology consisted of literature review in Germany in order to get information about the state of knowledge of agroforestry science, agroforestry in Panama and possible knowledge gaps.

After this literature research continued in Panama and Costa Rica, namely at the Universidad de Panamá and the library of the Smithsonian Tropical Research Institute in Panama City as well as at the library of CATIE (Centro Agronómico Tropical de Investigación y Enseñanza) in Turrialba, Costa Rica, which is the Centre for Tropical Agricultural Research and Higher Education. These institutions provided a reasonable amount of useful local literature that was not accessible at other institutions. The aim was to get more detailed information about agroforestry practices in Central America as well as to obtain first ideas about local plant species that might be suitable as understory species for different shade stages of an agroforestry system.

A list of possibly suitable plant species was elaborated during complementary scientific literature review on regional plant species.

2.4 Criteria checklist

In order to enable a profound scientific assessment of the suitability of selected plant species, a comprehensive criteria checklist (see chapter 3.1) was elaborated. This was done throughout the whole process of literature review, as this provided information about properties and needs, potential and threats of plants and hence led to criteria that plant species should be checked for.

A comprehensive study has been conducted about the combination of timber trees and staple food crops (Weber & Paul 2010). Timber trees are generally included, because they build the enriching overstory of the agroforestry system. Pure fruit trees do not allow a sequential agroforestry system with different species providing income in the distinguished shade stages (see Table 2 in chapter 2.5.2), because they grow on a longer term and cannot be separated for one or two shade stages only. Therefore these kind of plant species were excluded from the investigation. It was focused on non-timber forest products (NTFP), plant species with aromatic or medicinal properties and especially those with more than one usage, as this means, that the plant species could be grown for different user groups, different purposes and different market levels (local, regional, international), thereby making it less dependent on a certain user group or market area.

This checklist first enlisted the Latin name, common names, the botanical plant family and general comments about the plant species in question. The following three sections included criteria on 1. site related aspects, 2. plant related aspects and 3. social and economic aspects about the plant species. Various characteristics were added to these sections in order to assess the respective plant species in detail. All obtained information of the plant species were filled into the table in order to analyse their suitability for being implemented at one of the given shade stages. In order to facilitate the assessment procedure, values were assigned to each criterion describing numerically the suitability of the species regarding this very aspect. The criteria were valued in the following way: 0 = not fulfilled, 2 = not known/partly fulfilled, 5 = fulfilled. As those criteria with no available information were not necessarily not fulfilled and could still be suitable, they were given a higher value compared to a criterion which was not fulfilled. Yet, there needed to be a distinct difference between “not known” and “criteria fulfilled”, therefore there was a bigger difference between the valuation of these two criteria than between “not fulfilled” and “not known”.

However, not all criteria could be evaluated like this, for example those regarding the economic profitability. It was not possible to state that a certain yield had to be reached in order to make a plant species suitable for an agroforestry system, as the profitability depended on a variety of factors which varied in different regions: expenses for seedlings, quality, labourers, fertilizers, pesticides, mortality of seeds, transportation, storage and processing, yields and number of harvests per year as well as market prices of possible end products. These criteria were not ranked but considered important to calculate and thereafter assess the overall and realistic profitability of a plant species in a regional context.

In addition to the valuation system each criterion was given a weighting coefficient according to its assumed significance in order to set the criteria in context to each other creating a hierarchy of importance.

Those criteria that had to be fulfilled in order to generally make a plant species suitable for an agroforestry system were so-called “veto-criteria”: if only one of these criteria was not fulfilled, the plant species was automatically neglected and taken out of the consideration, because this indicated that it could not be grown successfully. These veto-criteria were: all site-related criteria except for a plant’s vulnerability to wind (as this could be handled with wind breaks) and its adaptability potential to environments different to their native one (this was only meant to be further information in case a plant species was to be planted in an environment where one site-related criteria was different to its native habitat). A plant species was also neglected if it was exotic to the site in question. It was not aimed at introducing new species to Panama, because this could bear great risks for the existing ecosystem and humans and may be connected to economic costs and human health risks or contribute to the competition for limited resources (Government of British Colombia no date) Furthermore native plant species support native wildlife without being harmful to local plant communities (North Carolina State University no date). If it was a tree of more than 6m height it was not considered an un-

understory tree species for an agroforestry system – unless it could be pruned to less than 6m. In case pruning or coppice was possible the species were checked for their suitability. This could have additional advantages, as cut parts might be used as mulch or fodder. Furthermore toxic, allelopathic and invasive abilities lead to an exclusion of a plant species, as these properties negatively influence an agroforestry system or in case of invasiveness even a whole region, respectively do not allow an agroforestry system which includes animals.

Besides the veto-criteria the remaining aspects were weighted with coefficients 1, 3 or 5 depending on its importance for the suitability for an agroforestry system. The coefficient was multiplied with the value (0 = not fulfilled, 2 = not known, 5 = fulfilled) attributed to the criteria. A coefficient of 5 was for example given to criteria such as the difficulty to establish a plant species, the needed knowledge, its locally acceptance, whether there was already an existing market and market potential or if the processing was cost intensive. The value of each criterion was multiplied with the assigned weighting coefficient.

Criteria that were still important to be considered but less decisive were weighted with factor 3: e.g. vulnerability to wind, experience with agroforestry systems, easy removal after cultivation, extent of needed fertilizers and pesticides, difficulty to transport and store, or whether the first harvest was possible in the year of planting.

Finally those aspects which were valuable to know but with a low impact on the decision for or against implementing it were multiplied by factor one. These included whether the plant could be used for multiple purposes, whether it had a medicinal and nutritional value, whether it was difficult to be grown organically or if there were any known safety concerns connected to it, amongst others.

According to this valuation system every criteria was provided with a final value. These were summed up first within the sections of “site-related criteria”, “plant-related criteria” and “social and economic aspects” and subsequently to an overall value. In the first section a total of 60 points was possible, in the second 325 and in the third 200 points, accounting for a possible overall value of 585. These figures were meant to be taken as a numerical and rational indicator for the suitability of a plant species for an agroforestry system in a given environment. The higher the value after summing up, the more suitable the plant species was considered for an agroforestry system in the region. However, these values are no economic analysis of the species, they should rather be taken to compare the suitability of different plant species as an overall value or separated into the different sections of site-, plant- and economic/social aspects.

2.5 Expert interviews

In order to get recommendations for further possibly suitable plant species for the defined shade stages of an agroforestry system and more detailed information on awareness levels, market potential, experience and acceptance of the preselected plant species, experts were interviewed. Experts are defined by Bogner and Menz (2005) as actors who are considered important for a particular topic and field of activity due to the specific knowledge they possess. The Oxford Dictionary (Oxford University Press 2012) defines an expert as “a person who is very knowledgeable about or skilful in a particular area”. Meuser and Nagel (1991) define experts as people who are part of the sphere of activity which determines the object of research, respectively who have privileged access to information about groups of people or decision-making processes. They state that expert interviews have been applied in different research areas where they are often combined with other methods.

However, similar to Höllerl (2009) in the case of this study experts do not provide information about groups of people, but about plant species for agroforestry systems. According to Meuser and Nagel (1991) the status of an expert is relational, as it depends on the research interest. In the forestry sector practitioners can be seen as experts, as practical experience and empiricism is as valuable for the approach at hand as scientific investigations. Thus experts were defined as those persons that have been working with agroforestry systems in the tropics respectively understory crops practically or scientifically or who have been dealing with products of plants that grow in the understory of tropical forests. This investigation aimed at including a variety of professionals (farmers, scientists, government institutions, among others) in order to gain diversified information from different perspectives.

Different expert groups were determined. The main reason behind this was that international scientists should be addressed differently than local Panamanian farmers. The questions should be adapted to their practical experience, also those referring to their educational background had to be different for the distinct experts. It is assumed that local farmers think in a more applied way, as they work practically with plants every day, hence possess knowledge on very different aspects compared to scientists who think in a rather abstract way and often do not have practical experience. The results were analysed referring to the expert groups in order to find out and distinguish between the knowledge and attitude of them in order to again give recommendations how to proceed with the gained results.

Local practitioners, mainly farmers, belonged to one group of experts. Their experience with, knowledge, and acceptance of plant species was especially important for determining which plant species should be recommended in the end: As the long-term goal is to encourage local farmers to include more trees on their agricultural plots and thus apply agroforestry systems, they will be those to plant the selected plant species. If the participants of this study did not accept them or did not know anything about how to grow and maintain the plants in question, this could be already an indication about their overall acceptance and that there will be no use in implementing them unless there will be a provision of intensive training and technical assistance.

13 experts were selected and contacted for this group mainly in form of personal visits, but also via phone and email, 11 of them were local farmers. They were chosen and considered experts, because they were either indigenous people known among local farmers who lived in remote areas working with less known species, because they were well known local healers and knew a lot about local medicinal and aromatic plant species as well as their properties. Another reason for choosing a farmer was that they were known by governmental institutions as farmers who did not only grow staple food crops but also experimented with other, less common crops, because they worked for Forest Finance, or because they worked for and with non-local experts who recommended them as possessing expertise on the topic at hand.

Another expert group was composed of Panamanian governmental institutions in order to find out what kind of plant species they know, recommend and whether they already have experiences with some of them, or if even some might not be accepted from a legal point of view. For this group six people were consulted in Panama, which worked for

- MIDA (Ministerio de Desarrollo Agropecuario de Panama; Panamanian Ministry of Agricultural Development),
- IDIAP (Instituto de Investigación Agropecuaria de Panamá; Insitute of Agricultural Investigation of Panama) and
- ANAM (Autoridad Nacional del Ambiente; National Environment Authority).

Another expert group consisted of scientists: local Panamanians, regional scientists from Central America, as well as international ones working either in Central America or dealing with tropical plant species and/or agroforestry systems in the tropics. In total 20 scientists were contacted in Panama, Costa Rica, Brazil, the USA and Germany. Three of these interviews were carried out personally in Panama, while the other scientists were contacted via phone and email. They were either found to be experts, because they worked at a University or research institute in the field of agroforestry, tropical plantation forestry and agriculture, botany or pharmacy (and consequently with medicinal plant species), or because they wrote books and articles on one of these topics. Some of them were also recommended due to their expertise by other scientists that were contacted before.

One more group consisted of five non-local practitioners, meaning those that were working practically in the field conducting agroforestry practices in Panama but who were not Panamanians. As they did not rely on the plant species for making a living, they are more experimental and also work with plant species that are not very common. Furthermore they possess knowledge about local, regional and especially international markets. Especially for the latter reason cooperation took place with two companies: biosfeer-Groede[2] and Agro2[3]. Therefore they were assumed to be able to assess the international market potential of certain products respectively what kind of products (fresh or dried parts of plants, powder, capsules, oil etc.) will be more successful at international markets. Furthermore it was assumed that they would have different opinions and attitudes towards plant species and planting methods.

Finally another group was composed of experts that work at nurseries in Panama, as they have detailed knowledge on how to grow, manage and maintain plant species. Four nurseries respectively their managers and engineers were contacted. This group, however, had to be cancelled at the end of the research period in Panama, as only one expert of this group could finally be interviewed. The managers could not be reached, as they were usually not working at the nursery itself but in project areas so that the response rate was too low. Hence this group was omitted and the one expert was assigned to the group of the scientists.

[2] A Dutch company which grows those medicinal plant species growing in the given environmental conditions and imports plant products of medicinal and aromatic plant species growing in the tropics.

[3] A Panamanian agribusiness cooperating with local farmers.

Table 1 illustrates the expert groups as well as the number of contacted and interviewed experts.

Table 1: Contacted and interviewed experts by expert group.

	Local Practitioners	Employees of Panamanian Governmental Institutions	Scientists	Non-local Practitioners
Contacted Experts	15	6	21	7
Interviewed Experts	7	5	6	5

Generally all groups were supposed to consist of the same amount of experts in order to ensure their comparability for the analysis. But as for the groups of governmental institutions, nurseries and non-local practitioners only a few were available, it was not always possible to design equivalent group sizes. It is obvious that there are more people internationally working on this topic than government institutions or nurseries in Panama only. Furthermore a larger number of international scientists was contacted, as some recommended other colleagues during the interview. Additionally it could not be known beforehand whether the contacted scientists were indeed experts on this topic. This was not the case for the group of farmers, as it can be assumed that those who are recommended by environmental institutions and forestry companies are knowledgeable in the given field.

2.5.1 Questionnaire

A questionnaire (see Appendix 1) was elaborated to get additional information from the experts in question regarding economic aspects and local acceptance, as not all information which was needed to assess the suitability of each plant species was accessible in the literature. According to Raab-Steiner and Benesch (2009) a questionnaire is used as a research instrument to obtain opinions, attitudes and positions about a specific topic.

Although five different expert groups were designed, only two slightly different questionnaires were elaborated for practitioners and non-practitioners in order to guarantee their comparability. The reason for this is that the questionnaire for scientists was transferable to governmental institutions and nurseries, as all of these employees possessed a university degree.

Questions were closed as well as open-ended, in order to get comparable answers on the one hand but to allow the participants to give more detailed information on the other hand, for example when explaining reasons for the recommendation of a given plant species. The closed questions were standardised, meaning summarized in categories due to comparability reasons (Atteslander 2008), while the open-ended ones were categorized after the interview. Finally some questions were semi-standardised (Raab-Steiner & Benesch 2009), as categories of answers were provided, but the participants were also given the opportunity to add an open answer. The reason behind these semi-standardised questions was that possible categories might have been missed in the process of compiling the questionnaire or could not have been known before due to its high complexity (Raab-Steiner & Benesch 2009).

2.5.2 Structure of the questionnaire

First of all the background of the interviewer and investigation was given in order to inform the expert about the general goal and structure of the study and questionnaire. Then some general formal questions regarding the participant's experience with agroforestry systems were used as icebreaker questions in order to make the interviewees feel comfortable. They were also asked for their allowance of being cited within this thesis[4]. Afterwards the experts were given a scenario of an agroforestry system. They were asked to imagine a tropical timber plantation consisting of one tree species with a spacing of 4x4 meter without any understory vegetation. As the general goal was to find ecologically as well as economically and socially suitable plant species for being implemented at different shade stages of an agroforestry system, these different shade stages were displayed as the following assumption model:

Table 2: Assumption model for shade stages on an agroforestry system.

Shade stage	Tree height	Percentage of shade
1	< 1 m	0%
2	2-3 m	20-30%
3	7 m	50-60%
4	Final height	Closed canopy

[4] The questionnaires are numbered and can be found on the enclosed CD for detailed information.

Table 2 indicates that with increasing tree height the percentage of shade rises as well. The reason for this design is the following: Trees are responsible for giving shade to understory plants, thus their properties were to be considered for the design of the shade stages. But as different tree species are characterized by different growth rates, crown and leaf sizes among others, the age of a stand could not be taken as an indicator for different shade stages. As the percentage of light reaching the understory is the important factor, which is in turn connected to the height of the tree, these criteria were taken for defining the simplified shade stages.

The participants were asked to recommend suitable plant species for the respective shade stages. These open questions were asked at this point of the interview and before the feedback questions regarding the preselected plant species, in order not to influence the participants.

In case the experts were able to name a species for a given shade stage, they were first asked whether they grew or worked with this species themselves. Afterwards the questions became more detailed and dealt with very specific management, economic and market aspects, as well as possible products that different parts of the plant could be processed to. It was not expected that this information of any plant species could be found in scientific literature, and furthermore it should be found out how this expert managed the plant in question, respectively how much he or she knew about it. Finally the expert was asked to give feedback about the main properties that made him or her recommend this very plant species as well as possible drawbacks and obstacles that might occur when implementing it into an agroforestry system.

After this section of the questionnaire the participants should make an order and state which aspects are most important to be considered when plant species are meant to be combined with tree species: tree-plant interactions, water availability, suitable light conditions, nutrient availability or others. This was included in order to investigate whether there is a general agreement amongst the different experts about the importance of light conditions. They were also asked about their experiences with the supply of quality seeds and seedlings.

The second section of questions was dedicated to the feedback and additional information about the pre-selected plant species. The objective of these questions was to evaluate the awareness level, acceptance and experiences regarding the plants in question. This should help to examine if some of the plant species might be applicable in the Panamanian context. The experts were first asked if they knew the plant species, and in case they did, whether they had worked with them, if they recommended them for an agroforestry system and in case they did for which shade stage. These questions were followed by more detailed management questions equal to those of the first section of the questionnaire. These questions were asked, because not all information about management and especially economic aspects could be found in scientific literature, but was necessary to analyse the potential of the different pre-selected plant species.

Additionally the management, use and especially economic aspects differ regionally. The goal was to find out to what extent this differs between interviewed experts and existing literature. Two plant species (Vanilla and Lemon Grass) were pre-selected but not included in the questionnaire, as they are very widespread and well known in Panama, and because there is already a lot of literature available about them. Another reason was not to enlarge the questionnaire too much and restrict it to really important aspects, as recommended by Atteslander (2008).

The survey ended with questions regarding the professional background of the participant, his/her age, nationality, career, education, practical experience as well as the regional focus area.

2.5.3 Implementation of interviews

The interviews were conducted personally (face-to-face) as well as via email over a period of four months. 15 interviews were made personally in Panama, especially with local practitioners, employees of governmental institutions, three scientists and one manager of a nursery. The interview was conducted orally without any technical device: questions were read aloud and answers noted down manually and digitalised afterwards. All Spanish and English native speaking experts were interviewed in their mother tongue, while the interviews of those with other native languages (e.g. Dutch or German) were held in English.

Those experts who could not be consulted personally due to a residence outside of Panama, holidays or a high workload, were first contacted via phone (if a number was available) and then via email with the questionnaire enclosed.

The implementation of the interviews was semi-standardised (Raab-Steiner & Benesch 2009): depending on the knowledge of the interviewee detailed questions were asked or skipped. In case the person could not recommend any plant species for a given shade stage (first section of the questionnaire), all questions relating to this shade stage were skipped.

2.6 Analysis

All obtained information was bundled in the developed criteria checklist for a systematic observation and analysis. The values within the checklist allowed for a numeric assessment of the results and an objective comparison of the different plant species. The results were analyzed for differences between the information sources which enabled a feedback on these. Furthermore the plant species were compared with each other – for their total suitability of agroforestry systems in Panama, but also for the different sections of the criteria checklist.

The results of the analysis led to a development of different scenarios of agroforestry systems in Panama (see chapter 5.2) containing sets of plant species that can grow successively in different shade stages, as well as to recommendations regarding how to further work with the gained information.

2.7 Project area

The project area of the Instiute of Silviculture of Technische Universität München and the study at hand is located in the Republic of Panama in the southern part of Central America which shares borders with Costa Rica in the west and Colombia in the east, while it is connected to the Caribbean Sea in the north and to the Pacific in the south (Fig. 2):

Fig. 2 Political Map of Panama (Source: Focus Publications (Int.), S.A.).

Panama covers a total area of 7.44 Mio. hectare (ha) (FAO 2010a) and inhabits 3.517 million people with a population density of 47 inhabitants per km^2 and an annual growth rate of 1.7% (2005-2010) (United Nations Population Division 2011).

Almost half of the Panamanian population (44%) lives in rural areas which are classified by Larson (2006) either poor or extremely poor (Blaser et al. 2011). While being the region's second smallest country inhabitants-wise, the UNDP (2011) attributes the regions' highest Human Development Index (HDI) to the country by ranking it number 58 out of 187 countries enlisted (in 2009 it was ranked 60 out of 182). This position indicates a "High Human Development", which is category two out of four.

According to the climatic classification of Köppen and Geiger (FAO no date) most parts of the country belong to the Aw climate zone, meaning tropical wet and dry with temperatures that remain above 18°C even in the coldest month and with a pronounced dry season characterized by less than 60mm of precipitation during the driest month. Some regions, however, in the western and central part of the country, are defined by an Am or Af climate. Am is the tropical monsoon climate defined by the same temperature characteristics as Aw but with a shorter dry season so that moisture is sufficient to maintain a wet ground throughout the year. Af is the climate of the tropical rainforest. There is an average precipitation of at least 60mm in every month without natural seasons (FAO no date).

Panama shows a very high biodiversity for its size including 957 bird, 259 mammal, 179 amphibian and 229 reptile species as well as 10.400 vascular plant species. 1059 plant species are endemic (Blaser et al. 2011). According to the International Union for Conservation of Nature (IUCN) (2011) 50 amphibian, 16 bird, 11 mammal and 11 plant species living in forest areas were either listed as vulnerable, endangered or critically endangered.

According to the Food and Agricultural Organization (FAO 2010a) 44% of Panama's total land area (accounting for 3.25 Mio. ha) was covered by forests in 2010, 98% of this forest was publicly owned. The decline of forest area decreased from -1.18% (1990-2000) to about -0.7 (2000-2010), but still 24.000 ha of forest area was lost during the latter time period. The International Tropical Timber Organization (ITTO) (Blaser et al. 2011) reports that the highest forest loss took place in the Darién Province – the exact project area of the TUM – with almost 4.400 ha per year. An estimated 2 million hectare of former primary forest areas were heavily degraded – compared to

700.000 ha of primary forest and 730.000 ha secondary forest still remaining (Government of Panama 2009).

Main reasons for deforestation in Panama are cattle-ranching, urbanization, agro-industrial development, open mining, unregulated shifting cultivation, poor logging practices, fire and charcoal production (ITTO 2005). Furthermore small-scale logging for subsistence has been contributing significantly to forest degradation (Blaser et al. 2011). 2.1 Mio. ha of the total forest area (65%) are located within protected areas, and 68.000 ha (2%) are under a management plan. The primary functions dedicated to the forests are multiple uses (43%), conservation of biodiversity (41%), production (14%) and protection of soil & water (2%). The area of planted forest increased during the last decades from 13.000 ha (1990) to 79.000 ha (2010) with an increase of 3.000-4.000 ha per year. Most of these forests have been planted by communities and private landowners: according to ANAM (2008) 60.000 ha of planted forest are managed by more than 1.000 small landowners after 1991.

This indicates that communities and private landowners are generally interested in planting trees which in turn disproves the widespread assumption that local farmers are not willing to plant trees. Theoretically 1.2 million ha could be used for the development of plantations. A national forest policy was introduced in 2003, and a national forest programme in 2008. Additionally the Panamanian Government is involved in REDD[5] initiatives and negotiations (Blaser et al. 2011; FAO 2010a). The forest law aims at sustainably managing and conserving forest resources and at giving incentives for reforestation, e.g. by not taxing private land area covered by forest. However, the implementation has been rather poor (Blaser et al. 2011), and forests generally do not play a big role in politics, because according to the government's information (Government of Panama 2009) they are not important for the country's economic development. Furthermore the awareness of sustainable management practices is low among stakeholders like commercial logging operators, local communities or settlers from other regions, and forests are generally perceived as a common good (Blaser et al. 2011).

A plan implemented by the government in 2010 could put additional pressure on the forests of the Darién Province, as the so far missing connection to Colombia should be opened up with infrastructure (Blaser et al. 2011).

[5] The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (United Nations 2009).

Referring to Blaser et al. (2011) the dominant forest type was deciduous semi-humid tropical forest on the one hand and dry, moist montane and submontane forest. Shifting cultivation and low productivity cattle-ranching take place in some regions which incorporate the forest into the land-use system. There are hardly incentives or distinct programs to promote or facilitate the management of natural forests. Therefore cutting permits do not consider sustainability.

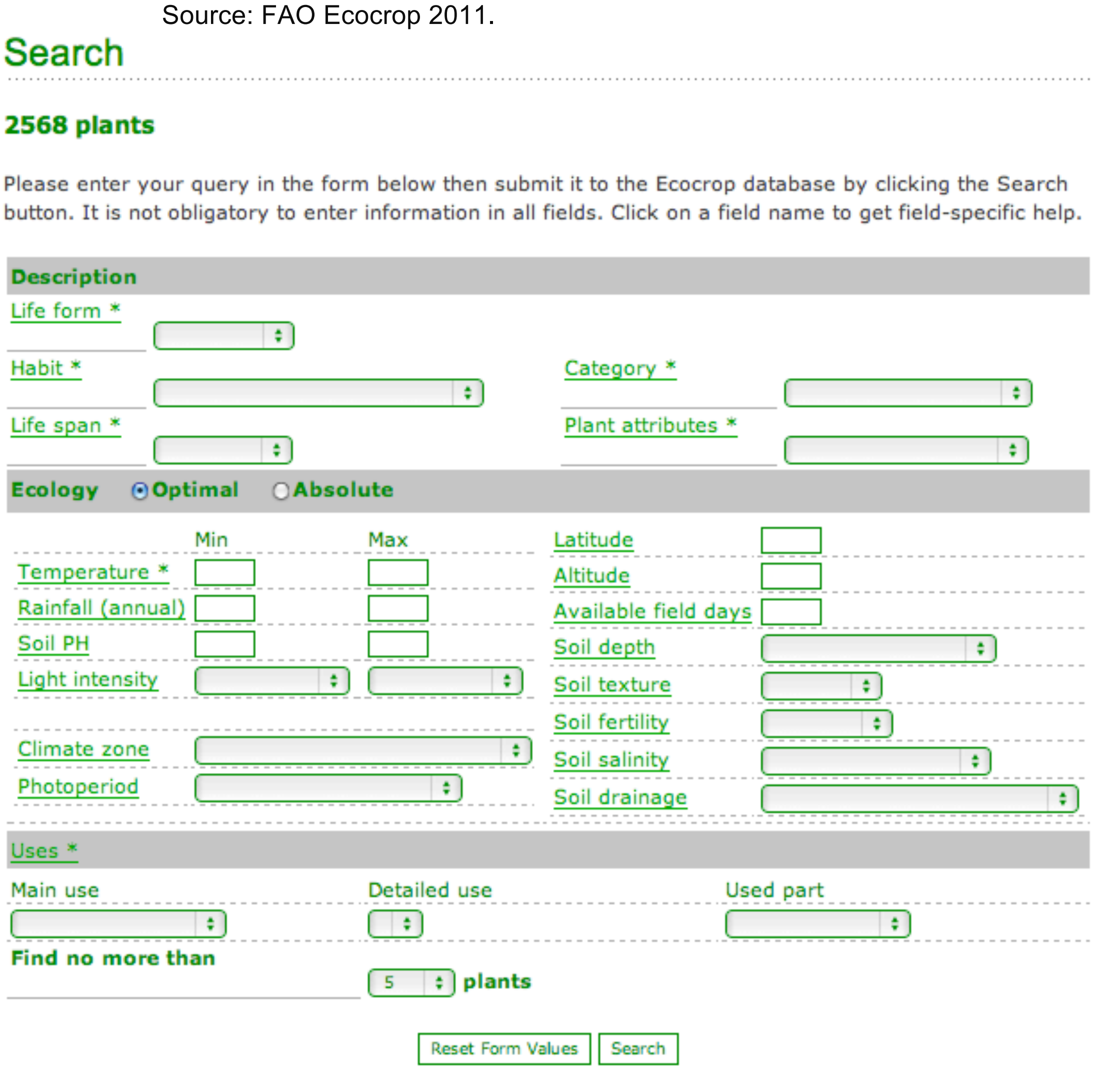
The project area of the TUM is located close to the border of the province called “Darien” in the eastern part of Panama. The village is called “Tortí” and belongs to the district of “Chepo” which is to be found about 125 km east of Panama City, or at 9°12’48” north latitude and 78°57’31” east longitude (Schuchmann 2011). Hilly landscapes up to 800 meters above sea level and a series of mountain ranges up to 1000m in altitude are characteristics of Darien Province (Blaser et al. 2011). The soils of the region show rather thin topsoil horizons with silt and clay content which also contain alluvial clay, gravel and sand (Moreno 2001). The project of the Institute of Silviculture of the TUM has been implemented in cooperation with Forest Finance, a German reforestation company that has been working in Panama for 13 years and has been collaborating with rural farmers. Typical timber tree species used by this company for reforestation activities are Zorro – *Astronium graveolens* Jacq., Cocobolo – *Dalbergia retusa* Hemsl., Zapatero – *Hieronyma alchorneoides* Allemão, Amarillo –*Terminalia amazonia* (J.F. Gmel.) Exell, Teak – *Tectona grandis,* Cedro amargo – *Cedrela odorata* L.. They have been combined with crops that are commonly grown in the region, provide returns after the first years and show potential for export (Maize - *Zea mays,* Beans – *Phaseolus vulgaris,* Yucca – *Manhiot esculenta,* Soya – *Glycine max,* Rice – *Oryza sativa,* Ginger – *Zingiber officinale,* Pigeonpea – *Cajanus cajan*) (Waltenberger 2010, Weber & Paul 2010).

3. Results

3.1 Criteria checklist

As mentioned earlier, the FAO provides a decision support tool for finding suitable plant species for specified environments. The following table (Table 3) has been provided online[6] to be filled in according to the given environment:

Table 3: Table to identify a suitable crop for a given environment. Source: FAO Ecocrop 2011.


Search

2568 plants

Please enter your query in the form below then submit it to the Ecocrop database by clicking the Search button. It is not obligatory to enter information in all fields. Click on a field name to get field-specific help.

Description

Life form *

Habit * | Category *

Life span * | Plant attributes *

Ecology Optimal Absolute

	Min	Max		
			Latitude	
Temperature *			Altitude	
Rainfall (annual)			Available field days	
Soil PH			Soil depth	
Light intensity			Soil texture	
			Soil fertility	
Climate zone			Soil salinity	
Photoperiod			Soil drainage	

Uses *

Main use | Detailed use | Used part

Find no more than 5 plants

Reset Form Values | Search

This table was taken as the basis for the development of the criteria checklist at hand. It contains most of the information needed to characterize site conditions a given plant species requires.

[6] Source: http://ecocrop.fao.org/ecocrop/srv/en/crop SearchForm.

For the identification of the climate zone the classification by Köppen & Geiger was taken by the FAO, and this was also adopted for this criteria checklist.

The course of action of the checklist of this study was opposite to that one of the FAO: The decision support tool of the FAO is designed in a way that given environmental factors are filled in and the device indicates which plant species are suitable for the conditions. In the case of this thesis plant species were recommended by experts and had to be checked for their suitability for an agroforestry system in Panama applying the checklist. Commonly used names of species were mentioned and had to be identified, so that identity information about the plant species was included in this study's checklist: Latin name, common names, botanical plant family and an option for a general comment in order to fill in information that is important to know about the plant species at the very beginning.

3.1.1 Site related criteria

During literature research four criteria were added to the list of the FAO for the section of site related criteria: the natural habitat, the maximum dry season duration a plant species can handle, its vulnerability to wind as well as its adaptability potential to environments that vary to its natural habitat (Table 4).

Table 4: First section of the developed criteria checklist about site related aspects including valuation and weighting coefficient.

Site related:	
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1
Suitability indicator for site related criteria (60 = max. poss. value)	

3.1.2 Plant related criteria

The table provided by the FAO does not include information about the plant species itself apart from its life form and span as well as its uses and used parts. But detailed plant-related information (e.g. height, rooting habit, interactions with other crops or trees, allelopathy, invasiveness) was necessary in order to determine whether plant species could be combined with each other in an agroforestry system (Table 5).

Table 5: Second section of the developed criteria checklist about plant related aspects including valuation and weighting coefficient.

	Weighting coefficient
Plant related:	
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3
Annual/perennial plant*	---*
Life form: grass, herb, shrub, tree, vine, ground cover*	---
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5
In which stage of the agroforestry system can it be planted? *	---
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1
Is it easy to establish? (0=no, 2=not known, 5=yes)	5
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3

Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3
Easy to transport and store? (0=no, 2=not known, 5=yes)	3
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap) *	---
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3
What are the main active nutritional and medicinal substances?*	---
Can it be processed to substances that can be exported easily (Powder/tincture/capsules)? (0=no, 2=not known, 5=yes)	3
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1
Main drawbacks*	---
Suitability indicator for plant-related criteria (325 = max. poss. value)	
*** Criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.**	

A plant species' vulnerability to diseases was important to know in order to assess the risk connected to it on the one hand side and to identify plant species that should better not be combined with each other on the other hand, because they were hosts of the same disease and could foster an insect infestation or fungi attack. But being aware of possible diseases could also lead to the opposite: knowing that a plant species is for example vulnerable to a certain kind of insect may result in the decision to combine it with a distinct plant species that hosts predator animals which feed on the insects in question.

As the criteria checklist was developed in order to assess plant species for their suitability for agroforestry systems, it was also important to know, if they had already been (successfully) grown in such systems. Furthermore information was desired in terms of if they were easily established and removed after conditions changed, as there are hardly species that grow in more than one of the designed shade stages and thus need to be removed to give space to another one. Data regarding perishability of plant products could indicate, whether a plant species should better be cultivated close to a market or processing facility in order to avoid a loss of quality due to transportation or storage.

The long-term goal was to encourage local farmers to implement agroforestry practices. For this reason it was of utmost importance to know if there is much knowledge needed about planting, managing and processing a plant and its products. If it was very difficult, it was assumed that it would be too difficult to be grown by local farmers unless they already knew the plant species and worked with it in the past.

Criteria about the expected date of the first harvest, an attributed medicinal value, its scientific proof and the processing possibility (to easily exported goods) had to be considered as well.

3.1.3 Social and economic criteria

Plant species were only considered suitable if they possessed any economic value (Table 6). These were needed to finally calculate and assess the economic profitability of the selected plant species for an agroforestry system:

Table 6: Third section of the developed criteria checklist about social and economic aspects including valuation and weighting coefficient.

	Weighting coefficient
Social and economic criteria:	
Is it locally accepted? (0=no, 2=not known, 5=yes)	5
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5
Market potential (0=low, 2=not known, 5=high)	5
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5
Costs per 1000 seeds/seedlings*	---
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5
Needed management (pruning, weeding, fertilizing, etc.)*	---
Working hours needed for one cycle (planting until harvesting) per ha*	---
Working hours needed for two cycles (planting until harvesting) per ha*	---
Number of harvests per year*	---
Yields (kg/ha/yr)*	---
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5
Possible end products*	---
Market prices for products*	---
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5
Suitability indicator for economic criteria (200 = max. possible value)	
Overall suitability indicator (585 = max. overall possible value)	

It was important to know if there is an existing market and market potential for plant products, if seeds or seedlings are easily available and how much they cost. Further information was needed on how much management and working hours are needed, in order to calculate the expenses for labourers. The criteria about the working hours for one and two seasons aimed at finding out if the effort is the same for one or two growing seasons. Information about yields, possible end products and market prices are most important and had to be collected in order to properly determine the profitability of a plant species.

Finally also social aspects had to be taken into consideration, as it was assumed that people are not willing plant to a species if it is not locally accepted or connected to cultural or religious reservations, even if it is considered profitable by an external person.

3.2 Literature review: Pre-selection of plant species

The pre-selected plant species are the result of literature research. In this section the information gained during literature review which resulted in the pre-selection of the species is displayed. The interviewed experts were asked for feedback regarding these species after the literature research (see chapter 3.3.4).

3.2.1 Noni (*Morinda citrifolia*)[7]

Exemplarily this criteria checklist will be found in the Appendix

(Appendix 2).

The criteria checklist shows that there is a lot of information available on Noni (*Morinda citrifolia*), facilitating a sound assessment of the plant species prior to interviewing experts. The criteria related to site conditions were all fulfilled: Its natural habitat is composed of different kinds of forests, but also open areas, grasslands and tide pools (College of Tropical Agriculture and Human Resources 2006; Nelson & Elevitch 2006). Also the given altitude, latitude, precipitation and temperature range as well as the maximum duration of the dry season fulfil the requirements of the species (Nelson & Elevitch 2006). Noni does not depend on a certain soil type but instead tolerates a wide range of soils, humidity conditions, acidity and also rocky soils. However, according to Nelson & Elevitch (2006) as well as the College of Tropical Agriculture and Human Resources (2006), it is not very competitive with ag-

[7] Number 53 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Noni.

gressive grasses and weeds that grow in deep, silty or heavy, compacted soils. Noni must also not be exposed to winds exceeding 33 kph, as this will diminish its growth and yields.

Although it originates from South and Southeast Asia, it was distributed all over the world by explorers, merchants and privateers in the 17th and 18th century (Nelson & Elevitch 2006). In Panama it is to be found all along the Caribbean coast and at the northern part of the Pacific side (Acosta 2005). It is a tree that becomes up to six or ten (Nelson & Elevitch 2006; Nowak & Schulz 1998) meters high, but can be pruned back to any height. It grows naturally in the understory of forests and therefore grows well in the vicinity of other trees and under different shade conditions: it thrives in full sun but also tolerates up to 80% of shade (Nelson & Elevitch 2006). However, it is susceptible to root-knot nematodes – for this reason Nelson and Elevitch (2006) recommend not to plant it in areas where other species susceptible to this disease grew before, e.g. papaya. The authors also state that as Noni attracts ants, sap-feeding insects like aphids can become a problem for some vegetable intercroppings.

The plant species does not require intensive fertilization or application of pesticides, but according to Nelson and Elevitch (2006) and the College of Tropical Agriculture and Human Resources (2006) a periodic application of organic or balanced fertilizers encourages plant growth and fruit production. Pesticides will become necessary if Noni is grown in monocultures, because under these conditions it becomes susceptible to a range of insect infestations and fungi.

Noni is supposed to have a high nutritional and medicinal value. Although not scientifically accepted as a medicinal plant yet, intensive scientific investigations have been conducted within the last two decades (e.g. Westendorf & Mettlich 2010, Fong et al. 2001, Issell 2001, Lui et al. 2001, Hirazumi & Furusawa 1999, Hirazumi et al. 1996, Hiramatsu et al. 1993). It contains numerous active substances including various amino acids, vitamins, calcium, iron, and phosphorous among others (Nelson & Elevitch 2006). A drawback, however, was the very intense smell of Noni. But current research by CIRAD (Agricultural Research for Development) and CITA (Costa Rica's National Research Center on Food Science) developed a technique to eliminate those substances responsible for the strong scent, so that this negative aspect can be taken out of future considerations (CIRAD 2012).

Noni is a multipurpose plant, all plant parts can be taken for different usages: fruits, leaves, wood, bark, seeds, flowers and roots are getting used as food supplements, medicine, animal fodder, firewood, dye for colouring fabrics, insect repellent, beverages, cosmetics, coastal protection, boundary markers (Nelson & Elevitch 2006, Nowak & Schulz 1998). It can be processed to easily transported substances such as powder, juice, pulp and capsules (Healing Noni 2012, College of Tropical Agriculture and Human Resources 2006, Nelson & Elevitch, 2006).

Most of the economic criteria could be valued after the literature review: Noni has been cultivated by humans for at least 2000 years, and there is nowadays an existing and growing international market – it has been sold in the USA, New Zealand, Australia (Nelson & Elevitch 2006) and the European Union, where it has officially been accepted as a “novel food” since 2003 (Westendorf & Mettlich 2010). The authors predict growing international market potential for Noni products.

Data were also available on suitable densities of seedlings per hectare, on harvests and yields per year, needed management as well as some market prices of end products.

However, information was missing about those economic aspects needed to proof Noni’s economic profitability, e.g. costs and mortality rate of seedlings, needed working hours for planting, maintenance and harvest as well as costs for processing. It also had to be found out, if it is locally accepted and if local farmers already have any experiences with the plant species in question.

Due to the properties described above Noni was assumed to be generally suitable as an understory plant for agroforestry systems in Panama. But further information and feedback was needed, therefore it was included in the expert interview.

3.2.2 Arazá (*Eugenia stipitata* McVaugh)[8]

Arazá (*Eugenia stipitata* Mc Vaugh) is a slowly growing (Nowak & Schulz 1998) plant species that originates from the tropical rainforest of the western Amazon region in Peru (e.g. Hernández Gómez et al. 2007, Nowak & Schulz 1998, Tai Chun 1995, van Kanten 1994). It is characterized by a high adaptability potential to different soil types and climates (Picón de Esteves & Ramírez Neyra 1991). According to Hernández Gómez et al. (2007) the precipitation range is the most important meteorological factor for the site selec-

[8] Number 37 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Arazá.

tion: the plant requires 200-300mm/month, or 2.000-3.000mm per year. Established plants can deal with a period of drought (which is not defined more detailed), but this will result in smaller fruits. The required annual temperature range varies between authors from 18-33°C (Hernández Gómez et al. 2007), 21-31°C (van Kanten 1994; Gonzales Tongoa 1990) to 22-30°C (Proyecto de Desarrollo Rural Managua 2001). Although there was no information regarding the concrete latitude and altitude range suitable for Arazá, the available site related data state that this plant species is in general suitable for the given conditions in Panama.

Arazá is a tree that grows up to 10m high (Hernández Gómez et al. 2007, Nowak & Schulz 1998), which does not make it very suitable as an understory species for an agroforestry system. But it grows very slowly and reaches only 3-3.5m after 10 years (Hernández Gómez et al. 2007). Furthermore pruning for formation and maintenance is recommended (Hernández Gómez et al. 2007, Proyecto de Desarrollo Rural Managua 2001, van Kanten 1994) in order to

a) keep a tree height which facilitates the harvest and

b) remove twisted or ill branches and those touching the ground, as this will result in infected fruits. These facts make it still a possibly suitable plant species.

Arazá is a perennial plant species with a first harvest at an age of 14-18 months (Hernández Gómez 2007, van Kanten 1994, Picón de Esteves & Ramírez Neyra 1991). Although not suitable for intensive shade, it should also not be exposed to full sunlight, as the fruits would get degraded. An overstory tree cover is also important to protect flowers from heavy rain (Hernández Gómez et al. 2007, Proyecto de Desarrollo Rural Managua 2001). Best conditions are therefore 20-30% of shade. The plant has already been successfully grown in agroforestry systems and is an important component of such systems in the Amazon, especially in Colombia (Hernández Gómez et al. 2007). First trials were conducted with Pejibaye (*Bactris gasipaes*), Acacia, Laurel, Musa, Yucca and Cowpeas (Picón de Estebes & Ramírez Neyra 1991). Especially good results were reached with an agrosilvicultural system of Laurel combined with Maize, Ginger and Arazá (van Kanten 1994). Agroforestry investigations also took place in Costa Rica (Vargas 1992).

The plant's susceptibility to diseases has been described differently by various authors. While the Proyecto de Desarrollo Rural Managua (2001) states that Arazá is not susceptible to pests and diseases, other authors (e.g. Hernández Gómez et al. 2007; Kays 1999; Tai Chun 1995; Lucas et al. 1994; Duarte 1992) enlist some insects (thrips, fruit flies, wasps), fungi (*Glomerella singulata, Colletotrichum gloesporoides*) and pathogens (*Gloeosporium sp)* which can damage the plant species or fruits and require a treatment with herbicides and pesticides. For this reason Tai Chun (1995) recommends not to combine Arazá with crops that host fruit flies, rust and anthracnose.

The fruits of the tree are very acid and can be processed to juice, jam, candies, ice cream, jelly, cocktails, vine, cake, cream, pulp and compote. They have a high content of carbohydrates, vitamins, nitrogen, protein and potassium (Hernández Gómez et al. 2007; Proyecto de Desarrollo Rural Managua 2001; Nowak & Schulz 1998, van Kanten 1994). However, considered one of the most perishable fruits, Arazá is very susceptible to damages during transport and characterized by a very short shelf life (Hernández Gómez et al. 2007; Proyecto de Desarrollo Rural Managua 2001; Nowak & Schulz 1998; Tai Chun 1995; Hernández & Galvis 1993)[9].

Regarding the social and economic aspects a knowledge gap was discovered, as there was no information available regarding availability and costs of seeds and seedlings, needed working hours for management, expenses for transportation and processing. However, the Proyecto de Desarrollo Rural Managua (2001) as well as Nowak and Schulz (1998) report that Arazá has different commercial uses at international level (juice is industrially processed and exported to Europe). However, according to Nowak and Schulz (1998) and Tai Chun (1995) it was not well known and rarely distributed (at least in the 1990s), but that it has been identified as having a tremendous agro-industrial potential for juice, jam and ice cream and therefore is more and more known and appreciated.

Arazá produces fruits throughout the year which can be harvested roughly every two to three months. Yields increase until the plant reaches an age of five years. Data regarding the yields vary greatly: Hernández Gómez et al. (2007) talk about up to 30t/ha/yr. Gonzales Tongoa (1990) and van Kanten (1994) calculate with an average of 60-80 fruits per tree and year with trees of an age of three to four years. With fertilization they gained 2-2.5t/ha/yr in the first year of production and up to 50t/ha/yr after nine years. The Proyecto de Desarrollo Rural Managua (2001) calculates with an average of around 22

[9] Cooling via and after transportation is a possible solution, but it is very difficult to find the right temperature, as an environment that is too cold also leads to physiological damages (Carmona 2001, Hernández 2001; Tai Chun 1995; Campbell 1994).

fruits per tree and year, 200g per fruit, ca. 1.600 trees per ha and a market price of C$2.50/kg. Therefore they gained around 7t/ha/yr referring to almost US$ 3.200/ha/yr in 2001[10]. Vargas (1992) finally calculated the yields for a plantation of four years with a spacing of 4x4m which resulted in 12.5t/ha/yr.

Thus the data available on social and economic aspects also make Arazá suitable for agroforestry systems. But as many data – especially on costs – were missing and it could not be found out if it was known, accepted and grown in Panama, this information had to be obtained via interviews with experts.

3.2.3 Borojó (*Borojoa patinoi* Cuatrec)[11]

Borojó (*Borojoa patinoi* Cuatrec) is a plant species native to Colombia that also grows in northern Ecuador and southern Panama (FAO Ecocrop 2011, National Tropical Botanical Garden Hawai'i 2011). Valencia and DeLaRosa (2009) as well as Mosquera et al. (2010) locate it broader by saying that it grows in the Amazon and Central America, respectively tropical America.

Borojó is a tree that reaches – depending on different authors – up to 3m (National Tropical Botanical Garden Hawai'i 2011), 7m (Ricker et al. 1997), 17m (FAO Ecocrop 2011) or even 25m (Ocampo & Balick 2009). However, it is a natural understory tree that grows very slowly and reaches 5m after seven years (National Tropical Botanical Garden Hawai'i 2011, Ricker et al. 1997). It has already successfully been grown in agroforestry systems by indigenous populations in Colombia who combined it with higher trees such as Peach Palm (*Bactris gasipaes* Kunth), Papaya (*Carica papaya* L.), Caimito (*Pouteria caimito*) and Cocoa (*Theobroma cacao* L.) as well as with plant species of similar height or smaller like Plantain (*Musa X paradisiacal* L.), Sugar Cane (*Saccharum officinarum* L.) or Pineapple (*Ananas sativus* L. Merr) (Ricker et al. 1997). Ricker (1997) recommends it as an understory plant for agroforestry systems, as it requires shade and performs better compared to full sun exposition.

The fruits of the tree have a very high nutritional value and are used as food as well as for medicinal purposes. A lot of beneficial medicinal effects are attributed to it, including impacts on kidney diseases, high blood pressure, diabetes, Alzheimer's, Parkinson's and cancer. It has also been used as an aphrodisiac (FAO Ecocrop 2011, National Tropical Botanical Garden Hawai'i

[10] C$1=US$0.18, value of 2001, (www.oanda.com).

[11] Number 11 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Borojó.

2011, Mosquera et al. 2010, Ocampo & Balick 2009, Valencia & DeLaRosa 2009, Ricker et al. 1997). An uncommon polyphenolic compound of the fruit is scientifically proven, which is at least partly responsible for its positive effects on health (Rutgers University 2008). Further scientific research has not been done on this plant species, but on a related species (*Borojoa sorbilis* Cuatrec) with identified *in vitro* antierythemal and anti-inflammatory properties (National Tropical Botanical Garden Hawai'i 2011, Rutgers University 2008).

