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Ethnobotany, diversity and cultivation potential of "Sacha inchi" (*Plukenetia* sp., Euphorbiaceae); the perspective oilseed crop from Peruvian Amazon

Ph.D. Thesis

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Statutory declaration

I, Ing. Blanka Křivánková, declare that this thesis, submitted in partial fulfilment of the requirements for the degree of Ph.D., in the Institute of Tropics and Subtropics of the Czech University of Life Sciences Prague, is wholly my own work unless otherwise referenced or acknowledged.

In Prague, September 30, 2012 Blanka Křivánková

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Abstract

Within the frame of this study qualitative and quantitative morphological data were recorded together with local knowledge about the diversity and potential uses of *Plukenetia volubilis* L., traditional oilseed crop, in the vicinity of Pucallpa, Ucayali region, Peru. Furthermore cultivation potential for the local farmers and possible implementation of this crop into local agroforestry systems was analyzed. Visible morphological dissimilarities in the plant appearance were confirmed but none of the findings could be considered as conclusive. Due to the knowledge of local people any specific effects on the growth and development of the plant neither in the quality of the plant products or its properties were accounted. Three common names for *Plukenetia volubilis* L. in the area were identified. Among the possible uses of plant and its parts the use of the seeds and extracted oil from it were the most acknowledged ones. Multiple uses of different parts of the plant, very often of more utilitarian character were indicated mostly by people from rural areas. Four tree species typically used in the local agroforestry systems, two leguminous trees and one promising fast-growing tree were recommended as pillars for sacha inchi (*Plukenetia volubilis* L.) within an agroforestry systems. Almost any crop or fruit as other associates would be recommended. Obtained results contributed to the enhancement of the economical, social and environmental benefits for the local farmers.

Keywords: agroforestry, diversity, ethnobotany, oilseed crop, Peruvian Amazon, *Plukenetia volubilis* L.

Abstrakt

V rámci této práce byla sbírána morfologická data kvalitativního a kvantitativního charakteru spolu s původní znalostí místních obyvatel o diverzitě a možném použití tradiční olejniny *Plukenetia volubilis* L. v oblasti města Pucallpa, regionu Ucayali, Peru. Dále byl analyzován kultivační potenciál a možné způsoby zapojení této olejniny do místních agrolesnických systémů. Přestože byly potvrzeny viditelné odlišnosti ve vzhledu rostliny, naše závěry nemohou být považovány za konečné. Žádné z pozorovaných odlišností není místními obyvately přikládán zvláštní význam, ani vliv na růst a vývoj rostliny, kvalitu získaných produktů, nebo jejich vlastností. Tři místní názvy označující druh *Plukenetia volubilis* L. byly zjištěny v této oblasti. Mezi nejčastěji identifikované možné využití této rostliny a jejich částí bylo jmenováno užití semen a z nich extrahovaného oleje. Užití této rostliny a jejich částí k více účelům, především užitkového charakteru, bylo uváděno především ve venkovských oblastech. Jako opora pro sachu inchi (*Plukenetia volubilis* L.) uvnitř agrolesnických systémů byly doporučeny čtyři druhy běžně používaných dřevin v místních agrolesnických systémech spolu se dvěma keřovitými druhy leguminóz a jednou nadějnou rychle-rostoucí dřevinou. Vpřípadě výběru dalších druhů do spolukultury, je možné použít téměř jakýkoliv ovocný druh, obiloviny, či okopaniny. Dosažené výsledky přispěly ke zvýšení ekonomického, sociálního a environmentálního přínosu místním zemědělcům.

Klíčová slova: agrolesnictví, diverzita, etnobotanika, olejnina, peruánská Amazonie, *Plukenetia volubilis* L.

List of abbreviation

AR = Antonio Raimondi

ASB = Alternative to Slash-and-burn

CBD = Convention on Biological Diversity

CVD = Cardio-Vascular Diseases

EB = Encyclopedia Britannica

FAO = Food and Agricultural Organization

FAOSTAT = Food and Agricultural Organization Statistics

GTZ = Gesellschaft für Technische Zusammenarbeit = Technical Cooperation Association

ICRAF = World Agroforestry Centre (formerly: International Centre for Research in Agroforestry)

INEI = Instituto Nacional de Estadística e Informática = National Institute of Statistics and Informatics

INIA = Instituto Nacional de Investigación Agraria = National Agricultural Research Institute

MINAG - Ministerio de Agricultura Ucayali = Ministry of Agriculture of Ucayali District

MOBOT = Missouri Botanical Garden

MPT = Multipurpose Trees

NGO = Non- governmental Organization

ONU = United Nations Organization

OTA = Office of Technical Assessment

PAME = Participatory Assessment, Monitoring and Evaluation

PAR = Participatory Action Research

PCA = Principal Component Analysis

PI = Pimental

PRA = Participatory Rural Appraisal

RRA = Rapid Rural Appraisal

SOM = Self Organising Maps

SWOT = Strengths Weaknesses Opportunities Threats

TCA = Tratado de Cooperation Amazonico = Amazonian Cooperation Treaty

UNESCO = United Nations Educational, Scientific and Cultural Organization

UNU = Universidad Nacional de Ucayali = National University of Ucayali

WEO = Oils of the World

WHO = World Health Organization

3D = Tres de Deciembre

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1. Introduction

Maintaning the biodiversity is now being more intensively considered as one of the most important assumption for permanent survival of human mankind (Raven and McNeely, 1998; Crucible II Group, 2000). The Amazon rainforest is still the most extensive tropical forest formation, and it is the place of the highest ecological diversity in the world (De Jong 1995). One of the reasons for tropical forest clearance is high population pressure and rapid population growth in the developing countries of the tropics (Park 1992).

Concerning food, loss of biodiversity can impact both agro-industrial economies and human health (Secretariat of CBD, 2009). Loss of this variety in food choices can lead to problems of malnutrition, especially micronutrient deficiencies due to dependency on nutritionally poor but calorie dense foods (Kuhnlein, Erasmus *et al.*, 2009). Neglected traditional crops are often the solution as unknown crops might become future cash crops due to their adaptation to local environment and hence provide an important tool for food security in the face of climate change (FAO, 1996).

Highly nutritious traditional food crop of the Peruvian Amazon, sacha inchi, gained a world's attention since the oil derived from the sacha inchi seed won the gold medal at the "World Edible Oil" competition inParis in 2004 (Agroindustrias Amazónicas, 2006). This "peanut of the Incas", or sacha inchi (scientific name: *Plukenetia Volubilis* L.) is a native plant whose origins lie in thePeruvian Amazon and its potential revenue from cultivation could aid poor indigenous and mestizo communities to move out of poverty and improve the diets in the same time (Hamaker *et al.*, 1992; Manco, 2005; Hoffmeijer, 2010).

The importance of oils and fats in human nutrition is well recognized and the increasing demand for vegetable oils to be used in food, livestock feed and nonedible industrial application signals an opportunity for local producers (Salunkhe *et al.*, 1992, Grace *et al.*, 2008). Despite the vast degradation of soil due to innapropriate or unsustainable agricultural practices, expansion of oil cropping may be easily achieved by implementing oil species namely sacha inchi into agroecological production systems (e.g. intercropping or agroforestry systems).

In the area of Pucallpa local farmers are well motivated to include sacha inchi in their plots nevertheless insufficiently informed about any comprehensible data about the plant including the sustainable management and best agronomic practices for viable small-scale production.

Therefore we decided specifically for this region to determine and evaluate diversity of sacha inchi on the basis of morphologic features evaluation and through ethnobotanical approach to identify whether the individual plants differs in any specific properties which might be crucial for its implementation into local agroforestry systems and consequently suggested some concrete means of its implementation due to the obtained information.

It is the inclusion of farmers knowledge, individual likelihoods and resources that is one of the most promising and effective ways how to fight against the deterioration of biodiversity and improve farmers livelihoods in the same time.

2. Literature review

2.1. Most biodiverse ecosystems – tropical rainforests

The term “biological diversity”, or short “biodiversity”, encompasses the diversity of life on earth, ranging from genetic diversity and diversity of species to the diversity of ecosystems. (GTZ, 2001).

Biodiversity consists of a hierarchy of definitions from themolecular level through taxa to the landscape level.The United Nations Convention on Biological Diversity (CBD) defines biodiversity as ‘the variability among living organisms from all sources including *inter alia*, terrestrial, marine and other aquatic ecosystems and ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems’ (CBD, 1992).

The biodiversity we see today is the fruit of billions of years of evolution, shaped by natural processes and, increasingly, by the influence of humans. This diversity is often understood in terms of the wide variety of plants, animals and microorganisms though it also includes genetic differences within each species - for example, between varieties of crops (CBD, 2000).

Maintaning the biodiversity is now being more intensively considered as one of the most important assumption for permanent survival of human mankind (Raven and McNeely, 1998; Crucible II Group, 2000). It is a general understanding that genetic diversity holds the core position in the three levels of agricultural biodiversity and includes the total amount of genetic information contained in the genes of individual crops, farm animals and agricultural microorganisms.

When it comes to species diversity a rainforest’s importance is truly incomprehensible. They spawn and support 50 percent of all living organisms on Earth even though they cover less than 5% of Earth's surface (Nix, 1997).

A tropical rainforest is the world's most spectacular example of a living ecosystem and the ultimate in biodiversity. Mainly occur inside the World's equatorial regions. (Nix, 1997) When undisturbed, tropical forest ecosystems are stable. The stability of the tropical forest ecosystem is the result of its capacity to "withstand climate and other hazards of the natural environment" (Richards, 1996). Several characteristics of the tropical forest create this stability:

1. The humid tropical forest is rich in the number of plant and animal species. It is the high level of species diversity that provides stability to the forest ecosystem.
2. Tropical forests are highly complex, the most complex of terrestrial ecosystems(Connell, 1978; Park, 1992). Plants and animals are intimately linked within the tropical forest ecosystem. The tropical forest is extremely more diverse in species and animals are not far ranging, which re-establishes and maintains local diversity.
3. Since tropical soils are generally poor in nutrients, the tropical forest ecosystem depends on a self-contained, almost closed, nutrient cycle. The nutrients cycled in the system are contained in the biomass, which serves as a form of vegetative storage. The forest itself acts like a giant "sponge" in its recovery and recycling of nutrients, with 65 - 85% of the vegetation's root system found within the topsoil layer (Moran, 1981; Hadly and Lanly, 1983; Uhl, 1983;).

There are twomain forest types: the closed forest and open forest (Hadly and Lanly, 1983). The closed forest grows where average annual rainfall is above 1600 millimetres. The closed forest has a continuous canopy, is multi-layered, and usually has abundant undergrowth. The floristic make-up may differ but each is adapted to similar conditions: high rainfall and high temperatures (Richards, 1975; Hadly and Lanly, 1983).

Closed and open forests are unevenly distributed in the tropical regions. Tropical America has 57% of the world's closed tropical forests, most of them within the Amazon Basin (Hadly and Lanly, 1983: OTA, 1984).

Moist tropical forests constitute a large part of the world’s biological mass and carry out an appreciable proportion of the biologically mediated processes that influence global hydrologic, nutrient and energy cycles. Approximately 40 % of all the solar energy is fixed inthese forests (Bormann, 1980). The major question is how to use these forestlands for human benefit on a sustained basis.

2.1.1. The Amazon rainforest

The river Amazon gives its name to several geographic areas. The great Amazon Basin covers a vast area of Brazil, southern Venezuela, south-eastern Colombia, eastern Peru, eastern Ecuador and north-eastern Bolivia. In the Amazon Basin, annual rainfall totals range from less than 2000 mm to almost 4000 mm. Seasonal periodicity of rainfall is the greatest in the southern and eastern portion of the basin, and it generally decreases towards the north and west (Jordan, 1989).

Viewed geologically, about one-half of the Amazon consists of two ancient upland areas, known as shields, which now rarely exceed 1,000 m in elevation. These uplands are separated by the Main River in the east. The rest of the Amazon is mostly a giant sedimentary basin that lies below 300 m in elevation and occupies approximately 35 per cent of entire drainage. 15 per cent of the basin area is formed by the high Andean westernwatershed of the Amazon (Goulding *et al*., 2003).

The division of the Amazon lowland region into three ecological zones, *terra firme*, *varzea* and *igapó*, is largely based on their different geomorphological history. *Terra firme* or *Altura* is the land of the Amazon Basin above the flood level, and the term *varzea* (*restinga*) or *igapó* is used only for the seasonally inundated floodplain of the Amazonian white water rivers, or by black water rivers, respectively (de Jong, 1995).

2.1.2. Vertical stratification of forests

It is due to perhumid conditions, together with a high and stable temperature, and those are reasons that the climax vegetation type is the tropical evergreen or semi-evergreen forest. The Amazon rainforest is still the most extensive tropical forest formation, and it is the place of the highest ecological diversity in the world.

Correspond to FAO (2000) the forests can have several structures distinguished according to number of layers. The number of vertical strata can vary from one to four (more than four can occur in exceptional cases) (see Figure 1). Each layer has a unique set of environmental conditions and organisms adapted to them.

Generally accepted layers of forest stratification are following (modified after Watson and Eyzaguirre, 2002; FAO, 2000):

Emergent layer (arboreal)

In natural forests, the emergents are hardwood evergreens with broad-leaves, which tower as much as 60 m with trunks that measure up to 5 m around. This uppermost layer consists of trees and therefore is a perennial layer. Sunlight is plentiful up here. In agroforests, this refers to the tallest individuals (up to 20 m). In this study the emergent layer is represented by trees and palms.

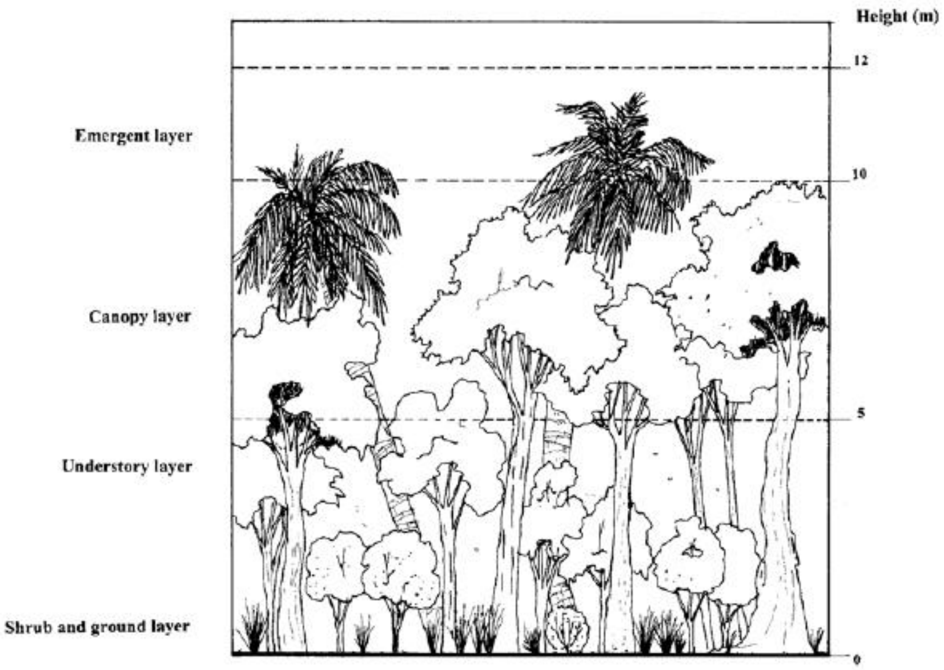

Figure 1. Vertical stratification of multistrata sytem (Gajaseni and Gajaseni, 1999).

The multilayer plant cover is an important indicator for sustainability. The stratified

Canopy layer (arboreal)

Most canopy trees have irregular crown and smooth, oval leaves. This green shield filters out 80 % of the light, preventing its transmission to the forest below. The canopy also stops the rain from reaching the plants below. Both perennials, like trees and palms, and annuals (*Musa* sp.) can be part of this layer.

The understorey (shrub and herbaceous)

In natural forest, this area gets only 2-15 % of the sunlight available to the canopy. In agroforests, this number is higher because of more favorable spacing. Limited light encourages the plant residents to grow larger leaves to reach the sunlight. Plants that grow in the understorey include young trees and palms, bushes and leafy herbaceous plants. These plants rarely exceed 3 m in height.

Ground or herb layer (herbaceous)

The forest floor forms the lowest level and receives only the rest of the sunlight and consequently, only plants adapted to shade grow there. On the floor there is litter of fallen leaves, seeds, fruits and branches that very quickly decompose.

Lianas (climbers)

This layer is represented by lianas; vines compose a part of understorey layer, whilst woody vines are found especially in the canopy layer.

2.1.3. Lianas in rainforest

Lianas have a major impact in tropical forests at the ecosystem level, particularly for processes such as whole-forest transpiration and carbon sequestration (Laurance *et al*., 1997; Meinzer *et al*., 1999; Gerwing and Farias, 2000). The abundance of lianas in tropical forests has often been cited as the single largest physiognomic difference between temperate and tropical forests (Richards, 1996).

Lianas (woody vines) are a conspicuous feature of tropical rain forests and important structural parasites of trees. Occasionally growing to 40 cm in diameter and several hundred meters in length, lianas exploit trees for physical support in order to reach the forest canopy. By creating structural stresses on trees and competing for light, moisture, and soil nutrients, lianas can reduce tree growth (Putz, 1984; Whigham, 1984; Perez-Salicrup, 1998) and reproduction (Stevens 1987), and increase rates of tree felling and limb breakage (Lowe and Walker 1977, Putz 1980, 1984).

Lianas typically constitute 25% of the woody stem density (abundance) and species diversity (species richness) in many tropical forests (Gentry, 1991; Appanah *et al.*, 1992). In forests such as those on the rim of the Amazon basin, liana diversity can be as high as 44% of the woody species, averaging 51 liana species ha−1 (Pérez-Salicrup *et al*., 2001).

2.1.4. Ecology of lianas

As with most plants and animals, liana species diversity increases with decreasing latitude (Gentry, 1991), but liana abundance and diversity increase proportionally with decreasing latitude at a much faster rate than in other major growth forms (e.g. trees, shrubs and herbs; with notable exceptions, such as epiphytic plants). For example, when taken as a proportion of the total flora, liana species richness increases fivefold from temperate to lowland tropical forests (Table 1). In comparison, the proportional increase in tree diversity is less than twofold, and shrub diversity increases by only one half (Table 1) (Schnitzer and Bongers, 2002). When examined as the proportion of woody species (trees, lianas and shrubs), liana richness increases from 10% of the temperate woody species to 25% of the tropical woody species (Gentry, 1991). Liana diversity, however, decreases with increasing altitude in the tropics (Balfour and Bond, 1993). Thus, along latitudinal and altitudinal gradients, liana abundance and diversity appear to peak in the relatively warm, lowland tropics (Schnitzer and Bongers, 2002).

Table 1. Percentage of woody species of total flora in three habitat types

Region	Lianas (%)	Trees (%)	Shrubs (%)
Prairie (1 site)	1	5	3
Temperate forest (7sites)	2	12	6
Continental tropics (7 sites)	10	21	9

* Woody species includes lianas, trees and shrubs but not herbs, vines, hemiepiphytes.

Source: Gentry (1991)

On Barro Colorado Island, Panama, 45% of all plant species 10 m tall are lianas (Croat 1978). In both neotropical and southeast Asian forests, 40–60% of all large ($10 cm diameter) trees typically bear at least one liana (Putz, 1983; Putz and Chai, 1987; Campbell and Newbery, 1993; Perez-Salicrup, 1998). Although they comprise less than one tenth of aboveground biomass, lianas produce up to 40% of all leaves in the forest (Ogawa *et al.*, 1965; Klinge and Rodriguez, 1974; Kato *et al.*, 1978; Putz, 1983; Avalos and Mulkey, 1999). Many lianas propagate vegetatively as well as by seed (Putz, 1984), enhancing their ability to proliferate under favorable conditions.

2.1.5. Lianas in fragmented forests

Lianas tend to proliferate in logged forests (Pinard and Putz, 1994) and are loathed by foresters because they suppress tree growth, deform boles, and increase tree mortality (Putz, 1991). Most liana species are light loving and respond positively to forest disturbance (Webb, 1958; Putz, 1984). Treefall gaps provide both increased light and abundant small trees and liana stems that provide crucial supports for climbing lianas. As they colonize gaps, lianas often inhibit the regeneration of small trees via shading and mechanical damage (Nicholson, 1958; Dawkins, 1961; Fox, 1968; Putz, 1984). Liana infestations also promote formation of large treefall gaps by entangling the crowns of adjoining trees; in peninsular Malaysia, liana-laden trees dragged down nearly twice as many neighbors when felled as did similarly sized trees that were liana-free (7.2 vs. 3.9)(Appanah and Putz, 1984).

Lianas have been shown to increase in fragmented forests in tropical Queensland (Laurance, 1991; 1997) and southeastern Brazil (Oliveira-Filho *et al.*, 1997; Tabanez *et al.*, 1997; Viana *et al.*, 1997), apparently in response to increased treefalls and lateral light penetration near forest edges. According to Laurance *et al.* (2001) rain-forest fragmentation alters many aspects of liana community structure (see Table 2). Lianas in fragments are more abundant and diverse, and infests a higher proportion of trees than in forest interiors. Liana communities near forest edges contains many small lianas, and relatively few large lianas. These patterns are quite similar to those found in 20–40-yr-old regrowth forests in Panama, which also had elevated liana abundance and diversity, but not biomass, relative to mature forests (DeWalt *et al.*, 2000). For lianas, forest fragments and regrowth may be similar ecologically in that each has an abundance of treefall gaps and small trees (Laurance *et al.*, 1997), which provide many trellises and increased light for actively climbing lianas.

Table 2: Results of ANOVAs comparing attributes of Amazonian liana communities betweenedges and interiors of three 10-ha rain forest fragments.

Attribute	$F_{1,66}$	P	Tukey's tests (P)
Liana abundance and diversity			
Abundance	9.84	0.003	Edge > Interior (<0.01)
Species richness	14.82	<0.001	Edge > Interior (<0.01)
Species diversity†	6.17	0.016	Edge > Interior (<0.05)
Tree infestations			
Percent of trees infested	8.61	0.005	Edge > Interior (<0.01)
Median no. lianas/infest-ed tree	0.32	0.573	…
Abundances of lianas in three climbing guilds			
Branch twiners	3.91	0.052	Edge > Interior (0.053)
Mainstem twiners	5.32	0.024	Edge > Interior (<0.05)
Tendril twiners	4.39	0.040	Edge > Interior (<0.05)
Proportions of lianas in three climbing guilds			
Branch twiners	3.30	0.074	Interior > Edge (0.08)
Mainstem twiners	2.01	0.161	…
Tendril twiners	1.91	0.172	…

Note: Data on liana abundance and species richness were $\log_{10}$-transformed, while infestation data and guild proportions were arcsine-transformed.