The fruit is getting processed to juice, jelly, pulp, candies, ice cream, wine, capsules, powder, and extracts which are getting exported to North America (FAO Ecocrops 2011, National Tropical Botanical Garden Hawai'i 2011, Tropics Health 2011, Mosquera et al. 2010, Rutgers University 2010).

However, there are also some drawbacks connected to Borojó: flower production starts roughly at an age of 3 years and fruits take around 8-12 months to ripen, thus the first harvest can only take place 4 years after planting. Furthermore it is a dioecious plant meaning that there are male and female plants making it more complicated to grow. Only female plants will produce fruits (FAO Ecocrop 2011, National Tropical Botanical Garden Hawai'i 2011, Ricker et al. 1997). Additionally to this Borojó is vulnerable to some insects and fungi, but there is no information on the extent of its vulnerability and how to protect the plant.

Another problem is its high perishability: as it continues to ripen after harvesting, it is very prone to physical damages. Therefore it should be harvested prior to maturity, transported in special packaging or processed very close to the production site in order to avoid a loss in quality (Mosquera et al. 2010, Ricker et al. 1997).

Borojó was prospected great economic potential (Ocampo & Balick 2009, Ricker et al. 1997), exceptional properties for the food and health market (National Tropical Botanical Garden Hawai'i 2011) and a potential for industrial use for dairy products (FAO Ecocrop 2011). It was checked in expert interviews for its regional acceptance and possible detailed information that could not be found in scientific literature.

3.2.4 Ginger (*Zingiber officinale*)[12]

There is a lot of literature available on Ginger in general and also specifically on its cultivation in Panama – published by the Universidad de Panama in Panama City. Although its origin is unknown, it has been used as a herbal and medicinal plant for at least 3.000 years in Asia and in England since 800 A.D. (Hart 2009, Ellert 2008, Heidböhmer 2006, Hübner & Wissing 2006). Scientists state that it originates from Southeast Asia and that it has been distributed during colonization so that is has been cultivated throughout the tropics and subtropics for centuries (e.g. Ellert 2008, Hübner & Wissing 2006, Talbott 2003, Ocampo Sánchez 2000). The medicinal effects attributed to Ginger range from stomach smoother, heart tonic, and blood pressure improvement to aphrodisiac properties. Its effectiveness and safety as a medicine has been scientifically proven for many diseases and symptoms, e.g. motion sickness (e.g. Hübner & Wissing 2006, Talbott 2003, Krämer 2000, Mante 1998).

In Panama the cultivation of this plant is very widespread, because all climatic and site conditions are fulfilled. Suitable precipitation and soil conditions are the most important factors for successful cultivation: although information regarding required annual precipitation vary between authors, they all agree that the plant species grows best under high precipitation levels (at least 2.000 mm/year), but that the soil needs to be loose, well drained, rock-free and high in organic matter to enable a proper development of the rhizomes – being the important and harvested parts of the plant (e.g. Valenzuela 2010, Ocampo Sánchez 2000, Delgado Martinez 1982).

Ginger grows well in full sun, but numerous trials in agroforestry systems have proven that it performs better under light shade conditions. While Valenzuela (2010) states that yields are highest under roughly 25% of shade, investigations of Amin et al. (2010) show that best results were achieved with a combination of Ginger and Mango providing about 60% of shade. Jaswal et al. (1993) intercropped it with different densities of Poplar and gained – equal to Amin et al. (2010) – higher yields in the intercropping system compared to pure Ginger plantations. However, the plant requires a high amount of nutrients (e.g. Krämer 2000, Mante 1998, Selbitschka 1991), therefore it needs to be ensured that it gets combined with species that do not compete for the same nutrients. This problem can be avoided by applying organic or synthetic fertilizers.

[12] Number 87 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Ginger.

As the plant species is vulnerable to a number of fungi, bacteria and insects, a treatment with pesticides might be necessary depending on the site. It should not be combined with plant species or planted on fields where other crops susceptible to root-knot nematodes grew before (e.g. Valenzuela 2010, Ocampo Sánchez 2000, Mante 1998).

As harvested rhizomes are not damaged easily, it is transported and stored easily and gets sold freshly and dried (Valenzuela 2010, Heidböhmer 2006, Ocampo Sánchez 2000). Its international trade is further facilitated by processing Ginger to products that can be stored even longer like powder, capsules, oil, tea and tincture, among others (e.g. Valenzuela 2010, Hart 2009, Heidböhmer 2006, Talbott 2003). Possible end products are for example pastries, candies, beer, tea, syrup, sweets, liqueur, jelly, cake, and curry powder blends. Ginger peels are getting processed to wine, and the plant's essential oil is used in the perfume industry (e.g. Valenzuela 2010, Heidböhmer 2006, Hübner & Wissing 2006, Talbott 2003, Krämer 2000, Selbitschka 1991).

However, much knowledge is needed to cultivate Ginger, as proper requirements regarding precipitation and soil conditions as well as the avoidance of diseases are crucial for succeeding.

Ginger was pre-selected for agroforestry systems in Panama, but still feedback by experts was needed, in order to find out the locally necessary aspects to consider when planting it, and especially if local practitioners recommend it as an understory species for an agroforestry system in Panama.

3.2.5 Cananga (*Cananga odorata*)[13]

Cananga (*Cananga odorata*) is native to South-East Asia, though its exact origin is not known. It was introduced to China, Africa, India and the Americas, so that it is today spread throughout the tropics (World Agroforestry Centre 2011, Manner & Elevitch 2006). The climatic conditions given in Panama were found suitable (World Agroforestry Centre 2011, Manner & Elevitch 2006). It is a tree that reaches up to 30 or 40m, but under cultivation it usually gets pruned to 3m, in order to facilitate the manual harvest of the flowers (World Agroforestry Centre 2011, FAO Ecocrop 2011b, Manner & Elevitch 2006).

Cananga has already been grown in agroforestry systems and is very common in home gardens where it has been intercropped with smaller food

[13] Number 12 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Cananga.

crops, but it also works as an understory plant in combination with higher trees. The plant is known as a pioneer species that colonizes open areas rapidly but also tolerates moderate shade. The shading, however, should not be too intense, as productivity reduces with increased shade (World Agroforestry Centre 2011, FAO Ecocrop 2011b, Manner & Elevitch 2006). Therefore shade stages one and two could work for this plant. It takes 1.5-2 years until the plant species produces flowers. It flowers throughout the year with possible peaks due to climatic conditions. Flowers are picked manually and need to be processed immediately after harvesting in order to get the highest possible yields of essential oil (Manner & Elevitch 2006). The oil has a very high value for expensive perfumery, and much of it is shipped to France or added to hair oil, soaps, and toiletries. Besides flowers the timber and bark can be used for the production of ropes, canoe parts, furniture or as fuelwood (World Agroforestry Centre 2011, Manner & Elevitch 2006). Fruits and bark have also been used in traditional medicine to prevent malaria, cure asthma and skin problems; it is also supposed to have aphrodisiac properties (World Agroforestry Centre 2011, FAO Ecocrop 2011b, Manner & Elevitch 2006).

The World Agroforestry Centre (2011) attributes Cananga a high market potential – in case that supply of essential oil can be assured. There was a case in Micronesia in the mid 1980s when a coconut product company planted 1 ha of Ylang-Ylang in order to substitute the highly priced imports from France. The project failed because of high labour input and low yields of essential oil. While Cananga was grown on a big scale before the First World War, it decreased afterwards and is nowadays only a smallholder business in the Philippines and provides oil for local consumption only. Today Indonesia, Madagascar and the Comoro Islands are the main exporters of Ylang-Ylang oil (World Agroforestry Centre 2011, Manner & Elevitch 2006).

3.2.6 Cat's Claw (*Uncaria guianensis*)[14]

There was not much literature available on climatic necessities and management, as most published scientific information deals with the medicinal properties of this plant species. According to Taylor (2012) it is indigenous to tropical areas of Central and South America, including Panama. Other authors (Talbott 2003, Dawn Bostic & Johns Cupp 2000) locate its origin in Peru but state that it is found throughout the tropics. It is a vine that can climb up to 30m high into the canopy (Taylor 2012, Morgenstern 2011) – depending on the height of the host tree. There is varying information on the plant

[14] Number 80 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Cat's Claw.

parts being used: while Morgenstern (2011) as well as Dawn Bostic and Johns Cupp (2000) say that only the bark is used for medicinal purposes, Taylor (2012) and Talbott (2003) explain that the bark and the roots are used, and that the primary active compounds are concentrated in the root.

Cat's Claw has a long history as a medicinal plant and has been used by indigenous people from Peru for at least 2000 years. Its medicinal value has been proven in various investigations of international scientists since the 1970s. They found out that certain substances have beneficial effects on the immune system, infections and severe diseases such as cancer, rheumatism and AIDS. In the USA it has been labelled a dietary supplement by the US Food and Drug Administration (Taylor 2012, Morgenstern 2011, Talbott 2003, Dawn Bostic & Johns Cupp 2000). The plant is getting processed to tea, capsules, tablets, liquid extracts and tinctures, which are getting exported to Europe and the USA (Taylor 2012, Dawn Bostic & Johns Cupp 2000). According to Taylor (2012) Cat's Claw has become popular in the industry of natural products, which lead to an increased market demand.

For these reasons Cat's Claw has been selected as a possibly suitable plant species for an agroforestry system, although there is not much information available. Being a vine it was supposed to be shade tolerant, as this kind of plant species usually grows in the understory on trunks of other trees. Therefore it was suggested to be possibly suitable for the fourth stage of an agroforestry system in Panama. Nevertheless more information – especially on management aspects – was needed to be collected, thus expert interviews were considered inevitable for obtaining these.

3.3 Results of the interviews

In this subchapter the results of the interviews shall be presented. This includes the general feedback to interviews, the recommended plant species, as well as the results regarding the pre-selected plant species.

3.3.1 General feedback

As explained in the methodology, four different expert groups were interviewed for their feedback and recommendations of shade tolerant NTFP species for the understory of agroforestry systems in Panama. The general response to the requests for interviews differed among the expert groups (Fig. 3):

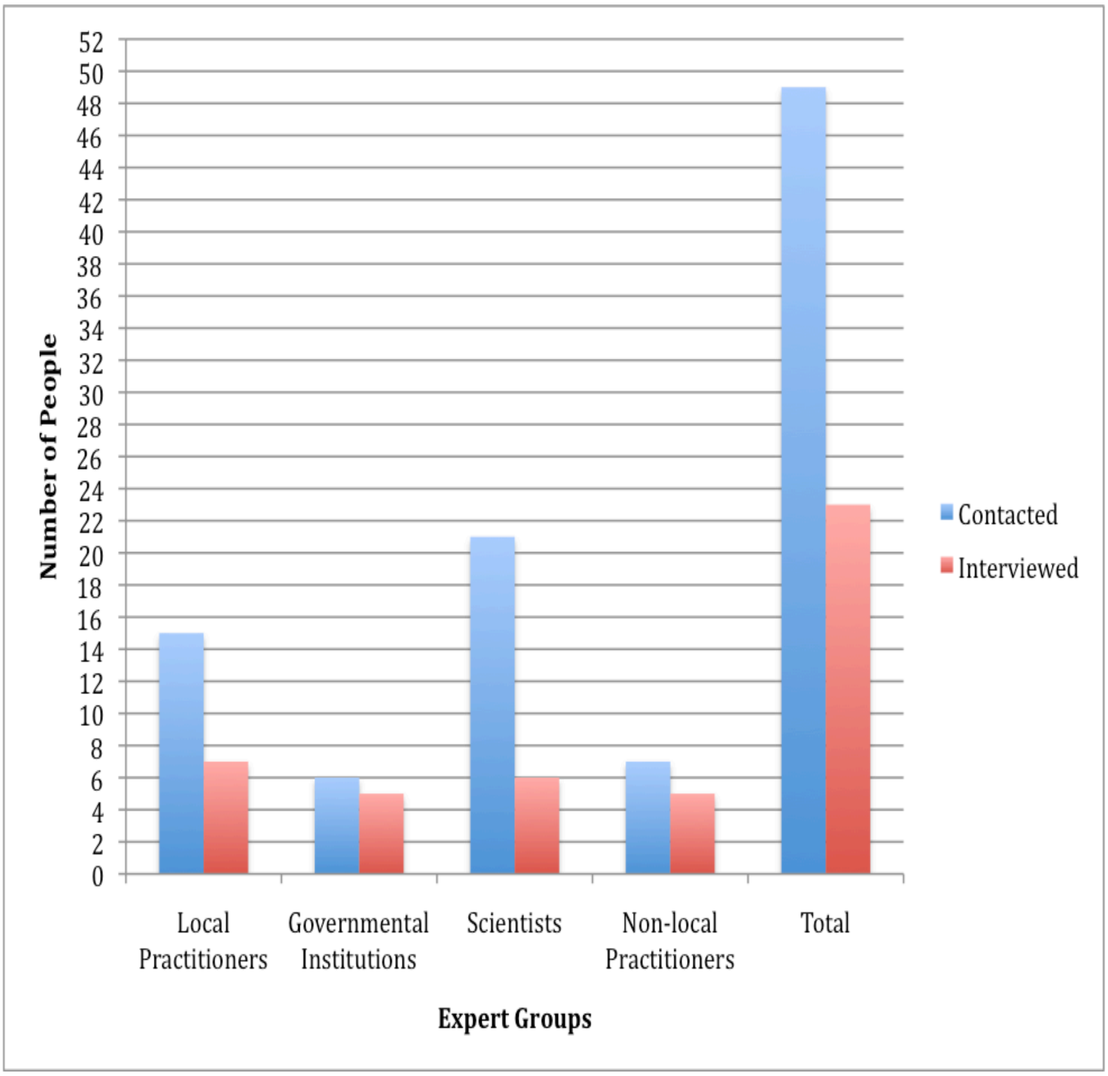


Fig. 3. General feedback to requests for interviews.

In total 49 experts were contacted and asked for an interview which was finally conducted with 23 people. The number of people (between five and seven) who answered the questionnaire was more or less equal for the different expert groups. But the number of people that were contacted varied: while most of the contacted experts of Panamanian governmental institutions and non-local practitioners answered the questionnaire, only half of the local practitioners did. Even more striking was the feedback of international scientists: 29% of those contacted filled in the questionnaire.

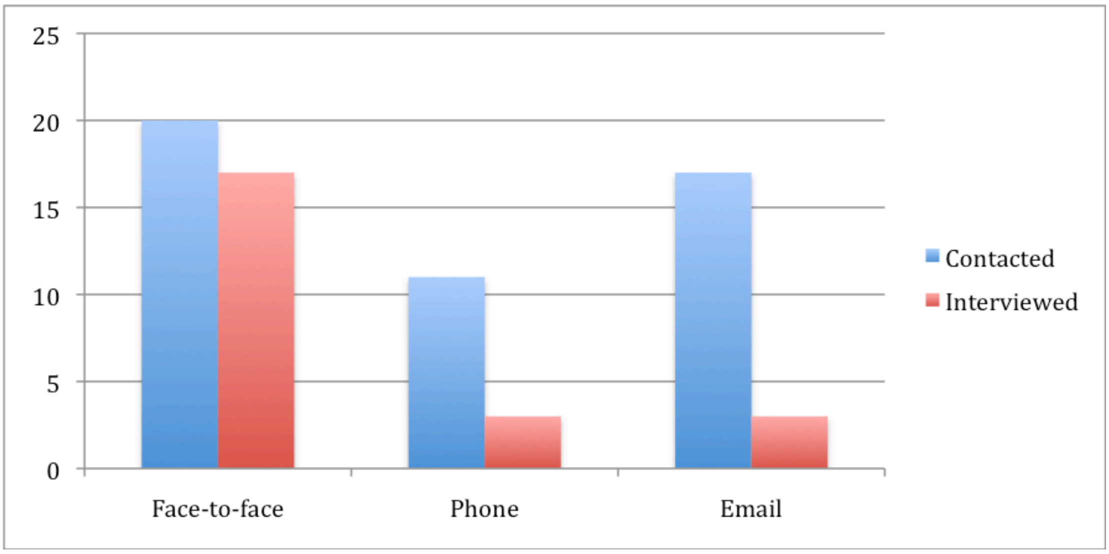


Fig. 4. Response regarding the way experts were contacted.

In general the feedback was best when experts were contacted face-to-face (Fig. 4): 41% of the contacted experts were approached in this way, and 85% out of these were willing to participate in the interview. Not all of those who were contacted via phone participated, but 27%. There were still 17 experts who could neither be contacted face-to-face nor via phone. Therefore they were only contacted via email. 18% of them answered the questionnaire.

3.3.2 Importance of suitable light conditions when combining plant and tree species

The interviewees were asked to put four aspects in an order to be considered when combining plant and tree species. They should begin with the most important one. The aspects were

a) interactions between plants and trees,

b) availability of water,

c) suitable light conditions and

d) availability of nutrients.

The experts were also given the opportunity to mention one more aspect in case they felt that one was missing. This question aimed at finding out how the experts judged the importance of suitable light conditions. 43% of the interviewed experts could not answer the question. Two experts of governmental institutions said that suitable light conditions were most important for a successful agroforestry system, whereas the majority of those who could answer the question (54%) put suitable light conditions on number two. This opinion was distributed evenly among the different expert groups. One scientist set it on number three whereas two local practitioners as well as one expert of a governmental institution said this was least important compared to the other aspects. A German scientist[15], answered that most important to be considered were economic, technical and social aspects.

3.3.3 General advices for obtaining high quality seeds and seedlings

Answers regarding the general availability of high quality seeds and seedlings were very rare, as hardly any of the interviewees had made personal experiences. An employee of MIDA[16], recommended buying seeds and seedlings at certified nurseries, for example provided by MIDA. A manager of a nursery in Panama City[17], stated that it is very difficult to obtain high quality seeds, but that it is crucial to use selected planting material. A German agriculturalist[18], underlines the difficulty by arguing that the availability is often restricted to local facilities which impede an extension to other areas. A German horticulturalist[19], recommended cooperating with research centres.

Obtaining seeds from the Forest Seed Bank of CATIE in Costa Rica might be an option, but they focus on the main tree species for reforestation (CATIE 2013), therefore it is unlikely that the institute will be able to provide seeds for understory species and even less probable for rather unknown and rarely planted species.

3.3.4 Feedback regarding pre-selected plant species

The feedback of the interviewed experts regarding the pre-selected plant species was included in the criteria checklists which were already filled out with the results of the literature review. In the interviews experts were first asked to recommend plant species freely for the different shade stages. Only

[15] Interview No. 17 on the CD enclosed.
[16] Interview No. 08 on the CD enclosed.
[17] Interview No. 13 on the CD enclosed.
[18] Interview No. 15 on the CD enclosed.
[19] Interview No. 17 on the CD enclosed.

afterwards feedback was requested regarding the pre-selected plant species, in order not to influence them for their recommendations for plant species. However, for a better understanding the feedback for the pre-selected species is displayed in this thesis prior to the additionally recommended plant species.

3.3.4.1 Noni (*Morinda citrifolia*)[20]

Noni was known by the vast majority of participants (N=23): only one scientist and one local practitioner did not know it, one scientist only heard about it (Fig. 5).

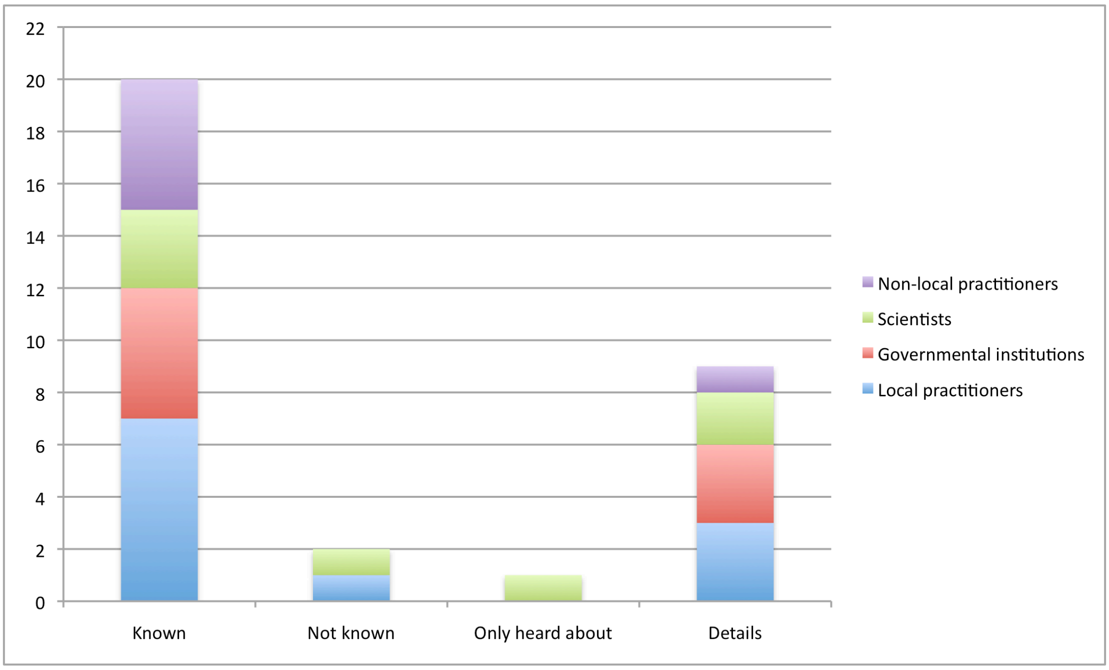


Fig. 5. General knowledge about Noni (Morinda citrifolia).

Not all participants who knew the plant species were able to give detailed information about the plant species: only 45% of them could.

Experts were asked to name all those plant parts that they thought could be used. In the case of Noni 60% of those who knew the plant species said that mainly the fruits were used (Fig. 6).

[20] Number 53 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Noni.

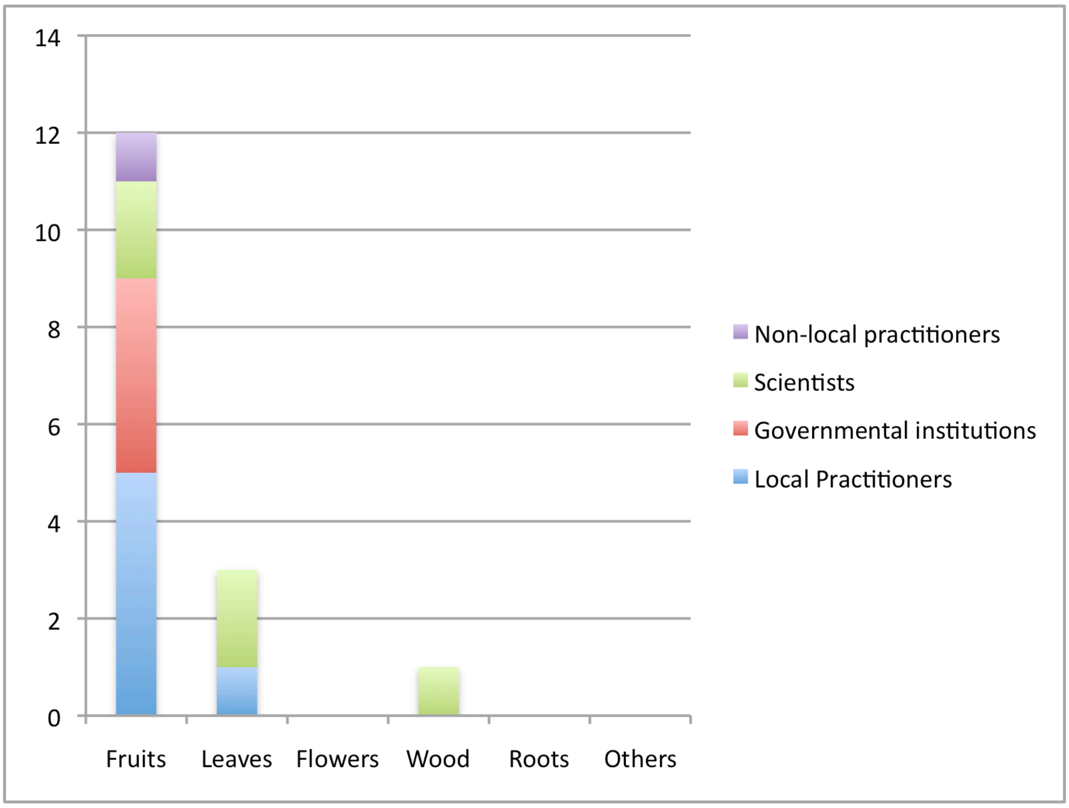


Fig. 6. Used parts of Noni (Morinda citrifolia).

67% of those who were able to give detailed knowledge about Noni stated that its cultivation was “very easy”. This included all local practitioners who answered this question. No expert stated that it was “rather difficult” or “very difficult”.

While the interviewees agreed pretty much on the difficulty to grow Noni, they had different opinions regarding the difficulty to transport the products of the plant: 55% of those who answered this question said that it was “very easy” or “rather easy”. The answers varied not only between experts in general but also within expert groups, so that no trend could be determined.

In case participants stated that growing or transporting the plant respectively plant products was “rather difficult” or “very difficult”, they were asked to explain why this was the case. The reason for Noni products being “rather” or “very difficult” to transport was the high perishability of the fruit. It ripens very quickly after being harvested and is easily damaged during transportation. Therefore a special packaging is necessary, and the fruits need to be transported and processed directly after harvesting.

The experts (N=23) were indecisive whether or not to recommend Noni for agroforestry systems in Panama. This also varied slightly between expert groups (Fig. 7):

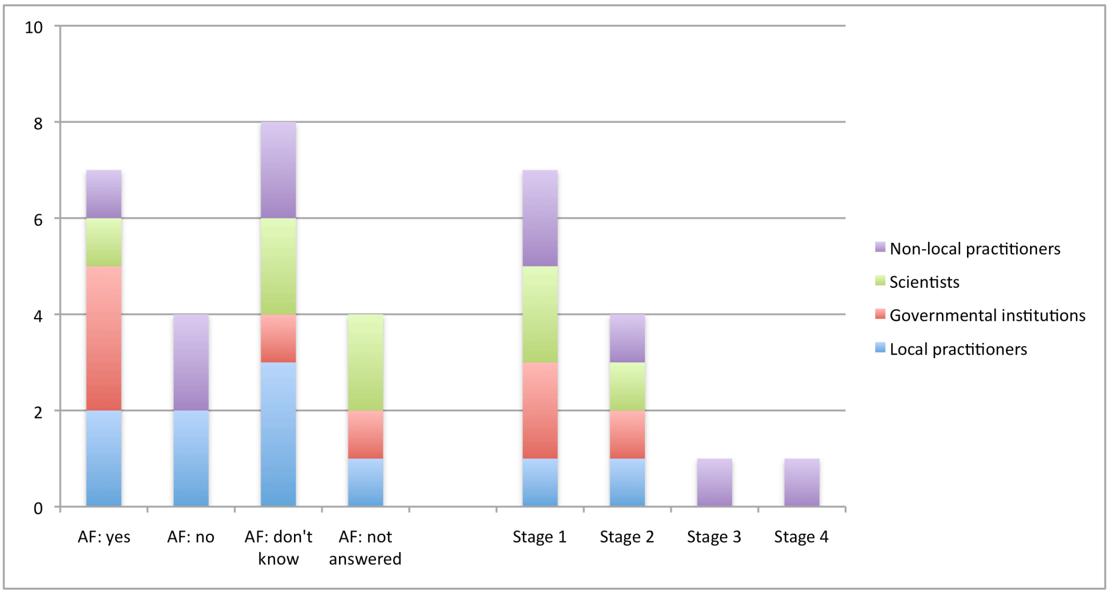


Fig. 7. Recommendation of Noni (Morinda citrifolia) for agroforestry systems in Panama and suitable shade stages.

In total 30% of the experts recommended it, while 17% did not, 35% did not know and 17% did not answer the question. The answers were more or less evenly distributed among the different expert groups. But it is striking that 60% of the employees of Panamanian governmental institutions recommended it and that none of these institutions stated that it was not suitable. The reason behind this was according to one of the experts[21] that the Panamanian government recognized Noni's market potential eight years ago and therefore gave plant seedlings to local farmers for free. But in the end this programme was not successful, because big amounts of fruits were needed to produce fruits, and local small-scale farmers were not able to produce these amounts. Therefore the employees of the government still state that it was generally suitable for agroforestry systems.

Reasons for recommending Noni were basically that it was easily managed, because it had medicinal properties and because the national (Panamanian) and international market situation was good. Arguments against Noni were that it was not suitable for agroforestry systems because it was very aggressive, because fruits were difficult to be transported, or because experts assessed its market situation differently and stated that it was not good.

[21] Interview No. 11 on the CD enclosed.

The interviewees recommended Noni mainly for shade stages one and two, meaning with no or only light shading of up to 20-30%. One non-local practitioner stated that the plant species could be cultivated in all four shade stages.

Figure 8 describes the market potential that different expert groups assigned to Noni. 35% of the experts (N=23) could not give an assumption about the plant's market potential. In general similar amounts of participants answered that it had a very low, rather low or rather high market potential, whereas only one non-local practitioner stated that its market potential was very high. While more local practitioners said that Noni's market potential was very low, more experts of governmental institutions assigned a rather high potential. This can also be explained with the experience the different experts made: the local practitioners planted it already and could not get rid of the fruits, because they themselves produced a lot, but it was still not enough for the demand of the processing companies. On the other hand experts of governmental institutions stated that it had a certain potential which could not be addressed successfully eight years ago.

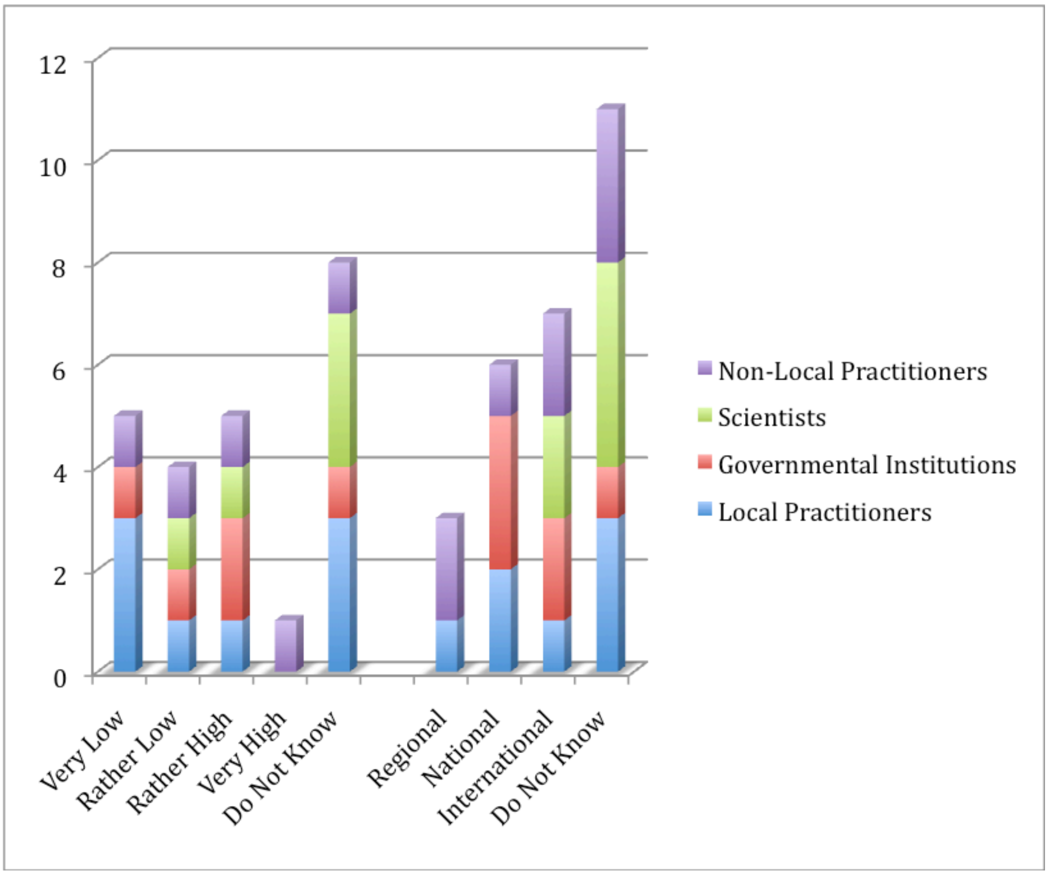


Fig. 8. Market potential of Noni (Morinda citrifolia) assigned by expert groups.

Regarding the question about the spatial level of importance it is important to know that interviewees were able to pick more than one answer, therefore the responses to this question could be higher than N=23.

The question whether Noni products were rather demanded regionally, nationally or internationally could not be answered by eleven interviewees. Seven participants attributed Noni an international market potential, six a national value and three of them regional importance.

3.3.4.2 Arazá (*Eugenia stipitata* McVaugh)[22]

Arazá was hardly known by the experts: only one local practitioner[23] knew it and recommended it for stage one of agroforestry systems in Panama. One scientist heard about it.

The practitioner was a medicine man who was living in a remote, densely forested part of the "Comarca norle diumas corremiento su sama". He was working as a botanist with medicinal plants and was able to provide detailed information about the plant species in question. He stated that only fruits were used and that the plant species was very difficult to be grown and transported. While he did not give a reason for the difficult transportation, he explained that the main difficulty to grow it was that there were no seeds available. He assumed its market potential to be very low. However, a non-local practitioner[24] did not know Arazá but other species of the genus Eugenia. He stated that the genus was very interesting with a high but yet untapped potential.

[22] Number 37 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Arazá.

[23] Interview No. 03 on the CD enclosed.

[24] Interview No. 19 on the CD enclosed.

3.3.4.3 Borojó (*Borojoa patinoi* Cuatrec)[25]

It was 43% of experts each who knew Borojó and who did not, and this was more or less equally distributed among the expert groups of local and non-local practitioners (Fig. 9). Out of the group of employees of governmental institutions more experts knew it than there were participants who did not – in contrast to scientists where it was the opposite: the majority of them did not know the plant species, while only one did. Detailed information on Borojó was provided by 70% of those who knew the plant species.

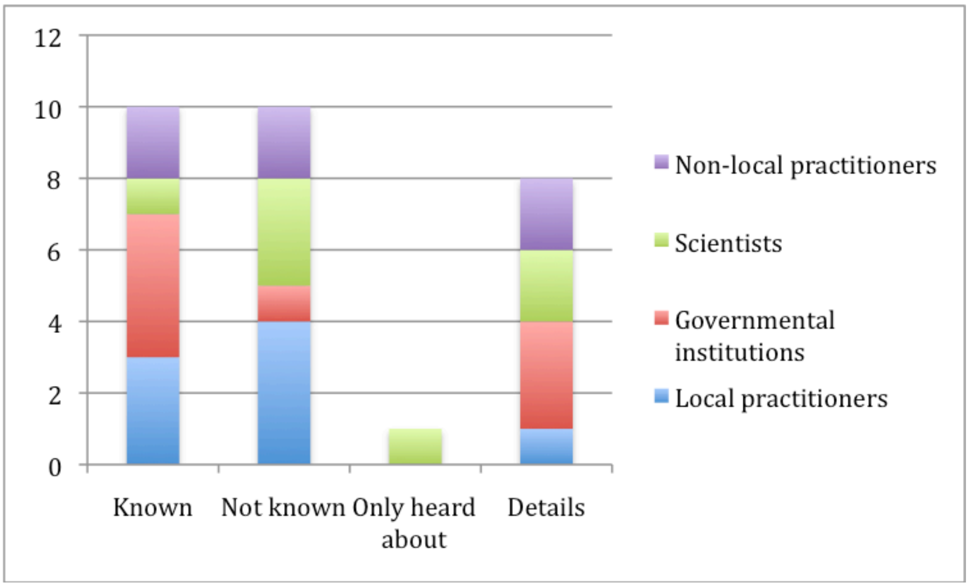


Fig. 9. General knowledge about Borojó (*Borojoa patinoi* Cuatrec).

75% of those who were able to give detailed information about Borojó said that mainly used parts of the plant were the fruits. Leaves and wood were mentioned by a few experts. While three of the employees of governmental institutions stated that it was “very” or “rather easy” to grow Borojó, four experts of different groups said that it was “rather difficult”. 75% of those interviewees who could give detailed information on the plant species assessed the difficulty to transport those parts of the plant that can be used. 67% of theses found it “very” or “rather easy”. None of the interviewees stated that Borojó was not recommendable for an agroforestry system, but 80% of those who knew the plant species said that it was suitable for this purpose (Fig. 10).

[25] Number 11 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Borojó.

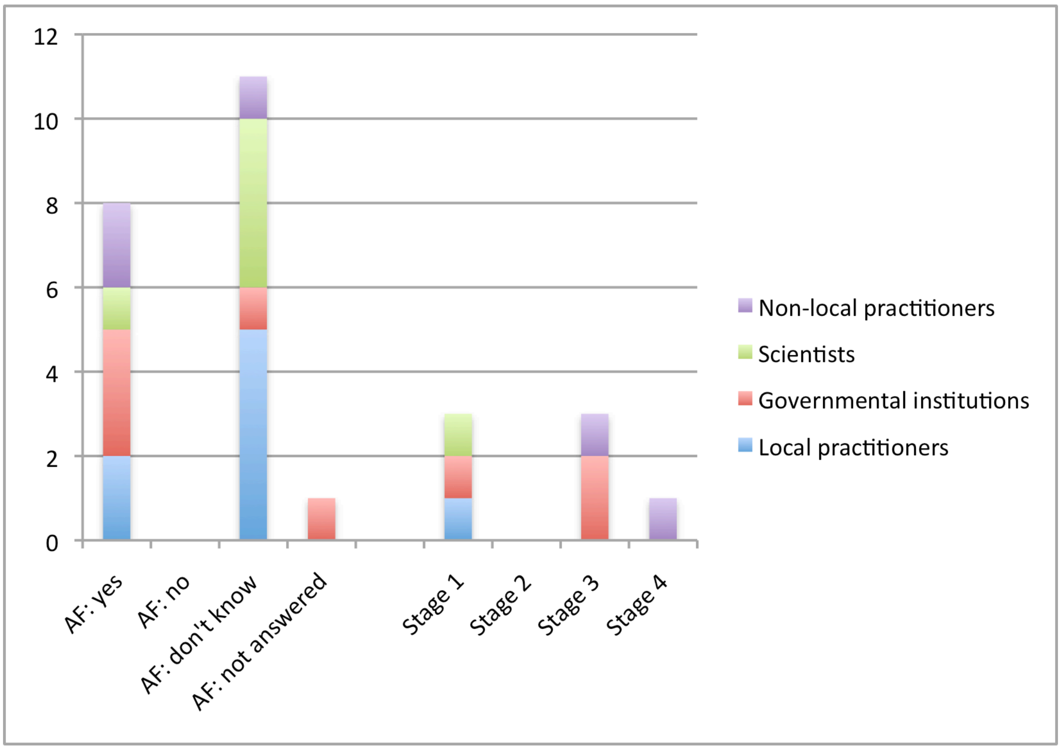


Fig. 10. Recommendation of Borojó (*Borojoa patinoi* Cuatrec) for agroforestry in Panama and suitable shade stages.

Reasons for recommending it were its good market situation, suitability for agroforestry systems, good adaptation, easy management and good nutritional value. Mentioned drawbacks were the difficult transportation of fruits and difficult management, doubtful acceptance by local farmers, the fact that much knowledge was needed, the market situation was bad, environmental conditions were not suitable and the limited availability of seeds.

Information regarding suitable stages of agroforestry systems varied: stages one and three were mentioned most frequently, meaning either full sun conditions or shading of around 50-60%.

Less than half of the interviewees (N=23) were able to provide information about the market potential of Borojó (Fig. 11).

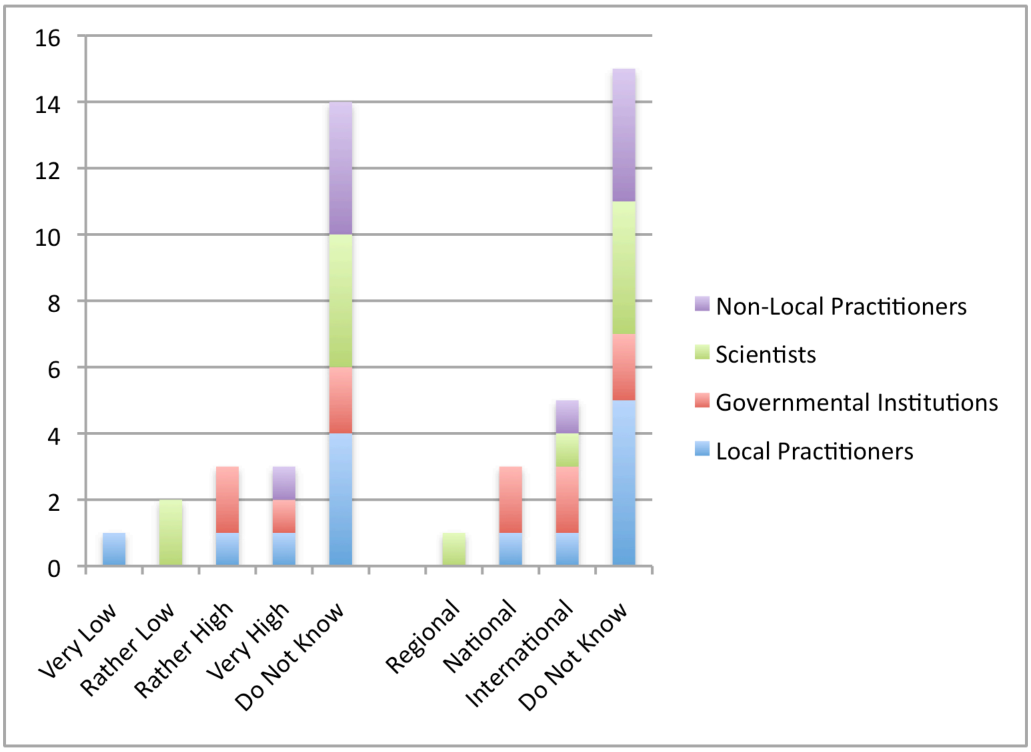


Fig. 11. Market potential of Borojó (*Borojoa patinoi* Cuatrec) assigned by expert groups.

67% of those who provided information assigned Borojó "rather" or "very high" market potential, whereas 33% said that it was "rather low" or "very low". 56% of the experts possessing detailed knowledge assumed that Borojó products were of international importance, and 33% said that they were rather nationally valuable.

3.3.4.4 Ginger (*Zingiber officinale*)[26]

Figure 12 shows that Ginger was known by all interviewed experts (N=23) except for one scientist who only heard about it. 59% of those who knew the plant species could also provide detailed information about this plant species. While the detailed knowledge was more or less evenly distributed among local practitioners, experts of governmental institutions and scientists, none of the non-local practitioners possessed detailed knowledge on Ginger.

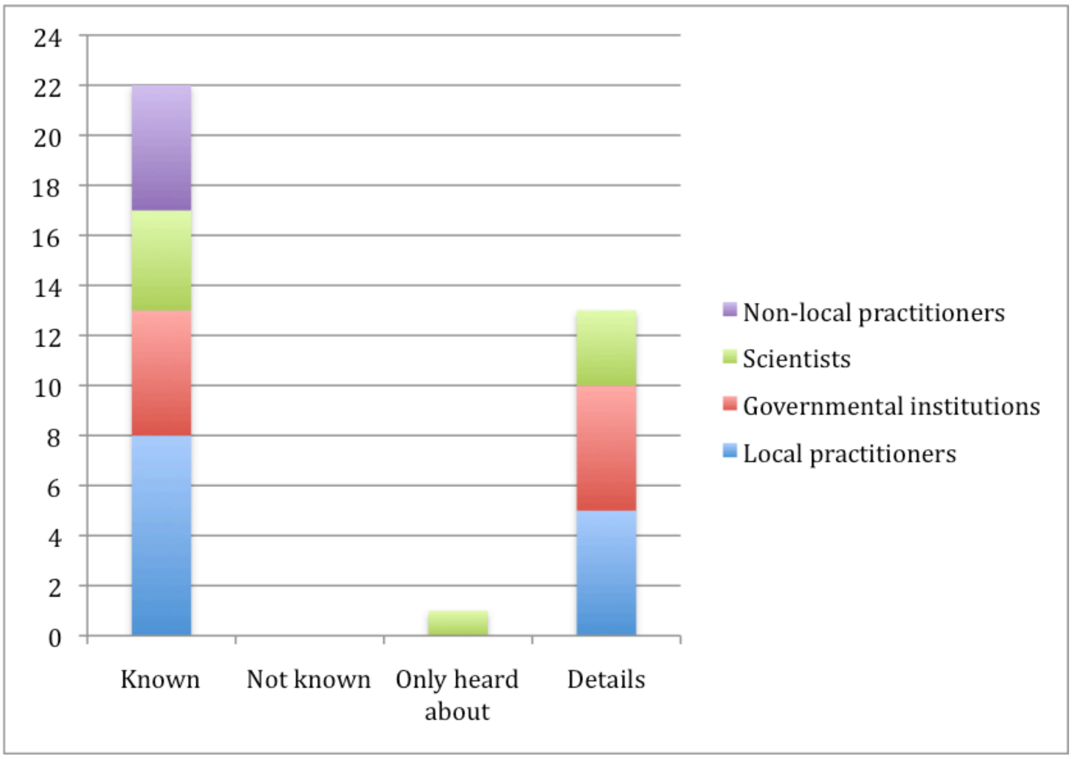


Fig. 12. General knowledge about Ginger (*Zingiber officinale*).

All of those who answered the question regarding the used parts of ginger stated that it was the “roots” that were used. In order to be ecologically correct, it should be mentioned that these parts are scientifically not the “roots” of the plant, but the “rhizomes” (e.g. Ocampo Sánchez 2010).

65% of the experts answered the question regarding the difficulty to grow Ginger out of which 73% said that it was “very easy” or “rather easy” –the remaining 27% had the opinion that it was “rather difficult” to cultivate the plant. Answers were distributed among expert groups, but almost all local practitioners (75%) said that it was “very easy”, whereas scientists rated it as rather difficult. The reason might be that local Panamanian farmers were very

26 Number 87 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Ginger.

familiar with this plant species, as most of them had been growing it on their own fields.

Mentioned reasons were to find the right soil type and humidity as well as fertilization levels (by a local practitioner[27] and an employee of Idiap[28]), while a scientist[29] recommended to pay attention when combining it with other agroforestry crops in order not to damage the rhizomes.

Almost all (93%) of those who answered the question about the difficulty to transport Ginger products said that it was either "very easy" (43%) or "rather easy" (50%).