† Using Fisher's α, a robust index of species diversity that is insensitive to sample size.

Source: Laurance *et al.*, (2001)

In the Amazon, rates of tree mortality and damage rise sharply in fragmented forests (Lovejoy *et al.*, 1986; Ferreira and Laurance, 1997; Laurance *et al.*, 1998*b*), causing many ecological changes and a substantial loss of living tree biomass (Laurance *et al.,* 1997; 1998*a*). Quantitative models incorporating these data suggest that biomass losses in fragmented tropical forests could be a globally significant source of greenhouse gases, releasing up to 150 million Mg of C emissions annually (Laurance *et al.,* 1998*d*).

2.1.6. Implications for fragmented forests

Proliferating lianas can have diverse impacts on fragmented forests. Forest fragments are especially prone to windstorms (Laurance, 1991; 1997; Laurance *et al.,* 1998*b*) and fire (Laurance, 1998; Nepstad *et al.,* 1999), and liana-infested trees are much more prone to damage from wind and fire than are liana-free trees (Putz, 1991). Heavy liana infestations can inhibit successional processes near forest edges and reduce tree biomass and density (Tabanez *et al.,* 1997; Viana *et al.,* 1997). In a positive feedback loop, lianas respond positively to forest disturbance and then appear to promote and exacerbate subsequent disturbances.

Lianas may also help drive floristic changes in fragments. Because they are generally long lived and slow growing, old-growth tree species are often prone to liana infestations (Laurance *et al.,* 2000). Pioneer trees such as *Cecropia* spp. and *Trema* spp. are, however, less vulnerable to lianas because of their rapid growth, monopodal form, large leaves, and flexible trunks, and also sometimes because of the activity of ants (Putz, 1984).

Biomass losses from fragmented forests appear to be an important source of greenhouse gas emissions, released upon decay of organic material (Laurance *et al.,* 1997; 1998*d*). Lianas increase in fragments at the expense of trees but compensate for only a small fraction of the biomass lost from deaths of trees. According to Laurance *et al.* 2001 in study area of Brazilian Amazon, forest plots within 100 m of edges lost a mean of 36.1 Mg/ha of dry tree biomass (Laurance *et al.,* 1998*a*), but gained only 0.46 Mg/ha of liana biomass (in part because lianas usually have much lower wood densities than primary-forest trees) (Putz, 1983). Thus, proliferating lianas compensated for ,1.3% of the biomass lost from elevated tree mortality. Some evidence suggests that liana growth may accelerate in response to anthropogenic increases in atmospheric CO2 (Phillips and Gentry, 1994). If so, proliferating lianas could exacerbate biomass declines and other ecological changes in forests, especially in fragmented landscapes (Laurance *et al.,* 2001).

Overall, it is becoming clear that lianas are important players in many aspects of forest dynamics, far more important than was realized a decade ago. The fact that forests are becoming increasingly disturbed worldwide will increase the relative importance of lianas in many aspects of forest dynamics (Schnitzer and Bongers, 2002). In regions where only small forest remnants survive, intensive management may be needed to control liana populations and facilitate forest recovery (e.g., Tabanez *et al.*, 1997; Viana *et al.*, 1997).

Lianas are major contributors to forest productivity (Putz, 1983) and provide food and resources for many animals (Emmons and Gentry, 1983; Gentry, 1991), but their abundance in fragmented forests can become unnaturally high, seriously affecting forest structure and functioning. In many tropical regions, lianas will play a key role in the ecology and dynamics of fragmented forests (Laurance *et al.*, 2001).

2.1.7. Deterioration of tropical rainforests

These rich and complex ecosystems, which have survived millions of years of natural environmental changes, are now facing a fight for survival. The rainforests are under permanent attack. The hands of people are inflicting more damage on the rainforests in a matter of years than the entire forces of nature have done over the geological time-scale. Some studies suggest that the tropical rainforest might once have covered an area of up to 15 million km^2 (about tenth of the Earth's surface). Estimates of the amount of destruction caused by human activities vary between a third and half of the original (Park, 1992). Every year the world loses about 10 million hectares (100,000 km2) of tropical forest – an area more than three times the size of Belgium (ASB, 2003). Roughly 60 per cent of the clearance is believed to be rainforest; the rest is accounted for by seasonally wet and dry forms of tropical forest.

Another 100,000 km^2 of tropical forest is seriously damaged or partially cleared each year (Park, 1992). Partial clearance is often associated with logging and extensive slash-and-burn farming; its ecological and environmental impacts are often as serious as those arising from total clearance.

None of the land-use systems that replace this natural forest can match it in terms of biodiversity richness and carbon storage. However, these systems do vary greatly in the degree to which they combine at least some environmental benefits with their contributions to economic growth and poor peoples' livelihoods. Evidence is available to support the hypothesis that forests believed to be primary are in fact products of human disturbance and management; for example, the lowland forests in the Yucatan region of Mexico were managed by the ancient Mayans (Goméz-Pompa and Bainbridge, 1990). Some evidence shows that primary forests in the Amazon Basin were burned by indigenous people dating back millennia. Whenever detailed analyses are made in the tropics, vegetation is found to be the product of past disturbance by people or by natural events including fire, wind, flood, or biotic outbreak. The biodiversity of ecosystems is actually believed to be dependent on natural disturbance (Lugo, 1990).

One of the reasons for tropical forest clearance is high population pressure and rapid population growth in the developing countries of the tropics. There are main links between population pressure and rainforest clearance – through continued collection and use of fuelwood, progressive intensification of traditional (shifting) farming techniques, and government-led resettlement schemes. But population is only one of the three main forces of rainforest destruction. Rainforest trees are a valuable hardwood timber resource which has a great economic value, particularly in developed countries. As a consequence, commercial logging is directly responsible for much forest clearance. The third purpose is to create grazing land for extensive ranching, particularly of beef cattle for the lucrative export market (Park, 1992). It is difficult to judge how important one pressure is relative to another, particularly on a global scale. The figures in Table 3 offer a view which suggests that farming activities are by far the major culprit. But the data should be treated with caution because they are based on very generalised estimates.

Table 3: Estimated rates of tropical rainforests clearence for different purposes

Purpose	Annual loss (km^2)	%
Commercial timber removal	45,000	18
Fuelwood gathering	25,000	10
Cattle grazing (South America)	20,000	8
Farming operations (minimal estate)	160,000	64
Total	250,000	100

Source: Park (1992)

A major concern of tropical forestry is the rapid disappearance of the last remnants of tropical moist forests throughout the world. Until very recently it was only in exceptional cases that the treatment of tropical forests could be described as systematic management. If tropical forests were exploited at all, it was rather along the lines of mining management.

There was no question of sustainability or silviculture. Forests were considered to be more of an obstacle to civilization than an economic asset (Lamprecht, 1989). Obviously, any favourable relationship between agroforestry and tropical moist forests would imply reducing the rate of destruction and eventually some stabilization of land use concerning natural forest areas that must remain in existence for protection and other services (Budowski, 1980).

2.1.8. Situation in Peruvian Amazon

The Amazon Basin is one of the 'hot spot' areas, in which rainforests are also critically threatened (Park, 1992). In the latest four decades the Amazon rainforest has witnessed a high rate of deforestation. The rate of annual deforestation in Latin America is estimated at 1.3% compared with 0.4% in Asia and 0.6% in Africa (Torres, 1993). Until the 1970s, the rainforest covered about two-thirds, or 4 million km^2, of the Amazon. Since then approximately 10-15 per cent of the rainforest has been heavily modified, although some of it has returned to secondary forest (Goulding *et al*., 2003). Brazil alone has at least three times more Amazonian rainforest than all other South American countries. Peru is second with approximately one-fifth of the rainforest area of Brazil, but it has at least three times more of it than any other Andean country. Brazil is the biggest deforester (in terms of area and speed), accounting for about three-quarters of the total world rainforest clearance. The Amazon rainforest in Brazil covers an area of 3.37 million km2 and roughly 10,000 km2 is cleared each year (Park, 1992).

Table 4: Plants used in the Amazon Basin

Uses	Number of species
Medicianal plants	3,213
Food	542
Wood	401
Pesticides	334
Colorantes	110
Utensils and tools	100
Ornamental plants	90
Cosmetics	37
Production of oil	36
Drinks	35
Condiments	22
Latex	21

Source: TCA (1997)

In spite of the fact that the Amazon Basin is still mostly covered by forest, the forest does not provide direct income for the large majority of people living there. Instead, the most important ways to earn an income in the interior are small-scale agriculture and fishing. But traditionally the forest is a large reservoir of natural resources as shown in table 4.

Mahara (1989) arranged the main proximate causes of deforestation in Amazonia in the following order: small-scale agriculture, cattle ranching, logging, road building, hydroelectric development, mining, and urban growth. Forestry itself is not the main cause of deforestation, although it may result in new roads which permit access to the forest. When a timber company has used a piece of land, it usually sells the land to farmers at a cheap price. After several years the productivity of agricultural land decreases and it is used as pastures. This may cause deforestation in the second step. In the long-term perspective, this damages land and implies continued deforestation in search for new land (Andersson and Pertoft, 1996).

Peruvian Amazon, where extensive human intervention such as deforestation of the Amazon forest during the last three decades have caused huge changes in natural environment, makes no exception (Smith *et al.,* 1999). The Amazon accounts for 63% of the total land area of Peru, with about 60% of arable land and 81% of land under permanent crops(TCA, 1997). The slash-and-burn agriculture around Pucallpa, the capital of Ucayali region, is a typical example of Amazon forest colonization. The regeneration of secondary forests on previously cleared land in the Amazon is a small promising development within the generally pessimistic scenario of tropical deforestation (Smith *et al.,* 1999). However, the continuous extensive human interventions have led to changes in strucuture of particular plant species and might very often be the cause of threat or even disappearance of genetic resources.

Losses of primary forest have grown rapidly since 1970s with improvements to the highway. Very little untouched forest remains near Pucallpa, and even the remaining forest shows some evidence of disturbance, for example the presence of weedy species e.g. *Imperata brasiliensis* Trin. (Fujisaka *et al.,* 2000).

The scale of annual deforestation was estimated at around 350,000 ha and the total as yet deforested area at 13 million ha which is around 13% of the total Amazonian forests in Peru (TCA, 1997). Between 1999 and 2005, disturbance and deforestation rates throughout the Peruvian Amazon averaged 632 square kilometers per year and 645 square kilometers per year, respectively, however 64% of all damage was concentrated in the area around the Ucayali logging center of Pucallpa, and along the road network that emanates from it (Oliveira *et al.*, 2007).

These numbers reveal very strong pressure on the natural resources of the Amazonian forest in Peru. The simplest reasons of this deforestation are identified by Torres (1993) as:
1. Constant search for land to satisfy the basic need of local people, i.e. alimentation.
2. Non-existence of any forest management which would be economically better alternative than shifting cultivation or ranching.

We may thus conclude that improvement of agricultural system in the Amazon Basin, possibly through improved agroforestry systems, might ease pressure on the remaining primary forests and slow down the rate of deforestation.

2.2. Agroforestry

2.2.1. Definition and concepts

Agroforestry is a new name for a set of old practices (Nair, 1993). The peculiar history of agroforestry and the complex relationships between agriculture and forestry explain some misunderstandings about the concepts and classification of agroforestry and reveal that, contrarily to common perception, agroforestry is closer to agriculture than to forestry.

Following its conceptualization as a land-use approach in the late 1970s, there was a surge of enthusiasm to define agroforestry (Nair, 1989). It was one of the first activities of the International Council for Research in Agroforestry to try to formulate a definition for it. This was achieved in 1982 by Lundgren and Raintree: ‘Agroforestry is a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboo, etc.) are deliberately used in the same land management units as agricultural crops and/or animals, in some forms of spatial arrangement or temporal sequence. In Agroforestry systems there are both ecological and economical interactions between different components’.

Leakey (1997) defines agroforestry as ‘a dynamic, ecologically based, natural resources management system that, through the integration of trees in farmland and rangeland, diversifies and sustains production for increased social, economic and environmental benefits'.

The key concepts of agroforestry are now well established, and it is generally accepted that agroforestry:

- is a collective name for land-use systems involving trees combined with crops and/oranimals on the same unit of land;
- combines production of multiple outputs with protection of the resource base;
- the cycle of an agroforestry system is always more than one year; and
- places emphasis on the use of indigenous, multipurpose trees and shrubs;
- is particularly suitable for low-input conditions and fragile environments;
- is more concerned with socio-cultural values than most other land-use systems;
- is structurally and functionally more complex than monoculture (Nair 1989).

The simplest definition gives Young (1997): 'Agroforestry = growing trees on farms'. From the project standpoint there are two fundamental ways of arriving at agroforestry: by integrating trees into farming systems of by integrating farmers into forests (Raintree, 1985).

2.2.2. Types of tropical agroforestry systems

Neither the concept nor the practice of agroforestry is new. The practice is obviously very old. Cultivating trees and agricultural crops in intimate combination with one another is an ancient practice that farmers have used throughout the world (Nair, 1993).

Between 1982 and 1987, ICRAF compiled an inventory of agroforestry systems and practices being used in the developing countries. It brought together, for the first time, a substantial body of information on a large number of agroforestry systems, their structures and functions, and their merits and weaknesses (Nair, 1989).

Agroforestry is practiced in almost all ecological regions of the tropics and the types of systems used are diverse and complex. In order to evaluate these systems and develop plans of action to improve them, it is necessary to classify them (Nair, 1989).

The commonly used criteria according to Nair (1993) for classifying agroforestry system and practices are: structure of the system (nature and spatial and temporal arrangement of components), function of the system (importance and role of components, production aims or outputs from the system), agroecological zones where the system exists or is adoptable, and socioeconomic scales and management levels of the system.

Components of agroforestry systems are trees, agricultural crops, pastures, livestock and soils. Other components, namely insects and fish, occur in specialized systems. In previous statements, only the biological (plant and animal) elements have been formally taken as components, but soils are an integral part of all agroforestry systems. The living components together with the soil make up the *plant-soil system* or *plant-soil-animal system*.

At the highest level, the classification is based on the components present (Young, 1997):

- Agrosilvicultural: Trees with crops
- Silvopastoral: Trees with pastures and livestock
- Agrosilvopastoral: Trees with crops and with livestock
- Trees predominant: Forestry with other components subordinate
- Special components present: Trees with insects or fish

In any one agroforestry system there can be more than one agroforestry *practice.* An agroforestry system is characterized by certain types of practices that, taken as a whole, form a dominant land-use system in a particular locality and determine its overall biological composition and arrangement (Nair, 1993). Main characteristics of the most common agroforestry practices in the tropics are shown in Table 5

Table 5: Main characteristics of the most common agroforestry practices in the tropics

	AGRISILVICULTURAL SYSTEM
Improved fallow	Woody species planted and left to grow during the 'fallow phase'
Taungya	Combined stand of woody and agricultural species during early stages of establishment of plantations
Alley cropping	Woody species in hedges; agricultural species in alleys in between hedges; microzonal or strip arrangement
Multilayer tree gardens	Multispecies, multilayer dense plant associations with no organized planting arrangements
Multipurpose trees on croplands	Trees scattered haphazardly or according to some systematic patterns on bunds, terraces or plot/field boundaries integrated with animals
Plantation crop combinations	1. Integrated dense multistorey mixtures of plantation crops, 2. Mixtures of plantation crops in usually alternate or other regular arrangements, 3. Shade trees for plantation crops; shade trees scattered, 4. Intercropping with agricultural crops
Homegardens	Intimate, multistorey combination of various trees and crops around homesteads other woody
Trees in soil conservation and reclamation	Trees on bunds, terraces, raisers, etc., with or without grass strips; trees for soil reclamation
Windbreaks and shelterbelts, live-hedges	Trees around farmlands/plots
Fuelwood production	Interplanting fuelwood species or around agriculturalands
	SILVOPASTORAL SYSTEMS
Trees on rangeland or pastures	Trees scattered irregularly or arranged according to some systematic pattern
Protein banks	Production of protein-rich tree fodder farm/rangelands for cut-and-carry fodder production
Plantation crops with pastures and animals	Example: cattle under coconut crops in south-east Asia and south Pacific
	AGROSILVOPASTORAL SYSTEMS
Homegardens with animals	Intimate, multistorey combination of various trees and crops, as well as animals around homesteads
Multipurpose woody hedgerows	Woody hedges for browse, mulch, green manure, soil conservation, etc.
	OTHERS
Apiculture with trees	Trees for honey production
Aquaforestry	Trees lining fish ponds, tree leaves being used as 'forage' for fish
Multipurpose woodlots	For various purposes (wood, fodder, soil protection, soil reclamation, etc.)

Source: Nair (1990)

The scale of management and extent of adoption of different agroforestry practices in a given system varies considerably. Any one of these practices can be developed in a particular area to the point where it forms a distinct type of land use in that area and thus becomes an agroforestry system. One essential point to note here is that an agroforestry practice can be found in a non-agroforestry land-use system (Nair, 1989).

Based on field experience from several countries, a different classification of agroforestry into six simple categories is proposed by Torquebiau (2000). These categories are discussed and summarized in Table 6. It is argued that this pragmatic classification encompasses all major agroforestry associations and allows simultaneous agroforestry to be clearly differentiated from sequential agroforestry, two categories showing contrasting ecological tree–crop interactions. It can also contribute to a betterment of the image of agroforestry and lead to a simplification of its definition.

Table 6: Classification of agroforestry in six structural categories

Crops under tree cover	Scattered trees in cropland Shade trees in plantation crops Parklands Crops in orchards Plantation crops combinations
Agroforests	Agroforestry homegardens Village forest gardens Mixed woodlots Agroforestry buffer zones
Agroforestry in a linear arrangement	Windbreaks and shelterbelts Boundary planting Live hedges Living fences Soil conservation hedgerows Alley cropping Roadside planting Woody strips
Animal agroforestry	Grazing or browsing in wooded or forested land Tree planting in rangeland Animal feeding with collected browse Browse banks
Sequential agroforestry	Shifting cultivation tree-improved fallows Taungya
Minor agroforestry techniques	Sericulture Lac production Apiculture with trees Tree-based aquaculture

Source: Torquebiau (2000)

There are thousands of specific agroforestry systems around the world, but only some 20 distinct agroforestry practices (Young, 1997; Nair, 1993). The same or similar practices are found in a various systems in different situation. The type of agroforestry system found in a particular area is determined to some extent by agroecological factors. However, several socio-economic factors, such as human population pressure, availability of labor and proximity to markets, also come into play, resulting in considerable variations among systems operating in similar or identical agro-climatic conditions.Sometimes, socio-economic factors take precedence over ecological considerations. Even in the case of systems that are found in most ecological and geographical regions, such as shifting cultivation and taungya, there are numerous variants that are specific to certain socio-economic contexts.

As a general rule, it can be said that while ecological factors determine the major type of agroforestry system in a given area, the complexity of the system and the intensity with which it is managed increase in direct proportion to the population intensity and land productivity of the area (Nair, 1989).

2.2.3. The role of agroforestry

The guiding principle of agroforestry is the intensification of agricultural as well as forest production on the land, whenever is feasible, without soil degradation (Budowski, 1980). Trees in agroforestry systems provide both products and services. Products are, for example, fuelwood, building materials, fodder, poles, stakes, timber, fruits, medicines, resins and gums. The relative importance of these products varies between systems, according to environment and socio-economic circumstances (Young, 1997). This range of products serves to diversify the output from the farm, giving a broader economic base and greater food security (FAO, 1989).

The service function includes shade (for human and livestock), reduction in wind speed, control of weeds and fencing. There is no doubt, however, that the major service function of agroforestry is its role in soil management, including control of erosion and maintenance and improvement of soil fertility (Young, 1997). The service functions at the farm level are, for example soil fertility improvement, erosion control, microclimate improvements, fencing, and demarcation of boundaries. On a large scale, trees can improve the hydrological cycle in watersheds, and play important role in the maintenance of soil, insects, plant and wildlife biodiversity (Ohlsson, 1999).

Beyond the diverse food and other products that trees provide for humans, they enhance food yields because they help conserve biodiversity that is essential to human survival and the integrity of the environment (Pimentel *et al.,* 1992). Natural biota not only helps degrade wastes, recycle vital nutrients, and pollinate crops and natural vegetation but also provide natural enemies of pests that attack crops and natural vegetation (Pimentel and Wightman, 1999). Just as many polyculture systems suffer less damage from pest, agroforestry systems are prone to less intense pest outbreaks than monocultures (Rathore, 1995).

2.2.4. Agroforestry species and tree crop interaction

Many of the species used in traditional agroforestry systems are well known as conventional agricultural or forestry plants, or as plants with other economic benefits. The most important characteristic that determines the place of a species in agroforestry is its amenability to integrate combination cultures (i.e., intercropping), not whether it is labelled as an agricultural, forestry, or any other type of species. Many of the relatively underexploited and lesser-known species – both woody and herbaceous – often times satisfy this criterion much better than many of the well known species.

The term "agroforestry species" usually refers to woody species, and they have come to known as "multipurpose trees" (MPTs). These are understood as those trees and shrubs which are deliberately kept and managed for more than one preferred use, product, and/or service; the retention or cultivation of these trees is usually economically but also sometimes ecologically motivated, in a multiple-output land-use system (Nair, 1993). Important woody perennial groups in agroforestry include fruit trees fodder trees, and fuelwood species; very important group with ability to improve soil fertility is a large group of leguminous trees.

The interaction between neighboring plants is often described as 'competitive'. Managing the competition between trees and crops for light, water and nutrients to the farmers` benefit is the biophysical determinant of successful agroforestry systems (Sanchez, 1995).
There are above- ground and below- ground interactions. In the tropical environment the above-ground competition for light is probably not as important as the below-ground

competition for water and nutrients. The general concept that all trees are deep rooted, and thus use the nutrients that are not available for plants, may be greatly overstated, as there are large differences between species and sites and the horizontal scavenging ability of tree roots in often underestimated (van Noordwijk *et al*., 1996). The trees will always use easy available nutrients from the upper soil layers and thus compete with agricultural crops. The tree is also clearly dominant in capturing resources than annual crop, but the mix of perennial trees with annual crop can be more efficient in light and nutrient capturing than the sole monoculture.

The rate of competition or complementarity between trees and crops always depends on the species used in the system, type of agroforestry practice, temporal and spatial management of the components and specific site conditions. According to this statement farmer always have some management possibilities to decrease the rate of competition and to increase complementarity.

2.2.5. Agroforestry systems and practices in the Amazon Basin

Amazonia is one of the most important ecological regions in terms of the human population it supports and diversity of agroforestry systems (de Jong, 1995). The agroforestry systems in Amazonia follow a trail that begins with the arrival of the first hunter-gatherers in prehistoric times, followed by the domestication of plants for agriculture, the development of complex societies rich in material culture, the decimation of these societies by European diseases, warfare, and slavery, the introduction of exotic species, and finally, the present-day scenario of widespread deforestation, in which agroforestry is ascribed a potential role as an alternative land use. Despite the upheavals which occurred in colonial times, greatly reducing the population of native tribes, a review of anthropological and ethnobiological literature from recent decades indicates that a great variety of indigenous agroforestry practices still exist, ranging from deliberate planting of trees in homegardens and fields to the management of volunteer seedlings of both cultivated and wild species. These practices result in various configurations of agroforestry systems, such as homegardens, tree/crop combinations in fields, orchards of mixed fruit trees, and enriched fallows. Together they constitute a stock of knowledge developed over millenia, and represent technologies that evolved along with the domestication of native forest species and their incorporation into food production systems. This knowledge is the basis for the principal agroforestry practice employed by farmers in Amazonia today, the homegarden, and has potential to contribute to the development of other agroforestry systems (Miller and Nair, 2006).

However, agroforestry practices among indigenous Amazonians have dissimilar characteristics and provide a range of different products and services. Because of the climatic conditions that favour rapid growth of a large number of plant species, various types of agroforestry plant associations can be found in areas with high human population, especially around the bigger population centres. Various forms of homegardens, plantation crop combination, and multistrata tree gardens are common in these regions. In areas with low population density the major agroforestry practice is shifting cultivation but also other systems, as trees on rangelands and pastures, improved fallow and multipurpose tree woodlots are presented (Nair, 1993). Thus the common agroforestry systems in this zone are:

- shifting cultivation,
- improved fallows,
- homegardens, forest gardens and other multistrata systems, and
- plantation crop combination.

As already mentioned above, in the Amazon basin there are two different land-forms which result in very different land uses. The main constraints to periodically flooded areas near the rivers are risk of field flooding, and the limited time available for cropping land (de Jong, 1995). The main constrain in the upland non-flooding areas is very low soil fertility. But seasonally flooded land appropriate for agriculture covers a limited area, and farmers have to compete for agricultural site on this soil, or practice farming on the upland infertile soil.

Results of Coomes and Burt (1997) research in western Amazonia indicate considerable variation in field characteristics, agroforestry cycles, and household agroforestry portfolios. Agroforestry practice is found to be strongly related to access to land within the community: households holding more land use both potentially more sustainable and more lucrative swidden-fallow agroforestry systems. These results question the view of indigenous agroforestry systems as intrinsically ‘stable, equitable, and sustainable’, and underscore the importance of studying local variation in indigenous agroforestry practices.

De Jong (1995) made a research on diversity of agroforestry systems in two different villages in the Peruvian Amazon, nearby the Ucayali river. The variation of agroforestry practices is considerable because of destination of the output, species composition, complexity and management patterns. The most widespread type - forest gardens were very variable and characterised by age, dominant fruit, forest tree species and other crop plants and its origin. Only several cultivated wody species were present in all types of forest garden and they were mostly native fruit trees as *Rollinia* sp., *Pouteria caimito, Inga edulis, Bactris gasipaes, Musa paradisiaca, Poraqueiba sericea*, and *Pourouma cecropifolia*. Tree species used for timber or construction purposes occuring in forest gardens were *Cedrela odorata*, *Vismia angusta* and *Calathea* sp., which is grown for it leaves used for wrapping. Work in forest gardens is done very infrequently and only for very short period. The principal management activities in forest gardens are weeding and harvesting, while in some fields new species continue to be planted, and thus production levels and labour investment are low. The large number of products yielded is primarily destined for household consumption. A few products may be sold in the market. Very little risk is involved in managing a forest garden since little is invested and not much can be lost.

Many agroforestry experiences from Peruvian Amazon are also listed in the study of TCA (1997). Native communities have long experience mainly with traditional slash-and-burn agriculture with combination of home gardens. The farmers cultivate desirable trees in secondary vegetation of fallow phase, usually native fruit and timber trees. New experiences are with cultivation of plantation crops (mainly coffee or cocoa) in association with fruit and timber trees, which provide also desirable shade.

The INIA (National Agricultural Research Institute) experimental station near Yurimaguas, Peru has also established many experimental plots with agroforestry systems, mainly combination of plantation crops (coffee, cocoa, pineapple), timber trees (*Cedrelinga sp.*), fruit trees (*Citrus sp., Bactris gasipes, Berhtolletia excelsa, Eugenia stipitata, Bixa orellana, Inga edulis*) and leguminous plants (*Arachis pintoi*, *Stylosanthes guaenensis, Centrosema macrocarpum*) as a cover crops (Arévalo, 2003, personal communication).

In the Brazilian Amazon Smith *et al.* (1996) observed on tree farming smallholders the most common associations of black pepper and orange, followed by cacao and rubber;

coconut and orange; manioc and banana; and manioc and orange. Results of their research is that the diversity of agroforestry systems ensures some resiliency from market and ecological shocks. Major constraints to expanding agroforestry in Amazonia include inadequate development of agro-industries, the virtual absence of credit, the lack of inexpensive irrigation systems and insufficient planting material of commercially-desirable varieties. Agroforestry would be fostered in the Amazon if more agroindustries were established in both urban and rural areas. Most farmers in the Amazon still do not have ready access to any industries that can process agroforestry products and they often lack title to their lands. Markets are growing for tropical fruits, juices and nuts, but much produce is lost because it cannot be processed (Smith *et al.*, 1996).

2.2.6. Traditional agroforestry and indigenous knowledge

Apart from contributing information to the debate on historical processes, ecological studies of traditional management of the land now tend to emphasize the usefulness of accumulated indigenous knowledge on the management of the natural resources for contemporary landuse. Indigenous or local people are no longer viewed as stubborn and backward, but as knowledgeable actors who skilfully manage their environment. Local knowledge could be one of the starting points, when designing alternative land-use systems in particular region (Remmers and Koeijer, 1992).

2.3. Ethnobotany and indigenous knowledge

2.3.1. Ethnobotanical approach and community development

Ethnobotany is the study of the interactions and relationships between plants and people over time and space. This includes the uses, knowledge, beliefs, management systems, classification systems and language that both modern and traditional cultures have for plants and their associated terrestrial and aquatic ecosystems. If plants did not exist, human life would not be possible. All members of the human family depend on plants for their survival in myriad different ways. Today we also depend on them for many of our opportunities to improve the quality of human life in the future. Plants are fundamental to the functioning of all human societies and to the operation of all ecosystems. Yet despite their central importance, plants are often poorly appreciated.

Our collective management of the world's resources is unsustainable at present. Rapidly rising population levels, the runaway growth of individual consumption, the continued use of inappropriate technologies and the erosion of traditional knowledge are progressively limiting the options for the future, and the kind of world that our descendants will inhabit. The application of ethnobotany is a possible way of breaking free of our passive approach to the world and dealing with this seemingly overwhelming set of challenges in a positive way (Balick *et al.,* 2007).

Ethnobotanists have traditionally directed their efforts towards one of two goals. Economic botanists sought to discover new natural products of commercial value, often for the benefit of the developed world, whereas ethnoscientists focused on achieving a theoretical understanding of how people perceive and manage the environment. Since the late 1960s, many ethnobotanists, building upon and modifying these early goals, have directed their attention to applying the results of their research to conservation and development problems.

The community projects in which they participate have various goals, including return of the research results to host communities, strengthening traditional systems of agricultural production, encouraging rational use of plants in health care and promoting traditional ecological knowledge (Cunningham, 2001).

2.3.2. Benefits of ethnobotany for agricultural production

Agroecology focuses on the complex ecological relationship that is at the foundation of any system of agricultural production. These include the interaction between crop plants and insects, soil microorganisms, weeds and many other elements of the local environment. Ethnobotanists can work alongside agroecologists to document traditional systems of agricultural production and to assist in transferring appropriate technology from one region or ethnic group to another. The ultimate goal of this efforts is to design agroecosystems that blend ecological concepts of integrated pest control and organic fertilization with elements of traditional polyculture – the cultivation of several species of crop plants in single plot, often intermixed with semi-cultivated plants.

Ethnoecological research may focus on indigenous systems of soil classification, local methods of insect control or the input of non-cultivated plants in agroecosystems, and has contributed to the general recognition of the value of polycultures. Ethnobotanists can play a catalytic role in suggesting which wild or semi-cultivated species can be incorporated into agroforestry or agroecosystems. They can also propose alternatives to environmentally destructive practices such as large-scale plantation agriculture or cattle-raising. Many of these alternatives have been inspired by ancient systems of cultivation that are only now being rediscovered, or by traditional systems that are finally being given to recognition they deserve (Cunningham, 2001).

2.3.3. Obtaining indigenous knowledge and the role of farmers

Indigenous knowledge is local knowledge that is unique to a given culture or society. It is the basis for agriculture, health care, food preparation, education, environmental conservation and a host of other activities. It reflects many generations of experience and problem-solving. It represents an immensely valuable data base that provides humankind with insights on how numerous communities have interacted with their changing environment including its floral and faunal resources (Warren, 1992; Ulluwishewa, 1993).
Local people have a wide knowledge of the ecosystem they live in and ways to ensure that natural resources are used sustainably. Therefore, indigenous knowledge of resource management provides a valuable information base which could be used (with adaptations) in the management of natural resources to create appropriate technologies leading to sustainable development. It can help other people learn how to live in harmony with nature and the environment in a sustainable fashion. A blend of indigenous knowledge and modern approaches may be most appropriate. Modern interest and practice of agroforestry is the example of such connection (Ulluwishewa, 1993).

Ulluwishewa (1993) see the impediment in communication gaps that exist between project personnel and local communities in the Third World. She follows with the solution that indigenous knowledge can facilitate communication by providing a better understanding of how people perceive their environment and develop their perceptions. The reasons are several. Indigenous knowledge represents the richness of the poor. It is the only major resource of the poor who have limited access to basic and essential material resources. Any strategy to alleviate poverty should recognize what the poor have instead of not have and should transform their creativity into advantage. Therefore, indigenous knowledge should be seen by any poverty alleviation program as a resource. Nevertheless, involvement strategy will undoubtedly enhance the self-confidence of the poor (Ulluwishewa, 1993).

Martin (1995) and additionally also Cunningham (2001) exhort that maximum effort should be made to document and integrate indigenous knowledge about land use, vegetation and forest management, non-timber forest products, medicinal plants, agroforestry, home-gardens, agriculture, and biodiversity. Ethnobotanical approaches enable the establishment of close dialogue and communication with local people, and may ultimately facilitate the elaboration of management plans which ensure participation by local people and avoid having an adverse impact on their life and their environment.

2.3.4. Ocassion for a critical approach

Nevertheless, indigenous knowledge cannot be accepted uncritically, as it has its limitations. The notion indigenous people live naturally in harmony with the environment is sometimes naïve. There is historical and contemporary evidence that indigenous peoples have also committed environmental 'sins' through over-grazing, over-hunting, or overcultivation of the land. It is misleading to think of indigenous knowledge as always being 'good,' 'right' or 'sustainable'. Especially under conditions where the local people are in fact recent migrants from a quite different ecological zone, they may not have much experience yet with their new environment. In these circumstances, some indigenous knowledge of the people may be helpful, or it may cause problems (e.g., use of agricultural systems adapted to other ecological zones). Therefore it is important, especially when dealing with recent migrants, to evaluate the relevance of different kinds of indigenous knowledge to local conditions (Langill, 2004).

Pratt and Loizos (1992) point out the need, however to maintain a healthy scepticism and critical view of processes described as ‘participatory’: the word has been used to describe anything from obligatory, through to genuinely democratic and enthusiastic involvement in a research project. It is crucial that local participation is genuine. It is pointless to bring local people into a data-gathering exercise which is of no interest to them in an effort to legitimize research through ‘participation’.

Whatever method or set of methods you use, it is important to consider the accuracy of responses you receive. How appropriate (or inappropriate) are the methods and questions? No single method has all the answers – all have advantages and disadvantages.

Nor can you always expect the answers you are given by local people to reflect your measures of time or quantity. 'Informant' accuracy, the responses you get from the people you interview or discuss things with, can vary greatly according to how they view your intentions. They may also see the issue in a different way. It is crucial to cross-check information from a mix of different methods, even if you only compare the results from just two methods. If every researcher did this, there would be far fewer misunderstandings than is commonly the case (Cunningham, 2001).

2.4. Health and biodiversity

2.4.1. Malnutrition issues in the region

The strong links between biological and cultural diversity uniquely position ethnobotany to help us craft effective local solutions to many of the global issues that confront us as a species. Some of the most challenging of these issues are food security, deforestation, pollution, the maintenance of human health, the quality of human life, and resource depletion of all kinds. (Balick *et al.*, 2007)

A cornerstone for environmental sustainability is biodiversity, generally understood as the variety of living things. Ecosystems are essential to human health in providing food security, adequate nutrition, resistance to infectious and vector borne diseases, mental health and reduction of disaster risk (Secretariat of CBD, 2009).

Concerning food, loss of biodiversity can impact both agro-industrial economies and human health. First, preserving biodiversity through sustainable agriculture not only provides farmers with a durable food source but also serves as a carbon sink and a breeding ground for different species. In addition, understanding of local crop genetic diversity allows for development of resilient alternative crops in the face of climate change. Second, human health and nutrition benefit from the complexity of ecosystems since ecosystems provide an assortment of foods to meet dietary requirements needed to achieve a healthy life. Traditional food systems rely on this diversity of vegetables, fruits and animal sources of foods for subsistence. Loss of this variety in food choices can lead to problems of malnutrition, especially micronutrient deficiencies due to dependency on nutritionally poor but calorie dense foods.

The FAO describes “traditional food systems” as foods that “Indigenous Peoples have access to locally without having to purchase them, and within traditional knowledge and the natural environment from farming or wild harvesting”(Kuhnlein, Erasmus *et al.,* 2009). This is in contrast to “market foods” which are customarily purchased and part of the globalized economy. Loss of traditional foods and dependency on market foods leads to important negative health consequences. The alternative to traditional foods will often be nutritionally poor but calorie dense foods. Consequent health effects are problems of malnutrition, including both micronutrient deficiencies and problems of over-nutrition. Currently, the effects of dependency on market foods can be observed in the obesity epidemic and its associate health effects in the Western world. Traditional food systems are often based on subsistence living. For example, the Awajun in the Peruvian Amazon receive 100% of their dietary energy intake from local food sources. In contrast, traditional foods can also serve as an important complement, like for the Inuit for whom it makes up 45% of their dietary energy (Kuhnlein, Erasmus *et al.*, 2009). Cataloguing and preserving traditional knowledge of local food system is crucial as unknown crops might become future cash crops. Traditional crops are often best adapted to their local environment and hence provide an important tool for food security in the face of climate change.

Access to health services by the populations of the countries in the Amazon region is very difficult, due to factors such as low population densities, lack of communications and huge cultural and ethnic differences, which make the application of conventional strategies to encourage, promote and administer health care even more difficult. Acute malnutrition, a low level of literacy, environmental deterioration and misuse of natural resources, are also influencing factors.

The search for a solution to the health problems of the populations of the Amazon region includes training in preventive health measures, a better understanding of biodiversity as a source of new medicines, as well as disseminating the traditional knowledge of the native populations concerning the properties of plants, animals and micro-organisms (FAO, 1996).

An intrinsic link emerges between these three concepts. First, traditional food systems are dependent on the natural environment. By preserving ecosystems and biodiversity, traditional knowledge and foods are also conserved. Biodiversity in turn plays a role in human development as it provides humans with a variety of services: from nutritional purposes to serving as a buffer for disease and natural disasters. Maintenance of ecosystem services is essential in providing alternative tools for overcoming depressions caused by unforeseen consequences of climate change. Conversely, if approached from a human perspective and nutritional standpoint, biodiversity provides individuals with greater dietary choices. Traditional knowledge of food systems expands this choice even further, allowing for greater health. Since increased dietary diversity decreases the likelihood of mortality, the result is an overall gain in human development due to the achievement of better health (Hoffmeijer, 2010).

2.4.2. Trends in global agriculture production

Globally, agricultural production has risen for all major food groups in the past 25 years, but the rate of change has been different between food groups: the rate of increase has been much faster for foods associated with diet-related chronic diseases. This applies both to the foods negatively associated with CVD, e.g. fats from meat and vegetable oils and those positively associated, e.g. fruits and vegetables (Hawkes, 2006).

Worldwide, cereals are the largest crop group, but production has been growing at an average annual rate of just 1.1% since 1982 (Table 7). In contrast, vegetable production grew at an average annual rate of 4.2% between 1982 and 2002, followed by oilcrops at 3.8%, meat at 2.8% and fish at 2.4% (FAOSTAT, 2005)

Table 7: Rate of increase of agricultural production, Latin america and world, 1982 -2002

Food product	Annual percentage rate of increase production, 1982 – 2002	
	World	Latin America and Caribbean
Cereals	1,1	1,5
Fruit	2,4	2,4
Vegetables	4,2	3,4
Meat	2,8	3,8
Fish	2,4	4,2
Oilcrops	3,8	6,0
Sugar, beet and cane	1,4	1,9
Milk and Eggs	1,4	2,6
Average rate	2,5	3,3

Source: calculated from FAOSTAT (2005)

The rates of change become more distinctive from a regional perspective. Production growth has been led by Asia, most notably China, but Latin America has also been a major source of growth of vegetable oils, meat and fish. Between 1982 and 2002, Latin America was the second fastest oilcrop- growing region, particularly of soybean oil (6.0% annual growth relative to 6.6% in Southeast Asia, where palm oil dominates) (Hawkes, 2006).

The importance of oils and fats in human nutrition is well recognized. These form a vital component of many cell constituents, are an important source of energy and act as a carrier of fat-soluble vitamins. Besides, they contribute significantly as functional ingredient in improving the sensory characteristics of several processed food products.
Oils and fats are mainly derived from plant and animal sources. About 71% of edible oils/fats are derived from plant sources (Salunkhe *et al.,* 1992).

2.4.3. Oilseed crops

Oilseeds are those crops in which energy is stored mainly in the form of oil. Some oil crops such as groundnut (peanut) can be used directly as a food, but others are exclusively processed to obtain fat or oil, and cake or meal (Hatje, 1989). The production of oilseed crops has expanded rapidly in response to the growing world population rising living standards. In addition, technological advances have lead to higher production levels and improvements in product quality and versatility. This has also paved a way for the development of technologies for the processing of nonfood products using oilseeds as the raw material (Salunkhe *et al.*, 1992).

The cultivation of oilseeds is documented since ancient times. Soybean has been an important food in China for thousands of years. The names of many oilseeds such as sesame and rapeseed appear in the Indian Sanskrit literature.

The oil crops are now grown all over the world. There are three major groups of oil crops:

1. Those that are annual or biennial such as soybean, sunflower, groundnut and rapesed.
2. The perennial crops such as coconut, babassu nuts and oil palms.
3. Crops such as cotton and corn germ, where the embryo, a rich source of oil is a byproduct.

Depending upon the use of oil, oilseeds can be classified into seeds which contain edible vegetable oil such as soybean, peanut, cottonseed, rapeseed, sunflower, sesame and those which contain nonedible oils such as castor beans. Another nonedible oil called tall oil is a byproduct of pine tree pulping in kraft paper mills. Although not a vegetable oil in the same sense as those from seeds, tall oil is nevertheless a dominant source of industrial oil (Pryde and Rothfus, 1989). There are forty different oilseeds whose oil can be used for human consumption (Lennerts, 1983). However only a small number of such crops are significant in the world's edible/non edible oil supply. Most cultivated oilseeds crops are listed in table 8.

Among the oilseeds, soybean accounts for more than 30% of the world's oilseed output. The major oilseed producing areas are in the temperate regions of the world.

Table 8: Commercialy important oil crops of the world

Common name	Scientific name	Family
Soybean	*Glycine max* (L.) Merr.	*Fabaceae*
Sunflower	*Helianthus annuus* L.	*Asteraceae*
Peanut	*Arachis hypogaea* L.	*Fabaceae*
Rapeseed	*Brassica napus* L.	
	Brassica juncea (L.) Coss.	*Brassicaceae*
	Brassica campestris L.	
Safflower	*Carthamus tinctorius* L.	*Asteraceae*
Sesame	*Sesamum indicum* L.	*Pedaliaceae*
Cotton	*Gossypium hirsutum* L.	*Malvaceae*
	Gossypium barbadense L.	
Oil Palm	*Elaeis guineensis* Jacq.	*Arecaceae*
Coconut	*Cocos nucifera* L.	*Arecaceae*
Maize	*Zea mays* L.	*Poaceae*
Rice	*Oryza sativa* L.	*Poaceae*
Castor	*Ricinus communis* L.	*Euphorbiaceae*
Linseed or flax	*Linum usitatissimum* L.	*Linaceae*
Niger	*Guizotia abyssinica* Cass.	*Asteraceae*
Jojoba	*Simmondsia chinensis* (Link) Schneider	*Simmondsiaceae*
Crambe	*Crambe abyssinica* Hochst ex. R E. Fr.	*Brassicaceae*
Olive	*Olea europea* L.	*Oleaceae*

Source: Salunkhe *et al.* (1992)

As mentioned above the oilseeds and their products have an important role to play in the economy of many countries. These are an essential component of human diet and a protein source in animal feed.(Salunkhe *et al.,* 1992) Highly nutritious traditional food crop of the Peruvian Amazon, sacha inchi, gained a world's attention since the oil derived from the sacha inchi seed won the gold medal at the "World Edible Oil" competition in Paris in 2004 (Agroindustrias Amazónicas, 2006). This "peanut of the Incas", or sacha inchi (scientific name: *Plukenetia Volubilis* L.) is a native plant whose origins lie in the Peruvian Amazon and its potential revenue from cultivation could aid poor indigenous and mestizo communities to move out of poverty and improve the diets in the same time. (Hamaker *et al*., 1992; Céspedes, 2006; Hoffmeijer, 2010).