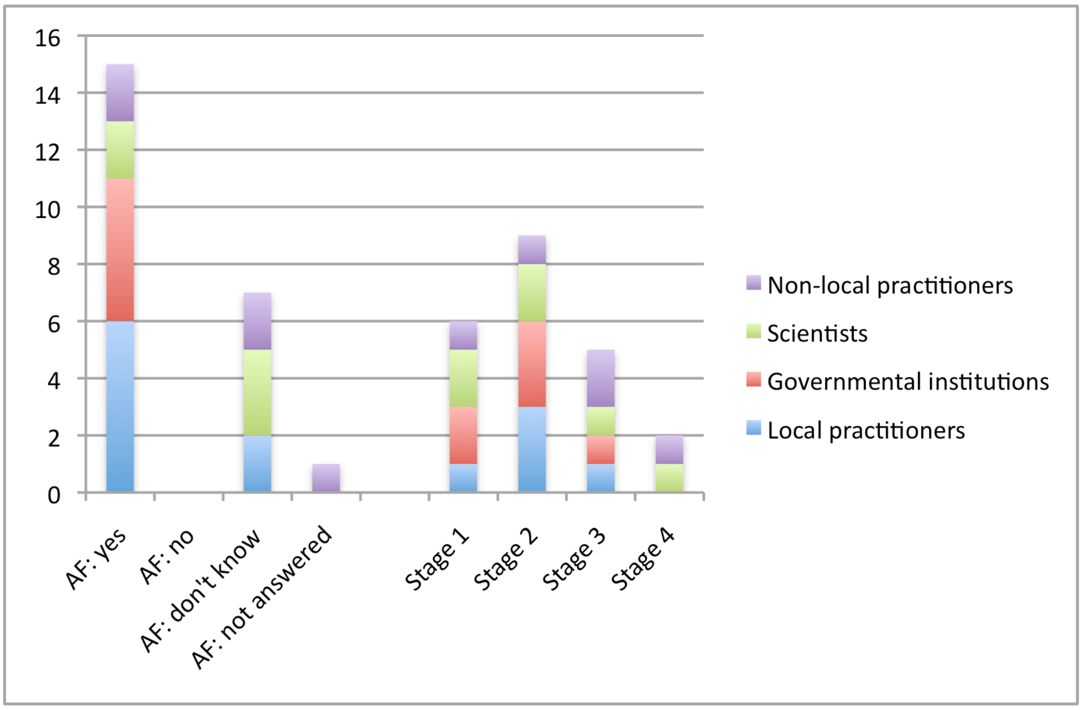


Fig. 13. Recommendation of Ginger (*Zingiber officinale*) for agroforestry systems in Panama and suitable shade stages.

The vast majority (68%) of interviewees recommended Ginger for agroforestry systems, as Figure 13 shows. None of the participants stated that it was not suitable, while 30% did not know whether to recommend it or not.

Ginger was mainly recommended due to its good market situation and its easy management. But also its suitability for agroforestry, its medicinal properties, its good adaptation to environmental conditions and its environmental benefits made experts recommend it. Mentioned drawbacks were that much

[27] Interview No. 05 on the CD enclosed.

[28] Interview No. 12 on the CD enclosed.

[29] Interview No. 17 on the CD enclosed.

knowledge was needed to grow it, its market situation was assessed as being bad, given environmental conditions were unsuitable and that ginger was not suitable for agroforestry, because it was already grown on large scale.

According to the interviewees Ginger was suitable for shade stages one, two and three of an agroforestry system, meaning it can handle full sun conditions as well as shade of up to 50-60%. However, Figure 13 also shows that stage two (20-30% shade) was most frequently mentioned (by 60% of those experts who recommended it for agroforestry).

The answers regarding the market potential of Ginger varied greatly (Fig. 14).

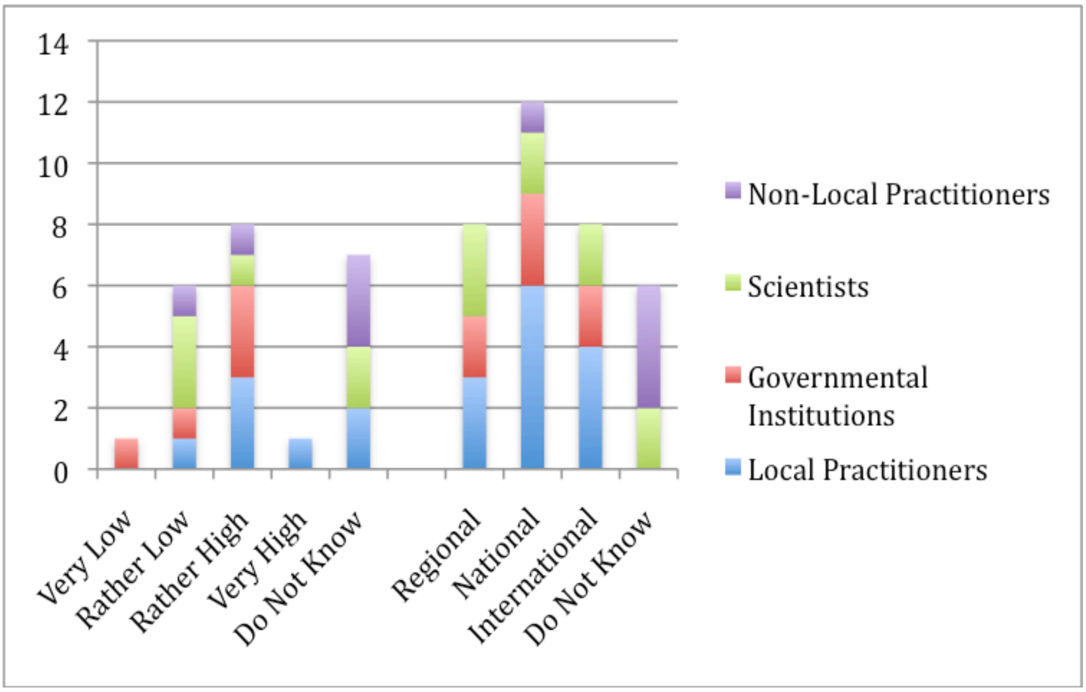


Fig. 14. Market potential of Ginger (*Zingiber officinale*) assigned by expert groups.

The majority of participants attributed it “rather low” (38%) or “rather high” (50%) potential, and one local practitioner “very high” potential. The interviewees did also not agree on the spatial level of importance, where more than one option could be chosen: While the majority (75%) said that Ginger products were of national importance, 50% of those who provided information on its market potential assigned Ginger additionally regional or international importance. The answers were very evenly distributed among the expert groups.

3.3.4.5 Cananga (*Cananga odorata*)[30]

Cananga was known by 43% of the interviewed experts (N=23), mainly by scientists and non-local practitioners (Fig. 15). Most of the local practitioners and experts of governmental institutions did not know this plant species. Detailed information was only available by one scientist and two non-local practitioners. This might be because Cananga is mainly used in expensive perfume industry and is hardly available at local markets (see chapter 3.2.5).

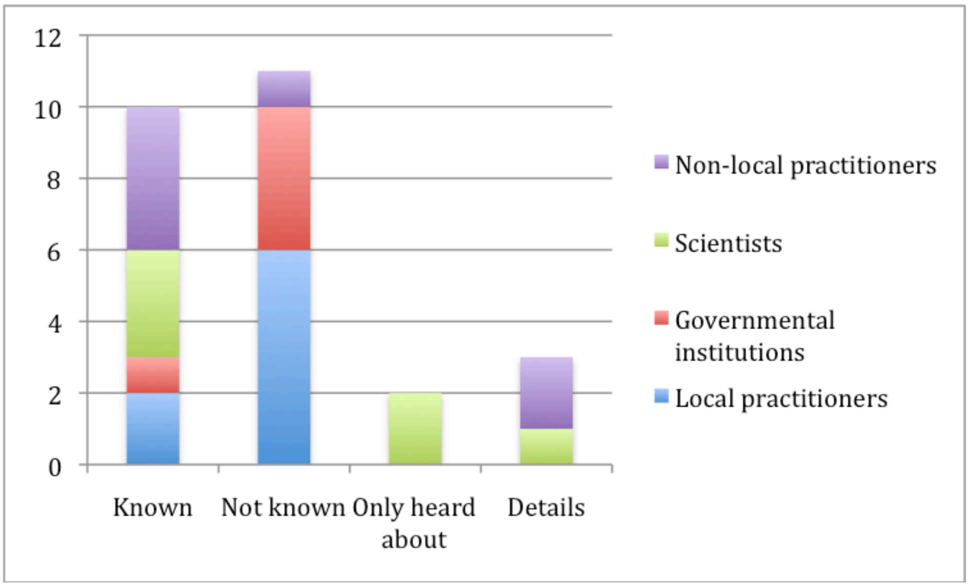


Fig. 15. General knowledge about Cananga (*Cananga odorata*).

The question regarding those parts of the plant that were getting used was answered by 30% of those who knew the plant species. All of them said that it were the flowers of the plant that are used. A scientist[31] and a non-local practitioner[32] explained that it is "very easy" to grow Cananga.

78 % of all interviewed experts did not know whether or not to recommend it for agroforestry systems, only two did so (the non-local practitioner[33] and the scientist[34]). One expert of a governmental institution[35] said that it is rather not suitable for being combined with overstory trees, as it requires a lot of light and takes 3-4 years in order to produce the first flowers. While the local practitioner did not give any information about a suitable shade stage of an agro-

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[30] Number 12 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Cananga.
[31] Interview No. 13 on the CD enclosed.
[32] Interview No. 21 on the CD enclosed.
[33] Ibid.
[34] Interview No. 13 on the CD enclosed.
[35] Interview No. 09 on the CD enclosed.

forestry system, the scientist argued that Cananga could be cultivated in any of the four stages.

Reasons for recommending Cananga were its easy management (as only the germination was difficult), its nice smell and the beneficial impact on the environment. Drawbacks, however, were mentioned more frequently, being its difficult management and the long time until first returns can be expected, the difficulty to transport the flowers, limited availability of seeds and labour intensive management.

Although Cananga was known by 43% of the participants, only two of them provided particular information about its market potential: one local[36] and one non-local practitioner[37] attributed Cananga a “rather high” market potential on an international level. But the non-local practitioner also stated that Cananga was only economically feasible if planted on large scale.

[36] Interview No. 04 on the CD enclosed.
[37] Interview No. 21 on the CD enclosed.

3.3.4.6 Cat's Claw (*Uncaria guianensis*)[38]

Cat's Claw was another plant species which was not widely known: 39% of the experts (N=23) knew it, another 39% did not know it, and 17% only heard about it. It was striking that none of the experts of governmental institutions knew it (Fig. 16). Detailed information was only available from two local practitioners, which account for 22% of those who knew it.

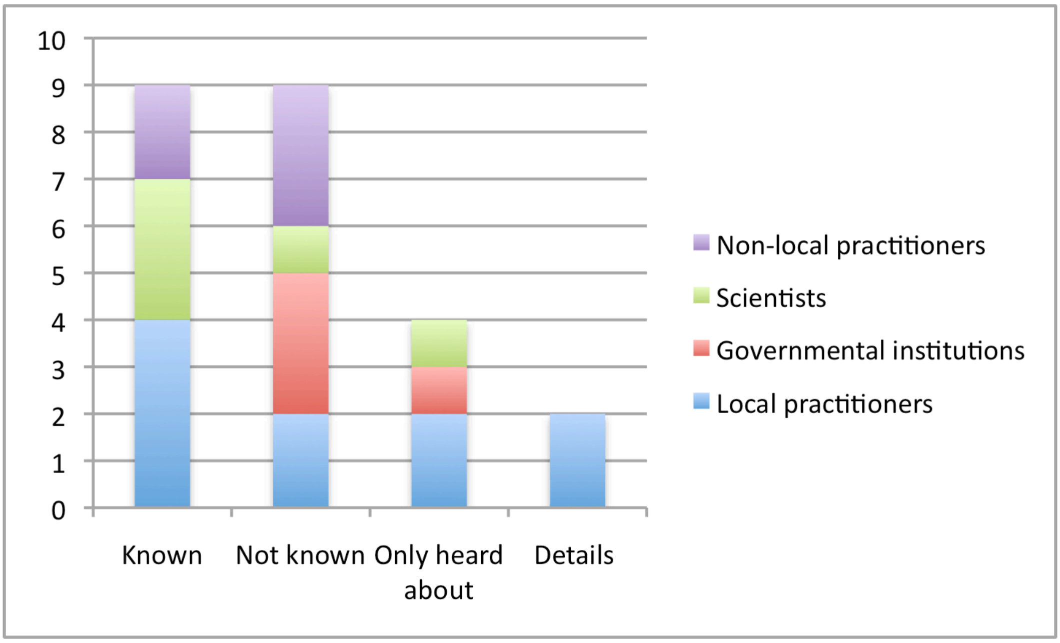

Fig. 16. General knowledge about Cat's Claw (Uncaria guianensis).

One scientist[39] said that Cat's Claw was used for its bark which was supposed to have medicinal properties. Two local practitioners[40] talked about twigs getting used. No other experts were able to give information about the used parts of the plant.

While the two local practitioners said that it was "very easy" and another one that it was "rather easy" to grow Cat's Claw, one non-local practitioner[41] said that it was "rather difficult" to be managed. He argued that being a vine Cat's Claw might damage the tree of the agroforestry system.

[38] Number 80 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Cat's Claw.

[39] Interview No. 14 on the CD enclosed.

[40] Interviews No.03 and 01 on the CD enclosed.

[41] Interview No. 19 on the CD enclosed.

The local practitioners[42] were the only ones who assessed the difficulty to transport Cat's Claw, respectively those parts of the plant that are getting used, and both stated that it was "very easy".

There was no expert who said that Cat's Claw was not recommendable for an agroforestry system, but only 50% of those who knew the plant species – three local practitioners and one scientist – who did recommend it.

The four experts who recommended Cat's Claw for agroforestry said that it was generally suitable for all four shade stages, but three out of them agreed on stage four as being most appropriate.

According to the low number of experts possessing detailed knowledge, only 17% of all interviewed experts (N=23) and 44% of those who knew Cat's Claw provided an assumption of its market potential and regional level of importance: they assessed its market potential as being "rather low" (22%), "rather high" (11%), and "very high" (11%). The scientist[43] and one local practitioner[44] saw its spatial level of importance to be at an international scale, one local practitioner[45] said it was of national and another one[46] that it was of regional importance.

3.3.5 Additional recommended plant species

Figure 17 shows the distribution of recommendations by different expert groups. Those experts that were interviewed recommended in total 68 species, most of them were recommended by scientists (38%) and employees of governmental institutions (32%). Sinke (personal communication 2011) of the Dutch company biosfeer-Groede (see chapter 2.5), who did not participate in the expert interview, provided a list containing 46 plant species that grow in tropical areas and to which he attributed a high market potential. Thus 111 plant species were mentioned, out of which eleven were recommended twice or threefold so that in total 100 different plant species needed to be checked (additionally to those pre-selected during literature review) for their suitability for agroforestry systems in Panama applying the criteria checklist.

[42] Interviews No.03 and 01 on the CD enclosed.
[43] Interview No. 14 on the CD enclosed.
[44] Interview No. 04 on the CD enclosed.
[45] Interview No. 03 on the CD enclosed.
[46] Interview No. 01 on the CD enclosed.

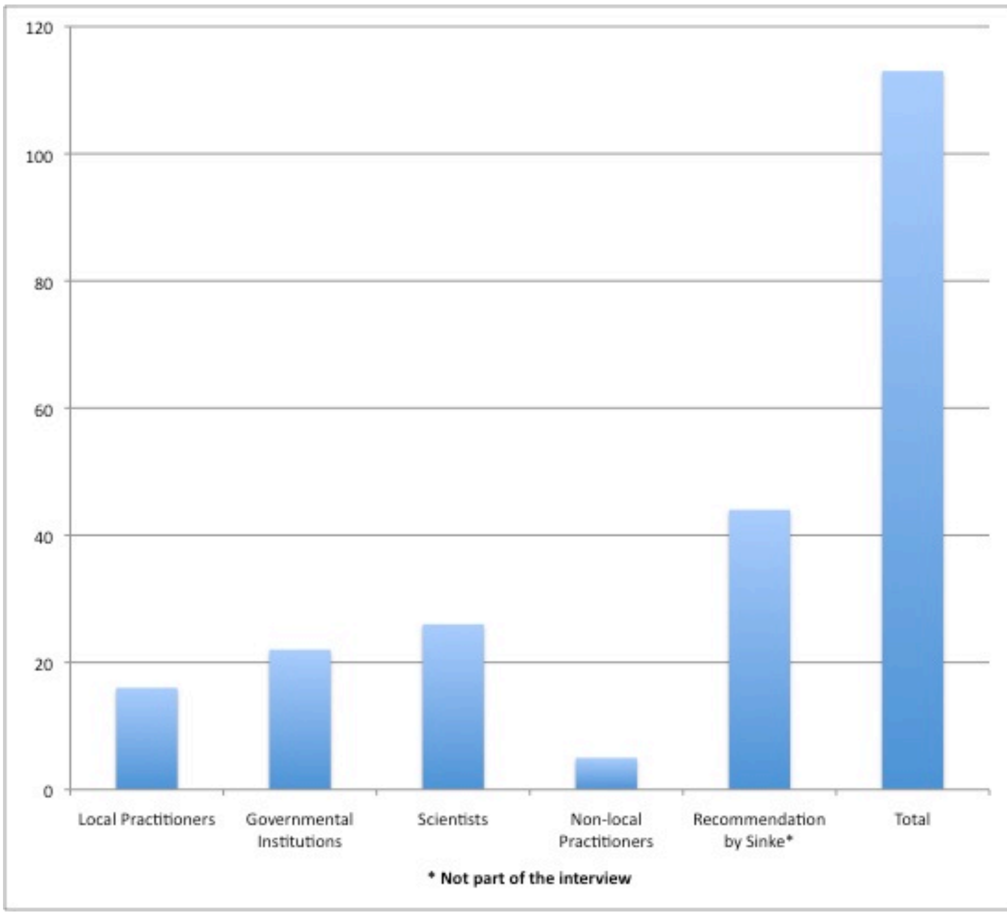

Fig. 17. Number of species recommended by expert group.

For shade stages one and three exactly the same amount of plant species were recommended (19 species each). For stage two it was 15 species, whereas for shade stage four 11 species were mentioned. In stages one, two and three it was three species in each stage that were mentioned twice or threefold, in stage four it was one species that was recommended by more than one expert. Furthermore six plant species were considered suitable for more than one shade stage.

The different expert groups recommended more or less equal amounts of plant species for the designed shade stages, numbers varied only slightly. Generally except from international scientist the expert groups knew least species to be recommended for shade stage four. The smallest number of recommendations by international scientists was for shade stage two.

One local Panamanian practitioner[47] running an organic supermarket in Panama City recommended three species due to their high market potential, but could not assign them to one of the shade stages. This was also the case

[47] Interview No. 04 on the CD enclosed.

with an international scientist[48] working as a professor for Pharmacology in Panama City, who mentioned six different plant species. The plant species provided by Sinke (personal communication 2011) were also not assigned to any shade stage, therefore 53 of the 100 recommended species could not be attributed to one of the shade stages.

Literature research was conducted following the expert interviews in order to find out if the suggested species were in fact suitable for the envisioned system in Panama. Figure 18 shows the number of species that were accepted and neglected. Besides the veto criteria explained above different criteria were chosen that made a plant species to be considered as not appropriate. These criteria are enlisted in Table 7.

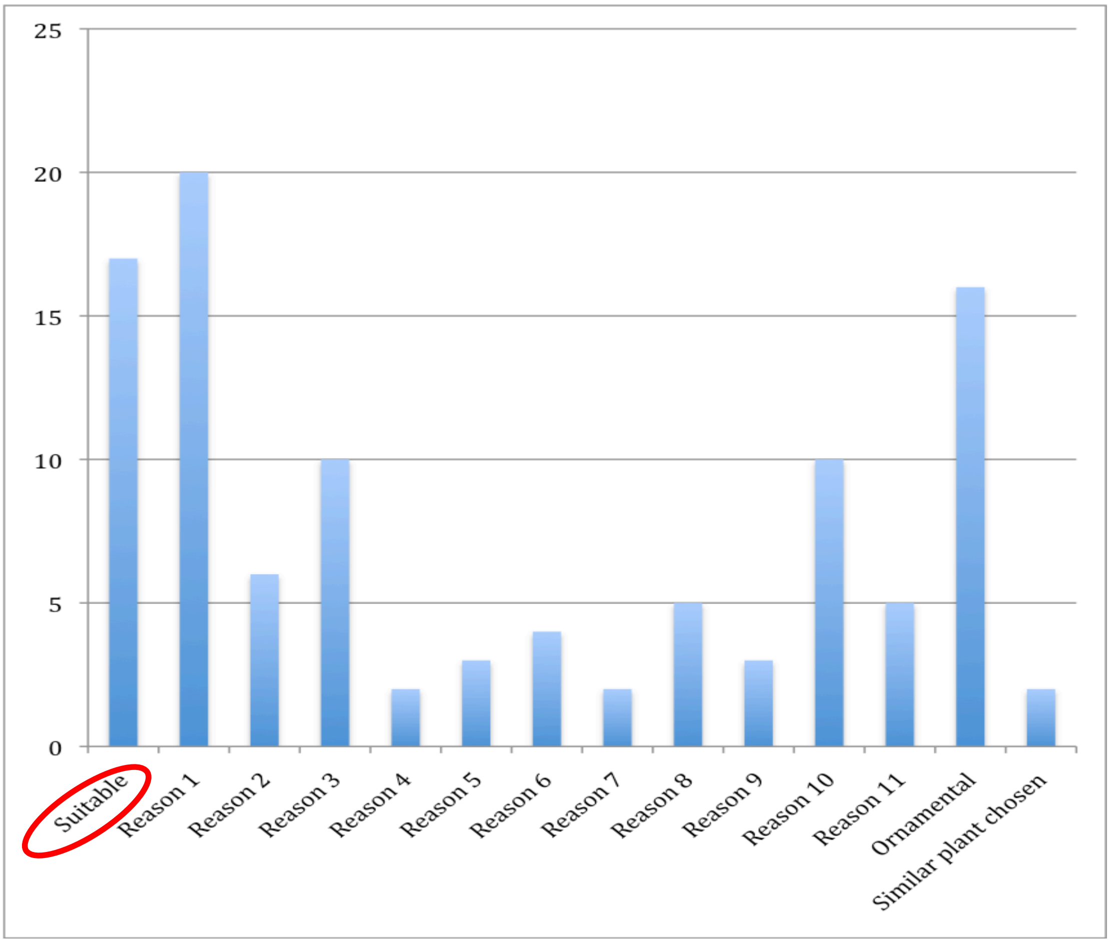

Fig. 18. Recommended plant species proven suitable and not suitable for an agroforestry system in Panama by reason (reasons see Table 7).

[48] Interview No. 14 on the CD enclosed.

Table 7: Reasons for excluding plant species from further investigation

Reasons for excluding plant species from further consideration:

1. Tree, too tall for AF
2. Exotic to Panama, not introduced yet
3. Invasive
4. Pure fruit tree
5. Not suitable for AF
6. Climatically not suitable
7. Staple food crop
8. Toxic/allelopathic
9. Already grown on large scale, highly scientifically investigated; possibly suitable, but neglected in the context of this thesis which deals with rather unknown species; furthermore it was suggested that local Panamanian farmers will be hardly able to compete on the market with suppliers that grow the plant species in question on large scale
10. Not enough scientific literature available in order to properly assess the suitability of the plant species
11. Could not be identified

All pre-selected and additionally in experts interviews recommended plant species will be displayed alphabetically by their Latin names in Table 8 including the expert group by which it was mentioned, as well as the suggested shade stage and if it was considered suitable respectively why it was neglected. Those plant species considered suitable are in bold letters. This list is also accessible on the enclosed CD. Suitable plant species are hyperlinked with the respective criteria checklist.

Table 8: All recommended plant species

	Latin Name	Common Names	Recommended by				Recommended for Shade Stage				Why recom-mended	Draw-backs	Accepted for AF in Panama?
			Local Pract.	Governm. Inst.	Scientist	Non-local Pract.	Stage 1	Stage 2	Stage 3	Stage 4			
1	Abelmoschus esculentus	Okra				x	x				3,8		No. Reason 2
2	Acanthea virilis	Potentiehout				x	Not known						No. Reason 1
3	Ageratum conyzoides L.	Billy goat weed				x	Not known						No. Reason 3
4	**Aloe Vera Auth.**			x				x					**Yes**
5	Ananas Lucidus (curauá)				x		x				1!		No. Reason 2
6	Annacardium occicentalis	Cashew				x	Not known						No. Reasons 1 & 5
7	Annona Muricata L.	Guanabana (Durian)				x	Not known						No. Reason 1
8	Areca catechu	Betel nut palm				x	Not known						No. Reason 1
9	Bactris gasipaes	Pifar	xx						xx				No. reason 1
10	Bixa orellana	Achiote, Annato			x	x	Not known						No. Reason 1
11	**Borojoa patinoi Cuatrec**	Borojó									1,2,3,4,5, 7,8	1,2,4,5	**Yes**
12	**Cananga odorata**	Cananga									1,2,6	3,4,5,7	**Yes**
13	**Capsicum frutescens**				x	x		x					**Yes**
14	Carapa guianensis	Andiroba				x	Not known						No. Reason 1
15	**Carludovica palmata**	Jipiijapa Palm, Panama Hat Palm		x				x	x		1		**Yes**
16	Cassia Alata L.	Candle bush				x	Not known						No. Reason 6

	Latin Name	Common Names	Recommended by				Recommended for Shade Stage				Why recom-mended	Draw-backs	Accepted for AF in Panama?
			Local Pract.	Governm. Inst.	Scientist	Non-local Pract.	Stage 1	Stage 2	Stage 3	Stage 4			
17	Catharantus roseus	Periwinkle				x	Not known						No. Reasons 3 & 8
18	Ceiba Pentandra	Kapok tree				x	Not known						No. Reason 1
19	Centratherum punctatum Cass.			x			x						No. Reason 10
20	**Cephaelis ipecacuanha; Psychotria ipecacuanha**	Ipecac			x		Not Known				7		**Yes**
21	Chenopodium ambrosioides L.	Worm seed				x	Not known						No. Reasons 8 & 10
22	Chrysophyllum cainito L.	Star apple				x	Not known						No. Reason 1
23	Chrysothemis pulchella (Donn. ex Sims) Decne	Corazón rojo		x					x				No. Reason 10
24	**Cissampelos pareira L.**	Abuta		x		x			x				**Yes**
25	Coffea canephora	Coffee	x	x				xx			1,3,6		No. reason 9
26	Copeifera officinalis	Copaiba Balsam				x	Not known						No. Reason 1
27	**Coriandrum sativum**	Coriander, Culantro		x			x	x			2,4		**Yes**
28	**Costus scaber**	Caña agria	x				x						**Yes**
29	Curcuma longa	Turmeric			x		Not known				2		No. Reason 2

No.	Latin Name	Common Names	Recommended by				Recommended for Shade Stage				Why recom-mended	Draw-backs	Accepted for AF in Panama?
			Local Pract.	Governm. Inst.	Scientist	Non-local Pract.	Stage 1	Stage 2	Stage 3	Stage 4			
30	Cyca circinalis				x					x			Ornamental
31	Cyca revoluta				x					x			Ornamental
32	**Cymbopogon citratus**	Lemon grass		x	x	x	x				6,2		**Yes**
33	Elaeis guinensis	Obe palm				x	Not known						No. Reason 1
34	Euterpe oleracea	Acai	x				Not known				1		No. reason 1
35	Eugenia dombeyi					x	Not known						No. similar species already pre-selected
36	Eugenia M. vexator Mayrciaria cauliflora					x	Not known						No. similar species already pre-selected
37	**Eugenia stipitata McVaugh**	Arazá									1,7	1,5	**Yes**
38	Glycine max	Soya				x	x				7,8,6		No. Reason 9
39	Guazuma ulmifolia	Guasimo	x				x				1,2		No. reason 1
40	Harpagophytum procumbens	Duivelsklauw				x	Not known						No. Reason 6
41	Hedychinum coronarium J. König (Heliotropo)			x					x				No. Reason 3
42	Hura Crepitans L.	Sandbox tree				x	Not known						No. Reason 1
43	Hymenaea courbaril L.	Jatoba				x	Not known						No. Reason 1

No.	Latin Name	Common Names	Recommended by				Recommended for Shade Stage				Why recom-mended	Draw-backs	Accepted for AF in Panama?
			Local Pract.	Governm. Inst.	Scientist	Non-local Pract.	Stage 1	Stage 2	Stage 3	Stage 4			
44	Justicia pectoralis	Tilo		x			x						No. Reason 10
45	Kalanchoe pinnata (Lam.) Pers.	Siempre viva		x				x					No. Reason 3
46	Lagerstroemia speciosa L.	Queens flower				x	Not known						No. Reason 1
47	Lippia Americana L.			x			x						No. Reason 10
48	Lundia sp. (Siko)			x						x			No. Reason 10
49	Manihot esculenta L.	Cassava				x	Not known						No. Reason 7
50	**Mansoa alliacea**	Ajo Sacha Hembra				x	Not known						**Yes**
51	Massangeana				x				x		4		Ornamental
52	**Momordica charantia L.**	Bitter Melon				x	Not known						**Yes**
53	Morinda citrifolia	Noni				x	Not known				1,2,7	1,3	No
54	Ocimum sanctum L.	Holy basil				x	Not known						No. Reason 2
55	**Orchidaceae**	Orchid species		xx			x			x	1,8,2		**Yes**
56	Passiflora edulis	Maracuya	x						x		2		No. reason 4
57	**Paullinia cupana**	Guaraná			x				x				**Yes**
58	Petiveria alliacea	Anamu	x				x	x	(x)	(x)	1		No. Reason 8
59	Phlebodium Decumanum	Calaguala				x	Not known						No. Reason 10

No.	Latin Name	Common Names	Recommended by				Recommended for Shade Stage				Why recom-mended	Draw-backs	Accepted for AF in Panama?
			Local Pract.	Governm. Inst.	Scientist	Non-local Pract.	Stage 1	Stage 2	Stage 3	Stage 4			
60	Phyllanthus amarus & niruri	Shatterstone				x	Not known						No. Reason 3
61	Phyllanthus urinaria L.	Changa piedra				x	Not known						No. Reasons 3 & 8
62	Physalis angulata L. - Mullaca	Wild tomato				x	Not known						No. Reason 3
63	Piper nigrum	Black pepper, Pimienta		x						x	2,1,3		No. Reason 5
64	Psidium guajava	Guava				x	Not known						No. Reason 1
65	Punica granatum	Pomegranate, grenadine	x				Not known				1		No. reason 6
66	Quassia amara				x	x	Not known						No. Reason 1
67	Ricinus communis L.	Castor bean				x	Not known						No. Reason 8
68	Scoparia dulcis L.	Sweet broom				x	Not known						No. Reason 3
69	Sechium edule	Chayote	x			x			x				No. Reasons 4 & 10
70	Simarouba officinalis	Dysentery bark				x	Not known						No. Reason 1
71	Siphonochilus aethiopicus	African ginger				x	Not known						No. Reason 2
72	Smilax officinalis	Sarsaparilla				x	Not known						No. Reason 5
73	Stachytarpheta cayennensis	Verbena				x	Not known						No. Reason 5
74	Stizophyllum riparium (H.B.K.) Sandw.			x					x				No. Reason 10

No.	Latin Name	Common Names	Recommended by				Recommended for Shade Stage				Why recom-mended	Draw-backs	Accepted for AF in Panama?
			Local Pract.	Governm. Inst.	Scientist	Non-local Pract.	Stage 1	Stage 2	Stage 3	Stage 4			
75	Sutherlandia frutescens	Kankerbossie (Pinitol ws)				x	Not known						No. Reason 2
76	Syzygium cumin L.	Jamun				x	Not known						No. Reason 1
77	Tabebuia serratifolia	Pau D'arco				x	Not known						No. Reason 1
78	Taraxacum officinale Weber e F.H. Wigg	Diente de Léon		x				x					No. Reason 3
79	Theobroma cacao	Cocoa	x					x					No. reason 9
80	**Uncaria guianensis**	Cat's Claw				x	Not known				1,2,7	1,2	**Yes**
81	Valeriana officinalis	Valeriana	x	x			xx				7,6,3,2		No. reason 6
82	**Vanilla planifolia**	Vanilla			x					x			**Yes**
83	Xanthosoma violaceum Schott	Otoe				x		x			1,2,4	4	No. Reason 7
84	Zamia furfuracea				x					x			Ornamental
85	Zamia obligua				x					x			Ornamental
86	Zebrina pendula Schnizl	cucaracha		x				x					No. Reason 10
87	**Zingiber officinale**	Ginger, jengibre, Ingwer	x			xx		xx	x		1,2,3,4,6, 7,8	1,4,6	**Yes**
88		Aglonemas			x				x				Ornamental
89		Alpinias			x				x				Ornamental
90		Anturios			x				x				Ornamental

No.	Latin Name	Common Names	Recommended by				Recommended for Shade Stage				Why recom-mended	Draw-backs	Accepted for AF in Panama?
			Local Pract.	Governm. Inst.	Scientist	Non-local Pract.	Stage 1	Stage 2	Stage 3	Stage 4			
91		Bodar		x				x					No. Reason 11
92		Buganvilia			x		x						Ornamental
93		Calatea			x				x				Ornamental
94		Croton			x		x						Ornamental
95		Galera de mono	x						x		1,7		No. Reason 11
96		Jazmines			x		x						Ornamental
97		Mata de limon		x				x					No. Reason 11
98		Mint			x		Not known						No. Reason 3
99		Palmera cubana			x			x			2,1		Ornamental
100		Raiz de India	x				x	x	x	x	1		No. Reason 11
101		Roelias			x		x						Ornamental
102		Sebrinos			x				x				Ornamental
103		Shatlera			x		x						Ornamental
104		Vehuco de estrella	x							x	1		No. Reason 11

Reasons for being neglected for Agroforestry Systems in Panama:

1 tree, too tall for AF
2 exotic to Panama, not introduced yet
3 weedy/invasive
4 pure fruit tree
5 does not grow with trees & shrubs/not suitable for AF
6 climatically not suitable
7 staple food crop
8 toxic/allelopathic
9 already grown on large scale, highly scientifically investigated
10 not enough scientific literature available in order to properly assess the suitability of the plant species
11 could not be identified

Reasons for recommendations:*

1 Good market situation/potential
2 Easy management
3 Suitable for agroforestry systems
4 Good adaptation to environments
5 Accepted by local farmers
6 Provision of environmental benefits
7 Medicinal properties
8 Good taste/smell/nutritional value

* categorized answers of interviewed experts

Mentioned Drawbacks:*

1 Bad market situation
2 Difficult management
3 Not suitable for agroforestry systems
4 Much knowledge needed
5 Limited availability of seeds
6 Environmental conditions are not suitable
7 Takes long for first returns
8 Labour intensive

* categorized answers of interviewed experts

Out of the 104 different plant species 17% were considered suitable and checked in more detail. 20% of the mentioned species were neglected, because they are tree species with a height of more than 6m and therefore not within the focus of the research. Still they were included in the table. 10% each were taken out of the consideration, because they showed invasive properties, or because there was not enough scientific literature available to properly assess the species' suitability. 18% were generally suitable, but they were disregarded, because similar plant species were already selected for detailed consideration or because they were ornamental plants which were due to personal observation assumed to be of rather low market potential in Panama because the target group who could afford ornamental plants was considered low respectively because keeping ornamental plants in homes was observed to be rather uncommon. For this reason only one ornamental plant species was mentioned in this thesis (see chapter 3.3.5.11). These are the main reasons for neglecting plant species.

The plant species considered suitable will be briefly described below. As four of the 17 possibly suitable species were already pre-selected, only 13 will be displayed here.

Due to the fact that the plant species were recommended in the interviews, they could not have been checked for further feedback by the other interviewed experts. Therefore the descriptions below refer solely to scientific literature and the knowledge of the very expert who recommended the species.

The grading of the plant species applying the numerical results of the criteria checklists will be displayed for all described plant species at the end of this chapter (see chapter 3.3.6).

3.3.5.1 Aloe Vera (*Aloe Vera* Auth.)[49]

Though Aloe Vera – probably native to the Arabic region, Sudan or southern Africa – generally prefers hot and dry climates with extremely hot summers, it adapts to more humid environments, so that it is also grown in most tropical and subtropical countries including Latin America (Tripathi et al. 2011; Christaki & Florou-Paneri 2010; Straubinger 2004). Furthermore it was recommended by an employee of a Panamanian governmental institution for stage 2 of an agroforestry system in Panama.

[49] Number 4 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Aloe Vera.

There was no information available on site related requirements of this cactus-like, perennial plant which grows up to one meter in height (Christaki & Florou-Paneri 2010; Straubinger 2004), but as it was said to be grown in Latin America it was assumed, that the site conditions are suitable. It grows usually in sunny areas, but according to Straubinger (2004) it grows equally well under shade conditions.

Aloe Vera leaves mainly get used in the medicinal, cosmetic and also health food industries (in the latter as an environmentally friendly and natural alternative for synthetic preservatives, and as a nutritional complement containing vitamins, minerals and essential fatty acids), but it also gets planted as an ornamental (Tripathi et al. 2011; Christaki & Florou-Paneri 2010; Mason 2007; Webb 2006; Straubinger 2004). The beneficial medicinal effects (reduction of acute external inflammation, promotion of wound healing; lowering the concentrations of blood glucose in diabetes and levels of blood lipid) are scientifically proven (Mason 2007). Leaf extracts are highly demanded and are processed to gel, oil, powder, granules, and capsules and marketed throughout the world (Webb 2006; Straubinger 2004). However, Aloe Vera gel can also have adverse effects, i.e. lead to allergies and eczema or might be tumour promoting (Christaki & Florou-Paneri 2010).

A drawback connected to the plant species is on the one hand that the desired liquid is only produced by the plant three to five years after planting, and on the other hand that due to its high demand it has already been cultivated on big scale in the USA, Australia and Spain (Straubinger 2004). According to Christaki & Florou-Paneri (2010) the gel of the leaves oxidises quickly.

3.3.5.2 Cayenne Pepper *(Capsicum frutescens)*[50]

Capsicum frutescens, was recommended for stage 2 of an agroforestry system by a scientist[51] as well as a non-local practitioner (Sinke – apart from interview). Commonly known as Red, Bird, Chilli, Cayenne, Guinea Pepper or Ají, it has been domesticated in Central America probably thousands of years ago. It was first grown in Panama from where it subsequently spread first to the neotropics and thereafter almost pan-tropically (Francis – no date a). Therefore the given site conditions in Panama suit the plant species. The perennial shrub, which is easily established (Katzer 2012) and commercially usually grown on an annual basis, becomes up to 1.2-2m high (depending on

[50] Number 13 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Cayenne Pepper.

[51] Interview No. 15 on the CD enclosed.

author: Dave's Garden 2012a: 1.2m; FAO Ecocrop 2007a: 2m; Francis – no date: 1.5m). According to Francis (no date a) it grows best in full sun but can handle some broken shade.

Fruits of the plant can be harvested for the first time 3-6 months after sowing and afterwards continuously throughout the year amounting to roughly 1t/ha (dried chillies) at low financial input and up to 5.5t/ha with more input (Katzer 2012; FAO Ecocrop 2007a; Francis – no date a). They are easily stored as whole fruits or powder under refrigeration and are used as a spice, as medicine (relieves muscles, joint and toothache, treats cough, asthma and a sore throat, among others), personal protection (pepper spray) and for deterring browsing animals. The plant is susceptible to several insect species, however, serious impacts are not very common (Francis – no date a).

3.3.5.3 Panama Hat Palm (*Carludovica palmata*)[52]

As the common name of the plant species already suggests, *Carludivica palmata* is a palm tree used for the production of the famous Panama hats which grows in tropical and subtropical climates (Pacific Island Ecosystems at Risk 2010). It was recommended for an agroforestry system in Panama by an employee of a governmental institution[53]. Because the trees are harvested for their leaves, but no plants are replanted, the species is according to the expert more and more disappearing. Being an understory plant species, it needs shady to partially shady conditions. It becomes up to 3-5m high (Dave's Garden 2012c; Pacific Island Ecosystems at Risk 2010 & 2002).

In Puerto Rico it is listed as a weed, because it invades disturbed habitats – however, there is no evidence for being a weed in agriculture, forestry or horticulture (Pacific Island Ecosystems at Risk 2010).

Besides using the leaves for the Panama hats they are also getting used as construction material for cords and thatches, to manufacture baskets, brooms, hunting traps and for medicine. Palm hearts and fruits can be eaten, and in Peru seeds are taken to produce oil (Bennett et al. 1992). The plant's value for the hat industry is higher than the importance it has for local people, though the return from crafts, edible shoots and roof thatches could be higher than those generated from hat production. For this reason and because the plant species grows in widespread but underutilized disturbed and open areas, Bennett et al. (1992) attribute a potential for increased cultivation while avoiding further destruction of primary forests. They address the highest

[52] Number 15 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Panama Hat Palm.

[53] Interview No. 09 on the CD enclosed.

est market potential to the palm heart, though harvesting this will kill the plant, while shoot harvesting could be done sustainably.

Information regarding the spacing between plants vary between authors: while the authors of Dave's Garden (2012c) state that a spacing of 2.4-4.7m would be appropriate, the interviewed expert recommended a spacing of 1x1m.

There was no information available on the economic criteria such as costs for seedlings, yields and market prices of end products, but Blaser et al. (2011) mention it as an important fibre plant in Panama. But as hats, mats, baskets and roof thatches are manufactured by hand, the interviewee stated that no investment in machinery will be needed. He recommended it for an agro-forestry system due to its high market potential. Shade stages 3 and 4 are most suitable.

3.3.5.4 Ipecac (*Cephaelis ipecacuanha*)[54]

Ipecac was recommended by a scientist[55] who is working as a Professor for Pharmacology at the Universidad de Panama. The long-living plant species is native to Panama, among other countries in Central and South America, and is rare nowadays, as wild plants are harvested for the market and because its habitat gets destroyed and degraded. The expert explained that so far production only takes place in India. This was underlined by scientific literature where it says that only a small fraction of the world demand is cultivated in India (USDA ARS 2012; de Oliveira et al. 2010). It is a perennial herb or shrub of up to 0.2m height that grows in the shaded understory of other plants and cannot handle direct, permanent sunlight. For this reason it is highly sensitive to habitat changes which allow sunlight to penetrate the formerly closed canopy (FAO Ecocrop 2007; de Oliveira et al. 2010; Salick 2006).

There was hardly information found about the plant-related characteristics of the plant species, but different authors (e.g. Brandão et al. 2012; de Oliveira et al. 2010; Kutalek & Prinz no date) state that it is cultivated for its roots which have medicinal properties. Also the interviewed expert argues that it is highly effective and today used especially in emergency medicine, as the medicinal effect is scientifically proven – according to Brandão et al. (2012) the plant species was included in the list of pharmacopoeia of many countries and the WHO.

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[54] Number 20 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Ipecac.

[55] Interview No. 14 on the CD enclosed.

There were also hardly data available on economic aspects. De Oliveira et al. (2010) and Brandão et al. (2012) state that commercial harvesting started in Brazil in the 18th century, when about four tonnes were annually transported to Portugal. The interviewee attributes a high market potential to the plant due to its high economic and medicinal value.

3.3.5.5 Abuta (*Cissampelos pareira* L.)[56]

While not mentioned by name that Abuta is native to Panama, it was recommended by an employee of a governmental institution[57] for stage 3 of an agroforestry system in Panama, and various authors state that it was native to tropical America, respectively from Mexico to Argentina (Singh et al. 2010; Gupta 2008; Francis no date b). Information on site-related requirements were scarce, but needed elevation and precipitation range are in accordance with given conditions in Panama. Its natural habitat consists of secondary & remnant forests and brushy pastures, among others (Gupta 2008; Francis no date b).

Abuta is a perennial climbing woody shrub or vine that reaches 3-6m up into the canopies of trees or along the ground. It grows very quickly and becomes up to 3m long within the first year. Though it is a vine that grows in combination with trees, it is rather intolerant of shade and therefore prefers open and disturbed forests. It has beneficial impacts on the soil, provides fodder for wildlife, but its main usage lies in its medicinal properties (e.g. Natural Resources Conservation Service 2012a; Singh et al. 2010; Taylor 1996a; Francis no date b). According to Singh et al. (2010) and Taylor (1996a) several medicinal effects are scientifically proven, including anti-pain, anti-inflammatory, antioxidant, anti-fertility, antibacterial, anti-malarial and anti-cancer – any safety concerns regarding toxicity could not be found in testing. All parts of the plant are used for these purposes, and they are getting processed to decoction, tincture, capsules, gel and juice (Jessurun 2012a; Singh et al. 2010; Gupta 2008; Taylor 1996a).

Taylor (1996a) states that Abuta has been used as a medicinal plant for thousands of years, and that those products are also used in North American herbal medicine. According to Francis (no date b) that plant products are sold throughout the world. While there was hardly any further information available on economic aspects, Francis (no date b) further recommends to protect the plant from heavy grazing in order to guarantee a good production. As it

[56] Number 24 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Abuta.

[57] Interview No. 12 on the CD enclosed.

flowers and fruits throughout the year, harvest could take place at any time of the year.

3.3.5.6 Coriander (*Coriandrum sativum*)[58]

Coriandrum sativum is commonly known as coriander, if grown for its dried seeds – if its leaves are meant, it is called cilantro (Washington State University 2008; Christman 2003).
According to scientific literature the plant is not suitable for the given conditions in Panama, because it prefers rather dry and cool climates, as it suffers from humidity, rain and high temperatures (UMassAmherst USDA 2012; Washington State University 2008; Christman 2003;). However, it was recommended by an employee of MIDA in Panama[59], who stated that it was introduced to Panama and became very widespread.
Referring to the expert and scientific literature it is an easily cultivated annual herb that grows up to 5.0-0.9m high and requires full sun to light shade. Though it has not been grown in agroforestry systems yet, the interviewed expert attributes it a beneficial interaction with trees. Pests and diseases are rarely reported, also a great need for fertilization was not connected to this plant species (NC State University 2012; Plants for a Future 2012; UMass-Amherst USDA 2012; Christman 2003).
Though mainly planted for the seeds and leaves, some authors (Katzer 2012a; Washington State University 2008; Christman 2003) report that also roots are used. The plant itself works as a repellent for aphids, leaves are used as a spice, while essential oil made from the seeds is used as a flavour, in perfumery and soap production. Roots are also used in perfumery, but additionally have a medicinal effect: a beneficial effect on cholesterol and triglyceride levels as well as antibacterial activity was scientifically proven. According to the interviewee plant products can easily be transported and stored, as they are getting processed to powder, oil, condiment or essential oil, while fresh leaves only have a short shelf life. (Plants for a Future 2012; Dhanapakiam 2008; Washington State University 2008; Lo Cantore et al. 2004; Christman 2003).

According to the interviewed expert there is an existing market for plant products in Panama, as leaves are sold at markets, in restaurants and butchers, whereas a liquid extract from the roots is sold to pharmaceutical companies who in turn export it. Harvest takes place once about 40-60 days after seed-

[58] Number 27 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Coriander.
[59] Interview No. 11 on the CD enclosed.

ing, therefore continuous planting is needed for constant supply (UMassAmherst USDA 2012; Washington State University 2008). The employee of MIDA recommended the plant species for stage 2 of an agroforestry system because of its easy management and good adaptation to different environments, but he also said that a lot of knowledge is needed to grow it.

3.3.5.7 Caña Agria (*Costus scaber*)[60]

Costus scaber, commonly called Caña Agria, Spiral Ginger, Wild Cane or Indian Head Ginger, was recommended by a Panamanian local practitioner[61] for stage 1 of an agroforestry system. Not a lot of information could be found, but it is native to Panama, where its preferred natural habitats are old tree-fall areas or open, disturbed sites and open forests. According to different authors this perennial herb becomes between 1.2m and 2.4m high and grows best in partial shade and rather dark places (Odenwald & Pope 2012; University of Connecticut 2012; University of North Florida 2012; Gupta 2008; Croat no date). The local practitioner states that Caña Agria was very easily established and that neither fertilizers nor herbicides and pesticides are needed to grow it. It is suitable as a cut flower, as it was very long lasting, but it is also cultivated for its medicinal properties – it is supposed to cure bladder and urinary problems as well as high cholesterol levels (University of Connecticut 2012; Lans 2006). However, literature confirming these properties could not be found.