2.5. Sacha inchi – *Plukenetia volubilis* **L.**

1.5.1. Name of the specie and taxonomy

The Euphorbiaceae is considered to be the fifth largest flowering plant family and comprises about 300 genera and 7500 species. (Gillespie, 1993; Gillespie and Armbruster, 1997). Euphorbiaceae family includes annual plants of medicinal, ornamental, alimentary and industrial importance, mainly characterized by the presence of milk substancy, as latex and three-capsule fruits(Bailey, 1949). Many members are important food sources; others are useful for their waxes and oils and as a source of medicinal drugs; dangerous for their poisonous fruits, leaves, or sap; or attractive for their colourful bracts (leaflike structures located just below flower clusters) or unusual forms. Although species of the family grow throughout the world, except in cold alpine or arctic regions, most of them are found in temperate and tropical regions. The family consists of annual and perennial herbs and woody shrubs or trees, rarely climbers. (EB, 2010).

Five subfamilies of Euphorbiaceae are currently recognized (classification of Webster, 1975; 1994). The family previously was divided into two major groups based on the number of ovules per locule, the biovulate taxa belonging to the Phyllanthoideae Pax and the uniovulate taxa to the Crotonoideae (Pax, 1890; Pax and Hoffmann, 1931; Webster, 1987). In Webster’s classification two subfamilies, Phyllanthoideae and Oldfieldioideae, include all biovulate taxa, whereas the remaining three subfamilies, Acalyphoideae, Crotonoideae, and Euphorbioideae, comprise all uniovulate taxa (Gillespie, 1997). All five subfamilies occur in Peru (MacBride, 1951).

Plukenetia belongs to the tribe Plukenetieae of the uniovulate subfamily Acalyphoideae, which is with its 116 genera in 20 tribes the largest, most complex and least understood of the five euphorbiaceous subfamilies (Webster, 1975; Gillespie, 1994; Webster 1994). Members of Acalyphoideae characteristically lack latex, and have eglandular inflorescence bracts, apetalous flowers and staminate flowers with valvate sepals. The tribe Plukenetiae is distinguished by the character combination of entire styles that are partly connate and often massive, and bisexual racemose or spicate (or rarely paniculate) inflorescence bearing cymose clusters of flower(s) as the basal node(s)n(Gillespie, 1993). Many species are frequently scandent; twining vines or lianas, both unusual habits in the family (Gillespie, 1994).

Thus full taxonomic classification of *Plukenetia volubilis* L. according to nomenclature database of Missouri Botanical Garden is following:

Kingdom: Plantae
Phyllum: Magnoliophyta
Class: Magnoliopsida
Order: Euphorbiales
Family: Euphorbiaceae
Subfamily: Acalyphoideae
Tribe: Plukenetieae
Genus: Plukenetia
Species: *Plukenetia volubilis L.*

According to spoken language or distribution the most used common names are following: Sp: sacha inchi, sacha inchic, sacha maní, inca inchi, maní del monte, supua, amui, sacha yuchiqui, sampannankli, suwaa

En: inca peanut, peanut of the Incas (Arévalo, 1996; Porras Montes 2008, personal communication)

2.5.2. Origin and distribution

The genus of Plukenetia includes 18 species of pantropical distribution. It was recorded in Malaysia, New Guinea, Borneo, México, etc. (Gillespie, 2007). Number of Plukenetia species in tropical America varies from 7 to 12 (Standley and Steyemark, 1949; Hutchinson, 1969) and to date is reported 12 in America, 3 in Africa, 2 in Madagascar and 1 in Asia; (Gillespie, 1993; Gillespie 2007).

The presence of Plukenetia volubilis in America was recorded in Bolivia, Brasil, Colombia, Costa Rica, Ecuador, French Guiana, Mexico, Panama, Peru, Surinam, Venezuela and in West Indies (see Figure 2) (Macbride, 1951; Correa y Bernal1992; Gilespie, 1993).

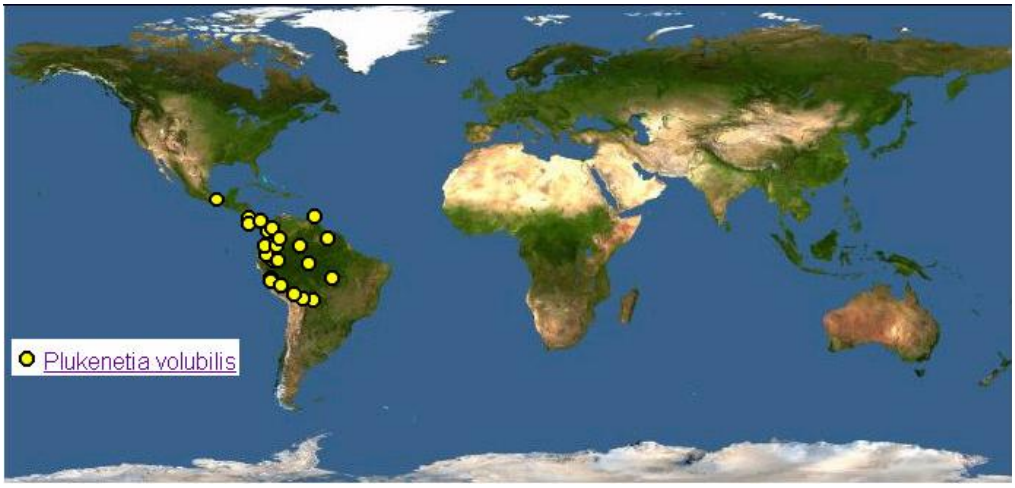

Figure 2 : Distribution of *Plukenetia volubilis* in the world (MOBOT, 2005)

In Peru itself, was reported in Madre de Dios, Huánuco, Oxapampa, San Martín, Rodríguez de Mendoza, Cuenca del Ucayali (Pucallpa, Contamana and Requena), in Putumayo and surroundings of Iquitos and Caballococha (see Figure3) (MacBride, 1951; Soukup,1970).

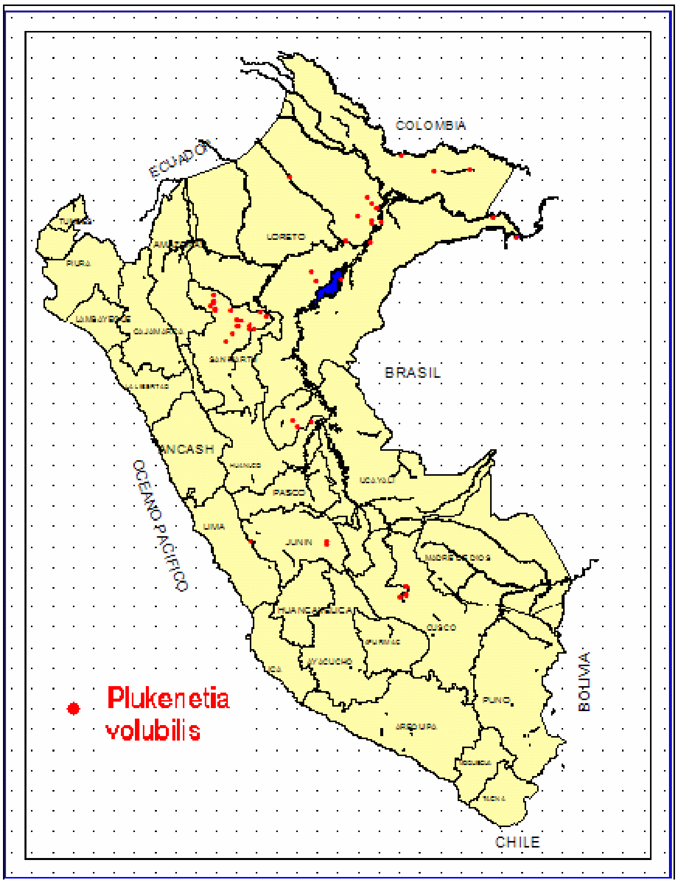

Figure 3 : Distribution of Plukenetia volubilis in Peru (INIA, 2007)

2.5.3. Morphological description

Plukenetia volubilis L. is monoecious twining vine or slender liana with stems up to 5 m long.

Leaves are alternate with petiole 2.5-7.5 cm long. Blade is mebraneous, triangular-ovate 9-16 cm long and 6-9 cm wide. Apex is long-acuminate and base truncate to cordate, glabrescent below, 3-veined at base.

Flowers are hermaphroditic. Inflorescence is axillary or terminal on short shoot, racemous 5-18 cm long. Female flowers are 1 or rarely 2 at base; male flowers white, numerous in condensed cymes above.

Fruit is deeply 4-lobed capsule 3.5-4.5 cm in diameter, glabrous, initially fleshy, becoming woody and dehiscent containing 4 seeds.

Seeds are lenticular, broadly oblong in outline 1.3-2.1 cm in diametre, brown with course dark brown markings (Gillespie, 1993).

2.5.4. Phenological description

Unlike the other oilseed crops vegetative growth and fructification of sacha inchi is continuous year round. The propagation of *P. volubilis* is most commonly done by seeds; both directly in field or in the nursery. Vegetative propagation may be done by cuttings.

Germination normally occur in two weeks after sowing. The stem and second green leaf appear in another week. Flowering is initiated in 3 months (90 days) after sowing by appearing first male flowers immediately followed by female flowers. The floral differentiation of both male and female flowers is completed in 7 to 19 days. Formation and development of the fruits start afterwards and in 4 months after flowering is terminated. Consequently, maturing process of fruits start and when the green capsules turn dark brown or almost black fruits are ready to be harvested. The maturing process of fruits take 15 – 20 days, initiates after 7,5 months after sowing and continuously goes on year round (Arévalo, 1996).

2.5.5. Ecological requirements

Sacha inchi is originally from the Amazon Rainforest, and what used to be a wild plant, now is cultivated widely in the region becoming a sustainable source of income to many families of the area. The plant is found anywhere from secondary forest edges to cane fields, over fences and to living like weeds in perennial crops plantations (Brack, 1999). It grows in hot, humid climate of Peruvian Amazon requiring a minimum temperature of 10°C and a maximum of 36°C. Higher temperatures are unfavourable causing the abort of flowering and the loss of leaves. (Arévalo, 1996; Manco, 2005).

As a twining vine bush, it is highly adaptable, growing at both low and middle altitudes of the rainforest. It grows from 100 m.a.s.l. of *Selva baja* (lowland jungle) up to 1500 m.a.s.l. in *Selva alta* (high jungle). Minimum precipitation per year is 850-1000 mm, equally distributed throughout the year. Longer periods of dry weather or lower temperatures cause growth retardation. The excess of water increase the infestation by diseases. (Arévalo, 1996; Manco, 2005; Guerrero,2006).

Sacha inchi grows in a variety of soils, it prefers acidic clay soils with high content of aluminium and requires low light intensity but constant water supply with appropriate drainage. The crop has also shown to be resilient to conditions of low fertility. Fertilizers are not needed for optimal growth in the first few years. Although requires low light intensity abundant light is advantageous. The more light plant recieve growth and development of branches, inflorescence and pods is more intense. On the other hand, too much shading diminish the flowering and production decreases. (Arévalo, 1996; Manco, 2005; Guerrero, 2006; Vasquez, 2006)

2.5.6. Properties and nutritional values

Analysis carried out in the Institute of the Food Science at Cornell University USA (Hazen and Stoewsand, 1980, unpublished data), established that the seeds of sacha inchi are highly nutritious. The seeds contains an unusual high level of oil (49%) and a relatively high content of proteins (33%)(see Table 9). They are especially rich in omega-3 and omega-6 fatty acids in comparison to other oleaginous seeds. The seed is also rich in omega-9, proteins, amino acids, vitamins A, D, and E. The high percentage (92%) of unsaturated fatty acids, also make it a valuable cholesterol reducer.

As a result of the studies carried out since 1980 in Peru, as well as in the United States and in other countries, it is known that this oil is the best amongst other vegetable oils used for the human consumption. Its rich composition of fatty acids demonstrates its high quality, included the polyunsaturated fatty acids of the Omega Group, in a higher content in comparison to other oleaginous seeds, used for the extraction of oil for the human consumption. The sacha inchi seed oil has a high content of the linolenic fatty acid, the most valuable oil of the Omega Group present in the composition of the fats (Hamaker *et al.*, 1992; Arévalo, 1996; Manco, 2005).

Table 9: Comparison of protein and fat compounds in different oilseed crops

Crop	Protein (%)	Fat (%)
Sacha inchi	33,3	48,7
Soybean	28,2	18,9
Peanut	23,4	45,3
Sunflower	24,0	47,5
Cotton	32,9	
Palm cruet	-	45,0

Source: Hazen and Stoewsand (1980) unpublished data

The following table 10 shows the content of the fatty acids nutrients and the composition of several oleaginous seeds used for the oil production for the human consumption. The analyses and studies made on these seeds demonstrate in all the aspects, the high quality and superiority of the oil and the nutrients of the Sacha Inchi.

Table 10: Fatty acid profile of Inca peanut oil compared to other oilseed oil[a]

Fatty acid	Inca peanut	Soybean	Peanut	Cottonseed	Sunflower
Total oil	54	19	45	16	48
Saturated					
$C_{14:0}$, Myristic	0.0	0.0	0.0	0.0	0.0
$C_{16:0}$, Palmitic	4.5	10.5	12.0	18.7	7.5
$C_{18:0}$, Stearic	3.2	3.2	2.2	2.4	5.3
Unsaturated					
$C_{16:0}$, Palmitoleic	0.0	0.0	0.3	0.6	0.0
$C_{18}:_0$ Oleic	9.6	22.3	41.3	18.7	29.3
$C_{18:2}$ Linoleic	36.8	54.5	36.8	57.5	57.9
$C_{18:3}$Linolenic	45.2	8.3	0.0	0.5	0.0
$C_{20:1}$ Gadoleic	0.0	0.0	1.1	0.0	0.0

[a] All values shown are percents. Values for soybean, peanut, cottonseed, and sunflower are taken from Bodwell and Hopkins (1985).

Source: Hamaker et al. (1992)

The total proteins of the Sacha Inchi in comparison with the patterns recommended by FAO/WHO/ONU (1985) for the feeding of children in pre-school age, from two to five years, and what it has recently been recommended for all the ages, excluding infants (FAO/WHO, 1990) is shown in the table 11, against the different seeds:

Amino Acid Profile of Inca Peanut Protein Compared to Other Oilseed Protein[a,b]

Amino Acid	Inca Peanut	Soybean	Peanut	Cottonseed	Sunflower	FAO/WHO/UNU Scoring Pattern[c]
Total protein, %	27	28	23	33	24	
Essential						
His	26	25	24	27	23	19
Ile	50	45	34	33	43	28
Leu	64	78	64	59	64	66
Lys	43	64	35	44	36	58
Met	12	13	12	13	19	...
Cys	25	13	13	16	15	...
Met + Cys	37	26	25	29	34	25
Phe	24	49	50	52	45	...
Tyr	55	31	39	29	19	...
Phe + Tyr	79	80	89	81	64	63
Thr	43	39	26	33	37	34
Trp	29	13	10	13	14	11
Val	40	48	42	46	51	35
Nonessential						
Ala	36	43	39	41	42	...
Arg	55	72	112	112	80	...
Asp	111	117	114	94	93	...
Glu	133	187	183	200	218	...
Gly	118	42	56	42	54	...
Pro	48	55	44	38	45	...
Ser	64	51	48	44	43	...
TEAA[d]	411	418	349	365	366	...
TAA[e]	976	985	945	936	941	...
TEAA as percent of TAA	42	42	37	39	39	...

[a] Values for soybean, peanut, cottonseed, and sunflower were taken from Bodwell and Hopkins (1985).
[b] Values shown are milligrams/gram of protein, unless otherwise noted ($N \times 6.25$).
[c] Recommended level for children of preschool age (2–5 years), although recently recommended for evaluation of dietary protein quality for all age groups except infants (Joint FAO/WHO Expert Consultation 1990).
[d] TEAA = total essential amino acids.
[e] TAA = total amino acids.

2.5.7. Uses

According to the properties mentioned above ‘sacha inchi’ is ideal for improving children alimentation and very desirable for recuperation after diseases and especially for aged persons alimentation (Brack, 1999).

The seed has been an important component of the local traditional food systems of many people of the Amazon. For example, the Secoyas, Handosas, Amueshas, Cashibos, Dapanhuas and Boras eat the toasted leaves and seeds before arduous labour for its energizing properties. In addition, oil is extracted from the seed and used both in a variety of meals and to alleviate muscular and rheumatic pains. The Mayorunas, Chayuhuitas, Campas, Huitotas Shipibas, Yaguas and Boras on the other hand have customarily grinded the seeds to produce a flour used both for cooking and cosmetic purposes. Traditional dishes based of sacha inchi include: ají de sacha inchi, cutacho, mantequilla de sacha inchi (butter from sacha inchi) inchi cucho (spicy nut), lechona api (banana pudding with nut), inchi capi (chicken soup with nut) tamal de sacha inchi, turrón de sacha inchi, etc. (Brack, 1999; Machaca Compomanes, 2009). Nowadays, the roasted seeds similar to almonds and sacha inchi ice-cream are very popular (Leon, 2009).

The crude leaves according to Soukup (1970) are commonly eaten by amazonian tribe of huitotos.Furthermore, the leaves of sacha inchi are considered as excellent forage (Manco, 2005).

Sacha Inchi oil has received a number of awards, notably the Gold Medal awarded at the International Competition: ‘Oils of the World’, WEO in Paris, France in 2004 and 2006. The oil also received awards at the top two Professional Fairs about Foods of the World: SIAL of France in 2004 and was featured in the 2006 ‘International Trends and Innovations Directory and ANUGA in Germany in 2005 as one of the top innovations of ANUGA.

Sacha inchi oil has a delicious taste and aroma. It is ideal for gastronomy: it can be taken with salads, stews and pasta. It can be added to cooked meals or taken in its pure form – 3 soft gel capsules or 1 tablespoon/day. It is also recommended for use in the cosmetics industry (Hoffmeijer, 2010).

The oleaginous properties of the seed also make it an interesting alternative source of fuel as it has the potential to be used as a biodiesel. Recent research has shown that sacha inchi has a high return rate of biodiesel to oil of 96.5% (Ramírez, 2008). The high nutritional value and potential source of renewable energy of sacha inchi stresses the importance to develop the cultivation of the seed at an industrial scale.

2.5.8. Further approaches

Overall, developing production of sacha inchi in a sustainable manner tackles a number of human development issues. First and foremost, cultivation and processing of sacha inchi would aid to alleviate economically deprived indigenous and mestizo communities by generating income from sales of a cash crop which would in turn provide them with greater food security. Second, research and development needed to develop the crop brings in the necessary infrastructure to allow genetic conservation of crop biodiversity. Finally, research has shown that sacha inchi oil is not only nutritionally valuable but also has the potential to be exploited as a biodiesel, presenting a sustainable alternative energy source for a country whose energy primarily comes from petroleum (45%) and wood burning (30%) (Calle and Coello, 2005).

Nevertheless rapid interest for the development of industrial scale cultivation of a traditional cash crop and increasing worlds' demand for sacha inchi oil can't be fulfilled without knowing more about the cultivation itself. No comprehensive data of different aspects of the plant have been conducted. E.g.: There are still missing information about the levels of genetic heterogeneity of different ecotypes; on floral biology of plant; agronomy and cultivation potential of specie; pests and diseases; complex nutritional studies etc. Thus more research in all these areas must be done to avail potential revenue from sacha inchi cultivation (Hamaker *et al.*, 1992; Arévalo, 1996; Manco, 2005).

3. Study area

3.1. Geographical location

The field research was conducted in Peruvian Amazon in the area near the city of Pucallpa. Pucallpa is the administrative city of Ucayali department and with up to half million inhabitants is the second important city of the Peruvian jungle. Only approximate data about population number are available due to fast population growth (5,2 % per year) (INEI, 2007). The city lies on the river Ucayali, at 154 m above sea level and is located 860 kilometres east from Lima. (Fujisaka *et al.*, 2000; Pimentel, 2004). With its location is the connecting port between the Peruvian Amazon and the rest of Peru. The longitude is about 74°W and latitude 8°S (Fujisaka *et al.*, 2000; Pimentel, 2004).

Figure 4: Location of study site of Pucallpa in Peru, bordering Brazil.

In spite of that present policies in Peru do not promote the destruction of the forest the whole area was hardly affected after the decades of deforestation and by rapid population growth that it all led to insupportable situation which is now present in whole Ucayali region.

3.2. Biophysical characteristics

The area is characterized by humid tropical forest cover and by hot and humid climate that varies only slightly throughout the year (Fujisaka et al., 2000; Lojka, 2005). The mean annual temperature is 25.7°C and the mean annual relative humidity reaches 80%. The rain period is from February to May and from September to November, the remaining months are dry. The rainfall during winter time is distributed in form of storms with large amount of rain per day. During summer time whole amount of rain is distributed more regularly. The rainfall ranges from 1500 to 2100 mm annually (a mean of 1546 mm in Pucallpa, with rainfall increasing to the west) (Vicha, 2008; Fig. 2).

However, in the last few years, probably due to high deforestation, the climate has changed slightly and the difference between dry and wet periods is not so sharp (Loker, 1993; Riesco and Arroyo, 1997; MINAG, 2002; Odar and Rodrígues, 2004). The latest studies shows that year by year the precipitation is decreasing by 1.3 mm on average and that there is a great precipitation variation between years with standard deviation of 382 mm per year, making agriculture business complicated as it is impossible to predict the climate for next years (Vicha, 2008).