Regarding the economic aspects literature was also scarce, but Odenwald & Pope (2012) as well as the interviewed Panamanian expert say that the maintenance level was very low, that no processing was necessary, and that 15cm of spire have a market price in Panama of US$3.

[60] Number 28 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Caña Agria.

[61] Interview No. 01 on the CD enclosed.

3.3.5.8 Lemon Grass (*Cymbopogon citratus*)[62]

According to scientific literature Lemon grass – also called Ginger Grass or Citronelle – is not native to Panama or Central America, but probably to India, Malaysia or Sri Lanka (Figueirinha et al. 2010; Scheper 2008; FAO Ecocrop 2007b; Katzer 2007). Nonetheless it was recommended by three different experts: an employee of the Panamanian governmental institution Idiap[63], a scientist[64] and a non-local expert (Sinke, apart from interviews). Furthermore it is widely cultivated in Panama (personal observation 2011). The FAO (Ecocrop 2007b) recommends the grass as a useful agroforestry plant with an economical life of four years, which becomes up to 1.2m high.

While it grows best in full sun, Scheper (2008) and Jessurun (2012b) state that it tolerates light shade. On its homepage the Missouri Botanical Garden (no date) states that Lemon Grass is easily established and hardly vulnerable to diseases. Different authors (e.g. Arnold 2011; Scheper 2008; Katzer 2007) attribute various uses to the plant: as a culinary and medicinal herb, ornamental plant, uses for the perfume industry, and also soil protection. This was also indicated by the employee of Idiap. The medicinal effects (anti-inflammatory properties, but also used against cough, cuts, headache, bladder disorders and asthma – Jessurun 2012b; Figueirinha et a. 2010) are scientifically confirmed.

Leaves can be harvested for the first time 120-140 days after planting and afterwards in an interval of 90-120 days. The yields are up to 0.2-0.4% of oil which accumulates to an average of 50-120 kg oil/ha/yr (FAO Ecocrop 2007b). International market prices are US$18/lb for herb and US$11.55/30ml for tincture (Jessurun 2012b).

The interviewed expert working for Idiap in Panama recommended it for stage 1 of an agroforestry system in Panama due to its easy management and environmental benefits.

62 Number 32 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Lemon Grass.

63 Interview No. 12 on the CD enclosed.

64 Interview No. 14 on the CD enclosed.

3.3.5.9 Garlicvine (*Mansoa alliacea*)[65]

Garlicvine, also called Bejuco de ajo, was recommended by a non-local expert (Sinke – apart from interviews). According to das Graças Bichara Zoghbi et al. (2009) it is native to Central and South America. Being a perennial vine, it has been commonly planted next to a tree, and it has been tested as a method to control shoot borers (*Hypsipyla* sp.) when combined with Cedrela or Swietenia (Natural Resources Conservation Service 2012b; Rainforest Conservation Fund 2012; das Graças Bichara Zoghbi et al. 2009;). However, the results of these investigations were not mentioned. It requires conditions with about 40% of shade. Its leaves, bark, roots and flowers can be used as a spice and as medicine. The plant is also grown as an ornamental. Various medicinal effects (lowering cholesterol levels, properties against fever, rheumatic pains, cough, malaria, among others) are scientifically proven. The plant parts are getting processed to powder, decoction, tincture and capsules which are easily transported and stored. In this form they are exported to the USA, Brazil and Peru (Rainforest Conservation Fund 2012; das Graças Bichara Zoghbi et al. 2009; Taylor 1996d; Taylor 1996e).
However, there were no economic data available, as the plant parts are so far only collected wildly from the forest and commercial plantations are very rare (das Graças Bichara Zoghbi et al. 2009).

3.3.5.10 Bitter Melon (*Momordica charantia* L.)[66]

Bitter Melon – or Balsam Apple, respectively Balsam Pear – was also recommended by the non-local expert (Sinke – apart from interviews). According to Hall et al. (2012) it is native to tropical America. It is an annual vine with different parts (fruits, seeds, roots, fruit pulp) being used as food and medicine. Nearly 100 studies have proven and verified many traditional medicinal uses including blood sugar and cholesterol lowering effects as well as its anti-tumorous and antioxidant activities. The plant parts are getting processed to decoction, tincture, capsules, powder and pulp, which is mainly exported to the USA. It is also used in Panama and other countries of Meso- and South America, China, India and Malaysia (Hall et al. 2012; Imhof 2012; Semiz & Sen 2007; Raintree Nutrition Inc. 1996b;). While information on economic aspects was not available, the following market prices were found

[65] Number 50 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Garlicvine.
[66] Number 52 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Bitter Melon.

online: US$218.15 for 1.000 seeds; US$22 per pound of herbs; US$11.55 for 30ml of tincture (Jessurun 2012c).

3.3.5.11 Orchids (*Orchidaceae* spp.)[67]

Orchidaceae is a very widely distributed plant family that can be found on all continents and climate zones except for pure deserts and polar zones. They can either grow on the ground or on trees. Although they grow on trees it is important to mention that various authors (Arnold 1994a; Rittershausen et al. 1993; Röllke 1993; Kohls & Kähler 1992; Pinske 1981) underline that they have no parasitic properties – they only chose this habitat to perceive more sunlight than they could get on the ground of dense forests.
The two experts of the Panamanian governmental institutions MIDA[68] and Idiap[69] who recommended orchids to be implemented in agroforestry systems also said that they do not harm the trees and that they are easily established. The expert of MIDA added that first the right light and humidity conditions as well as fertilization have to be determined which is not too easy, as they need some shade but still enough light. However, Arnold (1994a), Kohls & Kähler (1992) and Pinske (1981) argue that fertilization is generally not necessary, as the plant takes up nutrients from rainwater and dew. Additionally the Panamanian experts added that this is the case especially in the Panamanian environment where there is a lot of rainwater.

While orchids are generally used as a highly prized ornamental plant species that should – according to the interviewed experts – be grown close to a market as twigs can break easily during transportation, rhizomes can also be used for medicinal purposes which are meant to enhance libido, fertility and wound healing and work against diarrhoea (Senghas 1993).
Orchids are generally not susceptible to diseases, but it needs to be considered that a phytosanitarian permission is needed for exporting orchids on an international basis. Furthermore it takes 2-3 years until they produce first flowers (Arnold 1994a; Rittershausen et al. 1993; Pinske 1981).
While the employee of MIDA (when asked in the interview) attributed orchids a rather high national (in Panama) and international market potential, the expert of Idiap said that the national and international market potential is rather low. Both experts agree that the target group in Panama was rather small,

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[67] Number 55 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Orchids.
[68] Interview No. 08 on the CD enclosed.
[69] Interview No. 11 on the CD enclosed.

because the end product was so expensive that it was not affordable by the average Panamanian. However, their assessments of market prices vary greatly: The expert of MIDA puts it at US$80 per plant, whereas the expert working at Idiap states that a plant costs around US$5 per plant.
The two experts mainly recommended Orchids for agroforestry systems due to its easy management and good adaptation to different environments, as well as for its high market value and nice smell. While MIDA's expert recommended it for stage one of an agroforestry system, the employee of Idiap said it was suitable for stage 4.

3.3.5.12 Guaraná (*Paullinia cupana*)[70]

Guaraná was recommended by one scientist[71]. There is no information available on site requirements. Erickson et al. (1984) and the Committee on Herbal Medicinal Products (CHMP) (2012) state that it is native to the Amazonian rainforest. The interviewed expert said that the perennial vine was already successfully grown in agroforestry systems, mainly in Brazil, and that it is suitable for stage 3. The CMPH (2012) describes that stems, leaves and roots are used as a fish killing drug in Central and South America. Mainly the seeds and fruits of the plant are used. They are processed to drinks, food, medicine and shampoo. It has a variety of medicinal usages, which have been applied especially in traditional medicine by indigenous populations for centuries. Nowadays it is getting traded throughout the world, as some of the effects have been scientifically proven and powder, capsules and tincture can be easily transported and stored: It was exported to the USA and France in the 19th century and has also been sold in the Orient. Due to its high demand and expanding international markets seeds have been produced commercially in the Amazon (mainly Brazil) on 6.000 ha (CHMP 2012; Campos et al. 2010; Taylor 1996c; Erickson et al. 1984).

3.3.5.13 Vanilla (*Vanillia planifolia*)[72]

Vanilla was recommended by the same scientist[73]. It is a widely known plant species native to Central America and Mexico. Although it is a vine, no negative interactions with tutor tree species are reported. Due to its high market potential and an economic life of 10-15 years it has become a recommended

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[70] Number 57 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Guaraná.
[71] Interview No. 15 on the CD enclosed.
[72] Number 82 in the plant list provided on the CD enclosed. The Latin name is hyperlinked, which leads directly to the criteria checklist of Vanilla.
[73] Interview No. 15 on the CD enclosed.

agroforestry plant species, especially for sites containing a diversity of tree species with different heights.

A drawback, however, is the fact that the plant species takes 3-5 years for the first flowering – though plants propagated from longer cuttings are supposed to fruit 1-2 years after planting. Furthermore flowers have to be pollinated manually which requires a lot of knowledge and experience.

Vanilla has a wide usage as a spice, for high-quality confectionery, ice cream, but also in the perfume industry, for soaps and as a medicinal plant. As the plant species has been highly investigated, further information is available for example by FAO Ecocrop (2007c) and Naturland (2000).

The results of literature research, criteria checklist and expert interviews led to the development of different scenarios (see chapter 5.2) about how to combine which plant species in agroforestry systems in Panama. However, for the sake of clarity, these will be displayed in the recommendations, as the plant species analysed above were not tested for their de facto suitability in practical trials, so that the scenarios can only be suggestions. Practical investigations need to be the next step for a proper and comprehensive assessment of each plant species and possible combinations in agroforestry systems.

3.3.6 Grading of plant species due to values of the criteria checklists

In this subchapter the grading of every single plant species analyzed in this study shall be displayed according to the application of the criteria checklist.

Site-related Criteria

Within the section of the site-related criteria a **maximum of 60 points** could be reached according to the suitability of the plant species to the given climatic and environmental conditions. Figure 19 shows that the suitability varied greatly: The six most suitable plant species for the Panamanian conditions were found to be Orchid species, Ginger, Noni, Vanilla and Arazá, reaching values between 51 and 39.

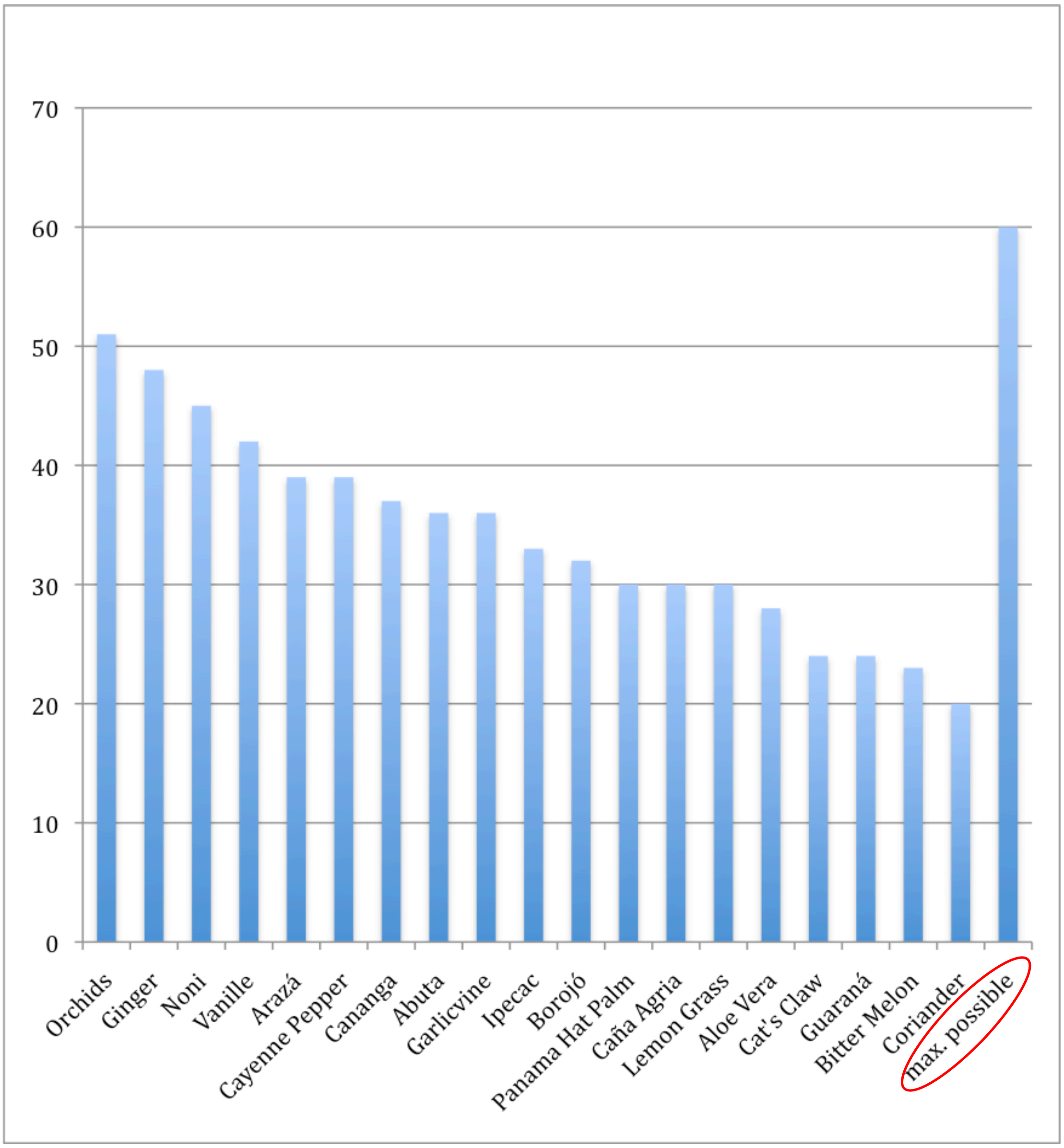

Fig. 19. Site-related grading of investigated plant species.

Those that were less suitable according to site-related criteria were Coriander, Bitter Melon, Guaraná, Cat's Claw and Aloe Vera with values of 20-28. While Orchids gained 85% of the possible 60 points, Coriander reached 33%. The latter plant species were not suitable for the Panamanian environment according to scientific literature, or not much literature was available on site requirements.

Plant-related Criteria

As Figure 20 shows the discovered circumstances for the plant-related criteria were very different.

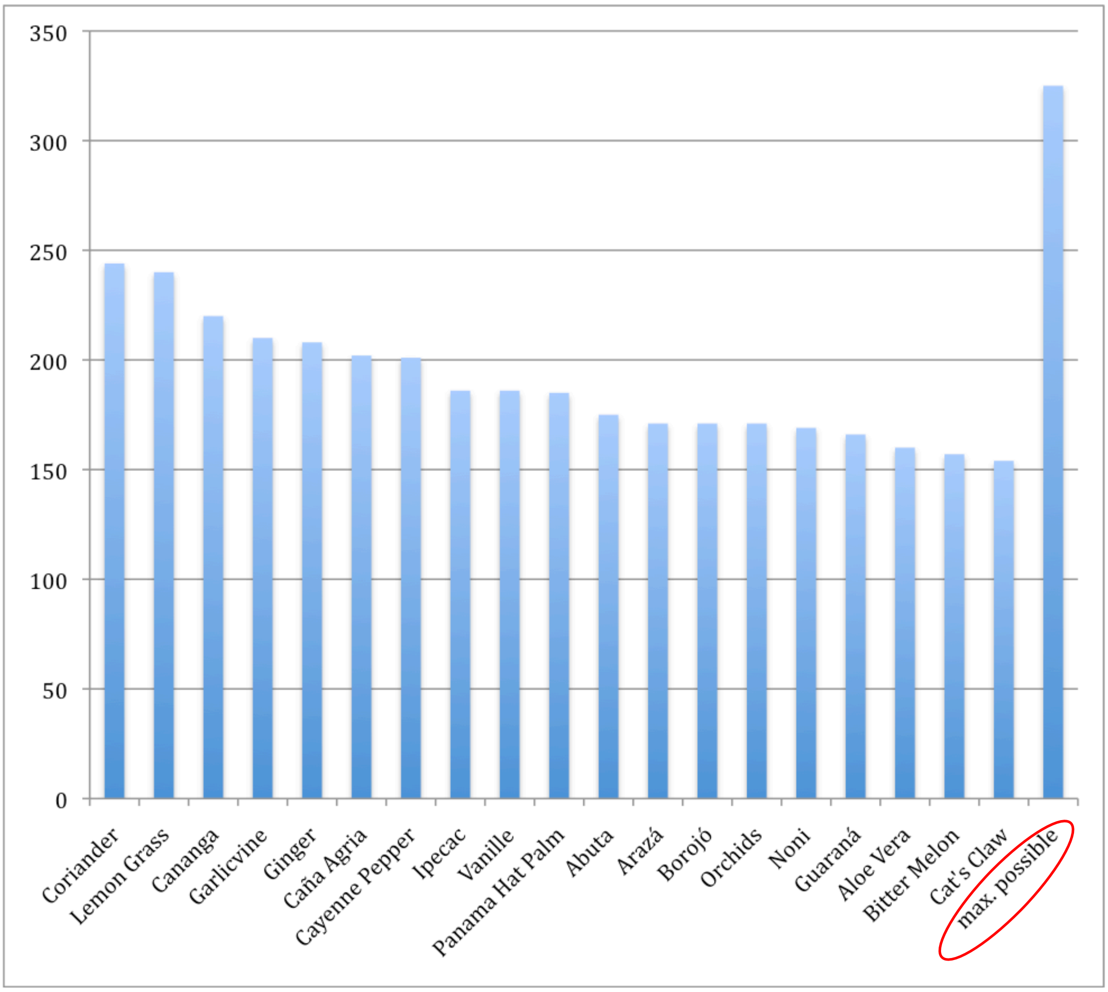

Fig. 20. Plant-related grading of investigated plant species.

First of all it is obvious that the variance between the single plant species was smaller: the best performing species according to the criteria checklists got 75% of the **possible 325 points**, whereas the one with least points gained 47%.

Coriander, the plant species performing worst regarding to the site-related criteria, performed best in this section of the criteria checklist. On the other hand Noni, which belonged to the most suitable plant species according to the first section, was amongst those plant species that gained lower values when it came to plant-related criteria of the checklist (e.g. susceptibility to diseases, interaction with other plant and tree species, rooting habit, height, difficulty to establish and remove the plant species, etc.).

Ginger was again one of the most suitable plant species, while Cat's Claw, Bitter Melon, Aloe Vera and Guaraná performed again not so well, like in the site-related section.

Economic and Social Criteria

In the part of the criteria checklist dealing with economic and social aspects a **maximum of 200 points** could be gained (Fig. 21). The best performing plant species – Ginger – got 88%, while the least suitable in an economic and social sense – Lemon Grass – gained 38%.

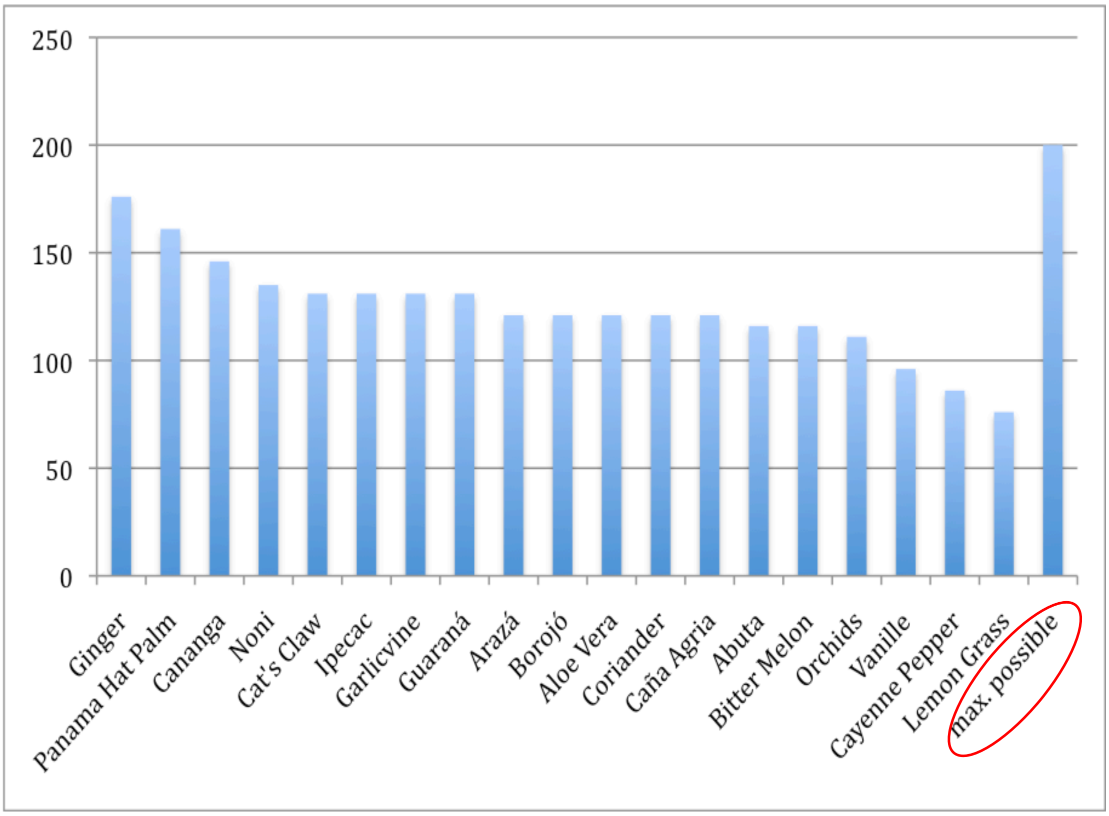

Fig. 21. Economic/social grading of investigated plant species.

Apart from Ginger it was again Cananga and Noni who belonged to the most suitable plant species, and Bitter Melon was again among those who gained less points.

Orchids – being the best performing species within the section of site-related criteria – did not get so many points in this part, equal to Vanilla. Reasons were mainly that they need special packaging and care during transportation, which is quite costly. Furthermore in the case of Vanilla the availability of high quality seeds and seedling was difficult.

Overall grading

When all three sections were taken together the variance between the best performing and the worst performing plant species was smallest compared to the separate examination (Fig. 22):

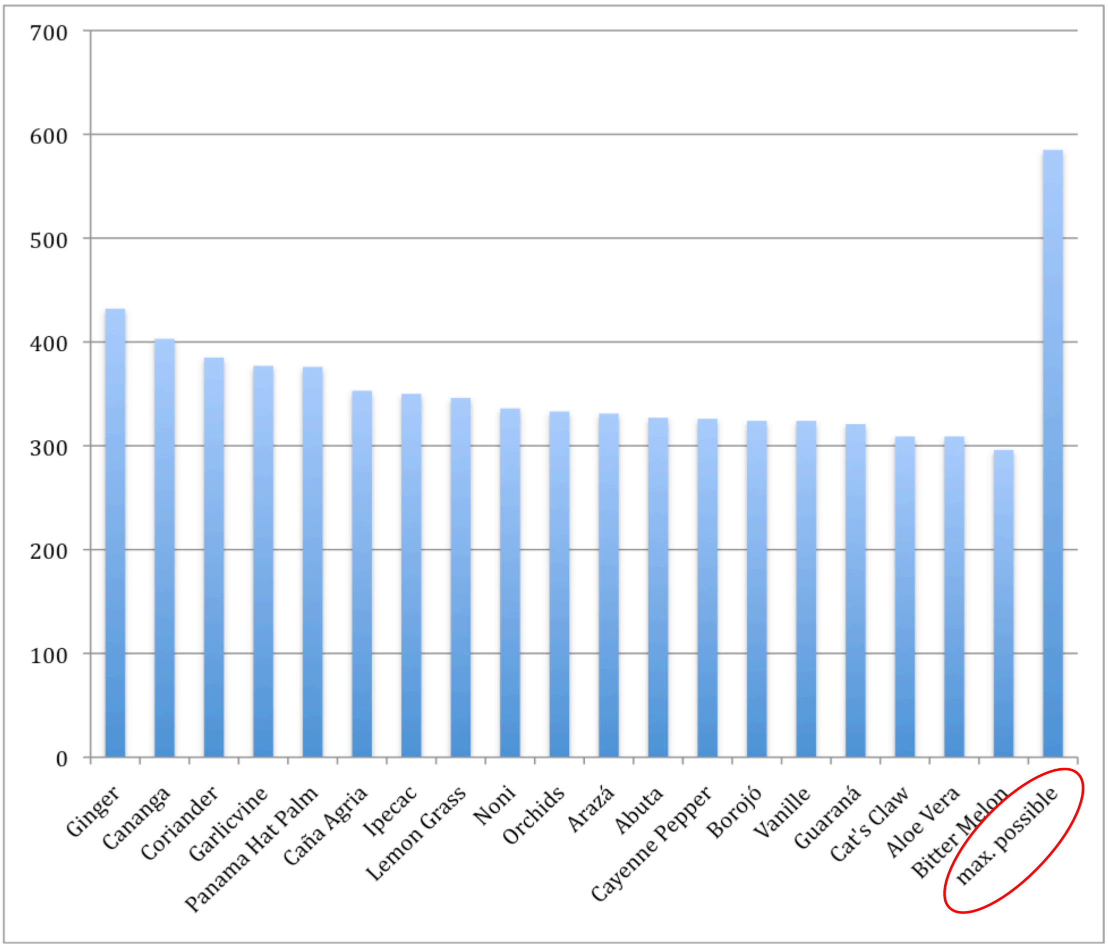

Fig. 22. Overall grading of investigated plant species.

Ginger was overall found out to be most suitable for an agroforestry system in Panama and achieved 74% of a **total of 585 points**, whereas Bitter Melon gained 51%. Coriander, which was the worst performing plant species in the first section, was in total the third most suitable species. And Noni, being partly among the best performing and the worst performing species in different sections was in the end in the middle. Besides Ginger Cananga, Coriander, Garlicvine and the Panama Hat Palm were the best performing plant species according to the application of the criteria checklist.

Guaraná and Aloe Vera belonged overall to the plant species that were selected because they were generally suitable, but the application of the criteria checklist gave a numeric indicator that they were less suitable compared to others. This was mainly due to a lack of scientific literature especially for the sections of plant-related and economic/social aspects. As given site conditions in Panama seemed to be not the most suitable for both plant species, the lower values summed up to find the species in the end to be less suitable than others.

When considering the different shade stages separately, the species that are suggested most appropriate were:

for stage 1)

- Ginger (*Zingiber officinale*),
- Cananga (*Cananga odorata*) and
- Lemon Grass (*Cymbopogon citratus*),

for stage 2)

- Ginger (*Zingiber officinale*),
- Cananga (*Cananga odorata*) and
- Coriander (*Coriandrum sativum*),

for stage 3)

- Cananga (*Cananga odorata*),
- the Panama Hat Palm (*Carludovica palmata*) and
- Garlicvine (*Mansoa alliacea*),

and for stage 4)

- the Panama Hat Palm (*Carludovica palmata*),
- Caña Agria (*Costus scaber*) and
- Ipecac (*Cephaelis ipecacuanha*).

4. Discussion

4.1 Discussion of the methodology

The applied methodology consisted of three different approaches: literature research, the development and application of a criteria checklist as well as expert interviews. These three parts shall be discussed separately:

4.1.1 Literature research

Literature research is the foundation of scientific investigations and provided the necessary basis for the investigation of the topic at hand. Scientific literature in Panama and Costa Rica provided a very different collection of possibly suitable plant species than literature research in Germany. Hence one of the assumptions of the thesis was verified: grey literature on plant species which is not available in international libraries and search machines exists – at least partly – but is only locally accessible and not linked with each other. Therefore literature research within different institutions in Panama, Costa Rica and Germany turned out to be the right starting point. Literature review in the project countries seems to be of general importance for scientists from abroad in order to find out what local scientists have been dealing with and especially in order to access literature which is only of local importance and thus is not internationally published.

4.1.2 Development and application of a criteria checklist

The criteria checklist aimed at practical applicability for implementing plant species in agroforestry systems and transferability to similar topics. The elaborated checklist is for sure not complete, as this always depends on the goal of an investigation. But in order to realize the aim of this study the checklist was sufficient and included many aspects that could not be answered for a number of plant species, because the information was not available, or because this aspect did not matter for the given plant species (e.g. proof of medicinal properties).

For the final assessment of suitability a valuation system and weighting coefficient was developed. As a criteria should be valued higher when information was missing compared to a criteria being not fulfilled, the overall result might be misleading when only looking at the final value: In case a plant species fulfils most of the criteria but does not fulfil other aspects which were higher valued and weighted, the final value might be lower than that of a plant species where hardly information was available. However, personal communication with farmers proved the weighing coefficients to be reasonable, as unknown parameters – which are connected to a certain risk – are judged similarly low compared to not fulfilled criteria. Yet, certain important aspects which are known to be not fulfilled might lead to the rejection of a certain plant species, whereas farmers might take the risk of growing a less known species with more unknown parameters if economic results seem promising. The suitability of a plant species was numerically reduced as soon as crucial factors had to be neglected. The final grading in which the suitability of plant species was analyzed both by section and in total proved that the valuation system worked: In the section referring to the site-related suitability those plant species received the lowest values where scientific literature indicated that they are not suitable for the Panamanian context.

The criteria checklist was proven to be a very useful tool for the structured compilation of information as well as the objective and numerical assessment of plant species. It turned out to be a suitable method for the structured comparison of different investigated species for their appropriateness for agroforestry systems. However, it was refrained from putting absolute figures for determining a plant species' suitability or non-suitability, because the composition of fulfilled, unfulfilled and unknown parameters could be so manifold that a threshold value might have not been the right representation of its suitability and therefore might have led to a different conclusion than the consideration of the numerical assessment without such a value.

Furthermore decision makers who adapt the criteria checklist or scientists who transfer it to other studies shall be given a comprehensive basis and an indication, but they shall be able to adapt the checklist and evaluate the results according to the given circumstances, their needs and priorities. While for example one study focuses on the site-related suitability, other scientists or farmers might want to choose those plant species that perform best in economic and social aspects. A threshold value might have impeded this, as it automatically influences the operator.

4.1.3 Expert interviews

As this study dealt with very different aspects (ecological, economic and social) aiming at a practical recommendation of understory plant species and was focussing on rather unknown local plants, expert interviews with different expert groups seemed to be the right approach: Only with the diversified input of experts' ideas, experiences and problems a comprehensive gain of knowledge was achievable (Bogner & Menz 2005), as this knowledge was neither accessible in scientific literature nor through measurements. However, this information could only be obtained with rather open questions, as qualitative research allows for deeper insights of participants' attitudes and perspectives than quantitative (Flick et al. 2000).

One problem connected to this approach was to find a reasonable amount of experts who were willing and appropriate to be included in the investigation. It was aimed at building roughly equally sized groups of experts in order to guarantee comparability. Some contacts to experts in Panama and to international experts were available, but still this study relied on the recommendation of further experts by those who were known. The general problem of expert interviews stated by Bogner and Menz (2005), that suggested experts cannot always be assessed correctly in the forefront. This also emerged in this thesis so that assumed experts were included in the interviews who turned out not to possess detailed knowledge about the topic.

However, these disadvantages of expert interviews were known and accepted beforehand. According to Meuser and Nagel (1991) the researcher him- or herself shall determine whether a person is an expert. If a person who gets interviewed recommends a third person for also being included, the reason for judging this third person an "expert" will be based on very different aspects than those the researcher him- or herself put for the definition of an expert for the distinct investigation. Therefore the quality of the expert interviews was diminished partly and lacks completeness. But this was not the pursuit of the study, as not all people who deal with the topic at hand could have been included – especially as other researchers would have defined an "expert" differently and as a result would have included other people.

Furthermore the investigation consciously focused on local Panamanian experts, and these were limited per se. Due to these experiences similar future investigations should ensure that enough participants are available beforehand. This can be done by conducting a profound search for experts by the researcher him- or herself previous to interviews and by interviewing only those people who fulfil distinct criteria which are determined according to his or her definition of an expert. Another option might be to make sure that a participant who recommends a third person as being an expert understands the researcher's perception of an expert in the distinct context by asking the participant if the person he or she recommends fulfils the scientist's criteria which define an expert.

Conducting expert interviews with so diversified participants as in this study resulted in certain problems – especially in the Panamanian context where on the one hand side highly educated Professors and employees of governmental institutions were interviewed and on the other hand local practitioners who mostly received only basic education. But exactly this was the interface that should be incorporated in the investigation. This was a factor of uncertainty, as it could not be known whether it will be successful and lead to any results to combine various different expert groups in an investigation.

Designing questionnaires for the diversified range of participants was problematic, as they were to be addressed appropriate to their background (farmers, scientists, non-local practitioners and employees of Panamanian governmental institutions), but still the questionnaires had to be comparable. It turned out that different experts possessed different information, and therefore the questionnaires could have been adapted more precisely to the different expert groups. However, this was not carried out in order to ensure a high degree of comparability. Another difficulty was the fact that the questionnaire contained many very detailed questions which could not be answered by many experts. This in turn bore the risk of diminishing the participants' motivation. They were included in the questionnaire in order to allow a structured collection of information in case a participant could provide these details. As rather unknown local plant species were expected to be recommended, it was assumed that detailed information could not be found in scientific literature, therefore the expert recommending a plant species should be asked for details. These two aspects – similarity of questionnaires for different expert groups and the amount of detailed questions – resulted in many experts not being able to answer some of these questions (see chapter 4.2). This was expected beforehand, especially regarding the detailed questions. Therefore the interview was planned on being semi-standardized, meaning that questions could be skipped in case it turned out that the interviewee did not know details (Raab-Steiner & Benesch 2009). The problem with too many detailed questions was probably bigger for those experts who filled in the questionnaire via email, as they had to read the questions by themselves. But they were informed about being able to skip questions at the beginning of each section with detailed questions in order to allow a semi-standardized investigation also via email. Interviews always contain weaknesses as human beings are influenced by different parameters that cannot be known beforehand and that are probably mostly unconscious. This needs to be considered whenever an interview is conducted.

Feedback regarding pre-selected plant species varied greatly for some species between different expert groups (see chapter 4.2), as practitioners focus on very different aspects or face different problems regarding the implementation of plant species compared to employees of governmental institutions, for example. This indicates, that another assumption which was set right at the beginning of the investigation (that different stakeholders possess different information) was verified. Therefore it was important to distinguish between experts and to include different expert groups into the investigation in order to obtain diversified results. A drawback was though, that each expert group consisted of a relatively small amount of experts which diminished its representativeness. This is according to Raab-Steiner & Benesch (2009), Kelle (2007) and Girtler (2001) often restricting qualitative approaches. But still it is considered the right method, as the quality of the rather small amount of participants was considered more valuable than the quantity of experts.

Summarized it can be said that literature research and expert interviews provided partly very different information, which became obvious due to the application of the criteria checklist. This indicates that the approach was generally the right one, as through this combination a knowledge gain was achieved that would not have been possible by applying only one of these methods. Especially the attitudes of the most important target group regarding the implementation of agroforestry systems on small-scale farms – being local farmers – were important, as there is no use in convincing scientists about a possibly suitable understory plant species if those who, in the end, are meant to combine them with trees were neglected throughout the investigation process. A plant species might be highly recommended by a scientist due to e.g. high market potential, but if the farmer does not plant it because there are no purchasers, the project will fail. Therefore this expert group must not be neglected in such a study and it was right to include them, although most of them could not provide detailed information and some turned out not to be very knowledgeable.

A methodological enlargement of this method would have been a so-called "Delphi-study": in this case the interviewees would have to go through a second and maybe third round of interviews in which each participant would have got the results, assessments and contradictions of the first round of interviews in order to adapt his or her own answers and attitudes and also to comment on those of the other experts. This aims at verifying and falsifying the results in order to finally obtain an agreement on the results (Atteslander 2008). In the context of this study it would have been useful, as the experts would have been given the feedback of the other experts regarding the pre-selected plant species and also the recommendations of further plant species. In this way there would have been a more precise assessment on which plant species could be suitable for an agroforestry system in Panama, especially given the fact that most of the recommended plant species were hardly known. They were not provided with profound scientific literature so that some possibly suitable species had to be neglected, because they could not be scientifically assessed for their suitability.

However, in the time frame and scope of this Master's thesis it was not possible to include this additional approach. This study does not make a claim to be complete: The search for possibly suitable plant species was restricted to non-timber species and species other than staple food crops. There are certainly many more species that might be suitable for agroforestry systems in Panama. In addition to this the Delphi-Method would have been hardly applicable due to the high amount of recommended plant species. A pre-selection by the researcher would have been necessary which would have resulted in a delayed second round of interviews, as the recommended plant species would have had to be checked with scientific literature for their suitability for agroforestry systems in Panama.

Generally such an investigation requires practical trials in order to realistically and practically assess the suitability of understory plant species for agroforestry systems in Panama. However, due to time restrictions this was not possible in the context of this master's thesis, as long-term studies would be needed due to the requirements for different shade stages and the fact that most of the possibly suitable plant species were perennial and produced harvestable part plants only several years after planting. Therefore this study is meant to be a baseline study providing necessary theoretical information for follow-up projects of the Institute of Silviculture of TUM on tree-crop combinations in Panama and thus aimed at extending the research project on Taungya.

4.2 Discussion of the results

4.2.1 Discussion of general results

As the results of the investigation consist mainly of human experiences instead of measurements, they might appear to lack precision – especially to natural scientists. However, due to these personal and local Panamanian experiences made by humans results were obtained that are crucial for the implementation of less known plant species for the understory of agroforestry systems. This was especially obvious when looking at how the results changed with continued application of methods: e.g. Noni showed a completely different picture before and after including the expert interviews in the results, but also among the different expert groups.

While it seemed to be a very promising plant species after literature research, it turned out to be not suitable for the Panamanian context, especially if local farmers are meant to implement it in their land-use practices. Employees of Panamanian governmental institutions as well as international scientists still attribute a high market potential and suitability for agroforestry systems to this plant species, but local small-scale farmers neglect it vehemently, because they grew it in the past and could not sell the fruits (see chapters 3.2.1, 3.3.4.1 & 4.4.2).

The final consideration of the suitability of all investigated plant species by grading them for different sections of the criteria checklist showed that plant species performed very differently in the separate sections, as the example of Coriander (see chapter 4.2.2) displays. This indicates the importance of distinguishing different categories, so that these can be evaluated and compared for each plant species separately.

Two questions of the questionnaire did not provide the desired information and therefore need to be considered with caution: The general question for recommendations regarding the availability of high quality seeds and seedlings and the question concerning the recommendation of pre-selected plant species for agroforestry systems in Panama. The question addressing the availability of seeds and seedlings was excluded for the practitioners, as it was assumed that local practitioners get their seeds and seedlings generally from their own fields, from neighbours or local markets, as they did not have the capacity to travel far distances for obtaining planting material. Furthermore it was suggested that the most important criteria for these experts regarding seeds was not the quality but the availability and the price. Excluding local Panamanian practitioners from this question meant that non-local practitioners were excluded as well, because they got the same questionnaire as the local ones. This was in the end found out to be problematic, because non-local practitioners probably look for high quality seeds and seedlings and therefore might have been able to give some valuable information. However, only four of the other experts who were asked this question (employees of Panamanian governmental institutions and scientists) were able to provide advice. The reason might have been that some of the scientists were not local and thus not able to assess local conditions, and that the other experts of these two groups did not deal with this topic. Therefore it can be summarized that the gained information on the availability of quality seeds and seedling can be taken as an advice of single experts, but not as a representation of the whole group of interviewees.

The question regarding the recommendation of the pre-selected plant species for agroforestry systems needs to be interpreted with caution, because it was realized that many experts argued that a given plant species was not recommendable because of a bad market situation or difficult management. However, this question focused on the ecological suitability of the preselected plant species. The reaction of many experts indicated that this question should have been formulated more precisely. While these answers were first considered not very helpful, they turned out to still include valuable information as experts answered them regarding to their personal context and thereby communicated the reasons why they did not recommend a particular species. Therefore the answers displayed that economic suitability and management aspects were more important for them than ecological criteria.

Another problem connected to the results was that one goal of the study could not be fulfilled which was to economically assess the suitability of recommended plant species in order to prove the profitability of the scenarios that were elaborated after the assessment of pre-selected and additionally recommended plant species (see chapter 5.2). The scenarios are meant to be a recommendation for practical trials. The reason for not being able to assess the economic suitability was that the experts provided less economic data than expected, so that an economic assessment was not possible. However, the scenarios can be taken as the theoretical basis for practical trials which will probably provide the economic data needed for the profound analysis of their profitability.

4.2.2 Suitability of the pre-selected plant species

The application of the elaborated criteria checklist using the information gained through literature research and expert interviews showed that opinions regarding suitability of pre-selected plant species varied. Therefore the results shall be discussed in this chapter and lead to the final recommendation for agroforestry systems in Panama or not. The results for each plant species will be discussed briefly.

Noni (*Morinda citrifolia*)

In scientific literature Noni is a highly valued plant species. Also the amount of Noni products that are available online suggest that it is a very recommendable plant species – given also the fact that it has been naturalized in Panama and regarding its low site requirements. However, the expert interviews showed that in the Panamanian context this plant species cannot be easily recommended. While scientists still attribute Noni a high value and market potential, all practitioners drew a different picture. As the Panamanian Government realized its potential and distributed seedlings for free eight years ago, local and non-local farmers planted them in their gardens and on their fields. The experiences with Noni prove the assumption of this thesis that the link is missing between those who produce and those who sell: The farmers produced a lot of fruits – according to their perceptions – but larger amounts of fruits were needed for juice production, as an employee of a governmental Panamanian Institution[74] stated. However, the Panamanian purchasers did not accept the small amounts of fruits of single small-scale farmers, and only collaborated with farmers who grew Noni on a large scale. Hence small-scale farmers made very negative experiences and are strictly neglecting the plant species, because they could not sell the fruits.

However, due to its high market potential especially in the pharmaceutical sector it might still be considered for agroforestry systems in Panama. Planting Noni might be successful if it becomes implemented in agroforestry systems by reforestation companies that cooperate directly with processing facilities, e.g. with “Tropic Products S.A.” which is located in the “Ciudad del Saber” in Panama City. In case this will be successful, small-scale farmers might be convinced to plant it again, but under different circumstances: They should be organized in farmer cooperatives in order to be more powerful and

[74] Interview No. 11 on the CD enclosed.

to deliver bigger amounts of fruits that are more attractive to processing facilities than small amounts of many different suppliers.

Due to the strong negative feedback of practitioners and employees of Panamanian governmental institutions Noni was taken out of the consideration of an agroforestry scenario in Panama.

Arazá (*Eugenia stipitata* McVaugh)

As Arazá was hardly known among Panamanian and international experts and it could not be figured out if it already grows in this country, no conclusion about acceptance could be drawn. This is surprising, considering its abundance in Costa Rica and Nicaragua. Therefore a definite recommendation for including it in agroforestry systems in Panama or not was not possible. Furthermore the expert interviews did not provide the desired economic data which were not available in reviewed literature.

But as the non-local practitioner attributed generally high but untapped potential to the genus *Eugenia* and because it has already been grown successfully in agroforestry systems in Colombia, the plant species shall be included in practical trials to a small extent in order to investigate production, market potential, processing and possible problems with perishability. Afterwards a profound statement about its suitability can be given.

Borojó (*Borojoa patinoi* Cuatrec)

Borojó has also been already grown in agroforestry systems in Colombia in various combinations as an overstory and an understory species. Therefore it seems like it can be planted in different systems and settings of agroforestry systems. However, many questions still remained unclear after the expert interviews, e.g. the most appropriate shade stage, economic aspects and acceptance by local farmers. Yet, it was well distributed and also well known as an understory species in Panama. Scientists state that it has a very high value as a medicinal plant species.

As it was attributed a good market potential, it was included in the scenarios of agroforestry systems in Panama (see chapter 5.2) in order to clarify those aspects where information was missing. This, however, only makes sense if practical trials are set for a long-term investigation, as the first harvest can only be expected four years after planting.

Ginger (*Zingiber officinale*)

Ginger was very well known by all participants of the expert interviews and highly appreciated by the most important target groups when it comes to the implementation of agroforestry systems in Panama, the local practitioners: They all knew it, most of them planted it themselves and therefore had profound knowledge regarding site-requirements and management aspects. Interestingly all farmers stated that growing ginger was easy, while scientists argued that this was rather difficult. The reason behind it might be that many local Panamanian farmers have included Ginger in their agricultural or horticultural portfolio and thus know where to grow and how to manage it, while scientists know that it is theoretically not that easy to find the right growing conditions. Furthermore it is likely that scientists and practitioners have a different perception of and requirement for quality of timber rhizomes.

Much information is provided on this plant species in scientific literature, but as it was not successfully included in the project of the TUM in Panama so far (Paul, personal communication 2011), it shall be included in the scenarios in order to find out, if combinations with different understory plant species will be more successful.

Cananga (*Cananga odorata*)

Cananga is a rather demanding plant species, as the germination is very difficult, the harvest is very labour intensive due to manual picking of flowers and protection against wind needs to be ensured. Furthermore it needs to be planted on a large scale for economic feasibility. On the other hand once established it is said to be easily managed and highly priced on the international market (see chapter 3.3.4.5).

One non-local practitioner[75] would like to cooperate with other growers in order to produce the amounts needed for economic profitability. But more information is required on suitability for agroforestry systems. Therefore Cananga shall be included in practical trials on a small scale in order to investigate site- and plant related aspects so that afterwards a decision can be taken to include Cananga in agroforestry systems and to build a cooperation between farmers or not.

[75] Interview No. 21 on the CD enclosed.

Cat's Claw (*Uncaria guianensis*)

Surprisingly not much information was available for site- and plant-related aspects of Cat's Claw, although it grows in Panama, and it is said to have a long history as a medicinal plant. Furthermore scientific literature indicated it as being popular in the industry of natural products with a growing market demand. However, those experts who could have provided information on management aspects – e.g. local farmers – are obviously not familiar with this plant species and probably not aware of the international industry of natural products, as the link to the market is missing. Therefore the desired gain of information on management options which was expected to be obtained through expert interviews could not be achieved for Cat's Claw. However, as it was attributed high international market potential due to its medicinal properties, it was included in the scenarios so that further information can be gained.

4.2.3 Suitability of those plant species recommended by experts

Only those plant species recommended in expert interviews were described in the results' chapter, which were generally considered suitable according to scientific literature. Consequently only for some of the recommended species the results needed to be discussed.

Generally information regarding environmental and climatic requirements was missing for many plant species, also for those which were finally selected as being possibly suitable for agroforestry systems in Panama. As they were recommended by local practitioners or employees of Panamanian governmental institutions and have been growing in Panama already, it was assumed that the given ecological conditions were suitable. This was for example the case with **Coriander** (*Coriandrum sativum*), which according to scientific literature does not grow in the Panamanian environment and therefore resulted in a rather negative assessment of the site-related suitability. But the Panamanian expert who recommended the plant species provided opposing information by stating that it was introduced to Panama long time ago and that it has in the meantime been widely grown in Panama. Therefore the plant species was – contradictory to what scientific literature suggested – assumed to be suitable for the given conditions. A reason for the divergent information could be that the expert did not recommend *Coriandrum sativum,* but the species *Eryngium foetidum* L., a form of Coriander which grows in Panama and is very widespread. Then again he stressed that it was introduced to Panama long time ago, which indicates that he meant *Coriandrum* *sativum*. However, practical trials will prove if *Coriandrum sativum* is suitable as an understory species for agroforestry systems in Panama.