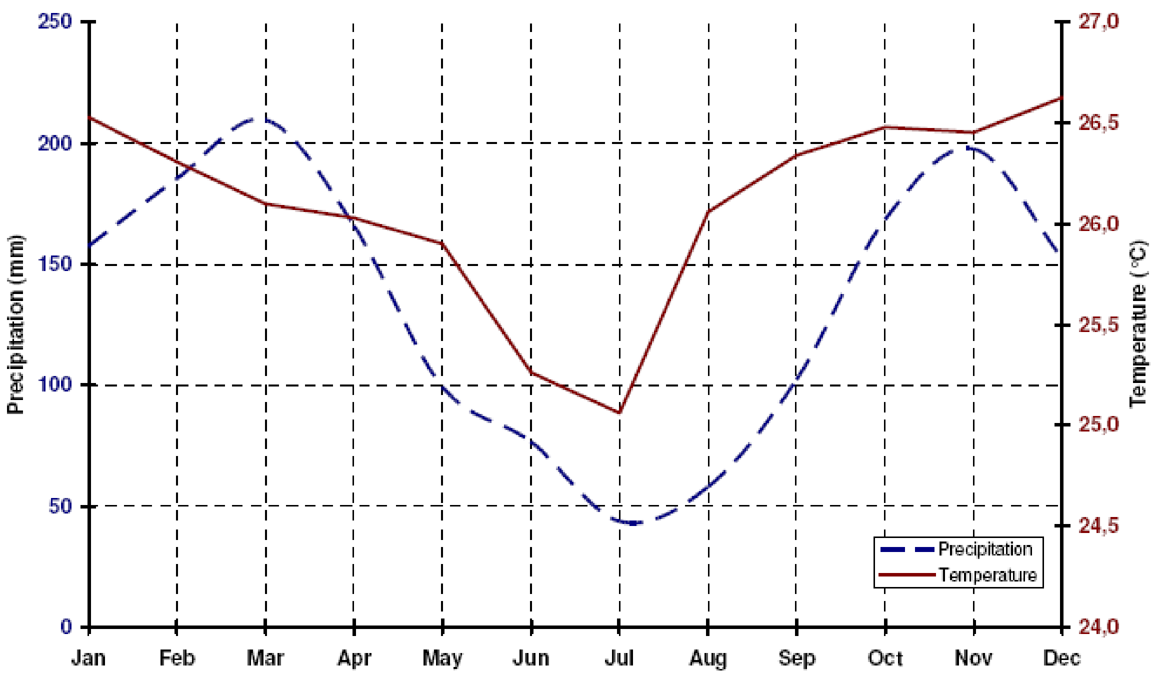

Figure 5: Average monthly precipitation and temperature in Pucallpa, Peru (Vicha, 2008)

According to Cochrane (1985), the original vegetation is tropical semi-evergreen seasonal forest, now mixed with palm forest, largely affected by current farming practices.

The Amazonian basin is divided into two zones which differ historically and geomorphologicaly. *Terra varzea* (locally called *Bajial*) is seasonally inundated while *terra firme* (*Altura*), where the project takes place, is located above the flood level and therefore is usually poorer in nutrients (de Jong, 1995). Soils of *terra firme* include well-drained forest areas of acidic (pH 4.4) Ultisols (Acrisols according to FAO/UNESCO classification system) (Fujisaka *et al.,* 2000; Cochrane *et al.,* 1985) of low P (2 μg/g) with aluminum saturation (30% to 70%) (Loker, 1993; de Jong, 1995; Riesco and Arroyo, 1997). The content of organic matter is low and texture is medium to high. These upland soils lack sufficient essential nutrients to sustain repeated harvests of trees and annual crops (Weber *et al.,* 1997). The texture of topsoil is loamy while the texture of subsoil is clayey. The depth is 150 cm. The upland terrain is usually flat or undulating. In general, these soils are of low quality for agriculture, but slightly better than many Oxisols found in the Brazilian Amazon (de Jong, 1995).

3.3. Socio-economic conditions

With a fast growing population with up to half million inhabitants nowadays, Pucallpa is Peru’s fastest growing jungle city, situated on the banks of the Ucayali river in the heart of the Amazon basin. The rural population density is estimated to be around 7 persons per km^2 (Riesco, 1995; INEI, 2007) and consists primarily of small-scale migrant crop farmers. The extraction and transformation of timber are the main economical activities of the region. Medical and educational facilities are severely limited. Pucallpa is a commercial centre and the logging and oil industries provide much of its revenue and contribute much to the rapid deforestation of the area.

In the last 50 years, the area around Pucallpa has witnessed deforestation at a rate of 20,000 hectares per year (Portillo, 1994), although present policies in Peru do not promote destruction of the forest. However, the degree of poverty in degraded lands of the Andean highlands is such that migration continues to the tropical lowlands (TCA, 1997), including Pucallpa region. Since most settlers in the Peruvian Amazon come from the above-mentioned non-forest regions (Andes, coast), they have little, if any, knowledge of the ecosystem and they adopted to slash-and-burn agriculture. This shift from coca leaf production to charcoal production has increased the pressure on hardwood trees and the forest in which these species grow. Also the expansion of the pasture area in the region, although temporarily slowed down, is likely to increase again, bringing further species losses in the areas affected (Fujisaka *et al.,* 2000).

A search is presently being conducted for alternative crops to reduce food imports and the region's economic dependance on coca cultivation. One solution to this problem could be to expand the use or find new food or feed uses for indigenous food-producing plants (Hamaker *et al.,* 1992).

4. Objectives and hypothesis

The facts mentioned in the preceding chapters indicate that the surroundings of Pucallpa are deeply destroyed by logging of tropical rainforest and consequent impact of local agricultural practices. Traditional slash-and-burn systems as practiced around Pucallpa make strong pressure on the environment and in the future they will no longer be feasible (Fujisaka *et al.,* 2000; Szott *et al*., 1999).

Concerning food, loss of biodiversity can impact both agro-industrial economies and human health. First, preserving biodiversity through sustainable agriculture not only provides farmers with a durable food source but also serves as a carbon sink and a breeding ground for different species. In addition, understanding of local crop genetic diversity allows for development of resilient alternative crops in the face of climate (Hoffmeijer, 2010).

Cultivation of sacha inchi (*Plukenetia volubilis* L.) promising oilseed crop native to Peruvian Amazon has the possibility of generating significant sources of income for local communities, improve their diets and implement this crop to environment in sustainable manner.

The present research was carried out based on the following hypothesis :

- All of the observed plants called by farmers sacha inchi are *Plukenetia volubilis* and not any other species, despite their visible morphological dissimilarities in the plant appearance.
- Implementing sacha inchi into agroforestry systems is possible and it can be used in local scale by smallholder farmers in the region of Ucayali.

The objectives of the present study are:

- to determine and evaluate morphological diversity of amazonian oilseed crop sacha inchi cultivated in Peruvian Amazon in the Ucayali department, on the basis of qualitative and quantitative features evaluation and through ethnobotanical approach
- to analyze its cultivation potential for the local farmers and possible implementation of this crop into local agroforestry systems

5. Materials and methods

5.1. Experimental study sites descriptions

The study was carried out at the Coronel Portillo province of the department of Ucayali in Peruvian Amazon. The evaluations were located in three mestizo communities or their surroundings, namely Antonio Raimondi, Tres de decimbre and Pimental, west from Pucallpa. All the villages are located in the district Campo Verde and are connected with the Lima-Pucallpa highway.

Antonio Raimondi is 25 km away from Pucallpa. Due to the method of shifting cultivation almost all of forest stands are already cut down and extensive area around the village is covered by weedy *Imperata* grass. Remaining young secondary forest is called *purma*.

Tres de deciembre is 22 km away from Pucallpa. With its location only 3 km southeast from Antonio Raimondi the character of scenery is very similar. Extensive areas covered by weedy *Imperata* grass and *purma.*

Pimental, located 35 km from Pucallpa, is also surrounded by vast area covered by weedy grass species of *Imperata* sp. and *Brachiaria* sp.. Cultivation of economically advantageous pepper has the tradition in this zone. The secondary forest can be found only with difficulty.

There are not available the meteorological data for particular areas but as they are not distant from Pucallpa, the seasonal variation of temperature and precipitation is almost the same (see chapter 2.2. Biophysical characteristics). Only the slight difference in the altitude of villages may be examined.

The soil composition in each site can be seen in table 12. The soil analysis was made by INIA (Instituto Nacional de Investigación Agraria) in Pucallpa and the University La Molina (Universidad Nacional Agraria La Molina) in Lima according to the methodology of Ayre and Román (1992). The soil samples were all taken from 10(15)-25(30) cm depth. Generally speaking, all soils are similar in most parameters and all of them are ranged in Acrisols (FAO/UNESCO classification system) / Ultisols (United States Department of Agriculture). The physical properties are considered to be good, although they contain low amount of organic matter. However, chemical parameters are very bad and show evidence of soil exhaustion caused by long and inappropriate exploitation. The soils are poor in Ca, P and also in Mg amounts and the effective cation exchange capacity is low. On the other hand, the aluminium saturation is very high (more than 75 %).

Table 12: Soil characterization on particular sites.

community	soil profile	clay particles (%)	loamy particles (%)	sandy particles (%)	soil type	pH	P (ppm)	K ($cmol_c$/l)	Ca ($cmol_c$/l)	Mg ($cmol_c$/l)	ClCe ($cmol_c$/l)	Al + saturation (%)	Cox (%)	N disp.
AR	10-30	25,92	35,28	38,80	loam soil	5,52	5,33	0,05	1,12	0,40	1,57	77,25	0,81	0,06
PI	10-30	26,08	45,56	31,36	loam soil clay sloam	4,10	11,62	0,27	0,24	0,17	0,68	94,47	0,95	0,07
3D	10-30	25,94	36,3	37,76	loam soil	5,55	5,71	0,03	1,08	0,36	1,62	81,02	0,83	0,06

5.2. Data collection – morphological evaluation

5.2.1. Description of evaluated plots

In the period from June 2007 until March 2010, the data were gathered from 8 distinct plots in three distinct communities mentioned above (Antonio Raimondi, Tres de deciembre, Pimental).

All the plots represented deliberately grown individuals as farmers designed and assesed cultivation due their knowledge and financial possibilities. The random sampling method was used in choosing particular individuals according to Kindt and Coe (2005) and 4 plants in each plot were marked.The exact location and number of evaluated plants are presented in Table 13.

Table 13: Location of particular plots

Location	Code	Latitude	Longitude	Altitude	Number of evaluated plants
AR - Boca Negra	AR 1	08° 22’ 27,8”	74° 43’57,4”	154 m AMSL	4
AR - Linderson	AR 2	08° 22‘ 01,4“	74° 42’ 18,7”	155 m AMSL	4
AR- Juber	AR 3	08° 21’ 57,7“	74° 42’ 20,5”	157 m AMSL	4
AR- German	AR 4	08° 21’ 52,3“	74° 42’ 21,2”	157 m AMSL	4
3 de deciembre	DE 1	08° 23’ 02,7”	74° 41’ 26,7”	147 m AMSL	4
PI - Luz	PI 1	08° 31’ 22,2”	74° 49‘ 19,6“	211 m AMSL	4
PI - Lirenza	PI 2	08° 31’ 43,4”	74° 51‘ 22,6“	204 m AMSL	4
PI - Esau	PI 3	08°31´38.7´´	74°46´36.7´´	205 m AMSL	4

5.2.2. Morphological description

The survey was conducted on the basis of suitable descriptor (see Appendix B). As far as there is no *Plukenetia volubilis* descriptor avalaible up to now, the appropriate one was created according to the guidelines “Developing crop descriptor list“ due to Bioversity International (2007) using the data from botanical description of Gillespie as mentioned in 1993. The scale of possible variance was designed using the only materials of *Plukenetia volubilis* morphology (Gillespie 1993, Gillespie 1994) and modified according to own observing. Each evaluated plant was sampled and confirmed to be *Plukenetia volubilis* and not any other specie. Botanical samples from each of the plants were collected and deposited in school herbarium of UNU in Pucallpa. Photo documentation of the collected samples is in the separate Appendix listed as B.

The descriptor was divided into two parts. The first part contained the quantitative characteristics due to the classification of Bioversity International (2007) such as tree height and basal diameter, the second part was concerned on the qualitative characteristics (e.g. colour of pods, shape of seeds, etc.) as indicated by Bioversity International (2007).

Table 14: Evaluated quantitative characteristics of sacha inchi

Metric data	Comments
height of plant (m)	measured by handy altimeter
basal diameter (cm)	measured in 10 cm above soil surface
branching height (m)	first branch from the ground
length of petiole (cm)	
blade length (cm)	
blade width (cm)	
leaf length (petiole + blade) (cm)	
inflorescence length (cm)	
length of stylar column (cm)	
number of seeds per capsule	in case of e.g. 4 and 5-lobbed on the same plant both to be mentioned
width of capsule (cm)	measured diagonally (crossways)
diameter of seeds (cm)	
weight of 10 seeds (g)	

Table 15: Evaluated qualitative characteristics of sacha inchi

Descriptive data	Comments
shape of crown	upright/broad/flat
shape of stem	cylindrical/irregular
colour of stem	green/brown
structure of stem	smooth/moderately rough/very rough
shape of leaf	triangular/ovate
shape of leaf margins	straight/undulating
presence of leaf hair	yes/no
colour of leaf	bright green/green/dark green
pointed top of leaf	long tip/short tip
colour of inflorescence	white/yellowish
single glandular knob at petiole apex	yes/no
presence of smell	yes/no
shape of capsule	star shape/irregular
colour of capsule	bright green/dark green
shape of seeds	oval : elliptical / irregular
colour of seeds	brown with dark brown markings / brown with violet markings / violet with brown markings

The particular measured and evaluated items are listed above in table 14 and 15 with appropriate comments. All measurements were taken ten times and from this value file an arithmetic mean was calculated to obtain the most probable value of the measurement and to reduce a measurement error.

Furthermore development and growth of each marked plant from June 2008 until December 2009 was observed to estimate particular time of growth and development of sacha inchi during the year in this region in comparison to area of its origin in higher altitude (department of San Martin) and the interaction of sacha inchi with different associated species as established by farmers for the data on cultivation potential.

Due to the farmers knowledge and financial possibilities the observed plants were placen in the plots with varying types of cultivation as shown in table 16.

Table 16 : Types of cultivation in evaluated plots

Location	Code	Type of cultivation
AR - Boca Negra	AR 1	mixed intercropping
AR - Linderson	AR 2	agroforestry
AR- Juber	AR 3	agroforestry
AR- German	AR 4	multiple cropping
3 de deciembre	DE 1	monoculture
PI - Luz	PI 1	monoculture
PI - Lirenza	PI 2	mixed intercropping
PI - Esau	PI 3	associated culture

Photodocumentation of all collected morphological data and specimens of plants was made to complete data gathering of this part.

5.3. Data collection – ethnobotany data

Different methods for obtaining various ethnobotany data and for confirmation of their reliability were used. Initially, in the period from May 2007 until October 2007 and from June 2008 until September 2008 data about general knowledge of plant, its local names and its uses were gathered. Structured interviews as recommended by Cunningham (2001) were used for this purpose and random sample of informants together with systematically chosen sample of respondents to ensure a representative cross-section of the community was chosen. All of the informants were from both, mestizo and indigenous villages in the surrounding of city of Pucallpa and from the city. To cross-check and verify these information discussion with informants were conducted. Thus all misunderstandings should have been eliminated.

In the period from June 2007 until October 2009 participatory rural appraisal (PRA) due to Chambers (1994) together with participatory assesment, monitoring and evaluating data - PAME method as indicated by Cunningam (2001) were used for obtaining data about the cultivation of plants, different designs of plots established by farmers and their general knowledge about the managing of plant cultivation of sacha inchi. Semi- structured open-ended interviews and discussions with farmers were conducted to cross check the obtained information.

All the questionnaries, interviews and communication with informants and farmers were conducted in the local language (Spanish) and the methodology used as suggested by Cunningham (2001) and Sthapit *et al.* (2000). We have also made photographic documentation and thus made the data collection for this part complete. For the ethnobotanical data collection see enquiries in Appendix C, for voucher specimens Appendix D.

In May 2008 one visit to the city of Tarapoto and various institutions focused in research and processinng of sacha inchi was realized in accordance with Cunningham (2001) to gather some unpublished working papers, local information about the plant cultivation and made some fotodocumentation as this is one of the areas the plants originaly comes from and where people have more experience with sacha inchi and managing its cultivation.

5.4. Statistical analysis

The statistical analysis of the qualitative and quantitative morphological characteristics will be performed by Basic Statistics within the software Statistica 7.0 CZ. The variability among plants in the tested population will be represented by the PCA (Principal Component Analysis) graphs (software Statistica 7.0 CZ).

6. Results

6.1. Evaluation of morphological features

6.1.1 Essential evaluation of quantitave characters

Thirteen morphological characteristics clasified as quantitative traits due to ”Developing crop descriptor list” guidelines from Bioversity International (2007) collected and recorded for each of the marked plant in all observed plots were evaluated by the basic statistical analysis and are presented in table 17. The mean values with standard error (SE), range (identifying sample minimum and sample maximum) and the coefficient of variation (CV) are listed there. These characters were processed for the whole set of all plots and marked individuals within the plots.

The first measured parameter was the height of plant reaching in mean 2.45 m (SE±0.11). The lowest plant sample was observed in location of Pimental at plot PI 1with 1.47 m and the highest plant sample occured at location of Antonio Raimondi at plot AR 2 with 3.50 m of height. There has been a coefficient of variation for all the samples 23%.
Another trait taken into account was basal diameter ranging from 1.00 to 2.20 cm with average value of 1.47 (SE ± 0.07). The smallest diameter (1.00) was measured at Antonio Raimondis location plot AR 1 and at Pimentals first location PI 1. The largest diameter (2.20) was obtained at Antonio Raimondi plot AR 4 thus a great coefficient of variation (24%) was recorded.

Another parameter with a great variation of 22% was branching height of plant. The mean of this characteristic was 11.20 cm (SE ± 0.46). Minimum value of this parameter (6.70 cm) occured at Antonio Raimondis plot AR 3 while maximum (17.00 cm) was observed at second measured field of Pimental PI 2.

Significant coefficients of variation were noted for all leaf parameters. Length of petiole with mean value of 4.88 cm (SE ± 0.22), minimum of 2.70 cm at first plot in 3 de deciembre DE 1 and maximum of 7.30 cm at AR 3 plot in location of Antonio Raimondi had variation of 24%. Coefficient of variation for blade length was 15%. Mean value of this parameter was 12.38 cm (SE ±0.35) while shortest one (8.90 cm) was observed at DE 1 plot at 3 de deciembre and the longest blade (15.80 cm) was at the third plot at Antonio Raimondi AR 3. Mean blade width was 7.65 cm with ranging values from 5.40 cm at first plot in 3 de deciembre DE 1 to 10.20 cm at second plot in Pimental PI 2 with variation of

18%. Parameters of whole leaf length (petiole + blade) had varition of 21% with mean value of 17.55 cm (SE ± 0.69). The shortest leaves of 11.80 cm occured at plot of 3 de deciembre DE 1 while the longest leaves of 30.30 cm were observed at location of Antonio Raimondi plot AR 3.

Greater coefficient of variation (24%) for inflorescence length was observed. The mean of this characteristic was 10.09 cm (SE ±0.46). The lowest measured value was 6.20 cm at Antonio Raimondis forth plot AR 4 while the highest measured value of 14.90 cm was obtained at third plot in Antonio Raimondi AR 3.

Length of stylar column varied between 1.30 cm and 2.56 cm with the mean of 1.74 cm (SE±0.07). The shortest columns (1.30 cm) were measured at location of Antonio Raimondi plot AR 1 and plot AR 4, while the longest one (2.56 cm) at another plot of Antonio Raimondi location AR 3.

The mean of seeds per capsule was 4.45 (SE ± 0.07) and coefficient of variation was 8%. The regular occurance of 4 seeds on one plant and any capsule with more seeds occured was recorded at locations of Antonio Raimondi plot AR 1, AR 2 and AR 4, plot DE 1 and PI 1. More frequent occurence of capsule with more than 4 seeds and with 6 seeds in capsule on the plant was found at location of Antonio Raimondi plot AR 3 and Pimental plot PI 2.

Another trait taken into account was diameter of capsule with mean of 4.04 cm (SE ± 0.08) and coefficient of variation of 11%. The lowest observed value was 3.30 cm at first plot in Antonio Raimondi AR 1 and the highest one 4.60 cm at 3 de deciembre plot DE 1.

The mean value for diameter of seeds was 1.71 cm (SE ± 0.05) ranging from 1.20 cm at plot PI1 in Pimental to 2.12 cm at third plot in Antonio Raimondi AR 3 and second plot in Pimental PI 2. Coefficient of variation for this characteristic was 16%.

The mean weight of 10 seeds was 45.91 g (SE ± 0.67) with variation of 8%. The smallest value of this parameter was 38.20 g in first plot at Pimental PI 1. The heaviest seed samples were recorded in Antonio Ramondis third plot AR 3 and Pimentals second plot PI 2.

To sum up, statistical significant differencies exceeding the coefficient of variation 15% were recorded for more than half of observed traits mostly connected with the visible growth and development of the plant (height of plant, basal diameter, branching diameter, length of petiole, blade length, leaf length, inflorescence length and length of stylar column). Lower but still significant coefficients of variation (8-11%) were recorded for the traits connected with seeds (number of seeds per capsule, diameter of capsule, diameter of seeds, weight of 10 seeds).

Table 17: Statistic evaluation of quantitave characteristics

	Mean±SE	**Range**	**CV (%)**
Height of a plant (m)	2.45±0.11	1.47-3.50	23
Basal diameter (cm)	1.47±0.07	1.00-2.20	24
Branching height (m)	11.20±0.46	6.70-17.00	22
Length of petiole (cm)	4.88±0.22	2.70-7.30	24
Blade length (cm)	12.38±0.35	8.90-15.80	15
Blade width (cm)	7.65±0.35	5.40-10.20	18
Leaf length (petiole + blade) (cm)	17.55±0.69	11.80-30.30	21
Inflorescence length (cm)	10.09±0.46	6.20-14.90	24
Length of stylar column (cm)	1.74±0.07	1.30-2.56	21
Number of seeds per capsule	4.45±0.07	4.00-5.30	8
Diameter of capsule (cm)	4.04±0.08	3.30-4.60	11
Diameter of seeds (cm)	1.71±0.05	1.20-2.12	16
Weight of 10 seeds (g)	45.91±0.67	38.20-51.30	8

SE Standard Error

CV Coeficient of variation

Mean values with standard deviations (SD) for the average values of each plot for every observed quantitative characteristic as mentioned above are shown in table 18.

The mean values for the whole collection (mean of tested collection) for particular parameters were identified. The average value of plant height was 2.44 m in average representing small dispersal of values. The mean value for basal diameter was 1.47 cm showing the small oscillation of values. Branching height with mean value of 11.20 indicated significant dispersal of values. Length of petiole with mean value of 4.88 cm showed significant sparsity of values. Mean value of blade length in tested collection reached 12.38 cm in average indicating considarable dispersal of values. The mean value of blade width was 7.65 cm with significant sparsity of values. Leaf length with mean value 17.55 cm showed wide range of values. The mean value of inflorescence length was 10.09 cm indicating great dispersal of values. Length of stylar column was 1.74 in avarage representing small oscillation of values. The mean value of number of seeds per capsule reached 4.45.and tested samples of collection showed stability in this trait. Diameter of capsule was 4.04 cm, diameter of seeds was 1.71 cm and the mean value of weight of 10 seeds was 45.91 g for this collection. All these traits showed low variation .

The mean values in location of Antonio Raimondi at plot AR 1 were the most significant for the traits of blade width (8.88 cm) reaching the highest value from all recorded plots and for the basal diameter (1,10), the length of stylar column (1.41 cm), number of seeds per capsule (4.25) and diameter of capsule (3.41 cm) representing the lowest values from all recorded plots. Height of plant (2.07 m), branching height (11.25 cm), length of petiole (5.22 cm), blade length (12.14 cm), leaf length (17.36 cm), inflorescence length (9.77 cm) and weigth of 10 seeds reached average values in comparison with other recorded plots. The mean value for diameter of seeds (1.46 cm) reached rather smaller values within the set of recorded plots.

The mean values in location of Antonio Raimondi at plot AR 2 were most significant for diameter of capsule (4.56 cm) indicating the highest value among all recorded plots. The mean value of basal diameter (1.88 cm), blade length (13.20 cm) and inflorescence length (11.80 cm) showed rather higher values among other recorded plots whereas the mean value of branching height (10.30 cm) indicated lower values within the examined plots. Height of plant (2.98 m), length of petiole (4.38 cm), blade length (13.20 cm), blade width (7.63 cm), leaf length (17.78 cm),length of stylar column (1.87 cm), number of seeds per capsule (4.50), diameter of seeds (1.70 cm) and weight of 10 seeds (46.73 g) showed average values in comparison with other recorded plots.

The most significant mean values in location of Antonio Raimondi at plot AR 3 were recorded for traits of length of petiole (6.78 cm), blade length (14.43 cm), leaf length (23.45 cm) and number of seeds per capsule (4.83) reaching the highest measured values from all examined plots. Another great mean value was recorded for branching height (9.75 cm) representing the lowest measured value from all the plots. Basal diameter (1.50 cm), length of stylar column (1.84 cm) and diameter of seeds (1.95 cm) showed avarege values in comparison with other recorded plots. Significantly higher values among the observed plots were recorded for blade width (8.05 cm), inflorescence length (11.63 cm), diameter of capsule (4.31 cm) and weight of 10 seeds (48.45 g). Considerably lower values among the examined plots were identified for height of plant (2.24 m).

The mean values in location of Antonio Raimondi at plot AR 4 were most significant for height of plant (3.24 cm) and basal diameter (1.95 cm) reaching the highest value among all recorded plots. The lowest value among the observed plots were measured for blade width (6.23 cm), inflorescence length (7.73 cm) and number of seeds per capsule (4.25). Considerably higher values among all examined plots were observed for length of petiole (5.30 cm). The lower values in comparison with other plots were recorded for blade length (11.03 cm) and length of stylar column (1.46 cm). Branching height (11.33 cm), leaf length (16.33 cm), diameter of capsule (3.98 cm), diameter of seeds (1.64 cm) and weight of 10 seeds (44.70 g) were of average values in comparison with other plots.

The most significant mean values in location of 3 de deciembre at plot DE 1 were noted for length of petiole (3.48 cm), blade length (10.18 cm), leaf length (13.65 cm) and number of seeds per capsule (4.25) reaching the lowest values from all measured plots. Height of plant (2.57 m), branching height (10.75 cm), length of stylar column (1.72 cm), diameter of capsule (4.13 cm), diameter of seeds (1.74 cm) and weight of 10 seeds (46.20 g) represented average values among the recorded plots. Considerably lower values of observed plots were identified for traits of basal diameter (1.28 cm), blade width (6.43 cm) and inflorescence length (7.80 cm).

The mean values in location of Pimental at plot PI 1 were most significant for inflorescence length (12.70 cm) and length of stylar column (2.26 cm) reaching the highest value among all recorded plots. The lowest values among the observed plots were identified for traits of height of plant (1.88 m), number of seeds per capsule (4.25), diameter of seeds (1.43 cm) and weight of 10 seeds (41.50 g). Branching height (11.68 cm) and leaf length (17.45 cm) represented average values among the observed plots. Significantly higher values of observed plots were noted for blade length (13.26 cm) and blade width (8.50 cm) whereas the lower values were recorded for basal diameter (1.15 cm), length of petiole (4.18 cm) and diameter of capsule (3.58 cm).

The most significant mean values in location of Pimental PI 2 were identified for branching height (13.33 cm), number of seeds per capsule (4.83), diameter of seeds (2.05 cm) and weight of 10 seeds (49.28 g) reaching the highest values of all measured plots. Basal diameter (1.45 cm), blade length (12.45 cm), blade width (7.85 cm), leaf length (16.85 cm) and inflorescence length (9.20 cm) showed average values of all measured plots. Considerably higher values among the examined plots were recorded for diameter of capsule (4.31 cm) whereas lower values for height of plant (2.156 m), length of petiole (4.40 cm) and length of stylar column (1.66 cm).

Table 18: Statistic evaluation of the average values of each recorded plot

Mean±Standard deviation	Height of a plant (m) Mean	Basal diameter (cm) Mean	Branching height (cm) Mean	Length of petiole (cm) Mean	Blade length (cm) Mean	Blade width (cm) Mean	Leaf length (petiole + blade) (cm) Mean
mean of tested collection	2.44±0.56	1.47±0.35	11.20±2.45	4.88±1.17	12.38±1.84	7.65±1.37	17.55±3.63
AR1	2.07±0.33[a]	1.10±0.08a	11.25±1.50a	5.22±0.97ac	12.14±1.07ab	8.88±0.46a	17.36±2.01ab
AR2	2.98±0.48bc	1.88±0.21bc	10.30±2.15a	4.83±1.08ab	13.20±1.64ab	7.63±1.49a	17.78±2.91ab
AR3	2.24±0.39ab	1.50±0.14ab	9.75±2.32a	6.78±0.41c	14.43±1.04b	8.05±0.81a	23.45±4.77b
AR4	3.24±0.17c	1.95±0.26c	11.33±3.13a	5.30±0.69ac	11.03±1.28a	6.23±0.71a	16.33±1.48a
DE1	2.57±0.36abc	1.28±0.05a	10.75±2.34a	3.48±0.61b	10.18±1.61a	6.43±1.00a	13.65±2.15a
PI1	1.88±0.35a	1.15±0.13a	11.68±2.22a	4.18±0.39ab	13.26±0.81ab	8.50±0.84a	17.45±0.97ab
PI2	2.156±0.21ab	1.45±0.26a	13.33±3.31a	4.40±0.60ab	12.45±2.01ab	7.85±1.88a	16.85±2.44a

Table 18: Continued

Mean±Standard deviation	Inflorescence length (cm) Mean	Length of stylar column (cm) Mean	Number of seeds per capsule Mean	Diameter of capsule (cm) Mean	Diameter of seeds (cm) Mean	Weight of 10 seeds (g) Mean
mean of tested collection	10.09±2.42	1.74±0.36ab	4.45±0.39a	4.04±0.43	1.71±0.28ab	45.91±3.53ab
AR1	9.77±1.26abc	1.41±0.09a	4.25±0.29a	3.41±0.14c	1.46±0.06a	44.55±0.79ab
AR2	11.80±2.52bc	1.87±0.41ab	4.50±0.41a	4.56±0.03b	1.70±0.14ab	46.73±1.73ab
AR3	11.63±2.66abc	1.84±0.51ab	4.83±0.39a	4.31±0.13ab	1.95±0.21b	48.45±3.69ab
AR4	7.73±1.26a	1.46±0.14a	4.25±0.29a	3.98±0.27ad	1.64±0.20ab	44.70±2.90ab
DE1	7.80±1.00ab	1.72±0.13ab	4.25±0.29a	4.13±0.36ab	1.74±0.36ab	46.20±4.94ab
PI1	12.70±0.56c	2.26±0.13b	4.25±0.29a	3.58±0.17cd	1.43±0.15a	41.50±2.22a
PI2	9.20±1.70abc	1.66±0.13ab	4.83±0.39a	4.31±0.16ab	2.05±0.07b	49.28±1.52b

To sum up, each of the observed plots recorded at least one of the traits arriving to the highest or lowest values in comparison to other plots. Two of the plots (AR 2 and PI 2) reached only the highest values of some traits nevertheless in both of the plots some lower values for different traits were observed. One of the plot (DE 1) showed only lowest value from the examined plots but as in the cases above the range of parameters was balanced and some higher values for different traits were measured.

6.1.2 Essential evaluation of qualitative characters

There were assesed sixteen more characteristics clasified as qualitative morphological characteristics due to Developing crop descriptor list (Bioversity International, 2007). These characteristics could not be evaluated by the basic statistics due to the form of outcome and were evaluated subjectively following a botanical order and the most immediate visible characteristic: shape of crown and stem, colour of stem, structure of stem, shape of leaf and leaf margins, presence of leaf hair, colour of leaf, pointed top of leaf, colour of inflorescence, single glandular knob at petiole apex, presence of smell, shape of capsule, colour of capsule, shape of seeds and colour of seeds. The results from the evaluation were summarized in the table 19 below.

Table 19: Rate of particular qualitative characters of evaluated plants

Morphological character	Expression	Rate(%)
Shape of crown	upright : broad : flat	64:32:4
Shape of stem	cylindrical : irregular	100:0
Colour of stem	green : brown	100:0
Structure of stem	smooth :moderately rough : very rough	93:7:0
Shape of leaf	triangular : ovate	68:32
Shape of leaf margins	straight : undulating	0:100
Presence of leaf hair	yes : no	0:100
Colour of leaf	bright green : green : dark green	25:57:18
Pointed top of leaf	long tip : short tip	50:50
Colour of inflorescence	white : yellowish	93:7
Single glandular knob at petiole apex	yes : no	100:0
Presence of smell	yes : no	0:100
Shape of capsule	star shape : irregular	82:18
Colour of capsule	bright green : dark green	86:14
Shape of seeds	oval : elliptical : irregular	57:43:0
Colour of seeds	brown with dark brown markings : brown with violet markings : violet with brown markings	64:25:11

Five of the selected traits were recorded with an intention to confirm the origin of plant and exclude other species of Plukenetia. All of these traits - shape of stem, shape of leaf margins, presence of leaf hair, single glandular knob at petiole apex and presence of smell - confirmed that all observed plants were *Plukenetia volubilis* species and not any other.

Six of the traits showed significant variation, two traits exhibited only small range, another two characteristics showed low variation and one trait exhibited any variation despite of being described in literature as one of the varying features.

In tested samples were identified the following leaf colours, colour of seeds and shape of crown where three different variations were observed. The colour of leaf was bright green (25%), green (57%) and dark green (18%). The colour of seeds was brown with dark brown markings (64%), brown with violet markings (25%) and violet with brown markings (11%). The shape of crown was upright (64%), broad (32%) and flat (4%). Two traits of the shape of seeds with high variation - oval (57%), elliptical (43%), irregular (0%) - were observed in our trial. Another two characteristcs with high variation of two different traits were observed. Pointed top of leaf was observed as a long tip (50%) and short tip (50%). Leaf shape was triangular (68%) and ovate (32%).

Small range of variation was identified in the shape of capsule and colour of capsule where two different traits were observed. Shape of capsule was star shape (82%) and irregular (18%). Colour of capsule was bright green (86%) and dark green (14%). Only low variation was found in colour of inflorescence with two different traits of white (93%) and yellowish (7%) and in structure of stem which was smooth (93%) and moderately rough (7%). According to literature very rough structure of stem may also be observed but this was not the case. Colour of stem was green (100%) and brown (0%) thus showed any variation despite of being described in literature as one of the varying features.

The greatest variation of the most variable characteristics was observed between both - particular locations of plots and single evaluated plants within it. Especially the plots of all AR locations showed these variations. The plants from the other locations of Pimental (PI 1, PI 2) and 3 de deciembre (DE 1) showed only small range or low range of variation among the single evaluated plants within the plot and some more significant variation among the locations.

6.1.3 Score evaluation of morphological characters

Collected data for both quantitative and qualitative characteristics were used to create the score plot by using PCA analysis (Fig.6) where the variability among tested samples was reflected. The first two axes together accounted for 58% of the total morphological and phenological variability.

According to the score plot several interesting facts were obvious. Only one plot showed the large uniformity and formed close cluster, two other plots showed lower rate of variation and formed more close clusters, whereas the others plots were more spread but very often following certain level of factor 1 or factor 2 crossing the both quadrants.

The plot with the lowest rate of variation and high rate of similarity among particular plants was the plot PI 1 from the location of Pimental. Another two plots with a lower rate of variation and higher rate of similarity were plots AR 1 and AR 4 from different locations of Antonio Raimondi. Plants from the AR 1 plot were localized in the same quadrant as the samples of PI 1 close to the axe of factor 2 whereas the samples of AR 4 are crossing the both minus and plus quadrants alongside the axe of factor 2.

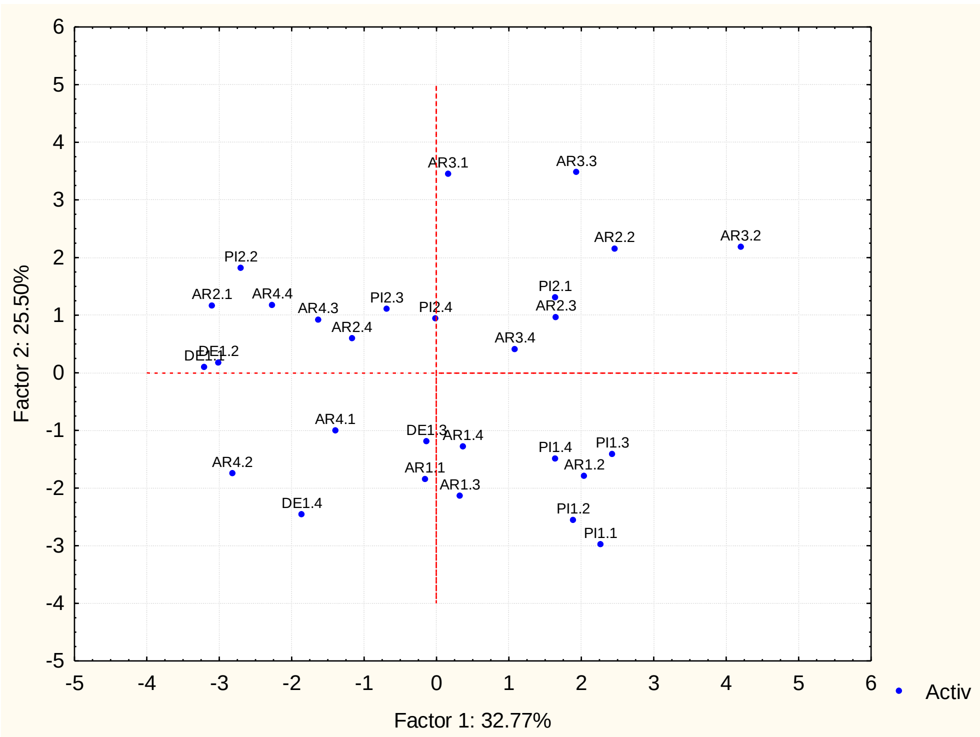

Figure 6: Score plot of particular recorded plant samples

Wider expansion and higher variation of single evaluated plants was present on the plot AR 3 of Antonio Raimondi where all the plants were localized within one sector and largest cluster in the graph was created.

The other situation was observed in the case of DE 1 plot from 3 de deciembre where two of the samples showed almost any variation and were localized on the similar spot while the other individuals were in bigger distance and thus possessed greater variation reaching wide expansion within the both sectors behind the axe of factor 2. The widest expansion and high variation was present among the samples from plot AR2 of Antonio Raimondi and PI 2 of Pimental. Nevertheless all plants are spread on the same level alongside the axe of factor 1 crossing from one sector to another.

6.2. Ethnobotany data

6.2.1 Local names and accounted diversity

Sixty different respondents were asked whether they can identify the plant which was shown them on the picture (*Plukenetia volubilis* L.) and in case they are able to do so under what name. All of the respondents were familiar with this plant and knew about its existence under the local name of sacha inchi. 82% of all the respondents knew the plant under another name - inca inchi and 63% of the respondents also identified the plant as maní del monte.

Table 20: Local names for *Plukenetia volubilis* L.in the vicinity of Pucallpa

Local name	Men (n)	Men (%)	Women (n)	Women (%)	Total (n)	Total (%)
Sacha inchi	38	63	22	37	60	100
Inca inchi	27	45	22	37	49	82
Maní del monte	17	29	21	35	38	63
Sacha yuchiqui	-	-	3	5	3	5
Inchi capi	2	3	-	-	2	3

Only 5%, all of them women, mentioned the title sacha yuchiqui among the other local names. 3% of respondents presented the plant as inchi capi when looking for the synonym title. Distribution of answers among the men women and particular titles is summarized in table 20.

The amount of approached respondents, representation of men and women among them and the rate in % is described in table 21. The quantity of enquired men within the group of respondents was slightly higher (63%) than the one of women (37%).

Table21: Number and representation of the respondents in the vicinity of Pucallpa

Representation of respondents		Systematically chosen repondents	Random sample of respondents	Total representation of repondents (n)	Total representation of respondents (%)
Men	n	10	28	38	-
	%	71	61	-	63
Women	n	4	18	22	-
	%	29	39	-	37
Total	n	14	46	60	-

Systematically chosen respondents were complemented with randomly selected ones. As indicated in table 22 men and women from both rural and town areas have been included. Balance between women and men respondents from the areas was kept and it prooved to be essential for the gained results. Nineteen men from rural population together with nine women from the same area made a total number of twenty-eight respondents while thirty-two respondents - nineteen men and thirteen women - were from the town population.

Table 22: Respondents' area of origin

Area of origin	Men (n)	Women (n)	Total (n)
Rural population	19	9	28
Town population	19	13	32

Only systematically chosen respondents (as described above) with 6 other respondents all being farmers and familiar with the growth and appearence of the plant were approched in order to identify some differences in local nomenclature according the visible differences in the appearence of plant. Four of the visible characteristics were explicitly mentioned and space for their own identification of some other noticable aspects was left. All the answers were indentical as recorded in table 23 for all the questions.

Each of the farmer noticed the differences of leaf colour, varying shapes of leaves, various number of seeds per capsule and seed colour among the single plants of sacha inchi nevertheless none of them indicated any specific meaning or properties of such a plant. No matter how disimilar the particular plants were all the respondents claimed to call them sacha inchi or by some of the synonyms as mentioned above but not by any other title.

Table 23: Identified diversity of plant according the appearence of plant

Visible disimilarity	Observing differences	Meaning for respondents*	Specific local nomenclature according to the observed differences
Leaf colours	yes	none	sacha inchi
Varying shapes of leaves	yes	none	sacha inchi
Various numbers of seeds per capsule	yes	none	sacha inchi
Seed colours	yes	none	sacha inchi
Other	none	none	sacha inchi

Note:* 14 systematically chosen respondents and 6 other respondents - farmers were approached with these questions

6.2.2 Acknowledged uses and products

When collecting the data about the acknowledged use of particular parts of the plant all of the respondents were approached. As indicated in table 24 thirty-seven informants were farmers as they were supposed to be the most relevant target group and source of information for this research. The vendors from local markets were also approached intentionally and ten of them took part in this enquiry complementing the sample of respondents by thirteen persons from other professions.

In order to make the identification of acknowledged use of sacha inchi easier for respondents explicit questions for the use of sacha inchi as a whole and particular parts were put. The list of acknowledged uses in the vicinity of Pucallpa is provided in table 25.

Table 24: Occupation of respondents

Occupation	Men (n)	Women (n)	Total
Farmer	23	14	37
Vendor on local market	4	6	10
Other	11	2	13

Among the most recognized uses and/or products from sacha inchi in the area were those connected with the seeds. Edible oil extracted from the seeds used for human consumption together with the oil for pharmaceutical and cosmetic industry was one of the most frequently acknowledged. Use of the seeds as a cooking ingredient, flour from the seeds for cooking and direct consumption of crude or fried peanuts of sacha inchi were widely identified.

Table 25: Acknowledged uses of sacha inchi in the vicinity of Pucallpa

Part of the plant	Use and products	Number of respondents (n)	Ratio men:women (n)	Number of respondents (%)
Entire plant	erosion control	23	13:10	38
	fodder	1	0:1	2
	composting	16	10:6	27
Leaves	fodder	4	3:1	7
	composting	7	5:2	12
Flowers and inflorescence	decoration	15	0:15	25
Capsules and peels	ornamental	8	4:4	13
	firing	28	16:12	47
	cover against erosion and weeds	17	9:8	28
	composting	14	8:6	23
Seeds	cooking ingredient	57	35:22	95
	fried seeds consumed as peanuts	43	29:14	72
	direct consumption	54	36:18	90
	edible oil	60	38:22	100
	industrial oil	37	30:17	62
	biofuel oil	4	3:1	7
	pharmaceutical oil	60	38:22	100
	cosmetic oil	58	37:21	97
	flour for food	48	28:20	80

Only about 25% of respondents or less had mentioned some uses generated of other parts of the plant with exception of use of the dried peels for firing which was mentioned by 50% of informants mostly from the rural areas. Ornamental use of capsules and peels together with the use of leaves and the entire plant as a fodder was proven only by 7% of informants. Ornamental and decorative use of capsules and flowers was recorded both in the town and rural areas for the most parts from women. In contrast use of the dried peels as a firing in household was declared only in rural areas by both men and women. These findings may point out at different perceiving and needs in town and rural areas.

Interesting responses were received about the use or function of the whole plant against erosion and for composting which was declared by 38% of respondents for the erosion control and 27% for composting all of them from farmers.

The most recent information about the possible use of sacha inchi oil as for biofuel was claimed by 7%.

To sum up, three synonym titles are frequently used to name *Plukenetia volubilis* L. plant in the vicinity of Pucallpa. Sacha inchi, inca inchi and maní del monte. Despite the visible differences on the individual plants such as disimilar colour of leaves, seeds or varying number of seeds per capsule any specific properties nor meaning is accounted to such a plants due to the respondents. Neither any more particular local name is given to the diverse plants.

Among the possible uses of plant and its parts the use of the seeds and extracted oil from it are the most acknowledged ones. The seeds are well known as for direct consumption or in the extracted form of edible oil for various purposes. More multi-role uses are declared in the rural areas where the dried peels are used as a firing, any of plant remains are used for composting and the whole plant is used for erosion and weed control when implemented into the common agricultural cultivation.

6.3. Cultivation potential

6.3.1 Observed types of cultivation and associated species

Different types of cultivation (using the stakes and without them) and various association in the cultivation observed among the evaluated plots in Ucayali region are shown in table 26. Both types of installment of sacha inchi on the stakes and without any were recorded.