The situation was similar with **Lemon Grass** (*Cymbopogon citratus*): Scientific literature did not say that it is suitable or already grown in Panama or surrounding countries with similar climatic and environmental conditions. However, as it was recommended by a local expert and furthermore personally observed that it has already been widely grown in Panama, it was considered suitable.

The same also happened with **Aloe Vera** (*Aloe vera* Auth.), as it usually grows in desert-like, rather hot and dry climates, and therefore it sounded rather contradictory that it should be also suitable for the Panamanian context. But some regions in Panama, e.g. Azuero, show a hot and dry climate, so that the plant species could thrive there. Furthermore it was recommended by an employee of a governmental institution who is aware of the local climatic conditions. Therefore it was included in the list of possibly suitable species. However, special attention will have to be paid on environmental and climatic aspects. Furthermore the gel of Aloe Vera leaves oxidises quickly making a rapid processing after harvest necessary which means that facilities will be needed close to the production areas. As this plant species is already grown on large scale, it is not sure whether small-scale producers will be competitive on the world market respectively if the local and national demand will be high enough to encourage local production.

In the case of **Guaraná** (*Paullinia cupana*) there was also no information found whether it grows in Panama, it was only said to grow in the Amazon. But as according to scientific literature some parts of the plant are traditionally used in Panama, it was concluded that these plant parts are not imported but harvested in Panama which means that the plant grows there. However, this has to be proved by further investigation and probably by interviewing Panamanian growers or those who use the plant.

For **Garlicvine** (*Mansoa alliacea*) there was not a lot of information available which can be taken as a profound basis for the assessment of its suitability. However, there exist some commercial plantations. This could be an indicator that it is generally suitable to be grown, and the available literature did not give any reason for not including it. Therefore it was decided that practical trials shall be conducted to verify its suitability for agroforestry systems in Panama.

Contradictory information was collected for **Caña Agria**: while the interviewed expert recommended this plant species for stage one of an agroforestry system, scientific literature states that it requires rather dark and shaded areas in the understory of trees. As by personal observation it was only seen in shaded areas in Panama, the later stages of the scenario were chosen for practical trials. These will contribute to solve the contradiction scientifically.

For the **Panama Hat Palm** (*Carludovica palmata*) different information regarding the necessary spacing was given. While the spacing of 1 x 1 m will be suitable for the given agroforestry system, a spacing of 2.4 - 4.7 m will make it unsuitable, as the spacing of the overstory trees was suggested to be 4 x 4 m. However, as there are also agroforestry systems with a wider spacing and as the density of trees will decrease due to thinning activities, this shall not be a reason for excluding the plant species from the consideration. The optimal planting distance will have to be further investigated, and maybe the practical trial has to be adapted to these requirements.

Ipecac (*Cephaelis ipecacuanha*) needs a closed canopy, as it does not tolerate any direct sunlight. This means that the structure of the overstory must not be changed while this perennial plant species is grown. However, in an agroforestry system the structure of the overstory changes frequently due to thinning and pruning. If the plant species will be able to handle such conditions, or if an agroforestry system can be managed in a way that the conditions stay the same for the period of Ipecac being grown will have to be investigated practically. Furthermore there was no plant-related information found on this plant, therefore no statement can be given for possible adverse effects on surrounding species.

Orchids (*Orchidaceae* spp.) were recommended, because they can grow on trees and therefore do not consume further agricultural or forest land. However, there was no information found if Orchids can be planted on trees, or if these epiphytes only grow naturally on trees. Furthermore the trees need to be quite big and strong in order to host this plant species. This sounds generally reasonable, as Orchids need a certain degree of shade which will be given when trees reach a distinct height. But as the tree species of the given

agroforestry system are valuable timber species, it is usually desired not to have too many branches, as these diminish the value of the timber. Therefore the feasibility of planting Orchids on tree species of an agroforestry system needs to be considered.
One of the Panamanian experts recommending Orchids stated that it was suitable for shade stage one, meaning without any shade. This, however, is contradictory to scientific literature which states that Orchids generally need shade. Furthermore the plants could not be planted on the branches of the trees, because they are still seedlings within the first stage. Therefore the recommendation of the first shade stage was neglected and stage four was chosen instead.

4.3 Final assessment of the results

Although both, the methodology as well as the results contained some minor weaknesses – out of which most were expected beforehand – the goal of obtaining a reasonable amount of recommendations for possibly suitable understory plant species which allow the development of different scenarios was reached.

The amount of recommended plant species that were considered possibly suitable after the application of the criteria checklist confirms the main assumption underlying this thesis: that there are local plant species which might be suitable understory plant species for agroforestry systems in Panama and for which local knowledge is available.

The implementation of the selected plant species in agroforestry systems might contribute to increase farmers' adoption of such systems given that practical trials turn out to be profitable. According to Garen et al. (2009) economic insecurity is an important aspect in Panama. These understory species allow growers to harvest different species from the very beginning and at different stages of the agroforestry system even under highly shaded conditions. Thus economic incentives will be given, investment risk will be distributed to different sources of income and timber trees can be an additional security as soon as they are old enough, because they only deliver first returns after several years (Lefroy 2009, Nuberg et al. 2009b). However, convincing farmers to implement trees on their farms and change their growing habits will not be that easy and further steps will be needed. These will be explained in the recommendations' chapter (see chapter 5.).

In the broader perspective the implementation of economically valuable understory species at all stages of an agroforestry system might lead to local farmers getting – indirectly – paid for maintaining ecosystem services: By keeping a ground cover consisting of diverse plant species they will provide services that may contribute to strengthening the region's biodiversity, hydrological cycle and other ecosystem services mentioned earlier (see chapter 1.2). Usually farmers do not get paid for these services of agroforestry systems (Binning et al. 2000, Thompson & George 2009), but when growing plant species that can be sold – maybe even internationally – they will indirectly also get money for the maintenance of ecosystem services.

5. Recommendations

Before the elaborated scenarios for agroforestry systems in Panama with the investigated plant species will be displayed, some general recommendations shall be put forward in order to support farmers' adoption of agroforestry systems.

5.1 General recommendations

First of all local farmers shall be included in the whole investigation and implementation process for agroforestry systems in Panama. This thesis was a first step to do so – together with other studies conducted by the TUM – and it proves how important it was. Therefore they shall also participate in discussions and decision making processes (also known as participatory research, e.g. when discussing and deciding which plant species are considered suitable and worth to be implemented in agroforestry system after practical trials) so that their knowledge and experience can be incorporated. This is considered crucial for the adoption of investigated systems. Furthermore it will save time and money, as the integration of local farmers' experiences and attitudes will avoid the investigation of plant species that might be neglected by farmers, because they planted them already without economic success, or because they are culturally not accepted.

In order to encourage farmers to include the finally practically tested and as suitable verified plant species in their agricultural land it is important to provide first-hand experience (Lefroy 2009), training and assistance on a long-term basis from practitioners they trust in. Support by local experts might be more fruitful than that of strangers, as local small-scale farmers – especially in remote areas – might have reservations against latter ones, as they might be considered as not knowing local peculiarities, conditions, perceptions, needs as well as teaching and learning methods. This is also recommended by Nuberg et al. (2009b).

It is furthermore very significant to provide financial incentives, e.g. subsidies or partnerships between landowners, the government or the private sector in order to share costs and risks. Small-scale forest enterprises and strategic business partnerships need to be developed, and ownership rights of local growers over land must be secured. Globally it has been discussed that regulatory barriers need to be removed, the poorest people protected and local producers involved in policy negotiations (Montagnini et al. 2006, Scherr et al. 2007, Lefroy 2009), because this has not been implemented so far on a global scale. In the Panamanian context cooperatives between local growers will be needed, as the experiences with Noni shows. This will re-inforce their market position, which enables them to access the market and negotiate with purchasers more realistically. Farmer associations might also help to gain higher producer prices due to improved market chains, technical equipment, reduced transportation costs, higher quantities and negotiations of better sales conditions (World Agroforestry Center 2006, FAO 2003, UNCTAD 2002, FAO 1997).

For Panama it will also be necessary to take into consideration that local growers generally prefer to combine trees with cattle instead of with other crops, and those crops they grow are usually staple food crops. This information was provided by Schuchmann (2011) and one interviewed expert of a Panamanian governmental institution. This background and general attitude of local growers will have to be kept in mind in order to understand possible reservations against the implementation of agroforestry systems which do not include livestock.

However, the scenarios described below (see chapter 5.2) are not meant to be exclusively implemented by local farmers ignoring the staple food crops they have been growing so far. They are rather suggested to enlarge their portfolio and to supplement cattle-ranching, so that they can generate income and increase biodiversity at the same time. Another option might be to include cattle within parts of the agroforestry trials at the first two stages instead of understory species. In these stages the overstory consists of small tress, so that there will be enough light for a grass cover and space for a grazing area. In this case precautions must be taken in order to avoid damages due to browsing.

5.2 Scenarios of agroforestry systems in Panama

The scenarios described in this section are recommendations for practical trials in Panama. Those plant species that were considered possibly suitable after the investigation of this study shall be tested in different combinations for their de facto applicability for the enrichment of timber plantations in Panama. The tables will show the plant species for the four designed shade stages. They have to be tested for their ecological and socioeconomic applicability, as especially for the latter aspect hardly information was available for most of the investigated plant species. Different spacing designs and tree-crop combinations shall be applied and the impact of varying light conditions on the performance of the species shall be investigated in order to find those conditions and combinations which are most profitable and complementary for over- and understory plant species.

In the first scenario (Table 9) of an agroforestry system in Panama Lemon Grass and Ginger were taken for shade stages one and two for two reasons: They need full sunlight but can tolerate light shade, and they will generate money within the first year of planting. Ginger can still be planted in stage 3. Abuta is a vine and therefore needs host trees to grow. But it needs intensive sunlight to grow. For this reason it shall be planted in stage 2 when the trees of the agroforestry system are already big and strong enough to host this plant species, but still small enough in order to allow enough sunlight to penetrate the canopy.

Table 9: Scenario 1 of possible understory combinations for agroforestry systems in Panama.

Plant name	Shade Stage 1				Shade Stage 2				Shade Stage 3				Shade Stage 4			
Lemon Grass	■	■	■	■	■	■	■	■								
Ginger	■	■	■	■	■	■	■	■	■	■	■	■				
Abuta					■	■	■	■	■	■						
Panama Hat Palm							■	■	■	■	■	■	■	■	■	■
Bitter Melon									■	■	■	■	■	■	■	■
Orchids											■	■	■	■	■	■
Ipecac													■	■	■	■

The investigation shall give information whether it can still be grown in stage 3 and when first monetary returns can be expected. The Panama Hat Palm – being a natural understory species – can be planted in the middle of the second stage and can be kept until a closed canopy is developed. Planting it a bit earlier than at the beginning of the third stage will enable to plant the annual vine Bitter Melon next to the trunk of the palm. As there was no information about suitable light conditions, shade stages 3 and 4 shall be tested. With this design Ginger, Bitter Melon and probably partly the Panama Hat Palm as well as Abuta will ensure financial cash flows during stage 3. Orchids can be included in the middle of stage 3, so that there will still be enough light available. They can be planted either on the Panama Hat Palm trees once Abuta will be removed, or on the branches of the timber trees of the agroforestry system. They need 2-3 years until they can be sold as ornamentals. This will also be the time for Ipecac to be implemented, as it cannot handle direct sunlight. The Panama Hat Palm as a small tree will provide additional shade to the timber component, so that a closed canopy can be ensured for Ipecac, which is a small plant species growing on the ground. Therefore in the final stage of the scenario it is assumed that the Panama Hat Palm, Ipecac as well as Orchids will provide cash flows for the growers.

For the second scenario (Table 10) Pepper was chosen as the main cash crop in the first two stages. The applicability of Cananga shall be tested, therefore it shall be included in this scenario to a small extent – however, it must not be an insufficient amount of plant species, so that results will still be representative. There are no economic profitable yields expected from planting Cananga in the scope of this scenario, as experts indicated that it needs to be grown on large scale in order to be profitable. It shall rather be found out which conditions are most suitable and what to consider when planting it, in order to provide information on its practical suitability for agroforestry systems. Therefore it shall be included in the first three stages. One non-local participant of the investigation at hand might start an association in order to cooperate with local farmers. This might make an economically profitable production of Cananga feasible.

Table 10: Scenario 2 of possible understory combinations for agroforestry systems in Panama.

Plant name	**Stage 1**				**Stage 2**				**Stage 3**				**Stage 4**			
Pepper																
Cananga																
Borojó																
Guaraná																
Bitter Melon																
Cat's Claw																
Ipecac																
Caña Agria																

Borojó produces first fruits after four years. For this reason it shall be planted in the first stage so that first returns can be expected at the end of stage two – besides those generated by Pepper. Borojó was recommended for stages one and three. This led to the decision to investigate it for the first three stages.

Guaraná is a vine which needs a tree to grow on, Bitter Melon as well. This can either be the timber tree, Cananga or Borojó. This will also provide information whether these two tree species are suitable for hosting vines, or if this will diminish their own production. While returns from Bitter Melon and Borojó can be expected for stage three, this is not assured for Guaraná.

Bitter Melon will still be included in stage 4 of the scenario, and the system shall be enriched with Cat's Claw, Ipecac and Caña Agria. As Cat's Claw is another vine, it will not consume additional space, but can be planted where Guaraná was removed. Ipecac and Caña Agria are supposed to grow in the understory of the timber trees, as they require dark places.

The third scenario (Table 11) shall include Aloe Vera in the first two stages, when a lot of sunlight is available. However, the valuable liquid of the plant species can only be harvested 3-5 years after planting, therefore Lemon Grass and Coriander were also included in stages one, respectively two, in order to ensure cash flows during these stages. Aloe Vera is also expected to generate income in stage two. Arazá grows under bright conditions, but it will need some shade as soon as it produces fruits. Therefore it appears suitable to plant it in the middle of stage 1, so that it will produce fruits as soon as the timber trees produce the needed shade, as the first harvest of Arazá fruits can take place 14-18 months after planting.

The Panama Hat Palm will be included again in the middle of stage 2 and will remain for shade stages 3 and 4, so that leaves can be harvested starting at the end of stage three, and in order to act as a host tree for Garlicvine and Vanilla. Garlicvine shall be planted at the end of stage two, as 40% of shade is optimal. In order to find out the most suitable growing conditions for Caña Agria, this plant species shall be grown in stage three of this system – compared to stage four in scenario two. In stage three economic returns might be expected from Arazá, Garlicvine, and partly from the Panama Hat Palm and Caña Agria. Vanilla will not be economically profitable in this stage, as first flowers develop only 3-5 years after planting. Therefore this plant species will remain in stage four together with the Panama Hat Palm, and Orchids shall be added.

Table 11: Scenario 3 of possible understory combinations for agroforestry systems in Panama.

Plant name	Stage 1				Stage 2				Stage 3				Stage 4			
Aloe Vera																
Lemon Grass																
Coriander																
Arazá																
Garlicvine																
Vanilla																
Panama Hat Palm																
Caña Agria																
Orchids																

It is recommended to carry out further interviews before implementing practical trials of the scenarios. These should be done especially with local practitioners in a follow-up study in order to obtain feedback regarding those plant species that were recommended in the expert interviews, as for these no assessment and estimation of the other experts could be collected in the scope of this study.

6. Affirmation

I, Ludgera Ewers, hereby declare in lieu of oath, that I composed the thesis at hand on my own with no means other than mentioned and that it, to the best of my knowledge, contains no material previously published, or substantially overlapping with material submitted for the award of any other degree at any institution. All information directly or indirectly taken out of publications by other authors is indicated as such.

Munich, January 2013.

Ludgera Ewers.

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8. Appendices

8.1 Appendix 1: Questionnaire

Questionnaire regarding the enrichment of agroforestry systems with Non Timber Forest Products (NTFP) in Darién, Panama

Background

My name is Ludgera Ewers, I am on an international study programme in Munich/Germany called „Sustainable Resource Management“ (MSc.). For my Master's thesis I am aiming at finding plant species that are suitable for enriching tropical timber plantations and secondary forests as an economically productive understory. Hereby I am excluding any staple food crops, as a lot of research has already been done on this. I am rather focussing on NTFP, especially plants with tolerances to different shade conditions, so that they can be implemented at different stages of the agroforestry system. These plant species must be of economic value in order to provide early revenues out of the reforestation activities respectively permanent revenues out of secondary forests. Thereby they should give incentives to local growers to keep the forests instead of cutting them in order to get productive agricultural land. An elaborated criteria checklist will help me to assess the suitability of each selected plant species. In order to get the necessary information I will combine literature research with expert interviews. This is done by selecting experts of different professional groups: scientists, employees of environmental institutions, local Panamanian and non-Panamanian producers and nurseries.
In return for your expertise and time I will be very happy to share the results of my thesis with you.

These questions were only included in the questionnaires for scientists and employees of Panamanian governmental institutions	These questions were only included in the questionnaires for local and non-local practitioners
1. May I name and cite you in my Master's thesis? ☐ yes ☐ no	
2. Do you work with understory crops in agroforestry systems? ☐ yes ☐ no	**1. Do you work with trees and plants that are not staple food crops?** ☐ yes ☐ only trees ☐ only plants

3. For how long have you been working in this field? **4. Do you conduct practical trials yourself?** ☐ yes, for ________ years ☐ no	**2. If yes: for how long have you been doing that?** **3. Do you mix trees and plants on one plot, or do you grow them separately?** ☐ on one plot ☐ separately **4. Which plants (trees and other plants) do you grow that are NTFP and not staple food crops?** **5. Do you grow them only for yourself or for the market/community?** ☐ only for myself ☐ for the market/community **6. For how long have you been selling to the market?** **7. At which market do you sell the products?** **8. How far is the market from where you live?**

Please imagine the following scenario of an agroforestry system: you have a forest plantation in Panama with one tree species. Trees of the same age are planted in exact rows, with a tree spacing of 4x4m and no further vegetation in the understory.
Climatic data: yearly temp. 18-35°C, average annual rainfall between 1300 and 3000mm with a dry period between January and March.
Referring to the World Reference Base for Soil Resources the dominant soil type of the Darién area is Cambisol, which is characterized by not having a layer of accumulated clay, humus, soluble salts or iron and aluminium oxides. They show a favourable aggregate structure and high content of weatherable minerals and thus can be used for agricultural purposes.[5]
The overstory of the agroforestry system consists of the following native tropical broadleaved tree species Glassywood (*Astronium graveolens*), Cocobolo (*Dalbergia retusa*), Zapatero (*Hieronyma alchorneoides*), Amarillo (*Terminalia amazonia*), Cedro Amargo/Spanish Cedar (*Cedrela odorata*) or Teak (*Tectona grandis*).

Please keep this scenario in mind for questions 9-12.

9. In **stage 1** you have a plot with recently planted tree seedlings that are smaller than one meter and give space to other plants in between. In this stage you will have **full sunlight**.

Which NTFP species do you know that is or might be suitable to be implemented as an understory crop in this stage? Restriction: no staple food crop.
Plant name:

Did you grow it yourself? ☐ yes ☐ no ☐ no, but I know someone who did	Do or did you grow the plant yourself? ☐ yes ☐ no ☐ no, but I know someone who planted it In case you stopped growing it: Why?

[5] World Reference base for soil resources (FAO): http://www.britannica.com/EBchecked/topic/707510/Cambisol (14.02.2012).

Has it already been grown in agroforestry systems? ☐ yes, with great success ☐ yes, with good success ☐ no ☐ I do not know If yes: where? In which combinations? Where do you obtain seeds/seedlings?	Did you grow it in combination with trees? ☐ yes ☐ no If yes: was it successful? ☐ yes ☐ no If not: do you have any suggestions why? Where can you buy the seeds/seedlings? ☐ at a local nursery ☐ at a nursery __________ km away from here ☐ from the neighbour/within the community ☐ Mercado de Abastos, Central Market Panama City ☐ own production ☐ ____________________ ☐ I do not know
What is the price for seeds/seedlings?	

The following questions will focus on the management aspects:

Which distance should be kept between plants and rows?

☐ between plants: ________

☐ between rows: _________

☐ I do not know

What kind of management is needed to grow the crop?

☐ weeding: ______ times per month

☐ pruning: _____ times per _________

☐ pesticides/herbicides: _________ applications per growth period
→ name of the pesticide: _________
→ dosage: _________

☐ fertilizers: _________ applications per growth period
→ name of the fertilizer: _________
→ dosage: _________
☐ I do not know

Which parts of the plant can be used?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ other

Which parts/products of the plant can be sold?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ other

How many harvests do you get per year?

☐ one ☐ two ☐ three ☐ four ☐ harvest all year long with an interval of ________ weeks ☐ I do not know

What are the expected yields (kg/ha)?

Which products can you make out of this plant?

Which machinery is necessary for the production?

How much does the production cost?

What is the selling unit?

What is the market price for the product(s)?

Please assess the difficulty to transport the parts/products of the plant from 1 (very easy) to 4 (very difficult):

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult to transport please explain why:

Please assess the difficulty to grow the plant species if you are not experienced with it: from 1 (very easy, no assistance needed) to 4 (much assistance needed):

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult, please state why:

Are the products of local, national or international importance?

☐ local ☐ national ☐ international ☐ I do not know

How would you describe its market potential?

☐ very low ☐ rather low ☐ rather high ☐ very high ☐ I do not know

Please briefly name the main aspects that make you recommend this plant species. Please put them in an order beginning with the most important one.

a) ________

b) ________

c) ________

d) ________

Are there any drawbacks connected to the plant species that need to be considered when implementing it into an agro-forestry system?

10. In **stage 2** of the agroforestry system the trees are 2-3 m high and give **light shadow (20-30%).**

Which NTFP species do you know that is or might be suitable to be implemented as an understory crop in this stage? Restriction: no staple food crop.

Plant name:

Did you grow it yourself? ☐ yes ☐ no ☐ no, but I know someone who did Has it already been grown in agroforestry systems? ☐ yes, with great success ☐ yes, with good success ☐ no ☐ I do not know If yes: where? In which combinations? Where do you obtain seeds/seedlings?	Do or did you grow the plant yourself? ☐ yes ☐ no ☐ no, but I know someone who planted it In case you stopped growing it: Why? Did you grow it in combination with trees? ☐ yes ☐ no If yes: was it successful? ☐ yes ☐ no If not: do you have any suggestions why? Where can you buy the seeds/seedlings? ☐ at a local nursery ☐ at a nursery _________ km away from here

	☐ from the neighbour/within the community ☐ Mercado de Abastos, Central Market Panama City ☐ own production ☐ ____________________ ☐ I do not know

What is the price for seeds/seedlings?

The following questions will focus on the management aspects:

Which distance should be kept between plants and rows?

- ☐ between plants: ________
- ☐ between rows: _________
- ☐ I do not know

What kind of management is needed to grow the crop?

- ☐ weeding: ______ times per month
- ☐ pruning: ____ times per _________
- ☐ pesticides/herbicides: _________ applications per growth period
  → name of the pesticide: _________

→ dosage: ________

☐ fertilizers: ________ applications per growth period
→ name of the fertilizer: ________
→ dosage: ________
☐ I do not know

Which parts of the plant can be used?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ other

Which parts/products of the plant can be sold?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ other

How many harvests do you get per year?

☐ one ☐ two ☐ three ☐ four ☐ harvest all year long with an interval of ________ weeks ☐ I do not know

What are the expected yields (kg/ha)?

Which products can you make out of this plant?

Which machinery is necessary for the production?

How much does the production cost?

What is the selling unit?

What is the market price for the product(s)?

Please assess the difficulty to transport the parts/products of the plant from 1 (very easy) to 4 (very difficult):

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult to transport please explain why:

Please assess the difficulty to grow the plant species if you are not experienced with it: from 1 (very easy, no assistance needed) to 4 (much assistance needed):

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult, please state why:

Are the products of local, national or international importance?

☐ local ☐ national ☐ international ☐ I do not know

How would you describe its market potential?

☐ very low ☐ rather low ☐ rather high ☐ very high ☐ I do not know

Please briefly name the main aspects that make you recommend this plant species. Please put them in an order beginning with the most important one.

a) ________

b) ________

c) ________

d) ________

Are there any drawbacks connected to the plant species that need to be considered when implementing it into an agroforestry system?

11. In **stage 3** of the agroforestry system the trees reach a height of about 7m and give intense shadow (**50-60%**).

Which NTFP species do you know that is or might be suitable to be implemented as an understory crop in this stage? Restriction: no staple food crop.

Plant name:

Did you grow it yourself?	Do or did you grow the plant yourself?
☐ yes ☐ no ☐ no, but I know someone who did	☐ yes ☐ no ☐ no, but I know someone who planted it
Has it already been grown in agroforestry systems?	In case you stopped growing it: Why?
☐ yes, with great success	Did you grow it in combination with trees?
☐ yes, with good success	☐ yes ☐ no
☐ no	If yes: was it successful?
☐ I do not know	☐ yes ☐ no
If yes: where?	If not: do you have any suggestions why?
In which combinations?	Where can you buy the seeds/seedlings?
Where do you obtain seeds/seedlings?	

	☐ at a local nursery ☐ at a nursery ________ km away from here ☐ from the neighbour/within the community ☐ Mercado de Abastos, Central Market Panama City ☐ own production ☐ ____________________ ☐ I do not know

What is the price for seeds/seedlings?

The following questions will focus on the management aspects:

Which distance should be kept between plants and rows?

- ☐ between plants: _______
- ☐ between rows: ________
- ☐ I do not know

What kind of management is needed to grow the crop?

- ☐ weeding: _____ times per month
- ☐ pruning: ____ times per ________
- ☐ pesticides/herbicides: ________ applications per growth period
  → name of the pesticide: ________
  → dosage: ________
- ☐ fertilizers: ________ applications per growth period
  → name of the fertilizer: ________
  → dosage: ________
- ☐ I do not know

Which parts of the plant can be used?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ other

Which parts/products of the plant can be sold?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ other

How many harvests do you get per year?

☐ one ☐ two ☐ three ☐ four ☐ harvest all year long with an interval of ________ weeks ☐ I do not know

What are the expected yields (kg/ha)?

Which products can you make out of this plant?

Which machinery is necessary for the production?

How much does the production cost?

What is the selling unit?

What is the market price for the product(s)?

Please assess the difficulty to transport the parts/products of the plant from 1 (very easy) to 4 (very difficult):

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult to transport please explain why:

Please assess the difficulty to grow the plant species if you are not experienced with it: from 1 (very easy, no assistance needed) to 4 (much assistance needed):

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult, please state why:

Are the products of local, national or international importance?

☐ local ☐ national ☐ international ☐ I do not know

How would you describe its market potential?

☐ very low ☐ rather low ☐ rather high ☐ very high ☐ I do not know

Please briefly name the main aspects that make you recommend this plant species. Please put them in an order beginning with the most important one.

a) _________

b) _________

c) _________

d) _________

Are there any drawbacks connected to the plant species that need to be considered when implementing it into an agroforestry system?

12. Finally you will have **mature trees and a closed canopy** in **stage 4** of the agroforestry system.

Which NTFP species do you know that is or might be suitable to be implemented as an understory crop in this stage? Restriction: no staple food crop.

Plant name:

Did you grow it yourself? ☐ yes ☐ no ☐ no, but I know someone who did	Do or did you grow the plant yourself? ☐ yes ☐ no ☐ no, but I know someone who planted it In case you stopped growing it: Why? Did you grow it in combination with trees? ☐ yes ☐ no

<table>
<tr>
<td>
Has it already been grown in agroforestry systems?
☐ yes, with great success
☐ yes, with good success
☐ no
☐ I do not know
If yes: where?
In which combinations?
Where do you obtain seeds/seedlings?
</td>
<td>
If yes: was it successful?
☐ yes ☐ no
If not: do you have any suggestions why?
Where can you buy the seeds/seedlings?
☐ at a local nursery
☐ at a nursery ________ km away from here
☐ from the neighbour/within the community
☐ Mercado de Abastos, Central Market Panama City
☐ own production
☐ ____________________
☐ I do not know
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What is the price for seeds/seedlings?
The following questions will focus on the management aspects:
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Which distance should be kept between plants and rows?

- ☐ between plants: ________
- ☐ between rows: _________
- ☐ I do not know

What kind of management is needed to grow the crop?

- ☐ weeding: ______ times per month
- ☐ pruning: _____ times per _________
- ☐ pesticides/herbicides: _________ applications per growth period
  → name of the pesticide: _________
  → dosage: _________
- ☐ fertilizers: _________ applications per growth period
  → name of the fertilizer: _________
  → dosage: _________
- ☐ I do not know

Which parts of the plant can be used?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ other

Which parts/products of the plant can be sold?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ other

How many harvests do you get per year?

☐ one ☐ two ☐ three ☐ four ☐ harvest all year long with an interval of ________ weeks ☐ I do not know

What are the expected yields (kg/ha)?

Which products can you make out of this plant?

Which machinery is necessary for the production?

How much does the production cost?

What is the selling unit?

What is the market price for the product(s)?

Please assess the difficulty to transport the parts/products of the plant from 1 (very easy) to 4 (very difficult):

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult to transport please explain why:

Please assess the difficulty to grow the plant species if you are not experienced with it: from 1 (very easy, no assistance needed) to 4 (much assistance needed):

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult, please state why:

Are the products of local, national or international importance?

☐ local ☐ national ☐ international ☐ I do not know

How would you describe its market potential?

☐ very low ☐ rather low ☐ rather high ☐ very high ☐ I do not know

Please briefly name the main aspects that make you recommend this plant species. Please put them in an order beginning with the most important one.

a) _________

b) _________

c) _________

d) _________

Are there any drawbacks connected to the plant species that need to be considered when implementing it into an agroforestry system?

13. In your opinion – which aspects are more important to be considered when you want to combine plants and trees? Please make an order starting with the most important aspect. ☐ tree-plant interactions, No. __________ ☐ water availability, No. __________ ☐ suitable light conditions, No. __________ ☐ nutrient availability, No. __________ ☐ other: __________, No. __________ ☐ I do not know	
14. In general: what are your experiences with or information regarding the supply of quality seeds and/or seedlings? What and where do you recommend to obtain quality seeds/seedlings?	
15. What is your practical/scientific experience with the plants listed below?	**14. Do you have information regarding the following plant species?**
Noni (*Morinda citrifolia*) Do you know this plant species? ☐ yes ☐ no ☐ I only heard about it, but do not know details	

Do or did you work with it?

☐ yes ☐ no

Do or did you grow it yourself?

☐ yes ☐ no

Do you recommend it for agroforestry systems in the humid tropics of Central America?

☐ yes ☐ no ☐ I do not know

if yes: at which stage?

☐ stage 1 (full sunlight)

☐ stage 2 (20-30% shade)

☐ stage 3 (50-60% shade)

☐ stage 4 (under mature trees with a closed canopy)

☐ I do not know

if not: why?

Where can you buy seeds/seedlings?

☐ at a local nursery

☐ at a nursery ________ km away from here

☐ from the neighbour

☐ Mercado de Abastos, Central Market Panama City

☐ own production

☐ ________

☐ I do not know

What are the costs for the seeds/seedlings?

Which parts of the plant can be used?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ ________

Which products/parts of the plant can be sold?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ ________

How many harvests do you get per year?

☐ one ☐ two ☐ three ☐ four ☐ harvest all year long with an interval of ________ weeks ☐ I do not know

How high are the expected yields?

Which products can you make out of this plant?

Which machinery is necessary for the production?

How much does the production cost?

What is the selling unit?

What is the market price for the product(s)?

Please assess the difficulty to transport the parts/products of the plant from 1 (very easy) to 4 (very difficult)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult to transport, please explain why:

Please assess the difficulty to grow the plant species if you are not experienced with it: from 1 (very easy, no assistance needed) to 4 (much assistance needed):

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult, please state why:

Do you assess the plant species and its potential products as being of regional, national or international importance?

☐ regional ☐ national ☐ international ☐ I do not know

How do you assess its market potential?

☐ very low ☐ rather low ☐ rather high ☐ very high ☐ I do not know

Please briefly name the main aspects that make you recommend the plant species. Please put them in an order beginning with the most important one.

a) __________

b) __________

c) __________

d) __________

Are there any drawbacks connected to the plant species that need to be considered when implementing it into an agro-forestry system?

Arazá (*Eugenia stipitata* McVaugh)

Do you know this plant species?

☐ yes ☐ no ☐ I only heard about it, but do not know details

Do or did you work with it?

☐ yes ☐ no

Do or did you grow it yourself?

☐ yes ☐ no

Do you recommend it for agroforestry systems in the humid tropics of Central America?

☐ yes ☐ no ☐ I do not know

if yes: at which stage?

☐ stage 1 (full sunlight)

☐ stage 2 (20-30% shade)

☐ stage 3 (50-60% shade)

☐ stage 4 (under mature trees with a closed canopy)

☐ I do not know

if not: why?

Where can you buy seeds/seedlings?

- ☐ at a local nursery
- ☐ at a nursery ________ km away from here
- ☐ from the neighbour
- ☐ Mercado de Abastos, Central Market Panama City
- ☐ own production
- ☐ ________
- ☐ I do not know

What are the costs for the seeds/seedlings?

Which parts of the plant can be used?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ ________

Which products/parts of the plant can be sold?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ ________

How many harvests do you get per year?

☐ one ☐ two ☐ three ☐ four ☐ harvest all year long with an interval of ________ weeks ☐ I do not know

How high are the expected yields?

Which products can you make out of this plant?

Which machinery is necessary for the production?

How much does the production cost?

What is the selling unit?

What is the market price for the product(s)?

Please assess the difficulty to transport the parts/products of the plant from 1 (very easy) to 4 (very difficult)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult to transport, please explain why:

Please assess the difficulty to grow the plant species if you are not experienced with it: from 1 (very easy, no assistance needed) to 4 (much assistance needed):

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult, please state why:

Do you assess the plant species and its potential products as being of regional, national or international importance?

☐ regional ☐ national ☐ international ☐ I do not know

How do you assess its market potential?

☐ very low ☐ rather low ☐ rather high ☐ very high ☐ I do not know

Please briefly name the main aspects that make you recommend the plant species. Please put them in an order beginning with the most important one.

a) __________

b) __________

c) __________

d) __________

Are there any drawbacks connected to the plant species that need to be considered when implementing it into an agroforestry system?

Borojó (*Borojoa patinoi* Cuatrec)

Do you know this plant species?

☐ yes ☐ no ☐ I only heard about it, but do not know details

Do or did you work with it?

☐ yes ☐ no

Do or did you grow it yourself?

☐ yes ☐ no

Do you recommend it for agroforestry systems in the humid tropics of Central America?

☐ yes ☐ no ☐ I do not know

if yes: at which stage?

☐ stage 1 (full sunlight)

☐ stage 2 (20-30% shade)

☐ stage 3 (50-60% shade)

☐ stage 4 (under mature trees with a closed canopy)

☐ I do not know

if not: why?

Where can you buy seeds/seedlings?

- ☐ at a local nursery
- ☐ at a nursery ________ km away from here
- ☐ from the neighbour
- ☐ Mercado de Abastos, Central Market Panama City
- ☐ own production
- ☐ ________
- ☐ I do not know

What are the costs for the seeds/seedlings?

Which parts of the plant can be used?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ ________

Which products/parts of the plant can be sold?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ ________

How many harvests do you get per year?

☐ one ☐ two ☐ three ☐ four ☐ harvest all year long with an interval of ________ weeks ☐ I do not know

How high are the expected yields?

Which products can you make out of this plant?

Which machinery is necessary for the production?

How much does the production cost?

What is the selling unit?

What is the market price for the product(s)?

Please assess the difficulty to transport the parts/products of the plant from 1 (very easy) to 4 (very difficult)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult to transport, please explain why:

Please assess the difficulty to grow the plant species if you are not experienced with it: from 1 (very easy, no assistance needed) to 4 (much assistance needed):

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult, please state why:

Do you assess the plant species and its potential products as being of regional, national or international importance?

☐ regional ☐ national ☐ international ☐ I do not know

How do you assess its market potential?

☐ very low ☐ rather low ☐ rather high ☐ very high ☐ I do not know

Please briefly name the main aspects that make you recommend the plant species. Please put them in an order beginning with the most important one.

a) __________

b) __________

c) __________

d) __________

Are there any drawbacks connected to the plant species that need to be considered when implementing it into an agroforestry system?

Ginger (*Zingiber officinale*)

Do you know this plant species?

☐ yes ☐ no ☐ I only heard about it, but do not know details

Do or did you work with it?

☐ yes ☐ no

Do or did you grow it yourself?

☐ yes ☐ no

Do you recommend it for agroforestry systems in the humid tropics of Central America?

☐ yes ☐ no ☐ I do not know

if yes: at which stage?

☐ stage 1 (full sunlight)

☐ stage 2 (20-30% shade)

☐ stage 3 (50-60% shade)

☐ stage 4 (under mature trees with a closed canopy)

☐ I do not know

if not: why?

Where can you buy seeds/seedlings?

☐ at a local nursery

☐ at a nursery ________ km away from here

☐ from the neighbour

☐ Mercado de Abastos, Central Market Panama City

☐ own production

☐ ________

☐ I do not know

What are the costs for the seeds/seedlings?

Which parts of the plant can be used?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ ________

Which products/parts of the plant can be sold?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ ________

How many harvests do you get per year?

☐ one ☐ two ☐ three ☐ four ☐ harvest all year long with an interval of ________ weeks ☐ I do not know

How high are the expected yields?

Which products can you make out of this plant?

Which machinery is necessary for the production?

How much does the production cost?

What is the selling unit?

What is the market price for the product(s)?

Please assess the difficulty to transport the parts/products of the plant from 1 (very easy) to 4 (very difficult)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult to transport, please explain why:

Please assess the difficulty to grow the plant species if you are not experienced with it: from 1 (very easy, no assistance needed) to 4 (much assistance needed):

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult, please state why:

Do you assess the plant species and its potential products as being of regional, national or international importance?

☐ regional ☐ national ☐ international ☐ I do not know

How do you assess its market potential?

☐ very low ☐ rather low ☐ rather high ☐ very high ☐ I do not know

Please briefly name the main aspects that make you recommend the plant species. Please put them in an order beginning with the most important one.

a) __________

b) __________

c) __________

d) __________

Are there any drawbacks connected to the plant species that need to be considered when implementing it into an agroforestry system?

Cananga (*Cananga odorata*)

Do you know this plant species?

☐ yes ☐ no ☐ I only heard about it, but do not know details

Do or did you work with it?

☐ yes ☐ no

Do or did you grow it yourself?

☐ yes ☐ no

Do you recommend it for agroforestry systems in the humid tropics of Central America?

☐ yes ☐ no ☐ I do not know

if yes: at which stage?

☐ stage 1 (full sunlight)

☐ stage 2 (20-30% shade)

☐ stage 3 (50-60% shade)

☐ stage 4 (under mature trees with a closed canopy)

☐ I do not know

if not: why?

Where can you buy seeds/seedlings?

☐ at a local nursery

☐ at a nursery ________ km away from here

☐ from the neighbour

☐ Mercado de Abastos, Central Market Panama City

☐ own production

☐ ________

☐ I do not know

What are the costs for the seeds/seedlings?

Which parts of the plant can be used?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ ________

Which products/parts of the plant can be sold?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ ________

How many harvests do you get per year?

☐ one ☐ two ☐ three ☐ four ☐ harvest all year long with an interval of ________ weeks ☐ I do not know

How high are the expected yields?

Which products can you make out of this plant?

Which machinery is necessary for the production?

How much does the production cost?

What is the selling unit?

What is the market price for the product(s)?

Please assess the difficulty to transport the parts/products of the plant from 1 (very easy) to 4 (very difficult)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult to transport, please explain why:

Please assess the difficulty to grow the plant species if you are not experienced with it: from 1 (very easy, no assistance needed) to 4 (much assistance needed):

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult, please state why:

Do you assess the plant species and its potential products as being of regional, national or international importance?

☐ regional ☐ national ☐ international ☐ I do not know

How do you assess its market potential?

☐ very low ☐ rather low ☐ rather high ☐ very high ☐ I do not know

Please briefly name the main aspects that make you recommend the plant species. Please put them in an order beginning with the most important one.

a) __________

b) __________

c) __________

d) __________

Are there any drawbacks connected to the plant species that need to be considered when implementing it into an agroforestry system?

Cat's Claw (*Uncaria guianensis*)

Do you know this plant species?

☐ yes ☐ no ☐ I only heard about it, but do not know details

Do or did you work with it?

☐ yes ☐ no

Do or did you grow it yourself?

☐ yes ☐ no

Do you recommend it for agroforestry systems in the humid tropics of Central America?

☐ yes ☐ no ☐ I do not know

if yes: at which stage?

☐ stage 1 (full sunlight)

☐ stage 2 (20-30% shade)

☐ stage 3 (50-60% shade)

☐ stage 4 (under mature trees with a closed canopy)

☐ I do not know

if not: why?

Where can you buy seeds/seedlings?

- ☐ at a local nursery
- ☐ at a nursery ________ km away from here
- ☐ from the neighbour
- ☐ Mercado de Abastos, Central Market Panama City
- ☐ own production
- ☐ ________
- ☐ I do not know

What are the costs for the seeds/seedlings?

Which parts of the plant can be used?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ ________

Which products/parts of the plant can be sold?

☐ fruits ☐ leaves ☐ flowers ☐ wood ☐ roots ☐ ________

How many harvests do you get per year?

☐ one ☐ two ☐ three ☐ four ☐ harvest all year long with an interval of ________ weeks ☐ I do not know

How high are the expected yields?

Which products can you make out of this plant?
Which machinery is necessary for the production?

How much does the production cost?

What is the selling unit?

What is the market price for the product(s)?

Please assess the difficulty to transport the parts/products of the plant from 1 (very easy) to 4 (very difficult)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult to transport, please explain why:

Please assess the difficulty to grow the plant species if you are not experienced with it: from 1 (very easy, no assistance needed) to 4 (much assistance needed):

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ I do not know

In case it is difficult, please state why:

Do you assess the plant species and its potential products as being of regional, national or international importance?

☐ regional ☐ national ☐ international ☐ I do not know

How do you assess its market potential?

☐ very low ☐ rather low ☐ rather high ☐ very high ☐ I do not know

Please briefly name the main aspects that make you recommend the plant species. Please put them in an order beginning with the most important one.

a) __________

b) __________

c) __________

d) __________

Are there any drawbacks connected to the plant species that need to be considered when implementing it into an agroforestry system?

16. Personal information:	**15.** Personal information:
What is your complete name?	What is your name?
What is your age?	What is your profession?
What is your nationality?	What is your education (school- and work-wise)?
What is your profession?	What is your nationality?
Which institute do you work for today?	How old are you?

For how long have you been working there? About your professional background: What did you study? What is your degree? Which institutions did you work for and for how long? Do or did you work practically outside in the field? ☐ yes ☐ no For how long have you been working in the field of NTFPs/agriculture in combination with agroforestry systems? What is your regional focus area? In case you would like to get the results of my thesis, please give me your email address you would like me to send it to.	Where were you born?
Thank you very much for your participation.	

8.2 Appendix 2: Example of a criteria checklist (Noni; *Morinda citrifolia*)

	Weighting coefficient	Plant information	value
Latin name		***Morinda citrifolia***	
Other common names		**Noni, Indian Mulberry**	
Botanical plant family		**Rubiaceae**	
General comment		Provides many environmental services and numerous products for people; multipurpose plant species[1] Grows very quickly[18] General problem: the value of the plant species is the fruit, but this is not valued in Panama anymore; in 2003 the Panamanian government gave seedlings for free, but it did not work, because big amounts of fruits are needed for the production of juice[19] It was grown on several hectares, but it did not work[20]	
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Tropical wet & dry (Aw), tropical wet (Ar)[9]	5
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Primary forest or shrub vegetation, dry to mesic forests, grassland, near shorelines, open areas, fallow, pasture, waste areas; no areas with aggressive grasses and weeds[1], lava flows, tide pools, forest understory, gulches[7]	5
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	1-800 m.a.s.l., depending on latitude; at 19° up to 760 m.a.s.l., at the equator up to 1200 m.a.s.l.[1] up to 1.500 m.a.s.l.[9]	5
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Between 19°north and south[1]	5
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	250-4000mm; for high yields: moderate rainfall (500-1500mm) evenly distributed over the year[1] 1.500-3.000 mm/year[9]	5
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Volcanic soil; grows in a wide range of soils, even in brackish tide pools close to the coast; accepts seasonal waterlogging, but prefers well drained soils; tolerates wide ranges of acidity: acidic to	5

		alkaline; grows very well on rocky soils; cannot compete well in deep, silty soils where grasses and weeds are abundant, or heavy, compacted soils; very salt resistant[1,7] Deep soils (<150 cm), medium texture, high fertility, low salinity, well drained[9]	
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Accepts at least 3-4 months, mature trees even 6 months or more[1]	5
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	20-35°C (mean max. temp: 32-38°C, mean min. temp: 5-18°C)[1] 24-30°C (=optimal, tolerates 12-36°C)[9]	5
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Plant growth and yields are diminished in windy areas; most important factor for the site selection; can survive in windy areas, but should not be exposed to winds exceeding 33kph[1]	0
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Tolerant to a wide range of environments[1]	5
Suitability indicator for site related criteria			**45/60**
plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	South and Southeast Asia; spread throughout the world in the 17th and 18th centuries by explorers, merchants and privateers;[1] in Panama distributed all along the Caribbean side and in the northern part of the Pacific side[4]	2
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	Depending on source 3-10m[1] or up to 6m[3]; can be pruned and thinned to any extent to keep it small and bushy which facilitates harvesting[1] 2-3m[25]	5
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Extensive lateral root system and a deep taproot[1]; not known if they negatively impact other plant species	6
Annual/perennial plant*	---*	Perennial[1,4]	
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Evergreen, bushy tree or shrub[1,3,4]	

Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Thrives in forest understory, benefits from organic matter and mulch provided by other plant species; should not be grown where other nematode-susceptible crops (such as papaya) grew before, as Noni is susceptible to it as well; Noni attracts ants, sap-feeding insects (i.e. aphids) can be a problem for some vegetable intercroppings.[1]	6
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5		10
In which stage of the agroforestry system can it be planted? *	---	1-2[25]	
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Endlessly, as shade tolerant to up to 80%[1] Suitable, as it can be planted in full sun, will produce fruits in the second year and produce more fruits the older it grows[7]; as shade tolerant it can grow in different stages of an agroforestry system	25
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Grows in the understory of tropical island forests and rainforests; grows well in full sunlight, but tolerates up to 80% of shade[1] Yes, it is shade tolerant[14] Needs full sunlight[20,26]	25
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto		2
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	No, as fruits are not damaged easily[1]	5
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Yes, it is easy to care for[1]	25
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Difficult to kill once it is established; new Noni plants sprout from exposed roots (root suckers)[1]	0
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not considered invasive by botanists, not invasive to a degree of threatening an ecosystem, but it is known for its ability to disperse, persist and colonize new areas[1] Aggressive regeneration, it's growth needs to be controlled[16,17]	2

Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Seeds are dispersed by birds and rodents, wind and rainwater; reproduction via seeds and stem cuttings[1,4,7] Grows in most commonly available growth media, natural or local forest soils mixed with sand, volcanic cinders and/or composed organic matter are best for seedling production; seeds germinate within 3-6 weeks when scarified, otherwise it may take 6-12 months; reproduction also via root suckers possible; vegetatively produced plants are not as strong and resistant as those grown from seeds[1,7] Easily reproduced[16]	2
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	No, but respond well to periodic applications of fertilizers. For intensive fruit production young plants can be encouraged with balanced fertilizers (14-14-14 or 16-16-16), organic fertilizers (7-7-7 or chicken manure, guano) or a yearly application of lime (1 lb per plant). Overuse of fertilizers can lead to heavy insect infestation.[1,7]	15
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	If grown in monocultures, as vulnerable to some fungi and insect infestations[1] Control of insects is necessary[17]	0
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	In diverse ecosystems there are usually no severe problems with pests and diseases; but it is susceptible to root-knot nematodes (Meloidogyne spp.), a small roundworm that causes galls and swellings on roots that weaken the plant; no diseases originating from bacteria, viruses, viroids or phytoplasmas; in large plantations it is susceptible to insect attacks by aphids, scales, weevils, leaf miners, whiteflies, caterpillars, thrips and mites; insect damage more severe in dry areas and full sun plantings, damage by fungi in rather wet areas; sanitation (i.e. picking up and removing infected leaves) or periodic application of approved fungicides can solve the problem.[1]	0

Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Yes, as fruits do not damage or bruise easily; generally no specials containers or precautions necessary; exposure to direct sunlight or high temperatures do not cause problems, thus no refrigeration needed if fruits are processed within hours after harvesting; best to harvest white but hard fruits, as they ripen quickly once this development stage is reached[1] No, as fruits are very perishable[12,19] Transportation is difficult: fruits ripen very fast, that is why they have to be transported quickly[13]	15
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Yes: Food supplement, medicine, animal fodder (fruits and leaves), canoe parts, firewood, red and yellow dye for colouring fabrics, insect repellent, beverages, cosmetics, fruit leather, famine food; boundary markers; bee forage; coastal protection; attraction of beneficial insects including lady beetles, spiders, praying mantises and insect predators like anoles, chameleons, lizards and geckos.[1, 3]	5
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap) *	---	Fruits, leaves, wood, stem, seeds, flowers, roots	
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Yes[1]	5
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes: according to the CRC Handbook of Medicinal Herbs[5] Noni has a number of documented activities for a wide range of diseases and conditions: headaches, fever, malaria, cancer, pain, tuberculosis, rheumatism, fractures, diabetes, sores, cuts, amongst others[1] Yes[13,14,17,18,23]	5
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	There are no scientifically accepted results about treatments with Noni, but it is increasingly perceived as being safe and useful; Noni research and development is very active, inventors are	

		attracted by it; inventions span an array of ailments and health issues; Doctors are prescribing it in some cases, i.e. in Hawai'i it is given to cancer patients by cancer specialists to fight a range of cancers; Noni leaves and fruits are anti-bacterial, anti-microbial, anti-inflammatory, analgesic and stimulating to the immune system, therefore it is a good first aid treatment.[1] There are more than 400 publications on Noni[8], its ingredients and impacts, especially on medicinal (cancer) research (e.g. Fong et al. 2001, Issell 2001, Lui et al. 2001, Hirazumi & Furusawa 19999, Hirazumi et al. 1996, Hirazumi et al. 1994, Hiramatsu et al. 1993) Clinically not proven, yet, but highly potential[21]	
What are the main active nutritional and medicinal substances?*	---	17 amino acids, Vitamins A, C, E, B1, B2, B3, B5, B6, B7 (Biotin), B9, B12, Calcium, Iron, Phosphorus, Magnesium, Zinc, Copper, Chromium, Manganese, Molybdenum, Sodium, Potassium[1]	
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Yes: fruit powder, juice, pulp, capsules[1,6,7,22]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	No, very easy to grow[17,18]	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	No. First harvest 9-12 months after planting, but fruits are small and few; better prune the plant in favour of a better harvest in the second year[1]	**0**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Organic fertilizers and farming methods can result in organic certification and an increased market value[1]	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	Has been consumed by millions without problems[1] scientifically proved that not harmful[8] No: USP certified Noni as being safe, no toxic properties[21]	**5**
main drawbacks*	---	Strong, unpleasant odor[1]	
Suitability indicator for plant-related criteria			**169/325**

Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	No	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Sold in the US and New Zealand as herbal and nutritional supplement, in the EU as a novel food, in Australia as a food, thus marketed in many areas[1], in the EU accepted as a novel food since 2003[8] Yes, the USA is the biggest consumer of Noni products[21]	**25**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	For 2000 years, maybe longer[1]	
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Worldwide markets are expanding every year: $400 million (2001) to projected $2 billion (2006)[1] There is no demand in Panama[12,] (except for Bocas del Toro) → bad market situation[13] There was a local supplier of Noni juice in Panama City, they were exporting to Japan in 2009; Noni was very popular five years ago, but is not demanded anymore, because new products are more demanded[15] There is no market[20] Yes: local and international[25]	**25**
Market potential (0=low, 2=not known, 5=high)	5	Noni's role in human and environmental health will be increasingly recognised; most important function may be medicine, as the plant is widely used in this field; there is a growing trend towards integrative medicine which Noni is part of[1] Not important anymore[12,15] Low commercial value[17,24] Very low, because many people grow it in their garden[18] Noni had its time, did not work in Panama[26]	**25**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Buy ripe fruits, take seeds out; one fruit contains 200-250 seeds[7]	**25**

Costs per seed/seedling*	---	US$0.50-1/seedling[22] US$0.30-1/seed[25]	
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	3-4.5m x 3-4.5m; taking 3.5m x 3.5m = 716 plants per ha[7] plants need a lot of space to grow[12]	
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5		
Needed management (pruning, weeding, fertilizing, etc.)*	---	Pruning lower branches will be good for weed control and fruit quality, pruning vertical branches of mature trees facilitates harvest, as it keeps plants low and bushy; young plants younger than three years may be pruned back after or during their first production of fruit; irrigation of young plants in dry conditions: once or more a week, up to 35 litres per plant[1,7]	
Working hours needed for one cycle (planting until harvesting) per ha*	---		
Working hours needed for two cycles (planting until harvesting) per ha*	---		
Number of harvests per year*	---	Throughout the year; usually harvested two or three times a month[1,7]·2-3 times/week[22]	
Yields (kg/ha/yr)*	---	During first year: no harvest; 2. year: 11kg/plant/year = 7.900 kg/ha/year 3. year: 22 kg/plant/year = 15.800 kg/ha/year 4. year: 44 kg/plant/year = 31.500 kg/ha/year 5. year: 82 kg/plant/year = 58.700 kg/ha/year 6. year: 109 kg/plant/year = 78.000 kg/ha/year* → yield assumptions: 716 plants per ha → necessary for high yields: good soil fertility and drainage, good water supply; adequate disease, pest and weed control as well as fertilizer additions (e.g. 2.7 kg of 10-20-20 per plant per year) → yields may diminish due to unfavourable weather, soil condition, pests and diseases → juice extraction efficiency of roughly 50% by weight[7] 11kg* of fruits/tree/year; 5 fruits needed to	

		produce 3.8l of liquid[12] high yields (not specified)[13,17]	
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Yes, special packaging needed to protect perishable fruits[19]	**25**
Possible end products*	---	Food supplements, juice, cosmetics, soap, tea[1] Medicine[11,18,22] Liquid[12,22] Medicine, juice, tea, drinks[13] Juice, pulp, medicine[14] Juice[15,16,19,23] Juice, concentrates, jam, medicine[17] Wine, drinks[22] Jam[23]	
Market prices for products*	---	US$ 6-12/gallon of juice (US$ 1.60-3.20/l) (2006)[1] US$ 18/60 capsules of Noni powder[6] US$68/kg of loose powder[6] US$ 49/1l Tahitian Noni Juice[9] US$ 60/6ml Noni seed oil[9] US$ 55/30ml Noni Leaf Serum[9] US$ 46/60ml Noni Leaf Spray[9] US$30/30ml Noni concentrate[9] US$30/75ml different Noni extracts[9] US$10/small bottle of liquid (not specified)[12] US$3/fruit (Bocas del Toro)[20]	
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	Extraction machine needed[19,23] Low demand of technology for production[22]	**10**
Suitability indicator for economic criteria			**135/200**
Overall suitability indicator			**336/585**

*** Criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.** **Blue = results of interviews of local practitioners** **Red = results of interviews of experts of governmental institutions in Panama** **Green = results of interviews of scientists** **Purple = results of interviews of non-local practitioners**	Sources	[1] Scot & Craig 2006. [2] http://www.pvs-hawaii.com/History_Culture/plants.ht. [3] Nowak & Schulz 1998. [4] Acosta 2005. [5] CRC Handbook of Medicinal Herbs. [6] Healing Noni, Farmer Direct Wholesale Noni Juice 2012. [7] College of Tropical Agriculture and Human Resources 2006. [8] Westendorf 2010. [9] FAO Ecocrop 2011. [10] Tahitian Noni (company) 2012. [11] Interview No. 06. [12] Interview No. 03. [13] Interview No. 01. [14] Interview No. 02. [15] Interview No. 04. [16] Interview No. 09. [17] Interview No. 08. [18] Interview No. 10. [19] Interview No. 11. [20] Interview No. 13. [21] Interview No. 14. [22] Interview No. 18. [23] Interview No. 23. [24] Interview No. 20. [25] Interview No. 22. [26] Interview No. 19. * data were given in libra per acre and converted to kg per hectare	

Detailed Criteria Checklists of Investigated Plant Species

Abuta – *Cissampelos pareira* L.

	Weighting coefficient	Plant information	value
Latin name		***Cissampelos pareira* L.**	
Other common names		**Abuta, Velvet leaf, pareira, alcotá, bejuco de mona, oreja de raton, hierba de peso, curarina, liane amère, liane-cordé, liane molle[1]**	
Botanical plant family		**Merispermaceae[2,6]**	
General comment			
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Secondary and remnant forests, river banks, hammocks, brushy pastures, roadsides and fencerows[1] Humid and dry forests	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	0-1.500m[1] up to 1.800m.a.s.l.[7]	**5**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	750-2.400mm/year[1]	**5**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	No exposed clay subsoils, compacted soils, excessively drained, or very poorly drained soils; accepts a wide variety of soil textures, pH levels, and soils derived from most parent materials including limestone and ultramafic rocks (serpentine)[1]	**5**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**

Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**6**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Not known	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**36/60**
plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Native from Mexico to Argentina and Peru on the New World mainland and in the West Indies, also native to Florida; found throughout tropical Asia and Africa (though not sure if native or introduced)[1] Found in subtropical parts of India, Asia, East Africa and America[3] Found throughout the Amazon in Peru, Brazil, Ecuador and Colombia[4] Indigenous to the Amazon rainforest, but also grows in India.[5] Native to tropical America and the tropical world[7] → not known, if it grows in Panama	**2**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	3-6m along the ground or into the crowns of trees; sprouts grow rapidly: at least 3m in the first year[1] 2-5m high[3]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Flexible lateral roots with sinkers and moderately abundant fine roots[1]	**6**
Annual/perennial plant*	---*	Individual stems are not long-lived, but by sprouting and layering, plants or clones may last many years[1] perennial[2]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Shrubby climber with relatively few branches[1] Shrub, vine[2] Climbing shrub[3] Woody, climbing rainforest vine[4] Climbs over shrubs or small trees[7]	**---**

Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Not known	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Not known	**10**
In which stage of the agroforestry system can it be planted?*	---	Not known	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Moderately intolerant of shade; does not grow under the closed canopy of high forest; grows in opened and thus disturbed forests[1]	**25**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	When planted in commercial potting mix without pretreatment, 26 percent of the seeds germinated between 28 and 61 days after sowing; seedlings are rarely abundant; Stems layer (root) wherever they contact the soil[1] By seeds[5]	**0**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Not known	**6**

Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	It adds to biodiversity and biomass, helps stabilize the soil, and furnishes food and cover for wildlife. A major interest in the species arises from the natural medicinal benefits of the plant's chemical contents.[1]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*	---	Roots, leaves, stem[3] Whole vine, seed, bark, leaf, roots[4] Roots, bark, leaves[5] Roots, leaves, tuber, bark[6]	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Not known	**2**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes: Known as the "midwife's herb," it has been used for centuries by native peoples of South America to treat menstrual cramps, prevent threatened miscarriage, control uterine hemorrhages, and ease childbirth and postpartum pain; also works against urinary infections, kidney stones, arthritis, snakebite, cough, dysentery, piles, ulcers, pain, indigestion, colic, skin irritations, stings, intestinal worms, and wounds[1,3,4] Used for the treatment of a wide variety of diseases in Traditional Chinese Medicine, Ayurveda and Western herbalism; antitumor potential and neuromuscular blocking effects; traditionally used to reduce fever and relieve pain, menstrual cramps, difficult menstruation, excessive bleeding and uterine hemorrhages, fibroid tumors, pre- and postnatal pain, colic, constipation, poor digestion, and dyspepsia, indolent ulcers, diarrhea; antiseptic properties; treats urinary tract infections and migraine; used for muscle inflammation,	**5**

		snakebites, rheumatism, dysentery, asthma; used to prevent threatened miscarriage and Stopp uterine hemorrhages after childbirth[3] Stops bleeding, balances mensturation, relieves pain, reduces spasms, relaxes muscles, stops inflammation, increases urination, lowers blood pressure, kills bacteria, prevents convulsions, fights free radicals, prevents ulcers, reduces mucus and fever, protects liver, balances hormones; for snakebite, venereal disease, rheumatism [4] Anti-dote for poisonous snakebites, diabetes, dropsy, gonorrhea, heart problems, jaundice, rheumatism, aphrodisiac[5] Abdominal pain, blood dysentery, contraceptive, cut wound, diarrhea, epilepsy, epiliptic fits, evil spirit, leucorrhoea, pain around umbilicus, rheumatoid arthritis, scrofuloderma, tonsil, worm infection[6]	
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Anti-pain, anti-inflammatory, antifertility, antioxidant activity, chemo preventive effects proven[3] Anti-inflammatory, antiulcerous, antioxidant, antibacterial, antimalarial, anti-cancer, anticonvulsant and antispasmodic actions confirmed[4]	**15**
What are the main active nutritional and medicinal substances?*	---	A number of alkaloids found in the tissues of the plant[1] Isoquinoline alkaloids[3]	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Yes: Decoction, Tincture, Capsules[4]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	Not known	**6**

Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	No. Tests did not show any toxicity[3]	**5**
main drawbacks*	---	---	**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**175/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Yes: Used in North American herbal medicine[4]	**25**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Thousands of years[4]	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Yes: Ground tissues and preparations are sold throughout the world in markets, shops, and mail-order companies.[1]	**25**
Market potential (0=low, 2=not known, 5=high)	5	Not known	**10**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Not known	**10**
Costs per seed/seedling*	---	Not known	**---**
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	Not known	**---**
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Protection against heavy grazing needed[1]	**---**
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	**---**
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	**---**

Number of harvests per year*	---	Flowers and fruits throughout the year in the Americas[1]	---
Yields (kg/ha/yr)*	---		---
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Possible end products*	---	Juice, decoction, gel[3]	---
Market prices for products*	---	Not known	---
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	Not known	**10**
Suitability indicator for economic criteria			**116/200**
Overall suitability indicator			**327/585**
*** criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.**	Sources	[1] Francis no date b. [2] Natural Resources Conservation Service 2012a. [3] Singh et al. 2010. [4] Taylor 1996a. [5] Jessurun 2012a. [6] Hansen 2003. [7] Gupta 2008.	

Aloe Vera – *Aloe barbadensis*

	Weighting coefficient	Plant information	value
Latin name		***Aloe barbadensis***	
Other common names		**Aloe Vera**[1,2.3]	
Botanical plant family			
General comment		The uncontrolled collection by the local communities for the herbal medicine vendors, usually harvest *Aloe* leaves, causing a serious threat to its population in the nature as well as to biodiversity. An understanding of germplasm diversity and genetic relationships in a germplasm collection is an invaluable aid for conservation and crop improvement strategies. In order to improve the medicinal value of *Aloe* vera and also to fill the gap between the demand and the supply of elite planting material, there is a need to conserve this species for sustainable use in future.[2]	
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Prefers hot and dry climates, but adapts to more humid areas[2,3]	**5**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**

Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Several months[3]	**5**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	Extremely hot summer months with high sun radiation; does not accept temperatures that are constantly below 10°C[3]	**5**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**6**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Not known	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**28/60**
plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	It is grown in most subtropical and tropical locations including South Africa and Latin America, then it was introduced to China, India and various parts of Southern Europe in the 17th century[1] Native to Southern Africa[2] It probably originates from the Arabic region or Sudan; nowadays cultivated throughout the world, in America huge Aloe Vera farms can be found[3]	**2**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	Ca. 1m[3]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Not known	**6**
Annual/perennial plant*	---*	Perennial[3]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Cactus-like plant[1]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Not known	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Not known	**10**
In which stage of the agroforestry system can it be planted?*	---	Not known	**---**

For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Prefers sunny sites, but grows equally well in the shade[3]	**25**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	pollination[3] no information if easy or not	**2**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Yes. Plant for medical and cosmetic purposes and in health food, also planted as an ornamental; it inhibits the growth of microorganisms responsible for foodborne illness in humans or animals as well as food spoilage. It does not appear to affect food	**5**

		taste or appearance, so it seems to be promise as a safe, natural and environmentally- friendly alternative solution to conventional synthetic preservatives[1] Ingredient of cosmetics[2] Medicine, cosmetics, nutritional complement[3] Most familiar as topical use in cosmetics and after-sun lotions; also ingredient of ointments for skin treatment, oral food supplement[4] External moisturiser[5]	
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*	---	Leaves[1,4,5]	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Yes: vitamins, minerals, saponins, essential fatty acids[4,5]	**5**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes: it has wound healing, anti-inflammatory, immunity, healing of first to second degree burns, antidiabetic, antioxidant, laxative, antibacterial, antifungal, antiviral and antitumor, age-related effects[1] Enhances the immune system of the body[3] Claimed to be anti-inflammatory, painkilling, itch-relieving and healing, reducing blood lipid and glucose levels[4] Reduces inflammation; hyperlipidaemic and hypoglycaemic agent; anti-platelet activity[5]	**5**
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Not sure: there is no clear understanding or scientific analysis of the basis for its attributed properties[1] Yes: reason for medicinal properties have recently been diagnosed by modern analysing methods; scientists proved 220 ingredients of Aloe vera gel[3] Not proven as a beneficial dietary supplement[4] Reduction of acute external inflammation, promotion of wound healing & pain and antipruritic effect proven; also lowering blood glucose	**6**

		concentrations in diabetes and reduction of blood lipid levels in hyperlipidaemia confirmed[5]	
What are the main active nutritional and medicinal substances?*	---	Anthraquinones and polysaccharides[1,4] contains 18 of the 22 existing amino acids, vitamins, minerals, trace elements, polysaccharides, in total 200 bioactive substances[3] polysaccharides, tannins, sterols, saponins, cholesterol, gamma-linolenic acid, arachidonic acid[5]	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Yes: Latex, gel, whole leaf extract[1] Gel, oil, powder[3] Granules used as laxative, proved by American Food and Drug Administration (FDA), tablets, capsules[4]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	No. it only develops the desired nutrients of the liquid three to five years after planting[3]	**0**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	anthraquinones (the main active substance) may have harmful effects, such as genotoxic, mutagenic and tumor promoting[1] There have been a few reports of harmful effects of Aloe vera gel such as eczema, allergic dermatitis or an increase in circulating leucocyte count probably as a result of stimulation of the immune system[1]	**0**
main drawbacks*	---		**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**160/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**

Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Yes, marketed throughout the world[4]	**25**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Thousands of years[1]	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Yes, there is an immense demand; therefore it has been cultivated on big areas using modern knowledge: vast plantations in the USA, Australia and Spain, in the northern USA it is even cultivated in greenhouses[3]	**25**
Market potential (0=low, 2=not known, 5=high)	5	Food and beverage market is a promising arena[1]	**25**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Not known	**10**
Costs per seed/seedling*	---	Not known	**---**
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	Not known	**---**
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Not known	**---**
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	**---**
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	**---**
Number of harvests per year*	---	Once a year three leaves of a mother plant can be harvested; harvest every 2-3 months the uppermost leaves can be cut[3]	**---**
Yields (kg/ha/yr)*	---	Not known	**---**
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Possible end products*	---	cosmetic-moisturizer, cleaner, sun lotion, mouthwash, shaving cream, deodorant, shampoo, toothpaste etc, food as flavouring compounds, preservative of fresh products and in medicine of	**---**

		humans or animals; health food (yoghurt, drinks such as tea)[1]	
Market prices for products*	---	Not known	---
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	The gel of the leaves oxidises rapidly when exposed to air, decomposes and looses much of its biological activities, so there are different processing techniques needed with regard to gel's sterilization and stabilization[1]	**0**
Suitability indicator for economic criteria			**121/200**
Overall suitability indicator			**309/585**
*** criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.**	Sources	[1] Christaki & Florou-Paneri 2010. [2] Tripathi et al. 2011. [3] Straubinger 2004. [4] Webb 2006. [5] Mason 2007.	

Arazá – *Eugenia stipitata McVaugh*

	Weighting coefficient	Plant information	value
Latin name		***Eugenia stipitata*** **McVaugh**[1]	
Other common names		**Arazá, Araca-boi, Guayaba Peruana**[1]	
Botanical plant family		**Myrtaceae**[2,4]	
General comment		Grows very slowly[2]	
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto		
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Tropical rainforest[1,2,6,8,9]	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	Most important meteorological factor for Arazá[1] 200-300mm/month[1]; 2.000-3.000/year (depending on source)[1,4,6,8] relative humidity: 84%[1,8]	**5**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	High water saturation[1] Adapts easily to acid soils, little fertility with deficiencies of phosphorous and magnesium; pH should be around 5; tolerates periodic floods of up to 15 days[1,8] Texture: sandy[4,8], depth > 50cm[4] High inclination and bad drainage should be avoided[8]	**5**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Established plants can deal with a period of drought (no details about duration), but it will result in smaller fruits[6]	**2**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	18-33°C[1] 21-31°C[6,8]	**5**

		22-30°C[4]	
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**6**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	High adaptation to soils and climate[5]	**5**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**37/60**
plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Originates in the western Amazon region (Peru)[1,3,6] Also grown in Colombia[1], Costa Rica[20] and Nicaragua[4], but not known if already grown in Panama	**2**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	up to 10m, but grows very slowly[2]: after 10 years it is 3-3.5m high[1] after 4 years 2.7m[6] other source: 2-15m[2] generally pruned to 2.5-3m[1,4,6]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Pivoting main root which can penetrate the soil 2-3m deep[4]	**6**
Annual/perennial plant*	---*	Perennial[5]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Evergreen shrub[2,6] or small tree[2] A tree with a short and ramified stem and a low crown with short, compacted branches[4]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	No combination with crops that host fruitflies, rust and anthracnose, as Arazá is susceptible to these[3] Good opportunity for strengthening the diversification in the courtyard[4] Important to plant Arazá below a tree cover to protect flowers from rain[1]	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Yes: important component of agroforestry systems in the Amazon (Colombia) (during unproductive stage good to be combined with species of short vegetation periods to decrease installation and maintenance costs)[1] Trials with *Bactris gasipaes*, Acacia, Laurel, Musa yucca and cowpeas[5]	**25**

		Good results of an agrosilvicultural system of Laurel combines with maize, ginger and arazá[6]	
In which stage of the agroforestry system can it be planted?*	---	20-30% of shade[4], suitable for stage 2; can be planted end of stage 1, as it needs 14-18 months until the first harvest; shade primarily needed for fruits, not for the plant itself	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Suitable Until stage 2 is coming to an end and the overstory crops give too much shade for arazá;	**25**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Yes Better development of the plant and better fruit production with less intense shade[1] A bit of shading leads to a higher weight, bigger sugar content and a better colour than those fruits exposed to direct sun light; the fruit gets degraded when it is permanently exposed to full sunlight[1]; Best: 20-30% shade[4]	**25**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Yes! Arazá is considered one of the most perishable fruits[4]	**0**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Reproduction with seeds, germination takes some months[2] Also via seeds, cuttings, layering[4,6] Other source: germination 15-20 days after planting[4]	**2**

Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	Recommended at the beginning of planting: 10-15kg manure into the whole (40x40x40cm) for the seedling, and during the first year 100g of NPK 10-18-12 and 5 more kg of manure every 4 months[6] No excess of nitrogen close to the harvest, as it will reduce the post-harvest life of some products[9] 3-5 g of 12-24-12 or 15-15-15 every two months while the seedling is in the nursery[4]	**0**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	No, as Arazá is not susceptible to pests and diseases; but you can still prevent it with a monthly application of "2 onzas de Mancozeb mas 1,5 onzas de MTD mas 3 onzas de fertilizante foliar con elementos menores diluidos en 20 litros de agua" (pro wieviel Hektar/Pflanzen?)[4]	**6**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Not susceptible to pests and diseases[4] Fruits get damaged by thrips (*Frankliniella occidentals* Pergrande), fruit flies (*Ceratitis capitata, Anastrepha sp*) and wasps (*Trigona*)[1] Affected by some pathogens (*Gloeosporium* sp)[1,3,10,11,15], fungi (*Glomerella singulata, Colletotrichum gloesporoides*) and scabs[1,3] If grown with other species that strengthen diversity, Arazá is not susceptible to insect infestations; if grown in monocultures, the following pests and diseases might occur: *Tegunutes guabae* (control with MDT), *Atta sp* (control with Counter), *Phyllophaga spp* (control with Furadán), *Phytophthora sp*, *Fusarium oxisporum* (use fungicides), *Capnodia sp*[4]	**6**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	No! very perishable and susceptible to damages during transport, as it continues to ripen → needs to be grown close to access roads and processing factories[1,2,4,16] Cooling is the most common form to extend the life of perishable products, but temperatures less than 10-13°C lead to physiological damages[3,12,13,17] → possible solution: dipping the fruits into Calcium-Chloride ($CaCl_2$) after harvesting; viable, economic	**0**

		and easy treatment in the field to improve the texture of the fruit[1] 1-Methylcyclopropene (1-MCP) can also be applied, it is very effective on flowers, apples, pears and other fruits[18], it is approved for Arazá[14,19] it is also recommended to put the fruits into separate plastic baskets to reduce damages (like it is done with papaya)[1]	
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Human and animal production[5]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*****	---	Fruits[1] Leaves as animal fodder?	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Yes. High content of carbohydrates[1,4,6]	**5**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Some species of the genus *Eugenia* are used for local anesthetica[22]	**2**
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Not known	**2**
What are the main active nutritional and medicinal substances?*****	---	Rich in vitamin A, B1 and C, nitrogen, protein and potassium, low in phosphorous; the fruit is very acid[1,4,6]	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Yes: juice, jam, candies, ice-cream, jelly, cocktails, vine, cake, cream, pulp, compote[1,2,4]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	No. Fruit production starts at an age of 14-18 months[1,6]	**0**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**

Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
main drawbacks*	---	Very sensitive fruits that has a very short shelf life[2,3,4] Not well known[21]	**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**171/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Juice has been industrially processed and exported to Europe in small quantities (1998)[2] Arazá is considered a plant with different commercial uses at international level[4]	**25**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Not known	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Yes, but it is not well known[3] and rarely distributed[2]	**25**
Market potential (0=low, 2=not known, 5=high)	5	Arazá is a plant species which becomes more and more known and appreciated.[2] It is identified to have tremendous agro-industrial potential for juice, jam, ice-cream[3] Low[21] The genus *Eugenia* generally has an untapped potential[23]	**25**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Difficult, as there are no seeds available[21]	**10**
Costs per seed/seedling*	---	Not known	**---**
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	4x4m, 3x3m if crowns will be pruned[6]	**---**

Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Pruning to 2.5-3m advisable to facilitate harvest and thin twisted or ill branches (pruning for formation and pruning for maintenance/health)[1,4,6] Weeding once a month, at least every two months[4]	**---**
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	**---**
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	**---**
Number of harvests per year*	---	70-80 days after flowering, fruit production increases until the plant is five years old;[1] number of harvests per year also increases to 4 harvests per year[4] fruit production throughout the year, harvests every second month[1,6]	**---**
Yields (kg/ha/yr)*	---	Annual yields in agroforestry systems at an age of four years: • combined with Acacia: 15.4t/ha • combined with Laurel: 19.0t/ha • combined with Musa: 25.7t/ha[6] average weight of a fruit: 200-500g, 71% of it is pulp[1] up to 30t/ha/year[1] 21,75 fruits/tree (average) → 1.587 trees/ha = 34.517 fruits/ha → 34.517 fruits x 200g/fruit = 6.903 kg/ha → 6.903 kg x C$2.50/kg = C$ 17.257/ha = US$3.179/ha (2001)[4] in the third and fourth year a tree (2m high) produces 60-80 fruits per year; 2-2.5t/ha/yr in the first year of production, up to 50t/ha/yr after 9 years with fertilization[6,8] 28t/ha/yr for 80 plants of an age of 8 years and a	**---**

		spacing of 3x3m[6] 12.5t/ha/yr in a four year old plantation at a distance of 4x4m[20] 50 libra/tree[21]	
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Yes, packaging and cooling needed due to high degree of perishableness[1,3]	**0**
Possible end products*	---	juice, jam, candies, ice-cream, jelly, cocktails, vine, cake, cream, pulp, compote[1,2,4]	**---**
Market prices for products*	---	C$2.50/kg fruit (1990 & 2001)[4,8] US$3-4/libra of fruit[21]	
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	Not known	**10**
Suitability indicator for economic criteria			**121/200**
Overall suitability indicator			**329/585**

*** Criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.** **Blue = results of interviews of local practitioners** **Red = results of interviews of experts of governmental institutions in Panama** **Green = results of interviews of scientists** **Purple = results of interviews of non-local practitioners**	Sources	[1] Hernández Gómez et al. 2007. [2] Nowak & Schulz 1998. [3] Tai Chun 1995. [4] Proyecto de Desarrollo Rural Managua 2001. [5] Picón de Esteves & Ramírez Neyra 1991. [6] van Kanten 1994. [7] Proyecto de Desarrollo Rural Managua 2001. [8] Gonzales Tongoa 1990. [9] Herrero & Guardia 1992. [10] Kays 1999. [11] Duarte 1992. [12] Carmona 2001. [13] Hernández 2001. [14] Hernández & Fernández-Trujillo 2004. [15] Lucas et al. 1994. [16] Hernández & Galvis 1993. [17] Campbell 1994. [18] Blankenship & Dole 2003. [19] Hernández et al. 2002. [20] Vargas 1992. [21] Interview No. 03. [22] Interview No. 14. [23] Interview No. 19.

Bitter Melon – *Momordica charantia* L.

	Weighting coefficient	Plant information	value
Latin name		***Momordica charantia* L.**	
Other common names		**Bitter melon[2,3,5], Balsam-apple[1,3], Balsam pear[5]**	
Botanical plant family		**Cucurbitaceae[1,2,3,5]**	
General comment			
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	In hammocks, disturbed sites, turf and ornamental landscapes[1]	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**2**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Not known	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**23/60**

plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	West Indies, Tropical America, Old World Tropics, Florida to Texas on the coastal plain[1] India[2] Tropical areas including parts of the Amazon, east Africa, Asia and the Caribbean and throughout South America[3] Indigenous to tropical areas including Asia, South America and Africa[5]	**5**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	Not known	**2**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Not known	**6**
Annual/perennial plant*	---*	Annual[1,2,3]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Weed with a creeping/climbing stem[1] vine[2,3]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Not known	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Not known	**10**
In which stage of the agroforestry system can it be planted?*	---	Not known	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**

Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Not known	**2**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Yes: food and medicine[3,5]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*****	---	Whole plant, fruits, seeds, roots[3] Fruit pulp, seeds[5]	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Not known	**2**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes: kills bacteria, viruses, cancer cells, leukemia cells, prevents tumors, treats diabetes, reduces blood sugar and –pressure, lowers body temperature and cholesterol; reduces inflammation, fights free radicals, enhances immunity and libido, cleanses blood, detoxifies, expels worms, balances hormones, mildly laxative,	**5**

		promotes milk flow; aphrodisiac[3] Used in traditional medicinal systems as hypoglycaemic and anti-diabetic agents; also reported as antioxidant, antimicrobial, antiviral, antihepatotoxic, antiulcerogenic[5]	
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Yes: over the years scientists have verified many traditional uses; nearly 100 studies have proven blood sugar lowering effect; also antitumorous activity and reduction of total cholesterol are documented[3] Antioxidant and chemoprotective activities are proven[5]	**15**
What are the main active nutritional and medicinal substances?*	---	Not known	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Yes: decoction, tincture, capsules, powder[3] pulp[5]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	Outer fruit coat, ripe fruits and seeds are toxic if eaten in large quantities[1]	**0**
main drawbacks*	---	Not known	**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**157/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the	5	Yes: available in the USA[3] (though it is also grown	**25**

EU, USA or Asia? (0=no, 2=not known, 5=yes)		there)	
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Long history as a medicinal plant by indigenous people in the Amazon[3]	---
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Yes: used in Panama, also in Brazil, China, Cuba, Haiti, India, Mexico, Malaysia, Nicaragua, Peru and Trinidad[3]	**25**
Market potential (0=low, 2=not known, 5=high)	5	Not known	**10**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Not known	**10**
Costs per seed/seedling*	---	Not known	---
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	Not known	---
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Not known	---
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	---
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	---
Number of harvests per year*	---	Not known	---
Yields (kg/ha/yr)*	---	Not known	---
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Possible end products*	---	Tea[3] Juice, dried fruit bits[5]	---
Market prices for products*	---	US$2.85/15 seeds US$23.00/100 seeds US$218.50/1.000 seeds US$833.75/1kg of seeds US$12.65/0.5 pound of herbs US$22.00/1 pound of herbs US$11.55/1oz tincture US$62.37/6oz tincture	---

		US$117.81/12oz tincture US$208.59/24oz tincture[4]	
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	Not known	**10**
Suitability indicator for economic criteria			**116/200**
Overall suitability indicator			**296/585**
*** criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.**	Sources	[1] Hall et al. 2012. [2] Imhof 2012. [3] Taylor 1996b. [4] Jessurun 2012c. [5] Semiz & Sen 2007.	

Borojó – *Borojoa patinoi* Cuatrec

	Weighting coefficient	Plant information	value
Latin name		***Borojoa patinoi* Cuatrec**[1,4]	
Other common names		**---**	
Botanical plant family		**Rubiaceae**[1,4,7]	
General comment		---	
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Tropics[7]	**5**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Tropical forests[7] Requires wet sites[20]	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	High rainfall > 4.000mm/year[2]	**5**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Well drained; soils of its natural habitat and origin area are poor in nutrients[2]	**2**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	Around 26°C[2]	**5**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**2**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Understory plant species that adapts well to natural environments[14]	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**32/60**

plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Native to the Chocló Region in Colombia, but also grows in southern Panama and northern Ecuador[4,5] Amazon and Central America[6] Native to tropical America[7]	**2**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	7-25m[1] 2-3m after 3 years, 5m after 7 years, max. 7m after 25 years[2] 3-17m[4] 2-3m[5]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Superficial roots[2], not known if it hinders other plant species	**6**
Annual/perennial plant*****	---*	Perennial[2,4]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*****	---	Small understory tree[2] Large evergreen shrub or small tree[4]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Not known	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Indigenous populations in Colombia combine it with • Pineapple (*Ananas sativus* L. Merr) • peach palm (*Bactris gasipaes* Kunth) • papaya (*Carica papaya* L.) • plantain (*Musa X paradisiacal* L.) • caimito (*Pouteria caimito*) • sugar cane (*Saccharum officinarum* L.) • cocoa (*Theobroma cacao* L.) agroforestry with borojó is recommended as an alternative to monocultures besides enriched forests[2] Does not know but could be good in teak plantations (problem: teak sheds leaves in summer, thus less shade for three months; if plant needs a lot of shade, it cannot be combined with teak)[20]	**25**
In which stage of the agroforestry system can it be planted?*****	---	As it needs some shading[2,5], stages 2-3 will be suitable	**---**

For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Yes; it grows naturally in the understory of higher trees[2,5] It even requires shade and grows better compared to full sun exposition, therefore recommended to grow it in the shade of other trees[2]	**25**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Yes; also recommended to establish processing facilities close to the production area[2]	**5**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Usually reproduced by seeds (germination 20-45 days after seeding)[2]	**5**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	Grows naturally on very poor soils[2]	**6**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Vulnerable to the following insects and fungi, but not known to which extent: Leaf-cutting ants, leafscale, larvae of moths, fungi (*Aspergillus* and *Penicillum*) can colonize the fruit, but do not harm it; the fungi *Colletotrichum* sp. attacks the stem and leads to fruits falling from the tree before they are mature[2] Insects get attracted by ripe fruits, therefore only	**6**

		short period for harvest, as fruits need to be ripe when harvested[20]	
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Difficult to transport, store and process[2,7] Often harvested and transported unripe in order to avoid damages, as it continues to ripen after picking[2]	**0**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Yes: food and medicine[1,7]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*****	---	Fruits[1]	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Yes: high levels of protein, minerals, essential amino acids, one of the highest levels of phosphorous and Vitamin B compared to other fruits, magnesium, iron, calcium, Vitamin C, silicium; natural source of energy[1,5,6] Yes[18,20,21]	**5**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes: used as an aphrodisiac and cure for kidney diseases, wounds, high blood pressure, bronchial afflictions, sugar problems, hypertension, cancer, diabetes, Alzheimer's, Parkinson's and HIV; anti-depression, anti-stress, anti-hangover, regulation of menstrual cycles, rejuvenation, rehabilitation from addictions[1,2,4,5,6] Prized for its tonic and cure-all qualities Works against cancer, is an important medicinal plant in Panama[11] Aphrodisiac[18]	**5**
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	No pharmaceutical research has been identified on *Borojoa patinoi* Cuatrec[5,10], but on related species (*Borojoa sorbilis* Cuatrec), which has good *in vitro* antierythemal and anti-inflammatory properties[1] Sold as a nutraceutical[5] Polyphenolic compound is proven, which is at least partly responsible for positive effects on health[10]	**0**

What are the main active nutritional and medicinal substances?*	---	Polyphenol – in contrast to other plant species, Borojó contains only one polyphenol in relative high concentration[10]	---
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Yes: powder, tablets, pulp, capsules, juice, jam,[1,2,3,9]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Difficult to grow, because there is not enough knowledge on agronomic management available[19] Yes, because there are male and female plants; only female plants produce fruits, but the male ones are needed for pollination[20]	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	No. first flower production when the tree reaches a height of 3m (after 3 years), fruits take 8-12 months to ripen[2] Dioecious plant: male and female plants needed, only female plants produce fruits, pollination via insects, hummingbirds and bats[2,4,5]	**0**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	No side effects known[1]	**2**
main drawbacks*	---	Perishes quickly[16]	**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**171/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	No. farmers and indigenous people in Panama are interested in this plant species[14]	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Yes, sold in North America[3,10]	**25**

Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Has been known since ancient times, scientifically identified in 1950[1]	---
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Marketed locally in Western Colombia where it is sold in large quantities (2009)[1,5] Also sold in North America[3,10] Liquid is getting sold in San Felix in Panama (rural area)[11] Gets sold in supermarkets and restaurants in Darién[12] It was very popular 2 years ago, but has not been asked for anymore; organic store in Panama sells imported products from the US[13] High demand/economic value[15] Engineer of a tree nursery did not sell a single plant: people are interested in the fruits but not in the plant; high demand especially in Colombia[17] It is difficult at the market[19] Juice is getting sold in small shops in Darién[20]	**25**
Market potential (0=low, 2=not known, 5=high)	5	Plant of considerable importance in Colombia; fruits command a high price in local markets in Colombia, as well as in the two biggest cities Bogotá and Medellín; great economic potential[1,2] Potential industrial use for dairy products (yoghurt, fermented milk)[4] Borojó has exceptional properties for the food and health market (2011)[5] Good market potential[14] No market for plants[17] Potential as a plant with a medicinal value[19] Very high due to high nutritious value; might be good as an energy drink, but availability is very low right now[20]	**25**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	There are no seeds available[11]	**10**
Costs per seed/seedling*	---	Package of 10 seeds: US$2.50, 100 seeds: US$14, 500 seeds: US$58[8] US$5/seedling[17]	---

		US$0.5-1.00/seedling[19] US$5/pound of fruits: hundreds of fruits can be extracted from one fruit; difficult germination: a lot of humidity needed and male & female seeds need to be identified[20]	
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	Not known	---
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Low production costs, as it is an understory tree which does not require the clearance of overstory trees[2] Difficult management[15] Easy management[16]	---
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	---
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	---
Number of harvests per year*	---	two harvest peaks peaks: April-Juni, October-December[2]	---
Yields (kg/ha/yr)*	---	Annual production: 2-76 fruits per tree, average = 16 fruits/tree/year[2] Average weight of one fruit: 450g, up to 90% of the fruit is pulp which contains roughly 300 seeds[2] Good yields (not specified)[20]	---
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Yes, as very perishable & soft[2,7,16,20]	**0**
Possible end products*	---	Juice, marmalade, jelly, pulp, compote, candies, ice cream, wine, mixer of alcoholic beverages, capsules, nutraceuticals, extracts[4,5,7] Liquid (perishes after two months)[11] Juice[13,20] Juice, medicine[15,16] Medicinal products[19] Ice cream[21]	---

Market prices for products*	---	Pulp, 500g: US$50 Tablets, 100 á 500mg: US$50[9] Capsules, 90 á 500g: US$19.99[10] US$3-4/libra of bark (15 cm of bark needed to produce ½ gallon of liquid)[11] US$7 for a small bottle (not specified) of liquid[11] US$35/l of juice (selling unit: 32 onzes)[13]	---
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	Extraction machine needed[16] Boiler, packing machine (if high quantities)[21]	**10**
Suitability indicator for economic criteria			**121/200**
Overall suitability indicator			**324/585**
*** Criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.** **Blue = results of interviews of local practitioners** **Red = results of interviews of experts of governmental institutions in Panama** **Green = results of interviews of scientists** **Purple = results of interviews of non-local practitioners**	Sources	1 Ocampo & Balick 2009. 2 Ricker et al. 1997. 3 Tropics Health 2011. 4 FAO Ecocrop 2011. 5 National Tropical Botanical Garden Hawai'i 2011. 6 Valencia & DeLaRosa 2009. 7 Mosquera et al. 2010. 8 Rare exotic seeds 2011. 9 Nutriward 2011. 10 Rutgers University 2008. 11 Interview No. 03. 12 Interview No. 01. 13 Interview No. 04. 14 Interview No. 09. 15 Interview No. 08. 16 Interview No. 11. 17 Interview No. 13. 18 Interview No. 14. 19 Interview No. 18. 20 Interview No. 21. 21 Interview No. 20.	

Caña Agria – *Costus scaber*

	Weighting coefficient	Plant information	value
Latin name		***Costus scaber***	
Other common names		**Spiral ginger[3,5] Wild cane[4] Indian Head Ginger[5]**	
Botanical plant family		**Costaceae[1,2,3] Zingiberaceae[4]**	
General comment		Fast growing plant species[5]	
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Suitable: old tree-fall areas or along trails[1] Open, disturbed sites or open forests[2] Forests[7]	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	No special soil requirements, widely adaptable[3] Moist but well drained[5] Consistently moist soil; pH 6.1-6.5[6]	**5**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**6**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Not known	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**30/60**
plant-related:			

Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Mexico to the Guianas, Bolivia and Brazil, West Indies; tropical moist forest in the Canal Zone in Panama, in Bocas del Toro, Darien and in premontane wet forests in Chiriqui and Coclé[1] Costa Rica, Central America[2] Native to Central and South America[3,8]	**5**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	1.5-2m[1] ca. 1.5m[2] 0.9-1.2m[3] 1.5-2.4m[5] 1.2-1.8m[6]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Not known	**6**
Annual/perennial plant*	---*	Perennial[6]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Herb[1,2]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Not known	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Not known	**10**
In which stage of the agroforestry system can it be planted?*	---	Not known	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Grows best in partial shade[2] Part shade to shade[3] Sun, part sun (must be kept moist if grown in full sun)[5] Grows at dark places[8]	**25**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**

Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Yes[3,7]	**25**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	By rhizomes, tubers, corms or bulbs[1,6] Not known if easy	**2**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	No fertilization needed[7]	**15**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Not needed[7]	**15**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Yes[5]	**0**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Yes, it is easy[7]	**15**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Appropriate to be used as a cut flower, as flowers are very long lasting (up to a month)[2] Medicinal properties[4]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*	---	Twigs, spire[7]	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Not known	**---**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes: cleans the bladder, used for urinary problems and high cholesterol levels[4]	**5**
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Not known	**15**
What are the main active nutritional and medicinal substances?*	---		**---**

Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
main drawbacks*	---	---	**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**202/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Not known	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Yes, locally[7]	**25**
Market potential (0=low, 2=not known, 5=high)	5	Very low regional and national market potential[7]	**0**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Not known	**10**
Costs per seed/seedling*	---	Not known	**---**
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	1.2-1.8m[6]	**---**

Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Low maintenance level[5] No weeding or pruning needed[7]	**---**
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	**---**
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	**---**
Number of harvests per year*	---	Can be harvested all year long[7]	**---**
Yields (kg/ha/yr)*	---	Not known	**---**
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	No[7]	**25**
Possible end products*	---	Spire[7]	**---**
Market prices for products*	---	US$3/15cm of spires[7]	**---**
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	No processing needed[7]	**25**
Suitability indicator for economic criteria			**121/200**
Overall suitability indicator			**353/585**
*** criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.**	Sources	[1] Croat (no date). [2] University of Connecticut 2012. [3] University of North Florida 2012. [4] Lans 2006. [5] Odenwald & Pope 2012. [6] Dave's Garden 2012b. [7] Interview No. 01. [8] Gupta 2008.	