Table 26: Types of cultivation and associations on different evaluated plots

No. of plot	Stake (yes/no)	Type of stake	Other associated plants	Type of cultivation
AR1	yes	artficial	Ají charapita, Hierba luisa, Limón, Naranja, Noni, Piňa, Yuca	mixed intercropping
AR2	yes	artificial and trees (Pashaco,	Ají charapita, Noni, Papaya, Pashaco, Piňa,	agroforestry

Table 26: Types of cultivation and associations on different evaluated plots

No. of plot	Stake (yes/no)	Type of stake	Other associated plants	Type of cultivation
		Tahuarí)	Plátano, Tahuarí,	
AR3	yes	artificial and leguminous tree (Mata ratón)	Papaya, Piňa,	agroforestry
AR4	yes	artificial	Ají charapita, Caňa de azúcar,	multiple cropping
DE1	yes	artificial	-	monoculture
PI1	no	-	-	monoculture
PI2	yes	artificial	Ají charapita, Naranja, Papaya, Piňa, Sangre de grado, Tomatos Yuca	mixed intercropping
PI3	yes	leguminous tree (Guaba)	-	associated culture

When using the stakes various trees were brought to bear the plant same as the artificial stakes were implied. Four different tree species were used as a pillar for sacha inchi. Scientific name, family and type of tree are indicated in table 27 together with scientific names, families and plant characteristics of the other plant associates from the evaluated plots.

Representation of other observed species in associations was composed from 15 species of 11 different families. Annual crops, vegetables, fruit and wood trees were included among these species.

Apart from plots DE1 and PI1 which were monocultures different types of agroforestry systems (as described in literature review chapter *1.2.2. table 5)* were identified.

Table 27: Observed plant associates in sacha inchi cultivation in the location of Pucallpa, Ucayali region

Local name	Scientific name	Family	Type of plant
Ají charapita	*Capsicum* sp.	*Solanaceae*	annual fruit
Caňa de azúcar	*Saccharum officinarum* L.	*Poaceae*	perennial crop
Guaba	*Inga edulis* Mart.	*Fabaceae*	leguminous fruit tree
Hierba luisa	*Cymbopogon citratus* (DC.) Stapf	*Poaceae*	perennial ornamental, aromatic and medicinal plant
Limón	*Citrus aurantifolia* (Christm.) Swingle	*Rutaceae*	fruit tree
Mandarina			fruit tree and aromatic plant
Mata ratón	*Gliricidia sepium* Kunth ex Steud.	*Fabaceae*	leguminous tree
Naranja	*Citrus sinensis (L.)* Osbeck	*Rutaceae*	fruit tree

Table 27: Observed plant associates in sacha inchi cultivation in the location of Pucallpa, Ucayali region

Local name	Scientific name	Family	Type of plant
Noni	*Morinda citrifolia* L.	*Rubiaceae*	medicinal plant (tree)
Papaya	*Carica papaya* L.	*Caricaceae*	fruit tree
Pashaco	*Schizolobium amazonicum* Huber ex Ducke	*Caesalpiniaceae*	fastgrowing hardwood tree
Piňa	*Ananas comosus* (L.) Merr.	*Bromeliaceae*	fruit
Plátano	Musa spp.	*Musaceae*	fruit tree
Sangre de grado	*Croton lechleri* Mueller Arg	*Euphorbiaceae*	medicinal plant (tree)
Tahuarí	*Tabebuia serratifolia* (Vahl) G. Nicholson	*Bignoniaceae*	hardwood tree
Tomato	*Lycopersicon esculentum* Mill.	*Solanaceae*	annual vegetable
Yuca	*Manihot esculenta* Crantz	*Euphorbiaceae*	annual crop

In the location of Tarapoto in San Martin region 8 different species from 7 different families were examined to be used in associations with sacha inchi. The list of species with scientific name, family and type of plant is shown in table 28. All listed species except the corn (maíz) were used as a pillar for sacha inchi. Two of the recorded species (mata-ratón and tahuarí) were also implemented in vicinity of Pucallpa.

Table 28: Plant associates in sacha inchi cultivation in the location of Tarapoto, San Martin region

Local name	Scientific name	Family	Type of plant
Amasisa	*Erythrina poeppigiana* (Walp.) O.F. Cook	*Fabaceae*	leguminous tree
Bolaina blanca	*Guazuma crinita* Mart.	*Sterculiaceae*	fast-growing timber tree
Cedro rojo	*Cedrela* sp.	*Meliaceae*	timber tree
Maíz	*Zea mays* ssp. *mays*	*Poaceae*	annual crop
Maraňón	*Anacardium occidentale* L.	*Anacardiaceae*	medium-sized tree
Mata-ratón	*Gliricidia sepium* Kunth ex Steud.	*Fabaceae*	small to medium-sized leguminous tree
Tahuarí	*Tabebuia serratifolia* (Vahl) G. Nicholson	*Bignoniaceae*	timber tree
Teca	*Tectona* sp.	*Verbenaceae*	hardwood tree

All together 23 different species from 11 different families were examined or implemented in both regions. Depending on the type of associated plant, family and the way of implementing it into the cultivation positive or negative aspects of sacha inchi may be underlined.

6.3.2 Implications of sacha inchi cultivation in agroforestry systems

Summarized strenghts, weaknesses/limitations, opportuinites and potential of cultivation of sacha inchi are listed in table 29.

When implementing sacha inchi into the agroforestry systems all of these factors need to be considered looking to the internal and external factors influencing growth, development of the plant, synergies and antagonstics with different species and another functions of the plant and its parts resulting into the positive or negative / useful and harmful effects.

Table 29: General strenghts, weaknesses/limitations, opportunites and potential of cultivation of sacha inchi

	Positive	Negative
	Strengths	Weaknesses / Limitations
Internal factors	• multi - role use of plant and its parts, • suitable associate for other crop species • any specific nor demanding requirements for soil and climate conditions • continuos all-year seed production • any toxicity nor agressivity ever recorded • absence of severe competitive effects with crops, particularly for water; • low invasiveness; • productive functions, or service functions other than soil improvement. absence of toxic substances in the litter or root residues; • high rate of production of leafy biomass	• decreased growth when in shadow • ability to suppress growth by binding the weaker trees when used as stakes
	Opportunities	Threats
External factors	• increased growth and yields in biodiverse systems and on fertile soils, • control of soil against erosion, • weed control • multi-role use of the plant and its parts • economic value ot the seeds • suitable specie into plant associated systems of production • significant long-term financial income even in associated cultures • lower costs for establishing the cultivation by implementation into the associated cultures	• pests and diseases (*Nematodas*) • more permanent -continous floods • higher costs for establishing the cultivation • more demanding in terms of short-term/immediate financial income

Deriving from the SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis above various species were identified as a promissing tree associates used as pillars for sacha inchi cultivation. Certain conditions need to be respected in order to implement the plant into the system succesfully and use the trees as a stakes efficiently. Selected suitable tree species for sacha inchi cultivation in Ucayali region are listed in table 30.

Table 30: Promissing tree associates (used as pillars) for sacha inchi in Ucayali region

Local name	Type of plant	Conditions for succesfull implementation
Amasisa	leguminous tree	keep it truncate (lower height, without or minimum branches)
Bolaina blanca	fast-growing timber tree	bigger trees cca. 5 years old trees grown
Bolaina negra	fast-growing timber tree	5 years old trees
Cedro rojo	timber tree	grown
Mata-ratón	leguminous shrub	keep it truncate (minimum branches)
Teca	fast-growing timber tree	grown
Tahuarí	timber tree	grown

By contrast to these species several of observed species above were not elegible to be included in the agroforestry system in association with sacha inchi playing role of the pillar for the plant.

Table 31: Examples of suitable species as intercropping associated within sacha inchi cultivation

Type/Use/Characterization of plant	Local name of plants	Scientific name
Annual crops	Aroz, Yuca	*Oryza sativa* L. *Manihot esculenta* Crantz
Aromatic plants or herbs	Ají charapita Culantro del pais Hierba Luisa	*Capsicum* sp. *Coriandrum sativum* L. *Cymbopogon citratus* (DC.) Stapf
Fruit trees	Anona, Limón, Naranja, Marañón, Palta, Papaya, Plátanos	*Rollinia mucosa* (Jacq.) Baill. *Citrus aurantifolia* (Christm.) Swingle Citrus sinensis *(L.) Osbeck* *Anacardium occidentale* L. *Persea americana* Mill. *Carica papaya* L. *Musa* spp.
Leguminous plants or trees	Guaba Ishpingo	*Inga edulis* Mart. *Amburana cearensis* (Allemão) A.C. Sm.
Medicinal plants	Noni Sangre de Grado	*Morinda citrifolia* L. *Croton lechleri* Mueller Arg
Wood species	Caoba Cedro Pashaco	*Swietenia macrophylla* G. King *Cedrela odorata* L. *Schizolobium amazonicum*

	Tahuarí	Huber ex Ducke *Tabebuia serratifolia* (Vahl) G. Nicholson

Not elegible species are guaba (*Inga edulis*), maraňón (*Anacardium occidentale*) and plátano (*Musa* spp.)

Applicable crops and tree associates for prosperous biodiverse systems implementing sacha inchi are listed in table 31 according the character/use of plant.

6.3.3. Models of agroforestry plots implementing sacha inchi for the vicinity of Pucallpa

Various models of agroforestry plots implementing sacha inchi in certain association enhancing its cultivation potential are shown in Figures 7,8,9 and 10. Examples of the suitable species to be included in all of the models of agroforestry systems below are listed above in table 30 and 31. Nevertheless more species can be included depending on the actual situation and specific conditions of the location of established plot.

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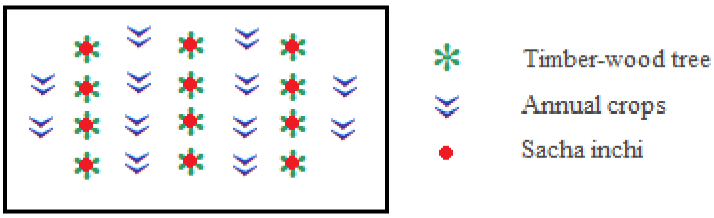

Figure 7: Model 1 - sacha inchi and timber-wood trees

Typical agroforestry system using the timber-wood trees as pillars for sacha inchi involving the annual crops and/or vegetables intercropped in the rows is described in Fig.7. As indicated in table 30 grown trees were more convenient to be used as pillars due to binding ability of sacha inchi.

Figure 8 introduced another type of agroforestry system using the leguminous trees as a pillar for sacha inchi including annual crops and/or herbs and vegetables intercropped in the rows. As indicated in the previous chapter it was recommended to keep the leguminous trees more truncate and exclude the use of guava tree.

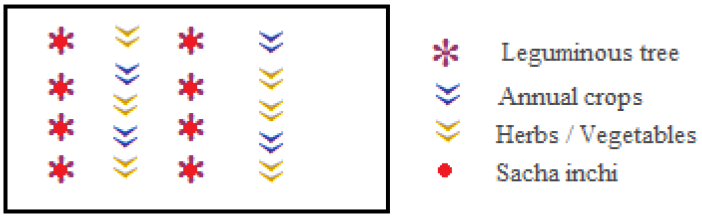

Figure 8: Model 2 - sacha inchi and leguminous trees

Artificial stakes were brought to bear sacha inchi in Fig. 9 complemented by the mixed cropping pattern of various fruit trees and annual crops. This model would be particularly suitable for establishing new agroforestry plot e.g. after slash and burn practice using remained firebrands as pillars.

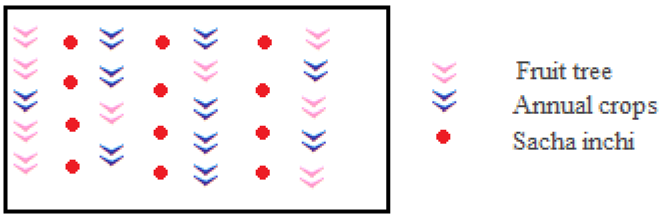

Figure 9: Model 3 - sacha inchi in mixed cropping system

Vastly biodiverse agroforestry plot was designed in Fig. 10 where the timber-wood trees were used as stakes for sacha inchi, intercropped with leguminous, medicinal and fruit trees involving annual crops, herbs and vegetables. This model assumed that selection and variety of species would be chosen by farmer himself, due to his options and preferences not necessarily including all of the mentioned types of plants nor trees.

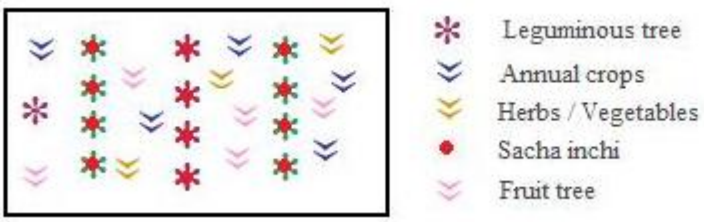

Figure 10: Model 4 - sacha inchi in vastly biodiverse agroforestry plot

7. Discussion

7.1. Morphologic variability

As mentioned by Webster (1975), Gillespie (1994) and Webster (1994) *Plukenetia* (genus of sacha inchi species) belongs to the tribe Plukenetieae of the uniovulate subfamily Acalyphoideae, which is with its 116 genera in 20 tribes the largest, most complex and least understood of the five euphorbiaceous subfamilies. As indicated by Arévalo (1996) confirmed by Manco (2005) and it proved in this study sacha inchi was not any exception and only few of its characteristics regarding the diversity were clarified.

According to Gillespie (1993) *Plukenetia volubilis* L. can be distinguished from other species of Plukenetia by the adaxial presence of single glandular knob at the petiole apex, length of stylar column varying between 15-30 mm long and the presence of 4 staminate sepals. We have thus confirmed the presence of all mentioned characteristics, any of them was in dispute thus we have ensured that all of the observed plants called sacha inchi were *Plukenetia volubilis* and not any other.

According to Arévalo (1996) noticeable visible dissimilarities of morphological characters among the individual plants could be observed. Considering the quantitative characteristics our results were in complete accordance with this statement when ten of thirteen observed features reached coefficient of variation exceeding 15% and seven of them exceeded 20%.

Due to Ward (2011) plant populations under different environmental selection pressures generally showed phenotypic differences. Such phenotypic differences could be the result of phenotypic plasticity and/or genetic diversification. This fact was taken into account nevertheless insufficient data helping to orientate in assesing the results were available.

Several interesting findings were found regarding the quantitative traits. As noted by (Brigs and Walters 1984) that the size and colour of seeds are genetically determined question whether the number of seeds per capsule were also genetically determined or partially influenced by extarnal factors. Individual plants within all the evaluated plots had 4-lobbed capsules together with 5 or more lobbed capsules on one plant when the highest measured mean values were recorded in the AR 3 plot with agroforestry system of cultivation. In the same type of cultivation also another characteristics (length of petiole , blade length and leaf length) reached the highest values and same situation for other traits happened in all others evaluated plots. Nevertheless as Vicha (2008) mentioned more particular longterm meteorogical data for particular locations were not available. Conclusive statement about the rate of influence of associated plants in the culture in any of the plots could not be done though.

When evaluating the qualitative morphological characters our results reached an accordance with the findings of Arévalo (1996) identifying variability of characters such as shape of leaf, colour of leaf, colour of inflorescence and/or shape of seeds. In contrast to her findings confirmed by the findings of Manco (2005) only two traits on the shape of seeds were observed despite their observation of three characters. Same incoherence with the statement of Manco (2005) about the colour of stem happened when only one colour was identified.

The observation of McMaster (1997) that for most crops temperature is the primary driving factor controlling phenology and subsequent development of the plant parts was applied when considering the results and looking for its interpretations. Despite this information the fact that the type of pollination was unclear as stated by Gillespie (1994) and Arévalo (1996) had to be taken into account and made all the assesment more complicated. Nevertheless Arévalo (1996) noted that despite this confusing actuality further observations and attempts to evaluate the variability of sacha inchi should be advanced.

According to the distribution of evaluated plants in the score plot large uniformity among particular plants was observed within the plot cultivated as monoculture. Significant uniformity within the plots where was more space for the development of the plant or less plants in associations was also recorded. There was no available literature nor research conducted on this topic but certain links to the diversity of sacha inchi in different associations were observed.

Possible explanation for this fact may lie in clarification of sacha inchis' phyllogeny. Considering that sacha inchi is allogamy plant as suggested in personnal communication by Cachique this presumption would justify that closer the neighbouring plants are the lower variability is observed. Nonetheless the origin of the seeds is a key element for further research on this issue and clear assesment of gained findings.

The only remark on the effect of associated cultivation of sacha inchi with other crops was made by Arévalo (1996) in regard to leguminous trees amasisa (*Erythrina poeppigiana* (Walp.) O.F. Cook) and mata-ratón (*Gliricidia sepium* Kunth ex Steud.) where the possible effect of this association on the growth of the plant, size and colour of leaves was mentioned but without any conclusive statement. Nevertheless we could not compare this observation as only one plot witch sacha inchi including mata-ratón was among evaluated plots.

Only few concluding results were found concerning the morphological variability and diversity of sacha inchi. Visible morphological dissimilarities in the plant appearance were confirmed nevertheless the most visibly significant observations proved to be of a low statistical importance which was a surprising detection. On the other hand the presence of these variabilities was unquestionable and further research on this issue would be needed.

7.2. Ethnobotany data

Three synonym titles consilient with the trade mark commercial products on the market bears (Industrias amazonicas, 2006) and as denoted by Arévalo (1996) and Manco (2005) as the most common local names for *Plukentia volubilis* L. were identified to be used most frequently in the vicinity of Pucallpa. Another name sacha yuchiqui was mentioned by 5% of respondents, all of them being women. Distribution of responses confirming the particular synonym titles of the plants was clearly dominated by the absolute knowledge of women respondents while men respondents had just partial cognizance.

Indication of inchi capi as a synonym for sacha inchi is more likely confusion from the side of the respondents as inchi capi is due to the local citizens, Brack (1999), Soukup (1970), Machaca Compomanes (2009) and others traditional soup made from peanuts or sacha inchi seeds. This type of response was typical example underlining the need for cross-checking information when collecting local knowledge and putting into practice as pointed out by Cunningham (2001).

Given that information about the plant diversity were more specialized knowledge and certain familiarity of respondents with the subject of research was required systematically chosen respondents as recommended by Cunningham (2001) were approached in order to receive more accurate responses. Taken into account the note of Cunningham (2001) and

Langill (2004) that the precise method of data collection may change through the course of study few more respondents mostly the ones from rural areas being farmers in the same time were approached together with the originally systematically chosen sample. Nevertheless very identical responses were obtained from all the respondents and despite the visible disimilarities of plants which were noted and indicated by all farmers any local nomenclature was given to the individual plants. They all claimed to see or perceive any differences in the yields of plant nor the quality of the obtained products thus there was no reason to distinguish the plants by any means. This fact also indicated that farmers' preferences were ruled by subsequent utilization and marketability of plants they grow as stated by Torrres (1993), Riesco (1995) and others and as far as these attributes are not affected there was no need nor the reason to differentiate the plant.

Collected data about the use and products of sacha inchi were considered as general knowledge thus approaching all the respondents was applicable. Nevertheless as Langill (2004) warns, indigenous knowledge cannot be accepted uncritically, as it has its limitations. Thus not only cross-checking and mix of the applied methods was required but slight diversification of respondents was quite advisable. Broad knowledge about the use of seeds and is extracted oil was recognized. Good accessibility of the products on the market and current awareness about its outstanding qualities (as observed by Hazen and Stoewsand, 1980 and Hamaker *et al*. 1992) could be the contributing factor.

While people in the city had more direct access to the final products less need for multi-role using of plant was observable and more aesthetic functions were recorded. On the other hand people from rural areas (farmers) indicated multiple uses of different parts of the plant, very often of more utilitarian and effectual character as in accordance with Nair (1993), De Sousa *et. al* (1999).

In the contrast to the observation of Brack (1999) and Machaca Compomanes (2009) any evidence of the consumption of crude nor roasted leaves was identified.

Other recorded uses were mostly connected with the cultivation of sacha inchi and certain agricultural practices or production. Use of the leaves and other parts of the plant as a fodder and for composting, dried peels as a soil cover against weed invasion and implementation of the plant into the production system in order to ensure the soil against erosion affirmed the shift of farmers to more sustainable and ecologically motivated systems of production as was mentioned by Nair (1993).

The interesting finding was the knowledge of respondents about the use of oil as a biofuel which was more recent information (Ramírez, 2008). This only proved that ethnobotany is the study of the interactions and relations between plants and people over time and space, including modern knowledge as Balick (2007) stated and this aspect should not be overlooked.

7.3. Cultivation potential

Different period of establishing the cultivation of sacha inchi in Ucayali region to the region of San Martín was corresponding with distinct climate conditions of both regions and various altitudes of the locations as seen in chapter 3.2. and due to Arévalo (1996) and Manco (2005). In accordance to this observation we were not obliged to do any further specific research on this characteristic and we could conclude that for successful agricultural production of sacha inchi in Ucayali region were no additional agroecological requirements than the ones alleged by Arévalo (1996) and Manco (2005).

As no comprehensive data of different aspects of the plant have been conducted (Manco, 2005; Guerrero, 2006 and Vasquez, 2006) including the agronomy and cultivation potential of species and according to Ramírez (2008) rapid interest for the development of cultivation of sacha inchi and its oil production emerged small-scale farmers in Ucayali region started to implement the crop into their systems immediately. Means of implementation into their systems were quite limited by the economical situation of the farmers and their knowledge thus more and less convenient types of production were observed. The results of Coomes and Burt (1997) indicating considerable variation in field characteristics, agroforestry cycles and household agroforestry portfolios were confirmed when observing the selected plots.

Between the most prosperous observed plots in terms of short-term economic income was the plot PI 1 from Pimental and DE 1 both of them monocultures. Cultivation of sacha inchi in DE1 plot was established with the use of artificial stakes thus even more demanding in terms of financial input while there were any stakes in plot PI1. Nevertheless both of these plots underlied to the patterns of monocultures as mentioned by Nair (1993) thus were not economically rentable in the long-term and provided some risk to the soil fertility as the sustainability was not ensured in accordance with FAO (2009 and2010).

The most prosperous observed systems were AR 1 and PI 2 in evaluated in accordance to FAO (2010) as both short-term and long-term perspectives. In both locations artificial stakes providing pillars for sacha inchi were implemented but as the cultivation was placed into agroforestry system more convenient type of production was observed. On the other hand in both of these cases some considerable financial input was required.

In accordance with Nair (1993) and FAO (2010) plots of AR 2, AR 3 and AR 4 evaluated as those with good prosperity and long-term perspective were typical examples of mix of perennial trees with annual crops thus convenient biodiverse agroforestry systems.