Cananga – *Cananga odorata*

	Weighting coefficient	Plant information	value
Latin name		***Cananga odorata*[1,2]**	
Other common names		**Cananga, Ylang-Ylang, various names in Asian languages[1,2]**	
Botanical plant family		**Annonaceae[1,2]**	
General comment		Agronomic research strongly recommended, as hardly information available[1] Pioneer species that colonizes open areas rapidly[2] Grows very fast[5]	
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Equatorial to subtropical maritime climate[2] Tropical wet & dry (Aw), tropical wet (Ar)[3]	**5**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Humid lowland of the tropics[1] Moist evergreen forest 6 teak forest[1] Lowland of humid tropics, secondary forests and agroforest; component of the tropical moist to semi-dry forest[2]	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Up to 850 m.a.s.l. naturally, planted found up to 1.200 m.a.s.l.[1] 1-800 m.a.s.l., up to 1.200 m.a.s.l. near the equator[2] 0-500 m.a.s.l.[3]	**5**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Tropics to subtropics[2]	**5**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	1.500-4.000 mm/year[1] 700-5.000 mm/year; distribution: handles summer, winter, bimodal and uniform rainfall patterns[2] 700-2.800mm/year (optimal 1.500-2.000mm/a)[3]	**5**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Light, well-drained soils; pH 4.5-8; prefers rich volcanic or fertile sandy soils; deep soils required for long taproot; waterlogging tolerated for prolonged periods; avoid alkaline and saline soils[1]	**???**

		Light, medium and heavy texture; handles shallow and temporarily waterlogged soils; tolerates a wide range of soils from clays to clay loams and sands[2] Shallow depth (20-50cm), heavy, medium or light texture, moderate fertility, low salinity and well drainage[3]	
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	2 months[2]	**5**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	Mean annual temperature: 21-27°C[1] 18-28°C mean annual temp.; 28-35°C mean max. temp. of hottest month, 10-18°C mean min. temp. of coldest month[2] 16-34°C[3]	**5**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Vulnerable to strong wind, as limbs break easily; but regrows vigorously after heavy wind damage[2] Very sensitive to wind, as branches are soft and flowers get blown away easily → wind breaks needed[8]	**0**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Not known	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**37/60**
plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Probably originates from South-East Asia (Thailand)[1,2,3]; introduced to China, India, Africa and the Americas[1] Native to the Indo-Malayan region, common in Micronesia, Polynesia and Melanesia, nowadays present throughout the tropics including tropical America (e.g. Costa Rica)[2] Mainly cultivated in India, but also in Panama[6] There are Cananga plantations in Madagascar[8]	**2**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	10-40m, often pruned to 3m[1] 10-20m, under cultivation often kept at 3m[2] 3-30m[3]	**5**
Is the rooting habit impeding the growth of other	3	No, long taproot[1,2]	**15**

plant species? (0=yes, 2= not known, 5=no)			
Annual/perennial plant*	---*	Perennial[1,2,3]	---
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Pendulous tree[1]	---
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	No negative interaction[2]	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Often intercropped with food crops[1] Mainly in homegardens; grows well together with other crops; understory plant of traditional agroforestry systems; particularly suitable for homegardens; young cananga trees are often interplanted with short-term food crops; it also works nicely as an understory species in traditional agroforests[2] Mentioned as a useful agroforestry species[3]	**25**
In which stage of the agroforestry system can it be planted?*	---	1&2, as it is a pioneer species that colonizes open areas rapidly, needs 1.5-2 years until flower production and tolerates moderate shade[2]	---
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Until overstory becomes too dense and provides too much shade[2]; suitable for planned system	**25**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Yes: Tolerates shade but grows best in full sunlight; often a component of the understory of traditional agroforestry systems, thus it tolerates moderate shading; reduced productivity with increased shade[2] Needs a lot of light[8]	**25**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Close to a distilling facility in order to reduce losses of oil yields[1,2]	**0**

Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Yes[2]	**25**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Slight; naturalized in introduced areas, but rarely considered a pest; seeds are dispersed by birds, bats, monkeys and squirrels, therefore plant gets widely dispersed; but: not considered an invasive species by Pacific Ecosystems at Risk[2]	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Seeds or wildlings; also naturally dispersed by squirrels, bats, monkeys and birds who eat oily fruits; germination rate is higher with seeds that have been stored for 6.12 months compared to fresh seeds; hot water treatment encourages germination[1] Regenerates easily; commonly by seeds (2-12 seeds/fruit); direct seeding in the field avoids damage of taproot[2] Very difficult germination[8]	**5**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Hardly information available, but stem borers, flower-eating beetles and insects causing wilting of leaves have been reported[1,2]	**6**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	No; flowers must be processed immediately and processing needs to be postponed, flowers need to be separated and kept in the shade in order to avoid fermenting[2] No, flowers are very soft and need refrigeration[5]	**0**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Yes: fragrance, food, medicine, timber[1,2]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*	---	Flowers: overpoweringly fragrant when mature; Timber used for boxes, small drums and matchsticks; Bark is used to produce coarse ropes[1]	**---**

		Flowers and timber[2] Wood used for canoe parts, furniture, fuelwood, cordage; bark, flowers[2]	
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Not known	**2**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes. It has several uses in traditional medicine: dried flowers used against malaria, paste of fresh flowers is supposed to cure asthma; also used for skin health; bark against stomach ailments; oil is useful for depression, distressed breathing, high blood pressure, anxiety, as an aphrodisiac[1,2]	**5**
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Not known	**15**
What are the main active nutritional and medicinal substances?*	---	Not known	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Yes: essential oil[1,2]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Only the germination is difficult, after that management is easy[8]	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	No. First flowering of cultivated trees after 1.5-2 years with a height of 2m[1,2,3]; at an altitude of 500 m.a.s.l. flowering starts after 7 years[1] No. Needs 2.5-3 years until first flowering[5] No. First flowering after 3-4 years[8]	**0**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	No. The Food and Drug Administration of the United States has proved the essential oil as "generally safe" in alcoholic drinks, pastries, candies, puddings, soft drinks and chewing gum[1]	**5**
main drawbacks*	---	Very labour intensive; therefore needed to be	

		cultivated on a large scale[8]	
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**220/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Yes: much of the distilled oil is shipped to France[2]	**25**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Production of ylang-ylang oil started in the Philippines and Indonesia; cultivation almost destroyed in Word War 1; today it is a smallholder crop in the Philippines cultivated for local use only; beginning of 20th century brought to Comoro Islands with high production in 1980s, but declined afterwards; same in Madagascar; in southern China production started recently (source: 1999) and was still expanding[1]	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Yes: Indonesia, Comoro Islands and Madagascar are main exporters of ylang-ylang oil[1] At the end of the 1980s the world production of ylang-ylang oil had a value of US$7 million; In many countries the main product is the flower itself which is traded only on a local level[1] Organic essential oil is getting sold in an organic supermarket in Panama City; product is imported from the USA[4] Yes: 1. International market for perfume industry, 2. Local market for essential oil[8]	**25**
Market potential (0=low, 2=not known, 5=high)	5	If a reliable supply of essential oil can be assured, the demand will probably remain strong[1] Not known if high potential Only economically feasible if planted on larger scale[8]	**10**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Not known; can be taken from fruits[2] Difficult to obtain seeds, as germination is very	**10**

		difficult; seeds are available at a specialist in Gamboa, also on Taboga Island in Panama[8]	
Costs per seed/seedling*	---	US$3/seedling (3 months old, 1m high)[5]	---
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	6x6m; closer spacing may lead to overcrowding and reduced productivity; a well managed plantation may remain productive for 50 years[1,2]	---
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Attention: bisexual flowers![1] Ring weeding and slashing of inter-rows important for optimal growth; pruning to 3m after 2-3 years; manual individual picking of flowers; distilling immediately after harvest[1,2] In order to produce commercially, much hand labour is needed for picking and pruning[2] Pruning at a certain height so that flowers can be reached for manual picking[8]	---
Working hours needed for one cycle (planting until harvesting) per ha*	---	Very labour intensive: picking by hand; flowers need to be processed to oil the very same day of picking, therefore a lot of workers are needed to pick a reasonable amount of flowers within a short period of time[8]	---
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	---
Number of harvests per year*	---	Flowers throughout the year with marked seasonal peaks after periods of dry weather[1] Flowers throughout the year, in Madagascar mainly during the rainy season[2]	---
Yields (kg/ha/yr)*	---	First small harvest in the second year; profuse flowering starts in year 4 and 5; a fully developed, well managed tree produces 30-100 kg of flowers annually, topped trees hardly produce more than 20 kg[1] Cultivated tree in full production: 20-100 kg of flowers per year, pruned trees hardly produce more than 20 kg; 1-2% of the flowers is distilled volatile	---

		oil[2] 4-5 kg/tree/year for a 4 year old tree, 8-10kg/tree/year for a 10 year old tree[3]	
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Yes: flowers are very soft and need refrigeration[5]	**0**
Possible end products*	---	Essential oil; used in perfumery, also for hair oil, soaps, toiletries, sometimes also in foods and beverages[1] Oil for perfume industry and essential oil for aroma therapy[2,4,7,8] Primary commercial product: distilled oil for perfume industry[2] Ylang-ylang oil is used in expensive perfumery[3]	**---**
Market prices for products*	---	US$5/60ml of organic essential oil in an organic supermarket in Panama City[4]	**---**
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	No: Steam distillation[1,2] Needed machinery: extraction and distillation machines[7] Distillation machine[8]	**25**
Suitability indicator for economic criteria			**146/200**
Overall suitability indicator			**403/585**

*** Criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.** **Blue = results of interviews of local practitioners** **Red = results of interviews of experts of governmental institutions in Panama** **Green = results of interviews of scientists** **Purple = results of interviews of non-local practitioners**	Sources	[1] AgroForestryTree Database 2011. [2] Manner & Elevitch 2006. [3] FAO Ecocrop 2011. [4] Interview No. 04. [5] Interview No. 13. [6] Interview No. 14. [7] Interview No. 23. [8] Interview No. 21.

Cat's Claw – *Uncaria tomentosa*

	Weighting coefficient	Plant information	value
Latin name		***Uncaria tomentosa***[1]	
Other common names		**Cat's claw**[1]	
Botanical plant family		**Rubiaceae**[1]	
General comment			
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**6**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Not known	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**24/60**

plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Indigenous to the Amazon rainforest and other tropical areas of South and Central America, including Peru, Colombia, Ecuador, Guyana, Trinidad, Venezuela, Suriname, Costa Rica, Guatemala and Panama[1] Montane rainforest of Peru[2] Native to Peru and its surrounding rainforests[3] Native to Peru, but found throughout the tropics, mainly in Asia and South America[4]	**2**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	Reaches up to 30m high in the canopy, but is a vine[1] Climbs up to 30m up into the canopy[2]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Not known	**6**
Annual/perennial plant*	---*	Not known	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Vine[1,4,5,10]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Not known	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Not known	**10**
In which stage of the agroforestry system can it be planted?*	---	Not known	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**

Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Not known	**2**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Not known	**2**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*	---	Bark, root[1] Inner bark[2] Root, bark of the root (primary active compounds are concentrated in the root)[3] bark[4,6]	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Not known	**2**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	yes: stimulates the immune system; reduces inflammation, protects cells, fights free radicals, asthma, diabetes and stomach problems, cleanses bowel, kills cancer and leukemia cells, tones and balances; relieves pain, kills viruses, detoxifies,	**5**

		cleanses blood, lowers blood pressure, reduces cholesterol, decreases depression, proved useful as an antioxidant, among others[1,2] treatment for a variety of infections and to promote wound healing; immune system support[3] anti-inflammatory, antirheumatic, contraceptive, treats gastrointestinal ulcers, tumors, gonorrhea, dysentery, various skin problems[4] yes[6,7,8] products are used for inflammation[9]	
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Yes, research since 1970s by Austrian, German, Spanish, French, Italian, Swedish, Argentinian and Japanese researchers; 4 US patents on how to extract oxindole alkaloids[1,2] Yes: half a dozen clinical trials suggest beneficial immune-modulating and other health supporting activities[3] Considered a dietary supplement by the US Food and Drug Administration, but no German Commission E monograph[4]	**15**
What are the main active nutritional and medicinal substances?*	---	Oxidole alkaloids, quinovic acid glycosides, antioxidants, plant sterols, carboxyl alkyl esters, proanthocyanidins, polyphenols, triterpines and others[1,2,3]	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	yes: capsules, tablets, fluid extract, tincture[1,4] capsules, tea[7] capsules[9]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	A bit difficult to be managed, because it is a vine[10]	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**

Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	Should not be taken before or following any organ or bone marrow transplant or skin graft; should not be combined with blood-thinning drugs or antacids[1] Not fully evaluated for safety during pregnancy; moderate gastrointestinal side effects like diarrhea have been reported during initial consumption[3]	**0**
main drawbacks*	---	May damage the forest crop, because it is a vine[10]	**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**154/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Has been used in Europe since the early 1990s as an adjunctive treatment for cancer and AIDS and other diseases targeting the immune system; today used in herbal medicine throughout the world[1] Traded in the USA[4] Yes: capsules are getting produced in the USA (brand: "Nature's Way"), distributed by a Panamanian supplier and sold in an organic supermarket in Panama City[7]	**25**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Has been used as a medicinal plant by indigenous people of the Amazon for at least 2.000 years[1]	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Yes; see above; has grown popular in natural products industry[1] Yes: capsules are getting produced in the USA (brand: "Nature's Way"), distributed by a Panamanian supplier and sold in an organic supermarket in Panama City[7] Medicine gets sold in local pharmacies in Panama[8] There is a big market, mainly in Peru and the Andes; capsules are produced in Peru[9]	**25**
Market potential (0=low, 2=not known, 5=high)	5	Market demand has increased[1] Rather low, because it is not a new product[7]	**25**

Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Not known	**10**
Costs per seed/seedling*	---	US$2-3/10cm twig that can be planted[5]	**---**
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	Not known	**---**
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Not known	**---**
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	**---**
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	**---**
Number of harvests per year*	---	Not known	**---**
Yields (kg/ha/yr)*	---	Not known	**---**
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Possible end products*	---	Tea[4] Salve[5] Medicine[6,7,8]	**---**
Market prices for products*	---	US$7/60 capsules[7] US$10/100 capsules[7] US$6/20 teabags[7]	**---**
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	No machinery needed, as sold as twigs of 15 cm[6]	**10**
Suitability indicator for economic criteria			**131/200**
Overall suitability indicator			**309/585**

*** Criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.** **Blue = results of interviews of local practitioners** **Red = results of interviews of experts of governmental institutions in Panama** **Green = results of interviews of scientists** **Purple = results of interviews of non-local practitioners**	Sources	[1] Taylor 2012. [2] Morgenstern 2011. [3] Talbott 2003. [4] Dawn Bostic & Johns Cupp 2000. [5] Interview No. 03. [6] Interview No. 01. [7] Interview No. 04. [8] Interview No. 10. [9] Interview No. 14. [10] Interview No. 19.

Cayenne pepper – *Capsicum frutescens* L.

	Weighting coefficient	Plant information	value
Latin name		***Capsicum frutescens* L.**	
Other common names		**Red pepper, bird pepper, chilli pepper, cayenne pepper, Guinea pepper, ají[1]**	
Botanical plant family		**Solanaceae[1,3,4]**	
General comment			
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	(abandoned) fields, vacant lots, river flood plains, roadsides, early secondary forest[1]	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	0-2.000m.a.s.l.[1] 0-1.800m.a.s.l.[2]	**5**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	300-4.300mm/year[1]	**5**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Soils of all textures and a wide range of fertility; best are a loose structure and moist, well-drained conditions; pH 4.3-9.7[1] pH 5.6-7.8[3]	**5**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	Does not tolerate frost, does not grow in temperatures below 7°C[1] Cooler night temperatures reaching 15°C favour fruiting, but flowering will be delayed if temperatures drop below 25°C[2]	**5**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**6**

Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Not known	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**39/60**
plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Original range is unknown, but scientists think that it has been domesticated in Central America thousands of years ago, possibly in Panama and then spread throughout the Neotropics; nowadays almost pan-tropically cultivated & naturalized[1]	**5**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	1-1.5m[1] 0.5-2m[2] 0.6-1.2m[3]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Short to long taproot (depending on soil conditions), many spreading lateral roots, moderately abundant fibrous roots[1]	**0**
Annual/perennial plant*	---*	Perennial (lives about 2 years if conditions are continually favourable); commercially grown only as annuals[1] Short-lived perennial, may live for 2-3 years[2]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Shrub[1,2]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Not known	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Not known	**10**
In which stage of the agroforestry system can it be planted?*	---	Not known	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Intolerant of shade, can only handle broken overhead shade, but fruits best in full sun[1] Full sun[3]	**25**

Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	No[1]	**5**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Yes[4]	**25**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Seeds: 72% of the seeds germinate between 13-34 days after sowing[1] From woody stem cuttings or seeds[3]	**5**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Not susceptible to fungi, but several insect species and nematodes can damage or kill individual plants; serious effects are rarely widespread[1]	**6**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Yes. Storage of seeds under refrigeration is safe after air-drying[1]	**15**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Yes: as a spice, for deterring browsing animals and insects, personal protection (pepper spray), as a medicine[1]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*	---	Fruits[1,4]	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Not known	**2**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes: relieve for muscles, joint and toothache, to treat cough, asthma, sore throat, stomach ache, seasickness, flatulence, also works as a stimulant[1]	**5**

Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Not known	**6**
What are the main active nutritional and medicinal substances?*	---	Capsaicinoids, vitamins A and C[1]	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Yes: condiment[1] Dried fruits or powder[2]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	Yes: after 3 months of growth[1] Yes: 120-180 days after sowing[2]	**15**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
main drawbacks*	---	---	**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**201/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Marketed throughout the world (no source)	**10**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Not known	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Yes (no source)	**10**
Market potential (0=low, 2=not known, 5=high)	5	Not known	**10**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Not known	**10**

Costs per seed/seedling*	---	Not known	---
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	45-60cm[3]	---
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Not known	---
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	---
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	---
Number of harvests per year*	---	First harvest after three months of growth, afterwards continuously as long as they live[1] Can be harvested throughout the year[4]	---
Yields (kg/ha/yr)*	---	1t/ha of dried chillies at low capital input, up to 5.5t/ha with higher input[2]	---
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Possible end products*	---	Fresh, dried, refined and ground condiment[1]	---
Market prices for products*	---	Not known	---
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	Not known	**10**
Suitability indicator for economic criteria			**86/200**
Overall suitability indicator			**326/585**

*** criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.**	Sources	[1] Francis (no date a). [2] FAO Ecocrop 2007a. [3] Dave's Garden 2012a. [4] Katzer 2012.

Coriander – *Coriandrum sativum*

	Weighting coefficient	Plant information	value
Latin name		***Coriandrum sativum***	
Other common names		**Cilantro, Culantro, Coriander, Chinese Parsley, Indian Parsley[1,6]**	
Botanical plant family		**Apiaceae[1,5,6]**	
General comment		When grown for its dried seeds, it is called coriander, when grown for its leaves, it is called cilantro[3,5] **According to scientific literature coriander is not suitable for the given conditions in Panama. But it has been growing there.**	
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Grows best in dry climates; suffers during humid/rainy weather[3]	**VETO**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Waste places and arable land, often by the sides of rivers[2]	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	No constant moisture[2,3]	**VETO**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Sandy and loamy, well-drained soils[2] pH: acid, neutral and alkaline; grows also in very alkaline soils; tolerated pH: 4.9-8.3; no constant moisture nor too much nitrogen[2] grows in almost every soil; prefers good drainage and regular watering[3] can grow on poor soils[10]	**5**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Annual temperature range (0=not	Veto	Grows best under cool conditions, as hot weather encourages	**VETO**

suitable, 2=not known, 5=suitable)		flowering. Withstands temperatures as low as -12°C[1] Tolerates light frost, but suffers from high temperatures[3] Requires cooler temperatures to thrive: Once the root of the cilantro plant gets above 24°C, it will bolt, sending up a flower stalk and turning the leaves bitter[5]	
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**2**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Not known	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**20/60**
plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Native to southern Europe[1] Native to southern Europe and western Mediterranean region; today it is grown almost everywhere[3] Probably Eastern Mediterranean (Greece) or Asia Minor[6] Grown as a spice crop all over the world[8] Introduced to Panama and now very widespread; it grows naturally[10]	**5**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	0.3-0.5m[2] 0.6-0.9m[3] 0.6m[4]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Has a very sensitive taproot – if disturbed this will damage the plant; therefore the plant should be seeded where it is supposed to grow in order to avoid transplanting and thus disturbing the taproot; or start in peat or paper pots which can be set directly into the soil[5]	**15**
Annual/perennial plant*****	---*	Annual[1,2,3,4,5]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*****	---	Herb[1]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Good companion for anise, dill and chervil, but not for fennel; repels aphids and carrot root fly[3] Grows well with caraway, anise and dill; should not be planted near fennel, as this will suffer[5]	**15**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	No, but it grows well in combination with trees[10]	**10**

In which stage of the agroforestry system can it be planted?*	---	Not known	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Needs full sun[1] Sun or semi-shade (light woodland)[2,3,4]	**25**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Very easy to cultivate[3,10] Grows very quickly, therefore should be planted frequently[4]	**25**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Yes[5]	**15**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	By seeds, they germinate 7-10 days after seeding when soil is kept moist; you get two plants out of one seed[1] By seeds[2,3,4]	**2**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	No[10]	**15**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Scythe for weed control[1] No need for pesticides[10]	**6**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Most important disease: *Pseudomonas syringae* (bacterial leaf spot), seedborne pathogen, therefore high quality seeding material is important; splashing water enhances development and spread, thus rain and sprinkler irrigation should be avoided[1] Seems to be free of pests and diseases[2] Has rarely any problems with insects or diseases[5]	**15**

		It needs some humidity, but this may lead to problems with phytophthora, especially when cultivated in big amounts[10]	
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Storage under low-temperature, high humidity conditions. A shelf life of 14 days can be expected if stored at temperatures close to 0°C. Due to its high water content storage slightly above 0°C is necessary to avoid freezing damage.[1] Dried seeds can easily be stored in airtight jars[3] Fresh leaves do not keep very well; cut stems are best placed in a glass of water, covered with a plastic bag and stored in the refrigerator[5]	**0**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Yes: An essential oil from the seed is used as a food flavouring, in perfumery, soap making etc.; the growing plant repels aphids; the seed contains about 20% fixed oil, this has potential for industrial use in Britain, it could become an alternative to oilseed rape; the oil can be split into two basic types, one is used in making soaps etc, whilst the other can be used in making plastics; dried stems are used as a fuel[2] Seeds are used in perfumery and pharmacologically, and to flavor gin and liqueurs; flowers are attractive to various beneficial insects[3] It is an essential part of curry powder[6] Essential oil of seeds may be useful natural bactericides for the control of bacterial diseases of plants and for seed treatment, especially in organic agriculture[9] Yes: leaves as a herb/spice for cooking (fresh or dried); roots are processed to liquid for usage in medicine or perfumery[10]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*	---	Leaves, seeds[1] Leaves, oil, seeds[2] Seeds, leaves, roots (latter only in Thailand as a condiment)[3] Whole plant: seeds, leaves, stems, all for cooking[4] Whole plant: roots, leaves, stems, seeds[5] Fruits, leaves, root (latter only in Thailand)[6] Leaves, roots[10]	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Not known	**2**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes: Antihalitosis; Appetizer; Aromatherapy; Aromatic; Carminative; D	**5**

		epurative; Expectorant; Narcotic; Stimulant; Stomachic; it treats flatulence, diarrhoea and colic; externally the seeds have been used as a lotion or have been bruised and used as a poultice to treat rheumatic pains; essential oil is fungicidal and bactericidal[2] Has been reported to have a number of possible medicinal attributes including antispasmodic, carminative and stomachic properties; also advocated as an anti-diabetic remedy; documented as a traditional treatment for cholesterol and diabetes patients[7] Seeds have been used to treat indigestion, diabetes, rheumatism and pain in the joints[8] yes[10]	
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Yes: A significant decrease in cholesterol and triglyceride levels was observed in animals fed on coriander seeds[7] A significant antibacterial activity was proven for essential oil of seeds, especially to bacterial pathogens of muschrooms[9]	**15**
What are the main active nutritional and medicinal substances?*****	---	Not known	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Yes: Powder, seeds, oil, condiment, essential oil[2,3]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/ processing? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	Yes: leaves can be harvested one month after planting, seeds after 90 days[3]	**15**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	The plant can have a narcotic effect if it is eaten in very large quantities; Powdered coriander and oil may cause allergic reactions and photosensitivity. Use dry coriander sparingly if suffering bronchial asthma and chronic bronchitis[2]	**0**
main drawbacks*****	---	Very short-lived plant; therefore plant new crops every three weeks to ensure a constant supply[5]	**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**244/325**

Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Yes: liquid of roots is sold in Panama to pharmaceutical companies who in turn export it[10]	**25**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	seeds have been used medicinally and as a food flavouring since ancient times[2] was cultivated in ancient Egypt, Greece and Europe for culinary and medicinal uses; one of the oldest spices mentioned in recorded history with evidence of its use more than 5000 years ago[3] one of the oldest herbs used by mankind[5]	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Yes: Leaves are probably the most widely used flavouring herb in the world[2] used extensively in Chinese, Indian, Middle Eastern, North African and Latin American cuisine[3] common spice in many countries of Europe, Latin America, Northern Africa, West, Central and South Asia[6] yes: leaves are sold at markets, in restaurants, butchers in Panama; the liquid of roots is sold to pharmaceutical companies[10]	**25**
Market potential (0=low, 2=not known, 5=high)	5	Leaves have a rather high local and national market potential; the roots are of international importance, but its potential is still getting investigated[10]	**25**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Not known	**10**
Costs per seed/seedling*	---	The seed consists of the whole fruit with two embryos inside, therefore one seed with produce two plants[1]	**---**
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	Between plants: a few cm, between rows, 30 cm → or: 30-40 seeds/foot. When planted denser, the plant competes more effectively with weeds; also facilitates harvesting, as plants are bunched in the field[1] 30-45cm[4]	**---**

Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	No thinning required; plantings are usually made every 7 to 10 days during the season to ensure a steady supply. Harvest should take place at the coolest time of the day, in order to maintain optimum post harvest quality, as respiration rate is high.[1] weeding once a month[10]	**---**
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	**---**
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	**---**
Number of harvests per year*	---	Harvest 40-60 days after seeding, i.e. when the plant is 10-15cm tall. It only the older, outside leaves are harvested, the plant will continue to produce new foliage until it goes to seed. It can take up to 120 days to produce mature seed (coriander). If it is cut a few cm above the ground, it can regrow for a second cutting, but it does not regrow very efficiently, therefore many growers only harvest it once.[1] Harvest all year long[10]	**---**
Yields (kg/ha/yr)*	---	1¾ tonnes per acre of seed[2]	**---**
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Yes: A high surface to volume ratio makes the plant very susceptible to water loss. Bags with a special design (those constructed of a partially permeable polymer or those with perforations for ventilation) may be used; still it needs to be kept at cool temperatures. When refrigeration is not possible, it should be kept in water and shaded from sunlight.[1]	**0**
Possible end products*	---	Leaves are used as a herb, dried seeds as a spice[1] Condiment, oil, essential oil[2]	**---**
Market prices for products*	---	US$0.10/10 leaves[10]	**---**
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	Not known	**10**
Suitability indicator for economic criteria			**121/200**
Overall suitability indicator			**385/585**

*** criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.**	Sources	[1] UMassAmherst USDA, 2012. [2] Plants for a Future, 2012. [3] Christman, 2003. [4] Evans, no date. [5] Washington State University, 2008. [6] Katzer, 2012a. [7] Dhanapakiam et al., 2008. [8] Eidi et al., 2009. [9] Lo Cantore et al., 2004. [10] Interview No. 11.

Garlicvine – *Mansoa alliacea* (Lam.) A.H. Gentry

	Weighting coefficient	Plant information	value
Latin name		***Mansoa alliacea*** **(Lam.) A.H. Gentry**	
Other common names		**Garlicvine**[1,4] **Bejuco de ajo**[2,4]	
Botanical plant family		**Bignoniaceae**[1,4]	
General comment			
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Tropical rainforest[4] Dry and wet forests; areas with low vegetation; small primary forests; not in open fields or flooded areas[6]	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	1.800-3.500mm/yr[6]	**5**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Not close to water bodies[6]	**5**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	20-30°C[6]	**5**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**6**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Not known	**2**

Suitability indicator for site related criteria		Suitability indicator for site related criteria	36/60
plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Native to Southern America: French Guiana, Guyana, Suriname, Brazil, Ecuador, Peru[2] Native to the Amazon rainforest; distributed throughout tropical South America: Brazil, Ecuador, Peru, the three Guyanas, Costa Rica, Peru[4] Brazil and from Argentina to Southern Mexico[6]	**5**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	2-3m[4]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Not known	**6**
Annual/perennial plant*****	---*	Perennial[1]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*****	---	Vine[1] Shrubby vine[4]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Not known	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Yes: Commonly planted next to the trunk of a tree;[5,6] being tested as a method to control shoot borers (*Hypsipyla* sp.) when planted together with timber species like Cedrela and Swietenia[5]	**25**
In which stage of the agroforestry system can it be planted?*****	---	Not known	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Yes: Needs shaded areas: about 40% of shade[6]	**25**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**

Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Branch stakes (not too green, nor too old)[6]	**2**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	No, Can be done with organic material[6]	**15**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Yes: Roots and stems can be stored in dry and open areas for 6 months, leaves for three months[6]	**15**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Yes: medicine and spice[4,6], also ornamental plant[4]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*	---	Leaves[3] Bark, leaves, roots[4,5,6] flowers[6]	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Not known	**2**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes, used in traditional medicine[2] Relieves pain, reduces inflammation, fever and spasms, calms coughs, eases colds & flu, kills viruses; lowers cholesterol, fights free radicals, kills bacteria and fungi[4] Used to treat colds, throat and respiratory ailments as well as to reduce fever[5]	**5**

Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Yes: Cholesterol lowering and antioxidant activities are scientifically proven, as well as use for arthritis and rheumatism[4] Against fever, rheumatic pains, colds, pneumonia, malaria, insecticidal, headache, cough, nausea, constipation; analgesic, antipyretic[6]	**15**
What are the main active nutritional and medicinal substances?*	---	Not known	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Yes: powder[3] Decoction, tincture, capsules[4] Decoction[6]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
main drawbacks*	---	Not known	**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**210/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Yes, to the USA[4]	**25**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Not known	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Yes: capsules are sold in stores in Brazil and Peru, also in the USA[4] Commercially important in Peru and to a smaller	**25**

		scale in northern Brazil; so far mainly collected wildly from the forest, but there are also domiciliary plantations for familiar use and small commercial plantations[6]	
Market potential (0=low, 2=not known, 5=high)	5	Fresh and dried leaves, bark, roots and stem could be commercialized as a perfume fixative, as medicine or as an ingredient of perfumes[6]	**10**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Not known	**10**
Costs per seed/seedling*	---	Not known	**---**
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	Not known	**---**
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Harvesting of leaves is done manually[6]	**---**
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	**---**
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	**---**
Number of harvests per year*	---	Not known	**---**
Yields (kg/ha/yr)*	---	Not known	**---**
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Possible end products*	---	Powder[3] Tea, tincture, capsules[4,6] essential oil, decoction[6]	**---**
Market prices for products*	---	US$28.00/1 pound of powder[3] Commercialized as a medicinal plant with retail prices of US$0.28/kg, thus US$2.700-4.200/ha/year; wholesale price: US$0.14/kg, thus US$1.400-2.100/ha/year[6]	**---**
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known,	5	Plant part can be air dried: leaves in the shade, roots and stems in the sun[6]	**25**

5=low)			
Suitability indicator for economic criteria			**131/200**
Overall suitability indicator			**377/585**
*** criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.**	Sources	[1] Natural Resources Conservation Service 2012b. [2] Germplasm Resources Information Network 2000. [3] Taylor 1996e. [4] Taylor 1996d. [5] Rainforest Conservation Fund 2012. [6] das Graças Bichara Zoghbi et al. 2009.	

Ginger – *Zingiber officinale*

	Weighting coefficient	Plant information	value
Latin name		***Zingiber officinale*[1,8]**	
Other common names		**Ginger, Ingwer, Jengibre, gingembre[1]**	
Botanical plant family		**Zingiberaceae[1]**	
General comment		Traditional herbal and medicinal plant for thousands of years[8] Can be planted as an alternative to Nyame and Otoe which are other tuber plants[34]	
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Tropic to subtropic[10] Tropical wet & dry (Aw), tropical wet (Ar), subtropical humid (Cf)[18]	**5**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Tropics and subtropics[1] It grows naturally in the understory of forests[1]	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	50-200 m.a.s.l., in Jamaica its cultivation is extended to 500-1.000 m.a.s.l.[1] up to 1.500 m.a.s.l., 300-900 m.a.s.l. is best[10,15] up to 1.900 m.a.s.l.[18]	**5**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Tropics to subtropics, i.e. between 23,5° north and 23,5° south[1,10]	**5**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	> 3.000 mm/year[1] > 2.000 mm/year, well distributed over at least 9 months[2] 2.000-2.500 mm/year[3] app. 1.500mm/year[10] moist conditions, 1.500-6.500mm/year (excellent drainage needed for high precipitation); evenly distributed with a drier period at the end of the growing season[15] 1.400-3.000 mm/year[18]	**5**

Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Light, loose and well drained and fertile Arenosols[1] Adapts to different soils, as long as they are well drained; loose soil important for a free development of the rhizome[1,2] Stagnating water has to be avoided[1,3] Loose, nutritious soil[8] Moist soil[9] Nutritious, sandy-clay with a good humus layer and not too wet[10] If possible soil should not be used for two succeeding cycles of ginger, as this enhances fungi attacks and thus reduced yields[12] Very high requirements regarding soil: needs to be very nutritious, change of soil required[14] Ideal pH: 5.5-6.5; requires deep (25-40cm), rock-free, sandy loam soil, high in organic matter with adequate drainage; lime can be applied to adjust the pH-value[15] Medium soil depth (50-150cm), medium or organic texture, high fertility, low salinity, well drained[18] Difficult to find adequate soil conditions; availability of water and proper drainage are important[27] Soil conditions are important: not too humid, not too arid[30]	**5**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Tolerates a drought period of three months; if it lasts longer, irrigation will be needed[1] 1-2 months prior to and during harvest[15]	**5**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	25-30°C[1] 20,6-35,3°C[2] 21-35°C (growth efficiency declines with temperatures <24°C and >30°C)[15]	**5**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known, but not very likely, as rhizomes grow below the surface	**6**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Good adaptability[33]	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**48/60**
plant-related:			

Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Originates from tropical Asia forests (India, Malaysia or Indonesia), today it is distributed throughout the tropics and subtropics; main producers are India, Nigeria, Sierra Leone, China, Fidji and Jamaica[1,4,8,9] Brought to Latin America by Spanish colonies in the 15th century (beginning 16th century12)[11] Nowadays cultivated in all tropical regions of the world[12] Origin is unknown, but it is indigenous to the tropics[15]	**2**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	Up to 1.20m[1] 1.5m[12] 50-120cm[15]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Tubes …	**6**
Annual/perennial plant*	---*	Naturally it is a perennial plant, but commercially it is grown on an annual basis[1] Naturally perennial, but as it is a highly demanding plant species, it often gets planted every year[8] Perennial, but has been cultivated as an annual plant[10,12,15]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Herb[1] Spice plant; perennial herb, shrub[8]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	May compete for nutrients[15]	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Yes, widely planted in agroforestry systems in the tropics under coconut, fruit trees, bitter melon, beans, *Ailanthus triphysa, Areca catechu* (betelnut), *Populus deltoids* (poplar), *Paulownia elongata, Vigna radiata* (mung beans), *Ipomoea batata* (sweet potato), *Brassica oleracea* (cabbage), *Zea mays* (sweet corn); yields of ginger are higher than in monocultures, as long as shade by upperstory is less than 50%; good to combine with legominous species to maintain nutrient &	**25**

		moisture balance; avoid intercropping with solanaceous crops like tomatoes, peppers and eggplant, as this may lead to bacterial wilt[15] Higher yields for ginger combined with mango than ginger in open fields in Bangladesh, shading by mango trees was 60±5%[16] Also more productive when combined with poplar than in monoculture, best spacing of poplar: 5x4m[17]	
In which stage of the agroforestry system can it be planted?*	---	1 and 2, eventually 3[15,16]	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5		**25**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	It tolerates shade, and light shade improves its productivity, although commercial cultivation is implemented in full sunlight[1] Grows in full sun light[8] No direct sunlight[9] Higher yields on shaded sites, too much sun may destroy the plants[10] Grows well in full sun, but adapts to partial shade; optimal conditions: 25% of shade[15] Yes, it can be grown in the understory[25]	**25**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	No	**5**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Not too easy, as proper precipitation and soil conditions required; field preparation is important to avoid diseases[15]	**0**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Yes	**15**

Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	No[15]	**5**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	A rhizome is planted into the soil[1] Vegetative (asexually) via rhizomes[8,10,15] Yes, easy to be reproduced[25]	**5**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	Yes, as it consumes a big amount of nutrients; Costa Rica: Recommended to apply 227kg of 12-12-17-2/ha, distributed to three stages of the cultivation: during sowing, after 90 and 210 days[5] Yes, requires a lot of nutrients[9] Yes, important are sufficient provision of nitrogen and phosphate (20-40kg/ha)[10] Yes, requires a high amount of nutrients[14] Application of organic or synthetic fertilizer to complement natural soil fertility; 3 applications/growing season[15] Appropriate fertilization is difficult[27]	**0**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Insect control important, as they spread diseases, damage foliage and rhizomes; intensity depending on site conditions; Insect pests: *Adoretus sinicus* (Chinese rose beetle), *Elasmopalpus lignosellus* (lesser corn stalk borer), *Eumerus figurans* (ginger maggot), *Meloidogyne incognita* (root-knot nematodes and lesion nematodes) Diseases: *Rolstonia solanacearum* (bacterial wilt), *Erwinia sp.* (bacterial soft rot), *Fusarium, Phytium*[15]	**0**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Vulnerable to fungi: *Rosellinia* sp., *Fusarium oxysporum*, *Sclerotium rostisii*, *Colletotrichum* sp.[5] To bacteria: *Pseudomonas solanacearum*, *Erwinia carotovora*, parasites: *Pythium* spp. and nematodes: *Meloidogyne* incognita and *Radopholus* similis as well as a cutworm called *Agrotis ipsilon*[1] Vulnerable to microbial and parasitic diseases, also to fungi[10] Strict sanitation practices and rotations with non-host of diseases needed to prevent infestation of	**0**

		bacterial wilt, as this contaminates an area for years[15] In traditional production areas there is a disease that makes cultivation economically not recommendable[32]	
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Yes; dried ginger can be stored for up to four years; fresh ginger can be stored in a fridge for some weeks[8] Storage at 12-14°C and 85-90% relative humidity allows storage for up to 6 months[15] Easy to be transported[30]	**15**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Yes: medicine, dietary supplement, in China used to detoxify meat[4] Can also be used for skin and hair[8] Today also used as a slimness product, because it stimulates the digestive system[12]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*	---	Rhizome[2] ≠ root![12]	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	yes	**5**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes: common stomach soother: used for treating motion and sea sickness; it combats diarrhea, flatulence and indigestion, cough, hoarseness, flu, headache, fever, bronchitis, inflammation, tumors; also applied for relieving inflamed joints and treating pain (osteoarthritis and rheumatoid); used as a heart tonic to promote heart health[2,4,6,7,9] Anti-bacterial, antiemetic, antihepatoxic, antioxidative, improving blood circulation, cardiotonic, antithrombotic, anticancerogen, fungicide[8,9] Positive effect on these diseases/symptoms: adipoistas, allergies, anxiety states, arteriosclerose, asthma, bronchitis, diarrhea, irritation of blood circulation, throat ache, hemorrhoid, herpes,	**5**

		headache, cramps, paradontose, rheumatism[8] Diseases and symptoms that can be cured with ginger: flatulence, colds, fever, problems with the cardiovascular system, stomach problems, dizziness, nausea[8] Diverse medicinal effects on digestive system, kidneys, heart functions, blood pressure, and many more, detailed information[10] Also used as aphrodisiac[12,14] Ginger products were available in a German pharmacy (Lüneburg) in 1475[14] Works against nausea[14] Treatment against several ailments including nausea, motion sickness, migraine, dyspepsia, reduces flatulence and colic[15] Yes, works against diarrhea and vomiting[20] Liquid produced against cough[21] Yes[23,27,28,29,30]	
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Proven as a treatment of motion sickness[4] In Germany it has been scientifically recognized as a medicinal plant since 1988[8,9] Almost all over the world ginger has been recognized as an effective natural medicinal plant[9] Scientifically more and more valued in Europe[12]	**15**
What are the main active nutritional and medicinal substances?*	---	Gingerol, shogaols, bisabolen, borneol, chavicol, cineol, curcumen, cymen, dehydrogingeron, geraniol, gingerdion, gingerol, hexahydrocurcumin, limonene, linalool, myrcen, neral, oleoresin, phytohormones, pinen, protease, sitosterol, terpineol, zineol, zingeron, zingiberol, zingiberon, calcium, iron, potassium, magnesium, natrium, phosphorous, amino acid[8,10,14] Vitamin A & B, niacin, essential oil[9]	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Powder, capsules, oil, tea, tincture[2,4,8,13,14,24]	**15**

Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	No, its cultivation is easy[2] Yes, it requires trained workers[8] Knowledge needed about optimal soil conditions and disease avoidance[15] Much attention is needed for the right amount of humidity[19] No. easy to grow and manage[21,29] No, it is very easy to grow and manage[23,26] Easy to be managed, but profound knowledge of agroforestry management is needed[25] Difficult to grow due to fertilization, finding adequate soil conditions, drainage and availability of water are important[27] Yes, much knowledge is needed, and because there is a lack of knowledge in Panama, it is difficult to be grown[33]	**0**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	Yes: 7-12 months after planting[1,9] Yes: depending on usage it can be harvested 5-10 months after planting[10] 10 months after planting[14] 7-12 months after planting[15]	**15**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	It can be grown in a natural system: planted in soils that have been un fallow for years; cultivation under natural shade conditions (whatever that means), no modifications; drawback: reduced productivity per area Or in the organic system: some modifications like calcium carbonate, natural fertilizers, manual weeding; this system achieves an adequate performance (whatever that means)[1] Organic fertilizers can substitute synthetic ones[15]	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	No reported interactions with other medicine or adverse effects[4]	**5**
main drawbacks*	---	It is a relatively long-term crop: almost a year needed until it can be harvested; therefore it is recommended to also plant shorter season cash	**---**

		crops to reduce the risk of occupying much land with no returns for almost a year; another problem: increased competition from China within the last decade, which challenges small-scale producers; therefore they have to identify niche markets and produce high quality ginger to outcompete cheap foreign imports[15] Ginger is not a niche crop; it is grown on large scale and thus may not be profitable in agroforestry[35]	
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**208/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Most probably, as very widespread in Panama	**25**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	In 1982 there was already a wide market in England and the USA, ginger achieved good prices[2] Nowadays widely used and sold[10] Yes, exported to the whole world[11,15]	**25**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	"Throughout history"[4] already used as herb, medicine and drug (religious ceremonies) around 3.000 B.C.[8] in antiquity it has been used against diarrhea and costiveness[9] ginger belongs to the oldest and most important herbal goods of the big culture groups[10] has been known and used as a spice and medicinal plant for thousands of years[8,11,13] used for medicinal purposes for at least 3.000 years, in England since 800 A.D.[12]	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Yes: mainly cultivated in Australia, Brazil, China, Costa Rica, Fiji, India, Jamaica, Japan, Nigeria, Sierra Leone, South-East Asia, Taiwan, Central Africa; almost half of the global harvest is produced in India[8,10] Used in cosmetics industry as a fragrance	**25**

		substitute[9] Yes, it is easy to sell[22,25,35] Yes, but at the moment the market situation is not very good, the demand is low[26] Yes, plant products are getting exported from Panama[28] Yes: wide economic use with local, regional and international importance[32]	
Market potential (0=low, 2=not known, 5=high)	5	Ginger products are more and more demanded by physicians, alternative practitioners and patients in Germany[9] Increased usage of ginger in Germany in recent times[10] Organically produced ginger becomes more popular and can be a new local and export market expansion opportunity for local growers[15] Good market potential for the Asian and US-American market if the product is organic[24] There is a good demand[30] Good market value[35]	**25**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Farmers usually keep 5-10% of harvested rhizomes as seeds for the next planting[15] Rhizomes can be bought at a supermarket and planted[23,30]	**25**
Costs per seed/seedling*	---	Not known	**---**
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	Around 1t (900-1.300kg) of rhizome needed to establish 1ha of cultivation[1] Different information regarding spacing: • 61-76cm between rows, 15-20cm between rhizomes • 60-75cm between rows and 40cm between rhizomes • 70-90cm between rows, 30-40cm between rhizomes[1] In Costa Rica: 2.000kg seeds per ha: 60-90g/seed; spacing: 20cm between plants, 1,20m between rows; spacing of 10cm between plants gives best	**---**

		results regarding total weight, dry weight and amount of big, medium and small rhizomes[2] Spacing: 25cm[9] 20cm between plants, 45cm between rows[10] 2.000kg of rhizome 'seed pieces' needed for 1ha of ginger, each piece 115-230g with at least 3-4 eyes each; spacing between rows 120-150 cm, between plants 15-30cm[15] Needs to grow dense in order to grow fast[20]	
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Especially weeding and hilling; manual harvesting[1] Eventually irrigation needed; hilling (done manually) 3-5 times per growing season to allow proper development of rhizomes[15]	**---**
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known, but labour intensive crop[15]	**---**
Working hours needed for two cycles (planting until harvesting) per ha*	---	Same as for one cycle, as annual plant species	**---**
Number of harvests per year*	---	1[15]	**---**
Yields (kg/ha/yr)*	---	With a spacing of 10cm between plants: up to 50.024kg/ha (not dried), resp. 32.990kg/ha (dry weight), spacing of 30cm between plants: 14.730kg/ha; best planting depth: 7.5cm[2] In India depending on site 4-41kg fresh ginger/**m^2**[10] 35 MT/ha in Hawai'i; 2-7kg/plant; 75% of the income goes to production costs (30% for field production practices, 25% for harvesting); average profit earned in Hawai'i 1999: $18.500/ha[15] more than one libra/plant[20]	**---**
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	No	**25**
Possible end products*	---	Fresh rhizomes, can be stored for up to 2 months, dried rhizomes (have to be stored airtight)[1] Spice, beer, pastry, candy, tea[3,4]	**---**

		Oil and oleorresina used in perfumery, beverages or direct consumption[2,14] Bread, jam, pastries, tea, syrup, powder, sweets, liqueur[8,9,12,14] Colorant, jelly, wine, beer, extract, essential oil[10] Cookies, cake, beer, wine[13] Candies, beverages, liqueur, ice cream, pastries, curry powder blends, sauces, perfume, wine (made from ginger peels)[15] Tea, drinks[19] Sweets, liquid, juice[21] Cookies, medicine, many different products[23] Vegetable, spice[24] Colorant, medicine, refreshing drinks, pastries, sweets[27] Chocolate, medicine[28] "ginger water", refreshments[29] medicine and food[31] fresh vegetable, dried chips, pickles, candies[32]	
Market prices for products*	---	US$5/60 capsules[4] US$4/kg fresh ginger (Hawai'i)[15] US$6/libra fresh ginger[20] UD$4/60-120ml of powder (certified organic)[24] US$2/pound of root (certified organic)[24] Each ginger product has local and international market prices which depend on quality[32]	**---**
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	Cleaning of rhizomes, removing attached soil: putting them into batteries with water pressure[1] Removing roots and soil, peeling (manually or by machine), bleaching or liming, drying (using sunlight or machines) and storing (depending on usage not all processes are needed)[10] In order to obtain essential oil, ginger needs to be cut into small pieces and treated with water vapour; essential oil will enter the vapour; after condensation it can be isolated from the surface of the water[14] Rhizomes are cleaned with water, maybe also with	**10**

		a soft brush or coconut fibre; air-dried and air cured with ventilation for 3-5 days; graded and packed for shipping[15] Plough, brushcutter[19] Root lifting machine and washing needed[32]	
Suitability indicator for economic criteria			**176/200**
Overall suitability indicator			**432/585**

*** Criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.** **Blue = results of interviews of local practitioners** **Red = results of interviews of experts of governmental institutions in Panama** **Green = results of interviews of scientists** **Purple = results of interviews of non-local practitioners**	Sources	[1] Ocampo Sánchez 2000. [2] Delgado Matinez 1982. [3] Mercedes Falcon 1986. [4] Talbott 2003. [5] Ministerio de Agricultura y Ganadería 1983. [6] House et al. 1995. [7] Cáceres 1996. [8] Heidböhmer 2006. [9] Krämer 2000. [10] Mante 1998. [11] Ellert 2008. [12] Hübner & Wissing 2006. [13] Hart 2009. [14] Selbitschka 1991. [15] Valenzuela 2010. [16] Amin et al. 2010. [17] Jaswal et al. 1999. [18] FAO Ecocrop 2011. [19] Interview No. 05. [20] Interview No. 03. [21] Interview No. 01. [22] Interview No. 07. [23] Interview No. 02. [24] Interview No. 04. [25] Interview No. 09. [26] Interview No. 08. [27] Interview No. 12. [28] Interview No. 10. [29] Interview No.11. [30] Interview No. 13. [31] Interview No. 14. [32] Interview No. 17. [34] Interview No. 21. [35] Interview No. 19.

Guaraná – *Paullinia cupana*

	Weighting coefficient	Plant information	value
Latin name		***Paullinia cupana***	
Other common names		**Guaraná**[1,2]	
Botanical plant family		**Sapindaceae**[3,4]	
General comment			
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**6**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Not known	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**24/60**

plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Native to the central Amazon Basin[1] Native to Amazonian rain forests, mainly cultivated in Brazil[2] Not known if introduced to Panama	**2**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	2m under cultivation with a diameter of 4m; in the Amazonian forest it reaches high into the forest canopy[1] up to 10m long[2]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Not known	**6**
Annual/perennial plant*	---*	Perennial[2]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Woody vine or sprawling shrub[1] Woody vine, grows to big orchards[2]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Not known	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Yes, in Brazil[5]	**25**
In which stage of the agroforestry system can it be planted?*	---	Not known	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Not known	**10**

Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Not known	**2**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Damages by a number of diseases, especially anthracnose[1]	**0**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Yes: Soft drink, high caffeine stimulant, local medicine[1] Food, drinks, medicine, shampoo[4]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*****	---	Mainly seeds; stems, leaves and roots are used in Central and South America as a fish-killing drug; seeds and roots are used for medicinal purposes[2] Seeds, fruits[4]	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Not known	**2**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes[1] In some regions of South America it is believed to serve as an aphrodisiac and protection from malaria and dysentery; proposed to possess analgesic, anorectic, anti-aggregant, anti-inflammatory, aphrodisiac, astringent, bronchorelaxant, cardiotonic, diuretic, gastrostimulant, immunostimulant, thermogenic and tonic activities; against physical fatigue, general tiredness and convalescence; in France	**5**

		used against mild diarrhoea, functional asthenia and for weight loss; 28 years of medicinal use in the EU and traditional use for more than 30 years in America[2] Stimulates, increases energy, dilates blood vessels, increases urination, soothes nerves, fights free radicals, reduces weight, relieves pain, enhances memory, mildly laxative, increases libido, kills bacteria, thins blood; cure for fever, headache, cramps, heart problems, migraine, neuralgia, diarrhoea, cellulite[4]	
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Yes: is an effective, cheap and nontoxic alternative for the treatment of fatigue in breast cancer patients who receive systemic chemotherapy[3] Yes: inhibits platelet aggregation of blood clots and breaks down already-formed clots; also effectiveness as energy tonic, for mental acuity and enhancement of long-term memory was scientifically proven[4]	**15**
What are the main active nutritional and medicinal substances?*	---	Not known	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Yes: Powder, capsules[2] Decoction, tincture, capsules[4]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
main drawbacks*	---	Not known	**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**166/325**

Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Yes: it is sold in increasing amounts to Europe, North America and the Orient[1] In the 19th century exported to France and the USA[2] Today used world wide[4]	**25**
Since when has it been cultivated by humans and used for the purposes mentioned above?*****	---	Has played an important role in Amazonian Indian society and South American culture[2] Has been used as a stimulant since pre-Columbian times[3] Indigenous people have been using it for centuries[4]	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Yes: Seeds are commercially produced in the Amazon near Manaus on 6.000 ha[1] Its popularity grows steadily worldwide[4]	**25**
Market potential (0=low, 2=not known, 5=high)	5	Excellent prospects for greatly expanded international markets[1]	**25**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Not known	**10**
Costs per seed/seedling*****	---	Not known	**---**
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *****	---	Not known	**---**
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*****	---	Not known	**---**
Working hours needed for one cycle (planting until harvesting) per ha*****	---	Not known	**---**
Working hours needed for two cycles (planting until harvesting) per ha*****	---	Not known	**---**
Number of harvests per year*****	---	Not known	**---**
Yields (kg/ha/yr)*****	---	Not known	**---**

Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Possible end products*	---	Carbonated soft drink[1]	**---**
Market prices for products*	---	Not known	**---**
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	Not known	**10**
Suitability indicator for economic criteria			**131/200**
Overall suitability indicator			**321/585**
*** criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.**	Sources	[1] Erickson et al. 1984. [2] Committee on Herbal Medicinal Products 2012. [3] Campos et al. 2010. [4] Taylor 1996c. [5] Interview No. 15.	

Ipecac – *Cephaelis ipecacuanha*

	Weighting coefficient	Plant information	value
Latin name		***Cephaelis ipecacuanha***[1] ***Carapichea ipecacuanha***[3,4,5,6]	
Other common names		**Ipecac**[1,3] **Raicilla, Brasilianische Brechwurzel**[2]	
Botanical plant family		Rubiaceae[2,3]	
General comment		Aerial stems clump together to form clusters with well-defined borders; cluster size ranges from several to hundreds of aerial stems; long-lived plant; rare nowadays due to commercial harvesting of wild plants, habitat destruction and degradation[3]	
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	tropical wet & dry (Aw), tropical wet (Ar), subtropical humid (Cf), subtropical dry summer (Cs), subtropical dry winter (Cw)[1]	**5**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Shaded understory[3,4]	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Between 15° north and 15° south[1]	**5**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	1100-1900mm/year (optimal 1300-1700mm/year)[1]	**5**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	pH 4.5-6.5 (optimal 5-6); soil depth 0.5-1.5m; texture: heavy, medium, light, organic; moderate to high soil fertility; low salinity; well drained[1]	**????????**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	19-32°C (optimal 23-27°C)[1]	**5**

Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**2**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Not known	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**33/60**
plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Native to Costa Rica, Panama, Nicaragua, Brazil, Colombia, Ecuador[2] Contemporary populations: 1. Atlantic range (central portion of the Mata Atlântica biome along the Brazilian coast), 2. Amazonian range (southwestern region of the Amazonia biome), 3. Central-American range (Nicaragua, Costa Rica, Panama)[3] Native to the Atlantic Forest[5] Only grown in India; Brazil used to be the biggest exporter[7]	**5**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	Up to 20cm[3]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Not known	**6**
Annual/perennial plant*	---*	Perennial[1,3]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Herb[1,3,4], shrub[1]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Not known	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Not known	**10**
In which stage of the agroforestry system can it be planted?*	---	Not known	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**

Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Needs a lot of shade, cannot handle direct and permanent sunlight[3]	**25**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**10**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Not known	**2**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Not known	**2**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*	---	Roots[1,3,5,6]	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Yes: vitamins and minerals[1]	**5**
Does it have a medicinal value? (0=no, 2=not	1	Yes. Widely used in traditional medicine by native	**5**

known, 5=yes)		Brazilians long before the arrival of European settlers; has expectorant, amoebicidal and emetic properties[3] Anti-diarrheal and emetic properties[5] Highly effective; specifically used in indigenous medicine against dysentery; today the main alkaloid of Ipecac is used in emergency medicine in cases of poisoning to trigger vomiting in small children[6]	
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Yes (amoebicidal and emetic properties)[3] Yes (anti-diarrheal and emetic properties); included in the list of pharmacopoeia of many countries and the WHO[5] Yes[6]	**15**
What are the main active nutritional and medicinal substances?*	---	Emetine[3,5,6] and cephaeline (isoquinoline alkaloids)[3,5]	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
main drawbacks*	---	Highly sensitive to habitat changes caused by clearing, selective cutting and incidental fires that allow permanent light penetration; does not grow in forest edge environments[3]	**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**186/325**
Social and economic aspects:			

Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Yes: about 4 tonnes were transported annually from Brazil to Portugal in the 18th century[5] Yes, to Europe in the 18th century[6]	**25**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Used in Brazil long before European settlers arrived[3] Used for centuries by Native Americans for medicinal properties[5]	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Commercial harvesting in Brazil since the 18th century; roots became a valuable trading good by this time; most of the world demand is provided by gathering of wild plants; only small fraction is commercially cultivated in India[3] Today it is used in emergency medicine[6]	**25**
Market potential (0=low, 2=not known, 5=high)	5	High, because it has a high economic value[7]	**25**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Not known	**10**
Costs per seed/seedling*	---	Not known	**---**
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	Not known	**---**
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Not known	**---**
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	**---**
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	**---**
Number of harvests per year*	---	Can be harvested throughout the year[3]	**---**
Yields (kg/ha/yr)*	---	Not known	**---**
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Not known	**10**

Possible end products*	---	Not known	**---**
Market prices for products*	---	Not known	**---**
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	Not known	**10**
Suitability indicator for economic criteria			**131/200**
Overall suitability indicator			**350/585**
*** criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.**	Sources	[1] FAO Ecocrop 2007. [2] USDA ARS 2012. [3] de Oliveira et al. 2010. [4] Salick 2006. [5] Brandão et al. 2012. [6] Kutalek & Prinz no date. [7] Interview No. 14.	

Lemon grass – *Cymbopogon citratus*

	Weighting coefficient	Plant information	value
Latin name		***Cymbopogon citratus***	
Other common names		**Lemon grass[1,2,3,4], ginger grass, citronelle[1,5], Zitronengras[4,5]**	
Botanical plant family		**Poaceae[3,4,5,6]**	
General comment			
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Fertile, heavy soils are best[1] Average, medium, well-drained soils; tolerates wide range of soils, but grows best in organically rich loams with good drainage[3] Fertile loam is best, but it tolerates many soil types including sand (though it needs more care then)[6] Moist loam soil with organic matter; pH 4.3-8.4[7]	**5**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Likes moisture, but can handle some drought (though its appearance will suffer)[6]	**5**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**

Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**6**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Not known	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**30/60**
plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Probably native to Sri Lanka or Malaysia[1] Southern India, Sri Lanka[3] Only known as cultivated plant[4] Malaysia (generally assumed)[5] Native to India and Sri Lanka[6]	**2**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	Up to 1.2m[1] 0.6-1.2m[3] up to 1.8m[6]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Not known	**6**
Annual/perennial plant*	---*	Perennial (economical live = 4 years)[1] Perennial, but suitable as annual[3,6]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Grass[1,4,5,6] herb[2] ornamental grass[3]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Not known	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Mentioned as a useful agroforestry species[1]	**25**
In which stage of the agroforestry system can it be planted?*	---	Not known	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Needs full sun, tolerates light shade[3,6,7]	**25**

Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Yes[3,8]	**25**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Seedlings or division of several leaf sections with attached roots[3] Seeds or division of old clumps[6] Easy propagation[8]	**5**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	No[8]	**15**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	No serious disease or insect problems observed; spider mites can be a serious pest when planted indoors[3]	**15**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Yes[8]	**15**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Yes: Culinary herb, rain garden, ornamental plant, herbal medicine, perfumery[3] Medicinal herb; aroma therapy, also used in insect repellents[4] Medicinal herb, perfumery, culinary herb, spice[5] Used in teas, beverages, herbal medicines, perfumery, soups[6] Soil protection[8]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*	---	Leaves[1,2,4,6,8] Leaves, stalks[5]	**---**

Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Not known	**2**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes: anti-inflammatory properties[2] yes[3] yes: used for digestive problems, colds, nervousness and weakness[4] yes: used against cough, cuts, headache, bladder disorders, asthma and as a diaphoretic[7] against colds[8]	**5**
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Yes[2]	**15**
What are the main active nutritional and medicinal substances?*	---	Citral (Geranial, Neral)[4,5]	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Yes: Essential oil for insect repellents, flavour of soft drinks, foods and in scenting soaps, various technical preparations, perfumes and cosmetics; grass is useful for soil improvement and erosion control[1] tincture[7]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	Yes: harvest starts at an age of 120-240 days; afterwards subsequently harvested every 90-120 days[1]	**15**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	Yes: if oil is consumed without being diluted, it can be toxic and even lead to death[4]	**0**
main drawbacks*	---		**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**240/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**

Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Has been used for centuries as the source of essential oil for perfumery, flavourings and herbal medicine[6]	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Market potential (0=low, 2=not known, 5=high)	5	Rather low market potential on local level[8]	**0**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Not known	**10**
Costs per seed/seedling*	---	Not known	**---**
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	Not known	**---**
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Not known	**---**
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	**---**
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	**---**
Number of harvests per year*	---	3-4[1] harvest all year long[8]	**---**
Yields (kg/ha/yr)*	---	Fresh grass yields to 0.2-0.4% oil with an average of 50-120kg oil/ha/yr[1]	**---**
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Possible end products*	---	Essential oil[1,4,5,6] Aromatic drink[2] Rhizome, herb, tincture[7] tea[8]	**---**

Market prices for products*	---	Rhizome: US$8.50/rhizome; US$48.03/10rhizomes Herbs: US$10.35/0.5lb; US$18.00/lb; US$79.82/5lbs Tincture: US$11.55/oz (29.3cc); US$20.45/2oz[7]	**---**
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	Not known	**10**
Suitability indicator for economic criteria			**76/200**
Overall suitability indicator			**346/585**
*** criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.**	Sources	[1] FAO Ecocrop 2007b. [2] Figueirinha et al. 2010. [3] Missouri Botanical Garden no date. [4] Arnold 2011. [5] Katzer 2007. [6] Scheper 2008. [7] Jessurun 2012b. [8] Interview No. 12.	

Noni – *Morinda citrifolia*

	Weighting coefficient	Plant information	value
Latin name		***Morinda citrifolia***	
Other common names		**Noni, Indian Mulberry**	
Botanical plant family		**Rubiaceae**	
General comment		Provides many environmental services and numerous products for people; multipurpose plant species[1] Grows very quickly[18] General problem: the value of the plant species is the fruit, but this is not valued in Panama anymore; in 2003 the Panamanian government gave seedlings for free, but it did not work, because big amounts of fruits are needed for the production of juice[19] It was grown on several hectares, but it did not work[20]	
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Tropical wet & dry (Aw), tropical wet (Ar)[9]	**5**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Primary forest or shrub vegetation, dry to mesic forests, grassland, near shorelines, open areas, fallow, pasture, waste areas; no areas with aggressive grasses and weeds[1], lava flows, tide pools, forest understory, gulches[7]	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	1-800 m.a.s.l., depending on latitude; at 19° up to 760 m.a.s.l., at the equator up to 1200 m.a.s.l.[1] up to 1.500 m.a.s.l.[9]	**5**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Between 19°north and south[1]	**5**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	250-4000mm; for high yields: moderate rainfall (500-1500mm) evenly distributed over the year[1] 1.500-3.000 mm/year[9]	**5**

Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Volcanic soil; grows in a wide range of soils, even in brackish tide pools close to the coast; accepts seasonal waterlogging, but prefers well drained soils; tolerates wide ranges of acidity: acidic to alkaline; grows very well on rocky soils; cannot compete well in deep, silty soils where grasses and weeds are abundant, or heavy, compacted soils; very salt resistant[1,7] Deep soils (<150 cm), medium texture, high fertility, low salinity, well drained[9]	**5**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Accepts at least 3-4 months, mature trees even 6 months or more[1]	**5**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	20-35°C (mean max. temp: 32-38°C, mean min. temp: 5-18°C)[1] 24-30°C (=optimal, tolerates 12-36°C)[9]	**5**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Plant growth and yields are diminished in windy areas; most important factor for the site selection; can survive in windy areas, but should not be exposed to winds exceeding 33kph[1]	**0**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Tolerant to a wide range of environments[1]	**5**
Suitability indicator for site related criteria			**45/60**
plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	South and Southeast Asia; spread throughout the world in the 17th and 18th centuries by explorers, merchants and privateers;[1] in Panama distributed all along the Caribbean side and in the northern part of the Pacific side[4]	**2**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	Depending on source 3-10m[1] or up to 6m[3]; can be pruned and thinned to any extent to keep it small and bushy which facilitates harvesting[1] 2-3m[25]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Extensive lateral root system and a deep taproot[1]; not known if they negatively impact other plant species	**6**
Annual/perennial plant*	---*	Perennial[1,4]	

Life form: grass, herb, shrub, tree, vine, ground cover*	---	Evergreen, bushy tree or shrub[1,3,4]	
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Thrives in forest understory, benefits from organic matter and mulch provided by other plant species; should not be grown where other nematode-susceptible crops (such as papaya) grew before, as Noni is susceptible to it as well; Noni attracts ants, sap-feeding insects (i.e. aphids) can be a problem for some vegetable intercroppings.[1]	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5		**10**
In which stage of the agroforestry system can it be planted? *	---	1-2[25]	
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Endlessly, as shade tolerant to up to 80%[1] Suitable, as it can be planted in full sun, will produce fruits in the second year and produce more fruits the older it grows[7]; as shadetolerant it can grow in different stages of an agroforestry system	**25**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Grows in the understory of tropical island forests and rainforests; grows well in full sunlight, but tolerates up to 80% of shade[1] Yes, it is shade tolerant[14] Needs full sunlight[20,26]	**25**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto		**2**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	No, as fruits are not damaged easily[1]	**5**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Yes, it is easy to care for[1]	**25**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Difficult to kill once it is established; new Noni plants sprout from exposed roots (root suckers)[1]	**0**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not considered invasive by botanists, not invasive to a degree of threatening an ecosystem, but it is known for its ability to disperse, persist and colonize new areas[1]	**2**

		Aggressive regeneration, it's growth needs to be controlled[16,17]	
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Seeds are dispersed by birds and rodents, wind and rainwater; reproduction via seeds and stem cuttings[1,4,7] Grows in most commonly available growth media, natural or local forest soils mixed with sand, volcanic cinders and/or composed organic matter are best for seedling production; seeds germinate within 3-6 weeks when scarified, otherwise it may take 6-12 months; reproduction also via root suckers possible; vegetatively produced plants are not as strong and resistant as those grown from seeds[1,7] Easily reproduced[16]	**2**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	No, but respond well to periodic applications of fertilizers. For intensive fruit production young plants can be encouraged with balanced fertilizers (14-14-14 or 16-16-16), organic fertilizers (7-7-7 or chicken manure, guano) or a yearly application of lime (1 lb per plant). Overuse of fertilizers can lead to heavy insect infestation.[1,7]	**15**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	If grown in monocultures, as vulnerable to some fungi and insect infestations[1] Control of insects is necessary[17]	**0**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	In diverse ecosystems there are usually no severe problems with pests and diseases; but it is susceptible to root-knot nematodes (Meloidogyne spp.), a small soundworm that causes galls and swellings on roots that weaken the plant; no diseases originating from bacteria, viruses, viroids or phytoplasmas; in large plantations it is susceptible to insect attacks by aphids, scales, weevils, leaf miners, whiteflies, caterpillars, thrips and mites; insect damage more severe in dry areas and full sun plantings, damage by fungi in rather wet areas; sanitation (i.e. picking up and removing infected leaves) or periodic application of approved	**0**

		fungicides can solve the problem.[1]	
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Yes, as fruits do not damage or bruise easily; generally no specials containers or precautions necessary; exposure to direct sunlight or high temperatures do not cause problems, thus no refrigeration needed if fruits are processed within hours after harvesting; best to harvest white but hard fruits, as they ripen quickly once this development stage is reached[1] No, as fruits are very perishable[12,19] Transportation is difficult: fruits ripen very fast, that is why they have to be transported quickly[13]	**15**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Yes: Food supplement, medicine, animal fodder (fruits and leaves), canoe parts, firewood, red and yellow dye for colouring fabrics, insect repellent, beverages, cosmetics, fruit leather, famine food; boundary markers; bee forage; coastal protection; attraction of beneficial insects including lady beetles, spiders, praying mantises and insect predators like anoles, chameleons, lizards and geckos.[1, 3]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap) *****	---	Fruits, leaves, wood, stem, seeds, flowers, roots	
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Yes[1]	**5**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes: according to the CRC Handbook of Medicinal Herbs[5] Noni has a number of documented activities for a wide range of diseases and conditions: headaches, fever, malaria, cancer, pain, tuberculosis, rheumatism, fractures, diabetes, sores, cuts, amongst others[1] Yes[13,14,17,18,23]	**5**
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	There are no scientifically accepted results about treatments with Noni, but it is increasingly	

		perceived as being safe and useful; Noni research and development is very active, inventors are attracted by it; inventions span an array of ailments and health issues; Doctors are prescribing it in some cases, i.e. in Hawai'i it is given to cancer patients by cancer specialists to fight a range of cancers; Noni leaves and fruits are anti-bacterial, anti-microbial, anti-inflammatory, analgesic and stimulating to the immune system, therefore it is a good first aid treatment.[1] There are more than 400 publications on Noni[8], its ingredients and impacts, especially on medicinal (cancer) research (e.g. Fong et al. 2001, Issell 2001, Lui et al. 2001, Hirazumi & Furusawa 19999, Hirazumi et al. 1996, Hirazumi et al. 1994, Hiramatsu et al. 1993) Clinically not proven, yet, but highly potential[21]	
What are the main active nutritional and medicinal substances?*	---	17 amino acids, Vitamins A, C, E, B1, B2, B3, B5, B6, B7 (Biotin), B9, B12, Calcium, Iron, Phosphorus, Magnesium, Zinc, Copper, Chromium, Manganese, Molybdenum, Sodium, Potassium[1]	
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Yes: fruit powder, juice, pulp, capsules[1,6,7,22]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	No, very easy to grow[17,18]	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	No. First harvest 9-12 months after planting, but fruits are small and few; better prune the plant in favour of a better harvest in the second year[1]	**0**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Organic fertilizers and farming methods can result in organic certification and an increased market value[1]	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	Has been consumed by millions without problems[1] scientifically proved that not harmful[8] No: USP certified Noni as being safe, no toxic properties[21]	**5**

main drawbacks*	---	Strong, unpleasant odor[1]	
Suitability indicator for plant-related criteria			**169/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	No	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Sold in the US and New Zealand as herbal and nutritional supplement, in the EU as a novel food, in Australia as a food, thus marketed in many areas[1], in the EU accepted as a novel food since 2003[8] Yes, the USA is the biggest consumer of Noni products[21]	**25**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	For 2000 years, maybe longer[1]	
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Worldwide markets are expanding every year: $400 million (2001) to projected $2 billion (2006)[1] There is no demand in Panama[12,] (except for Bocas del Toro) → bad market situation[13] There was a local supplier of Noni juice in Panama City, they were exporting to Japan in 2009; Noni was very popular five years ago, but is not demanded anymore, because new products are more demanded[15] There is no market[20] Yes: local and international[25]	**25**
Market potential (0=low, 2=not known, 5=high)	5	Noni's role in human and environmental health will be increasingly recognised; most important function may be medicine, as the plant is widely used in this field; there is a growing trend towards integrative medicine which Noni is part of[1] Not important anymore[12,15] Low commercial value[17,24] Very low, because many people grow it in their garden[18] Noni had its time, did not work in Panama[26]	**25**

Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Buy ripe fruits, take seeds out; one fruit contains 200-250 seeds[7]	**25**
Costs per seed/seedling*	---	US$0.50-1/seedling[22] US$0.30-1/seed[25]	
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	3-4.5m x 3-4.5m; taking 3.5m x 3.5m = 716 plants per ha[7] plants need a lot of space to grow[12]	
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5		
Needed management (pruning, weeding, fertilizing, etc.)*	---	Pruning lower branches will be good for weed control and fruit quality, pruning vertical branches of mature trees facilitates harvest, as it keeps plants low and bushy; young plants younger than three years may be pruned back after or during their first production of fruit; irrigation of young plants in dry conditions: once or more a week, up to 35 litres per plant[1,7]	
Working hours needed for one cycle (planting until harvesting) per ha*	---		
Working hours needed for two cycles (planting until harvesting) per ha*	---		
Number of harvests per year*	---	Throughout the year; usually harvested two or three times a month[1,7], 2-3 times/week[22]	
Yields (kg/ha/yr)*	---	During first year: no harvest; 2. year: 11kg/plant/year = 7.900 kg/ha/year 3. year: 22 kg/plant/year = 15.800 kg/ha/year 4. year: 44 kg/plant/year = 31.500 kg/ha/year 5. year: 82 kg/plant/year = 58.700 kg/ha/year 6. year: 109 kg/plant/year = 78.000 kg/ha/year* → yield assumptions: 716 plants per ha → necessary for high yields: good soil fertility and drainage, good water supply; adequate disease, pest and weed control as well as fertilizer additions (e.g. 2.7 kg of 10-20-20 per plant per year) → yields may diminish due to unfavourable weather, soil condition, pests and diseases → juice extraction efficiency of roughly 50% by	

		weight[7] 11kg* of fruits/tree/year; 5 fruits needed to produce 3.8l of liquid[12] high yields (not specified)[13,17]	
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Yes, special packaging needed to protect perishable fruits[19]	**25**
Possible end products*	---	Food supplements, juice, cosmetics, soap, tea[1] Medicine[11,18,22] Liquid[12,22] Medicine, juice, tea, drinks[13] Juice, pulp, medicine[14] Juice[15,16,19,23] Juice, concentrates, jam, medicine[17] Wine, drinks[22] Jam[23]	
Market prices for products*	---	US$ 6-12/gallon of juice (US$ 1.60-3.20/l) (2006)[1] US$ 18/60 capsules of Noni powder[6] US$68/kg of loose powder[6] US$ 49/1l Tahitian Noni Juice[9] US$ 60/6ml Noni seed oil[9] US$ 55/30ml Noni Leaf Serum[9] US$ 46/60ml Noni Leaf Spray[9] US$30/30ml Noni concentrate[9] US$30/75ml different Noni extracts[9] US$10/small bottle of liquid (not specified)[12] US$3/fruit (Bocas del Toro)[20]	
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	Extraction machine needed[19,23] Low demand of technology for production[22]	**10**
Suitability indicator for economic criteria			**135/200**
Overall suitability indicator			**336/585**

*** Criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.** **Blue = results of interviews of local practitioners** **Red = results of interviews of experts of governmental institutions in Panama** **Green = results of interviews of scientists** **Purple = results of interviews of non-local practitioners**	Sources	[1] Scot & Craig 2006. [2] http://www.pvs-hawaii.com/History_Culture/plants.ht. [3] Nowak & Schulz 1998. [4] Acosta 2005. [5] CRC Handbook of Medicinal Herbs. [6] Healing Noni, Farmer Direct Wholesale Noni Juice 2012. [7] College of Tropical Agriculture and Human Resources 2006. [8] Westendorf 2010. [9] FAO Ecocrop 2011. [10] Tahitian Noni (company) 2012. [11] Interview No. 06. [12] Interview No. 03. [13] Interview No. 01. [14] Interview No. 02. [15] Interview No. 04. [16] Interview No. 09. [17] Interview No. 08. [18] Interview No. 10. [19] Interview No. 11. [20] Interview No. 13. [21] Interview No. 14. [22] Interview No. 18. [23] Interview No. 23. [24] Interview No. 20. [25] Interview No. 22. [26] Interview No. 19. * data were given in libra per acre and converted to kg per hectare	

Orchid – *Orchidia* spp.

	Weighting coefficient	Plant information	value
Latin name		***Orchidia* spp.**	
Other common names		**Orchid**	
Botanical plant family		**Orchidaceae[4]**	
General comment			
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	In all climate zones[5]	**5**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Canopies of trees, at the edge of the forest, clearings, river banks[5] Grow everywhere except for in deserts[6] Understory of forests[8]	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	500-1700m.a.s.l.[5]	**5**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Suitable, as it grows in all climate zones[5]	**5**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	Depends on species, but for certain species of the tropical climates the given precipitation range is suitable	**5**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	As epiphytes they grow on trees, but can need loose, well drained material[1]	**5**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Can withstand a longer dry period[4]	**5**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	Depending on species between 20 and 30°C[1]	**5**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**6**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	High[3,5]	**5**

Suitability indicator for site related criteria		Suitability indicator for site related criteria	51/60
plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Widely distributed plant family, to be found on all continents[1] Originates probably from Asia, but is today distributed throughout the world except from polar regions[3,4]	**2**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	Below 6m	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	No[2]	**15**
Annual/perennial plant*	---*	Perennial[1,3,4,6]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Epiphyte[1]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Orchids grow on trees, but they are no parasites and do not have negative impacts on the tree[1,2,3,4,5] Grows on trees but does not harm them[8]	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Not known	**10**
In which stage of the agroforestry system can it be planted?*	---	Stage 1[7] Stage 4[8]	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Yes; it needs shade, especially in summer[1]	**25**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Yes[7]	**0**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	It is not very easy to find the right light conditions	**0**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	It is not very easy to find the right light conditions and fertilization, but once the right conditions are found, it is easy to grow[7] Yes, it is easy to establish this plant[8]	**0**

Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	yes	**15**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Layering, cuttings, seeds[1] Propagation by seeds is very difficult; vegetative reproduction by division of plants is very easy; meristem; layering[2,5] Seeds, division, meristem[3]	**2**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	No, takes nutrients from rainwater and dew[2,3,4] Not needed in the Panamanian environment[7,8]	**15**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	No, not needed[7,8]	**15**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	There are only a few diseases, mostly mites and sap-sucking insects[1,4] Hardly susceptible to diseases[2]	**15**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Not very easy, because certain humidity needs to be maintained and certain packaging is required to protect the plant[7,8]	**0**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Ornamental plant; is supposed to have aphrodisiac properties[6]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*	---	Whole plant as ornamental, rhizome for medicine[6] Whole plant[7,8]	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	No; not edible	**0**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes: aphrodisiac, enhances fertility, works against diarrhea, has wound healing properties[6]	**5**
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Not known	**6**
What are the main active nutritional and medicinal substances?*	---	Not known	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Not known	**6**

Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Yes, knowledge on appropriate humidity and light conditions is needed[7]	**0**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	Seedlings need 2-3 years until the first flowering[1]	**0**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	No, as hardly fertilizers and pesticides are needed[7,8]	**5**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	no	**5**
main drawbacks*	---	In order to export plants for the international market a phytosanitarian permission is needed[8]	**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**171/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Yes[7,8]	**25**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Not known	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Yes[7]	**25**
Market potential (0=low, 2=not known, 5=high)	5	Rather high national and international market potential, though the target group is pretty small, because the end product is so expensive that Panamanians cannot afford it[7] Rather low national and international market potential, because Panamanians cannot afford it[8]	**10**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Not known	**10**
Costs per seed/seedling*	---	Not known	**---**
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	Not known	**---**

Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	---
Needed management (pruning, weeding, fertilizing, etc.)*	---	Pruning, weeding[7] No pruning or weeding needed[8]	---
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	---
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	---
Number of harvests per year*	---	Not known	---
Yields (kg/ha/yr)*	---	---	---
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Yes, packaging needed to protect sensitive flowers[7]	**0**
Possible end products*	---	Ornamental plants	---
Market prices for products*	---	Up to US$80/plant[7] US$5/plant[8]	---
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	No processing needed	**25**
Suitability indicator for economic criteria			**111/200**
Overall suitability indicator			**333/585**
*** criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.**	Sources	[1] Rittershausen et al. 1993. [2] Pinske 1981. [3] Kohls & Kähler 1992. [4] Arnold 1994a. [5] Röllke 1993. [6] Senghas 1993. [7] Interview No. 08. [8] Interview No. 11.	

Panama hat palm – *Carludovica palmata*

	Weighting coefficient	Plant information	value
Latin name		***Carludovica palmata***	
Other common names		**Panama hat plant**[1] **Paja toquilla**[5]	
Botanical plant family		**Cyclanthaceae**[1,4]	
General comment		An understory palm tree used for the production of hats; is more and more disappearing, because it is not getting replanted[6]	
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Tropical & subtropical climates[1]	**5**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Open areas in tropical moist forests[1,5]	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	Needs ample water[1]	**2**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Well drained, rich in humus[1] Requires consistently moist soil[2,5] Common on disturbed alluvial soils[5] The plant grows well in moist, alluvial soils and recovers readily from flooding[5]	**2**
Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	Not known	**2**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**6**

Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Not known	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**30/60**
plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Native[1,3,4] one of the most widely used plants in lowland Ecuador[5]	**5**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	3m or higher[1] 1.8-3.6m[2] 4-5m[3]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	Not known	**6**
Annual/perennial plant*	---*	Perennial[2]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*	---	Palm-like plant[1,5] Shrub[2,3]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	Not known	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	No[6]	**0**
In which stage of the agroforestry system can it be planted?*	---	Not known	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Yes: requires shade to partial shade[1] Sun to partial shade[2]	**25**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	No[1]	**5**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	Not known	**2**

Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Yes[6]	**25**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Invades disturbed habitats; in Puerto Rico listed as a weed; but no evidence for an agricultural/forestry/horticultural weed[1]	**2**
Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Propagated by seeds[1,2,3]	**2**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	Few pests trouble it, although occasional infestations of scale or mealybugs can be treated with insecticides if needed[1]	**15**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Yes[6]	**15**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Yes: indigenous uses in Amazonian Ecuador: construction material (thatch & cord), crafts/baskets, brooms, food (palm heart & fruits), fish/hunting traps, medicine; in Peru oil is getting extracted from seeds[5]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*	---	Leaves, coarser material[4] leaves[6]	**---**
Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	Not known	**2**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes: Indigenous populations in Amazonian Ecuador use chewed meristem to stop infections of cuts[5] Decoction made from leaves is supposed to have hemostatic properties[5] Indigenous people in Colombia burn the stem and apply the ash to bruises[5]	**5**

Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Not known	**6**
What are the main active nutritional and medicinal substances?*	---	Not known	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	No[1]	**2**
main drawbacks*	---	---	**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**185/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Yes: Widely cultivated as ornamentals[1]	**25**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Not known	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Its value to the hat industry presently exceeds its considerable importance in the lives of indigenous inhabitants in Amazonia. Nonetheless, native crafts, roof thatch and edible shoot production could potentially exceed the return from the Panama hat industry. Since *C. palmata* grows in disturbed open areas that are widespread but	**25**

		underutilized, this species could be cultivated without further destruction of primary forests.[5]	
Market potential (0=low, 2=not known, 5=high)	5	Perhaps the greatest potential for *C. palmata* is the use of the heart. The flavour of the buds is good, though not as good as palm hearts. However, the shoots can be harvested sustainably since collection does not kill the plant. With limited assistance small canning plants could be created concurrent with market development of this product.[5] Rather high market potential on local and national level[6]	**25**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Seeds can be collected from fruits[2] Available from indigenous people and farmers in Bayano and Darién, Panama[6]	**25**
Costs per seed/seedling*	---	Not known	**---**
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	Spacing: 2.4-4.7m[2] 1x1m[6]	**---**
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Weeding once a month[1]	**---**
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	**---**
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	**---**
Number of harvests per year*	---	1-2[6]	**---**
Yields (kg/ha/yr)*	---	Not known	**---**
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Not known	**10**
Possible end products*	---	Hats (Panama hat)[4,6], baskets, mats, roofs[4]	**---**
Market prices for products*	---	Not known	**---**

Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	No machinery needed, as hats are getting produced manually[6]	**25**
Suitability indicator for economic criteria			**161/200**
Overall suitability indicator			**376/585**
*** criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.**	Sources	[1] Pacific Island Ecosystems at Risk 2010. [2] Dave's Garden 2012c. [3] Pacific Island Ecosystems at Risk 2002. [4] Germplasm Resources Information Network 2006. [5] Bennett et al. 1992. [6] Interview No. 09.	

Vanilla – *Vanilla planifolia* L.

	Weighting coefficient	Plant information	value
Latin name		***Vanilla planifolia* L.**	
Other common names		**Vanilla, Vanille, Bannitta, Panili; Anggrek, Waanilaa, Mexican or Bourbon vanilla[1,2]**	
Botanical plant family			
General comment		Principle producers are Madagascar, the Comoros, the Seychelles, Mascarene Islands, Java and a few Pacific Islands west of Central America and the Lesser Antilles[1]	
Site-related:			
Climate zone (0=not suitable, 2=not known, 5=suitable)	Veto	Humid climate[1] Aw (tropical wet & dry), Ar (tropical wet)[2]	**5**
Natural habitat (0=not suitable, 2=not known, 5=suitable)	Veto	Thinned out areas on natural sites (natural forest clearings, fallen trees), alongside secondary forest vegetation, areas of meadow forest systems[1] Warm, wet tropical low land forests[2]	**5**
Altitude range (0=not suitable, 2=not known, 5=suitable)	Veto	0-600 m.a.s.l.[2]	**2**
Latitude range (0=not suitable, 2=not known, 5=suitable)	Veto	Up to latitudes of 20°N-20°S[1,2]	**5**
Optimal precipitation range (0=not suitable, 2=not known, 5=suitable)	Veto	1.500-2.500mm/year[1] optimal: 2.000-2.500mm/year, absolute: 1.500-3.000mm/year; needs frequent but not excessive rain: too heavy rain during ripening process of fruits harms these[2]	**5**
Soil requirements (depth, texture, fertility, salinity, drainage, pH) (0=not suitable, 2=not known, 5=suitable)	Veto	Light, humus-rich soils without water-logging, pH around 7[1] Shallow soils with a medium, organic to light soil texture and moderate to high fertility, low salinity and well drainage; pH: optimal: 5.5-7, absolute: 4.3-8[2]	**2**

Max. dry season duration (0=not suitable, 2=not known, 5=suitable)	Veto	2-3 months[1] requires 2 drier months for flowering[2]	**5**
Annual temperature range (0=not suitable, 2=not known, 5=suitable)	Veto	Average temperature of 25°C[1] Optimal: 21-30°C, absolute: 10-33°C[2]	**5**
Vulnerability to wind (0= vulnerable, 2=not known, 5=not vulnerable)	3	Not known	**6**
Adaptability potential to natural environments (0=low, 2=not known, 5=high)	1	Not known	**2**
Suitability indicator for site related criteria		**Suitability indicator for site related criteria**	**42/60**
plant-related:			
Origin: native/exotic (0=exotic, 2=not known or introduced, 5=native)	Veto	Tropically-humid regions of Mexico and Central America; also grows wild in forests of South America[1] Native to Central America and southeastern Mexico[2]	**5**
Height (0= tree > 6m, 2=not known 5=plant species < 6m)	Veto	Can be kept at height of 1.6-1.8m[1] Can climb up to 5-15m[2]	**5**
Is the rooting habit impeding the growth of other plant species? (0=yes, 2= not known, 5=no)	3	No[1] Aerial roots at the stem[2]	**6**
Annual/perennial plant *****	---*	Perennial[1,2]	**---**
Life form: grass, herb, shrub, tree, vine, ground cover*****	---	Climbing orchid[1] Herbaceous vine[2]	**---**
Interactions with trees and other crops (0=competition, 2=not known/no strong interactions, 5=facilitation)	3	No negative interactions[1]	**6**
Already successfully grown in agroforestry systems? (0=no, 2=not known, 5=yes)	5	Yes: particularly suitable as an additional crop on diversified agroforestry sites; easily combined with banana and cacao, also possible with *Theobroma grandiflora* (Copuazú), *Hevea brasiliensis* (rubber), *Persea americana* (avocado), *Camellia sinensis* (tea) and many other plants that require similar site conditions; should not be combined with pigs and chickens, as they can damage the plants[1] As it is a climbing plant, it is always combined with	**25**

		tutor trees (*Erythrina* spp., *Gliricidia sepium* and *Inga* spp. are recommended); should be combined with medium-sized trees (15m and more), as they will grow into the crown of the tree; site conditions are more important than the choice of the tutor tree; most important is the integration of a wide variety of trees into the agroforestry system where trees from lower and mid levels need to be combined; combining vanilla with only one tree species is not recommended, as these systems are more susceptible to diseases[1] Mentioned as a useful agroforestry crop[2]	
In which stage of the agroforestry system can it be planted?*	---	3-4	**---**
For how long can it be grown in an agroforestry system? (number of years until conditions changed too much for the plant to grow with an economic profit) Suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Yes[1] Economic life: 10-15 years[2]	**25**
Is the intensity of shade tolerated by the plant species suitable for the planned system? (0=no, 2=not known, 5=yes)	5	Yes; Needs a balanced light : shade ratio[1] Optimal: light shade; tolerates heavy shade[2]	**25**
Does it have allelopathic properties? (0=yes, 2=not known, 5=no)	Veto	Not known	**2**
Does it have to be grown close to a market due to perishable plant products (fruits/flowers)? (0=yes, 2=not known, 5=no)	1	No[1]	**5**
Is it easy to establish? (0=no, 2=not known, 5=yes)	5	Seedlings should be planted 6-12 months after trees have been planted; ideally they are planted just before the rainy season begins; pollination difficult[1]	**0**
Is it easy to remove after conditions changed? (0=no, 2=not known, 5=yes)	3	Not known	**6**
Does it show invasive abilities? (0=yes, 2=not known or not very severe, 5=no)	Veto	Not known	**2**

Type of reproduction --> is it easy to be reproduced? (0=no, 2=not known/some treatment needed, 5=yes)	1	Vegetative propagation via shoot seedlings: seedlings should be selected carefully to ensure high yields with good quality vanilla, therefore the productivity of the parent plant should be tested, before the seedlings are cut off; seedlings must be healthy and up to 80cm long[1]	**0**
Great need for fertilizers? (0=yes, 2=not known, 5=no)	3	Large quantities of organic fertilizer needed for conventional plantations in order to guarantee long-term productivity and keep production costs at an economical level; however no data about nutrient demand, nor fertilizer recommendations are available[1]	**0**
Great need for herbicides and pesticides? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Vulnerable to diseases? (0=yes, 2=not known, 5=no)	3	The following diseases occur on vanilla cultivations: Fungi: *Fusarium oxysporum* (roots & shoots), *Colletotrichum vanillae* (Anthracnose: leaves, shoots & fruits), *Puccinia sinamononea* (honguillo, roya; bottom of leaves) Pests (barely play a role): some bug, butterfly, beetle, snail species and dwarf cicadas can cause damage; free-roaming pigs and chickens can also damage plants[1]	**0**
Easy to transport and store? (0=no, 2=not known, 5=yes)	3	Yes: when sealed in metal tins or wax paper they can be stored for up to a year when kept at temperatures around 5°C[1]	**15**
Can it be used for multiple purposes? (0=no, 2=not known, 5=yes)	1	Yes: used as a spice and for perfume; also for high-quality confectionery, baking, ice-cream, alcoholic extract[1] Flavours chocolate, beverages, ice-cream, custard, cakes, desserts, puddings, spice; perfumes, soaps; has a medicinal value as well[2]	**5**
Which parts of the plant can be used? (whole plant, whole plant above ground, fruits, flowers, leaves, wood, bark, roots, sap)*****	---	Fruit[1,2]	**---**

Does it have a high nutritional value (nutrients, phyto nutrients* & minerals)? (0=no, 2=not known, 5=yes)	1	no	**0**
Does it have a medicinal value? (0=no, 2=not known, 5=yes)	1	Yes: metabolic, digestive & endocrine system applications[2]	**2**
Is the medicinal effect scientifically proven? (0=no, 2=not known, 5=yes)	3	Not known	**2**
What are the main active nutritional and medicinal substances?*	---	Vanillic acid, alcohols, ester of cinammic acid, p-hydroxybenzaldehyde[1]	**---**
Can it be processed to substances that can be exported easily (Powder/tincture/gemmo)? (0=no, 2=not known, 5=yes)	3	Yes: capsules, powder, vanilla sugar, alcoholic extract[1]	**15**
Is much knowledge needed for planting/growing/maintaining/harvesting/processing? (0=yes, 2=not known, 5=no)	5	Yes[1]	**25**
Can it be harvested in the year of planting? (0=no, 2=not known, 5=yes)	3	No, first blossoming 3-4 years after planting[1] No, plants from cuttings of 30cm take 3-5 years to flower and fruit, cuttings of 90-100cm flower and fruit after 1-2 years[2]	**0**
Is it difficult to be grown organically? (0=yes, 2=not known, 5=no)	1	Not known	**2**
Are there any safety concerns connected to this plant species (allergic reactions, fototoxicity)? (0=yes, 2=not known, 5=no)	1	Not known	**2**
main drawbacks*	---	Difficult to grow, high quality standards required officially or by importers[1]	**---**
Suitability indicator for plant-related criteria		**Suitability indicator for plant-related criteria**	**186/325**
Social and economic aspects:			
Is it locally accepted? (0=no, 2=not known, 5=yes)	5	Not known	**10**
Are there any known cultural or religious reservations against the plant species? (0=yes, 2=not known, 5=no)	3	Not known	**6**
Are plant products already getting exported to the EU, USA or Asia? (0=no, 2=not known, 5=yes)	5	Yes: Traded throughout the world[1]	**25**

Since when has it been cultivated by humans and used for the purposes mentioned above?*	---	Not known	**---**
Is there an existing market for the plant/product? (0=no, 2=not known, 5=yes)	5	Yes[1]	**25**
Market potential (0=low, 2=not known, 5=high)	5	Not known	**10**
Availability of seeds/seedlings (0=difficult, 2=not known, 5=easy)	5	Difficult, as you have to get high quality meterial[1]	**0**
Costs per seed/seedling*	---	Not known	**---**
Density: seeds/seedlings per ha --> costs per ha (excluding costs for workers) *	---	Two seedlings besides each tutor tree; density can be up to 400 and 800 plants/ha; gaps between plants should be big enough in order to prevent a spread of diseases[1]	**---**
Mortality rate of seedlings/young plants (0=high, 2=not known, 5=low)	5	Not known	**10**
Needed management (pruning, weeding, fertilizing, etc.)*	---	Shade management, trimming, rejuvenation are important for disease control; for facilitated pollination and harvest the tip of the shoot should be bent over a suitable branch as soon as it reaches a height of 1.60 to 1.80m; then it should be stuck into the ground, covered with soil to encourage rooting; thereby the plant is continually rejuvenated and will thus be less vulnerable to diseases; shoots that have already borne fruits can be used as new plants: this trimming will facilitate the growth of new shoots, contribute to rejuvenation of the plant and improve the overall health of the whole plant[1] To maintain an appropriate light : shade ratio tutor trees and additional vegetation needs to be trimmed during less sunny times[1] Artificial pollination needed[1]	**---**
Working hours needed for one cycle (planting until harvesting) per ha*	---	Not known	**---**
Working hours needed for two cycles (planting until harvesting) per ha*	---	Not known	**---**

Number of harvests per year*	---	Harvest 6-9 months after pollination; once a year[1]	---
Yields (kg/ha/yr)*	---	30-40 fruits for 4 or more years[1] variable: good yields are about 2.5-4t/ha/year (fresh fruit, meaning 500-800kg/ha of cured beans)[2]	---
Need for certain packaging/cooling during transportation? (0=yes, 2=not known, 5=no)	5	Yes: packaging needs to fulfil these functions: Aroma protection, protection against damages, conservation against loss or gain of moisture, surface area for advertising and product information, note of the ecological origin[1]	**0**
Possible end products*	---	Vanilla sticks, powder, sugar, perfume[1] Essential oil[2]	---
Market prices for products*	---	Not known	---
Types of processing: cost intensive? High investment needed at the beginning? What about running expenses for processing? (0=high, 2=not known, 5=low)	5	Fermenting and drying for a few months after harvesting → harvest → sweat fruits in a heap → lay out in the sun → fermentation (blanket, box) → spread, smooth, twist and spread balsam → drying → sorting and packaging[1]	**10**
Suitability indicator for economic criteria			**96/200**
Overall suitability indicator			**324/585**
*** criteria marked like this provide information which is necessary for designing an agroforestry system (e.g. if it is a perennial or annual grass, shrub, tree) but do not give information about its general suitability for an agroforestry system; especially economic criteria are marked, because all these costs and returns have to be considered separately for calculating if the plant species can be grown economically profitable; therefore these criteria are not valued.**	Sources	[1] Naturland 2000. [2] FAO Ecocrop 2007c.	