The last observed already established cultivation including sacha inchi in Pimental PI3 was unsuccessful example of the implementation. Despite the fact that guaba (*Inga edulis)* is one of the most suitable and promissing tree species to be included in the agroforestry systems in the region (Lojka 2005, Preinninger 2008) it proved to be one of the few species competing with sacha inchi and suppresing each other.

Nonetheless regarding the fact this multipurpose tree is popular among the farmers throughout the region and with great importance for the farmers in the area of study site (Lojka *et al.,* 2005) further research focused on its association with sacha inchi might be considered.

As indicated by Lojka *et al.* (2008) guaba fallows enables higher levels of farm outputs to be achieved and from both environmental and productivity perspectives are attractive. It was stated by Arévalo (1996) and confirmed by Manco (2005) that cultivation of sacha inchi have the same benefits. Inclusion of both of these species into one agroforestry system thus might be both environmently and cost beneficial in short-term and long-term perspective in the same time as derived from the findings of FAO (2009 and 2010). Suitable way of its implementation excluding the use of guaba as a pillar for sacha inchi may be an interesting incentive for further research.

Derived from the observation of examined species in the vicinity of Tarapoto (San Martín) put together with the data from the vicinity of Pucallpa 7 tree species were identified to be suitable for successful establishment of agroforestry system with sacha inchi. All of these species except the teca tree were recorded by Rousova (2007) to be commonly used in the region thus any unexpected difficulties during the implementation should not arise.

According to (Sanchez 1995) large part of current agroforestry research is dedicated to the question of managing the competition between trees and crops for light, water and nutrients to the farmers` benefit is the biophysical determinant of successful agroforestry systems. As Arévalo (1996) and Manco (2005) indicated sacha inchi shown to be resilient to conditions of low fertility and not requiring any fertilizers for optimal growth nevertheless associated culture with leguminous trees or crops was shown to be very suitable. It was confirmed as Guerrero (2006) mentioned that too much shading diminished the flowering and decreased the production thus the elected tree species for the function of pillar had to be grown.

In accordance with Rousova (2007) local farmers commonly cultivated significant amount of species implemented into the agroforestry thus there was a wide range of species which could be selected into the agroforestry systems with sacha inchi. As indicated by Sanchez (1995) and Lojka (2005) the most problematic part of agroforestry, and the main reason for limited adoption of new agroforestry systems, is the question of tree-crop interaction, either competition or complementarity. This aspect was prioritized when suggesting the plots involving sacha inchi and due to its low invasiveness and absence of severe competitive effects with crops, particularly for water no limitations were found in this regard.

De Jong (1995) said that variation of agroforestry practices is considerable because of destination of the output, species composition, complexity and management patterns. More models of agroforestry systems plots implementing sacha inchi was thus suggested to anticipate individual needs and resources of farmers.

8. Conclusions

The aim of this study was to make an initial step in clarification of morphological diversity of sacha inchi thus to contribute to the current ongoing research on this issue. The basic hypothesis that all of the observed plants called by farmers sacha inchi are *Plukenetia volubilis* despite their visible morphological dissimilarities in the plant appearance and not any other species was confirmed. Nevertheless the most visibly significant observations proved to be of a low statistical importance.

Local people were included into the research and according their knowledge and observations any specific effects on the growth and development of the plant neither in the quality of the plant products or its properties were accounted to the plants with visible distinctions due to their evidence.

The results from the morphological features data collection pointed out to the possible effect of the surrounding environment in terms of plant associates to the certain characteristics of the plant such as leaf colour or the shape of leaf margins. Another distinction could be affected not only by the type of associated plant but also by the type of production where sacha inchi was implemented. Observable differences between the monocultures, agroforestry intercropping system and multi-strata systems were recorded.

Nevertheless these findings should be the subject of further research on this issue and could not be considered as conclusive.

In the second part of the study ethnobotany approach was put together with agroecological research in order to use the obtained data for more effective and appropriate implementation of sacha inchi into local agroforestry systems.

Three synonym titles frequently used to name *Plukenetia volubilis* L. plant in the vicinity of Pucallpa were identified. Sacha inchi, inca inchi and maní del monte. Among the possible uses of plant and its parts the use of the seeds and extracted oil from it were the most acknowledged ones. The seeds were well known as for direct consumption or in the extracted form of edible oil for various purposes. More multi-role uses were declared in the rural areas where the dried peels were used as a firing, any of plant remains were used for composting and the whole plant was used for erosion and weed control when implemented into the common agricultural cultivation.

Based on the participative methods of observation and in accordance with farmers' knowledge, individual likelihoods and resources four different designs of agroforestry systems including sacha inchi were suggested. The importance of implementing local species in order to facilitate the adaptation of suggested systems was regarded. Four tree species typically used in the local agroforestry systems, two leguminous trees and one promising fast-growing tree were recommended. By contrast, guaba tree (*Inga edulis* Mart.) typical component of local agroforestry systems was not suitable for conjunt cultivation with sacha inchi as far as it was used as a pillar for its cultivation. As for other associates for the agroforestry systems including sacha inchi almost any crop or fruit would be recommended.

Previous findings thus confirmed second set hypothesis that implementing sacha inchi into agroforestry systems is possible and it can be used in local scale by smallholder farmers in the region of Ucayali. However there are some implications which need to be regarded. Nonetheless, this fact is not an obstacle rather than advantage for the local farmers when looking for the crop improving their diets to include in their current cultivations ensuring significant income in the same time.

We may conclude that implementing of sacha inchi into local agroforestry systems has very big potential to enhance the economical, social and environmental benefits for the local farmers. There are not any serious obstacles or demands for its implementation. Nevertheless a lot of comprehensive data about the species is still not acknowledged and are needed to be the subject of further research whereas all the obtained results of this study are only small part contributing to re-exploring of this ancient indigenous oilseed crop.

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10. Appendices

Appendix A: Photos of sacha inchi

the plant of sacha inchi

inflorescence

4-lobed fruit

harvested fruits

sacha inchi seeds

Appendix B: Descriptor for sacha inchi (Plukenetia volubilis L.)

Collecting form

Sample identification

Name of collecting person/institute: *Blanka Krivankova*

Code for plant sample:

(due to the code for location as below)

Photograph no.:

(identical with code for plant sample)

Collecting date of sample *[yyyymmdd]*:

Species: *Plukenetia sp.*

Common name: *sacha inchi*

Collecting site location

Country of origin: *Peru*

Location: km: direction: *Campo Verde* from: *Pucallpa*

Code for location:

Latitude:

Longitude:

Altitude: (m. a. s. l.)

Collecting site environment

Collecting / acquisition source: *farm or cultivated habitat*

a) wild habitat b) farm or cultivated habitat c) market or shop

c) institute, exp. station, research org., genebank d) seed company e) weedy, disturbed

f). other (specify): or ruderal habitat

Higher level landform: *basin*
a) plain b) basin c) valley d) plateau c) upland d) hill e) mountain

Additional information: *e.g. type of cultivation, associated crops yes/no, prevailing stresses if any (drought, pests, dieseases etc.)*

Data collection of morphological features

Quantitative characteristics

Height of plant (m):

Basal diameter (cm):
Measured in 10 cm above soil surface

Branching height (m):
First branch from the ground
Length of petiole (cm):

Blade length (cm):

Blade width (cm):

Leaf length (petiole + blade) (cm):

Inflorescence length (cm):

Length of stylar column (cm):

Number of seeds per capsule:
In case of e.g. 4 and 5-lobbed on the same plant - both to be mentioned

Width of capsule (cm):
Measured diagonally (crossways)

Diameter of seeds (cm):

Weight of 10 seeds (g):

Qualitative characteristics

Shape of crown: upright/broad/flat

Shape of stem: cylindrical/irregular

Colour of stem: green / brown

Structure of stem: smooth/moderately rough/ very rough

Shape of leaf: triangular/ ovate

Shape of leaf margins: straight / undulating

Presence of leaf hair: yes / no

Colour of leaf: bright green/green / dark green

Pointed top of leaf: long tip / short tip

Colour of inflorescence: white / yellowish

Single glandular knob at petiole apex: yes / no

Presence of smell: yes / no

Shape of capsule: star shape / irregular

Colour of capsule: bright green / dark green

Shape of seeds: oval / elliptical / irregular

Colour of seeds: brown with dark brown markings / brown with violet markings / violet with brown markings

Appendix C: Ethnobotanical data - questionaire

Date of collection:

Location:

Respondent: man/woman

Area of origin: town/rural

Occupation: farmer/vendor at local market/other

Local/vernacular name:

Plant uses for: entire plant
leaves
flowers and inflorescence
capsules and peels
seeds

For systematically chosem informants only - *mostly farmers*

Do you observe some dissimilarities in the appearance of individual plants?

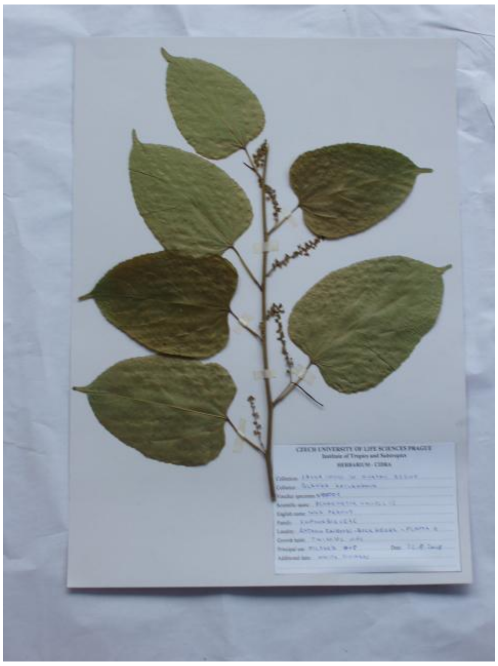
If yes, for which characteristics?

Do you consider this characteristics somehow specific?

If yes, how?

How do you call such a plant? *(local name)*

Appendix D: Photo documentation of voucher specimens



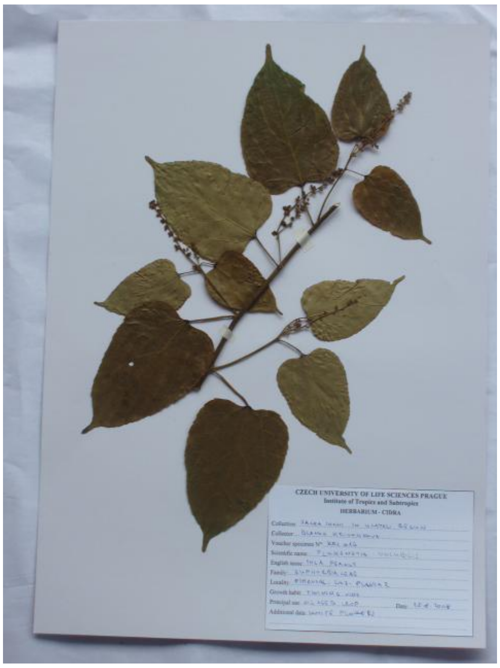
Plant sample AR 1.1

Plant sample AR 1.2

Plant sample AR 1.3

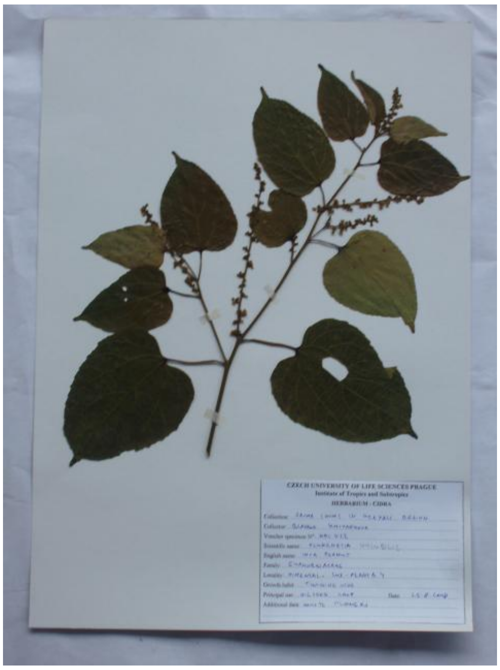
Plant sample AR 1.4

Plant sample AR 2.1



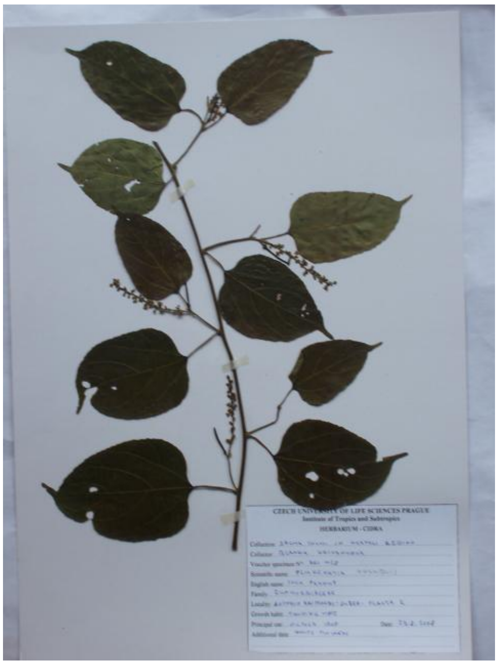
Plant sample AR 2.3

Plant sample AR 2.3

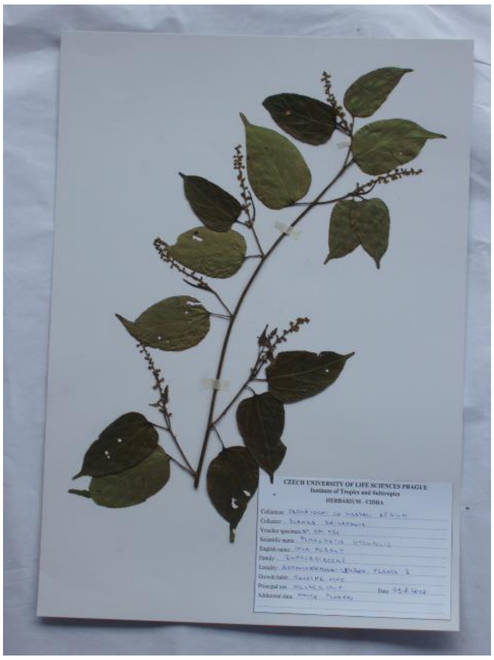


Plant sample AR 2.4

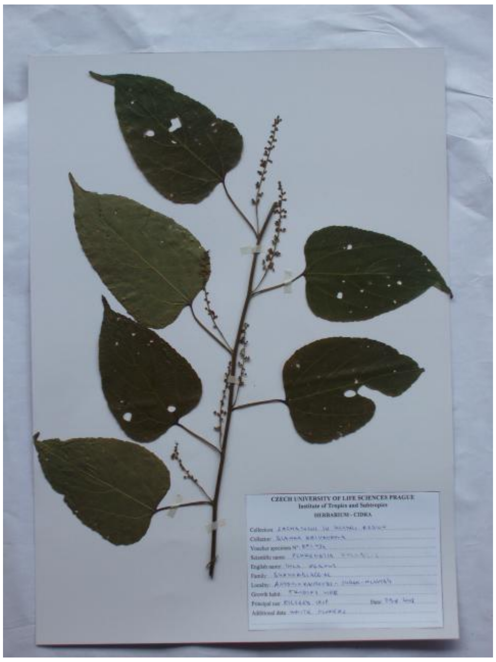
Plant sample AR 3.1



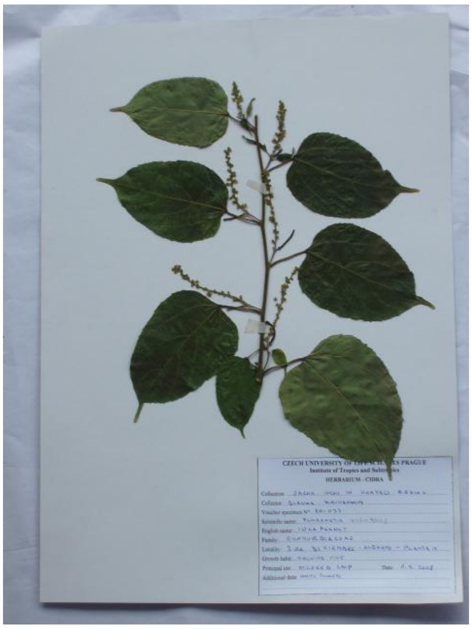
Plant sample AR 3.2

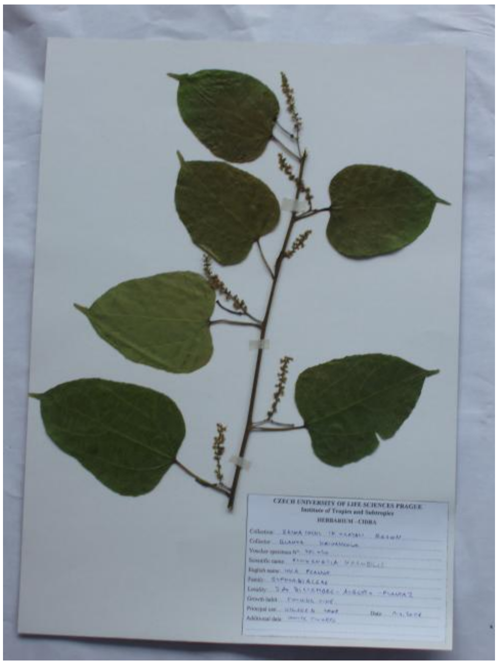


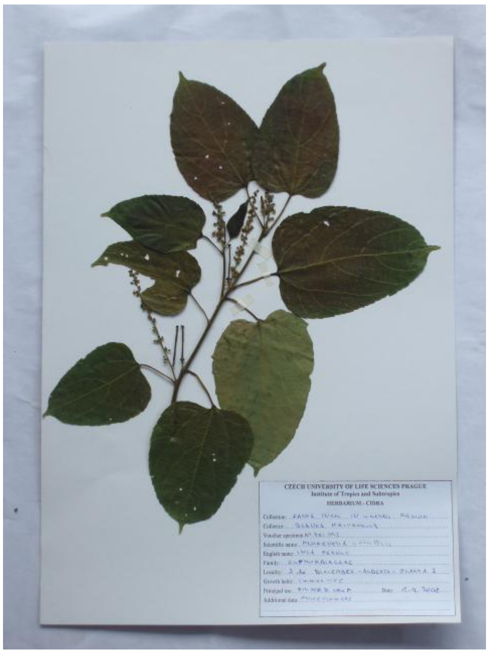
Plant sample AR 3.3

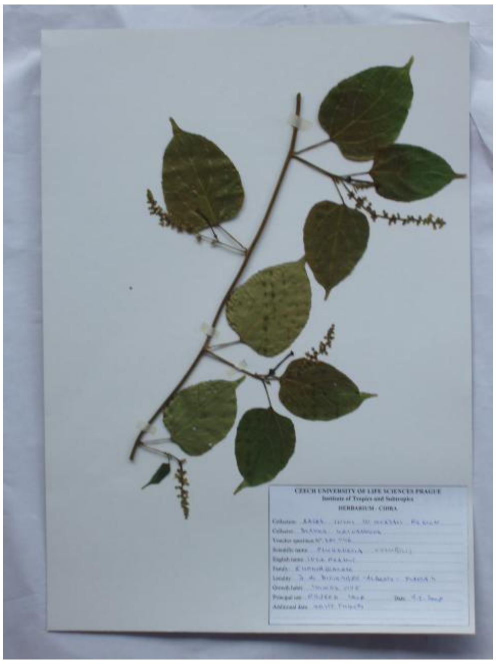


Plant sample AR 3.4

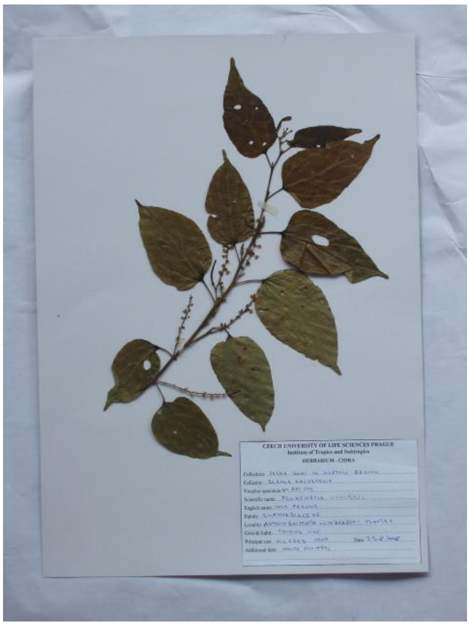

Plant sample PI 1.1


Plant sample PI 1.2

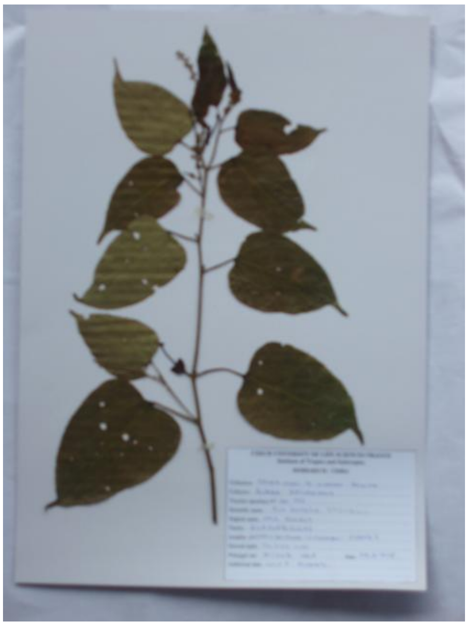

Plant sample PI 1.3



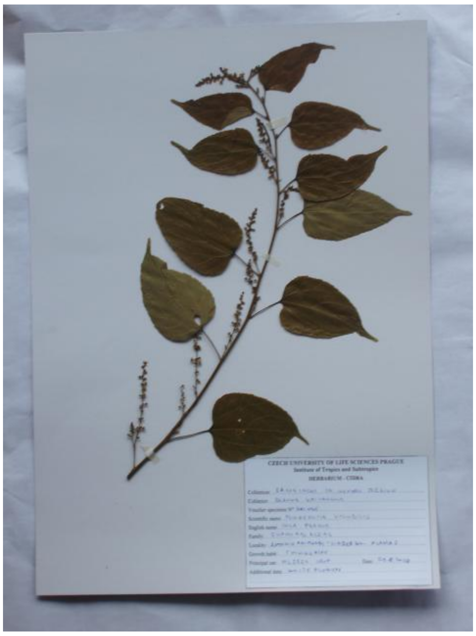
Plant PI 1.4



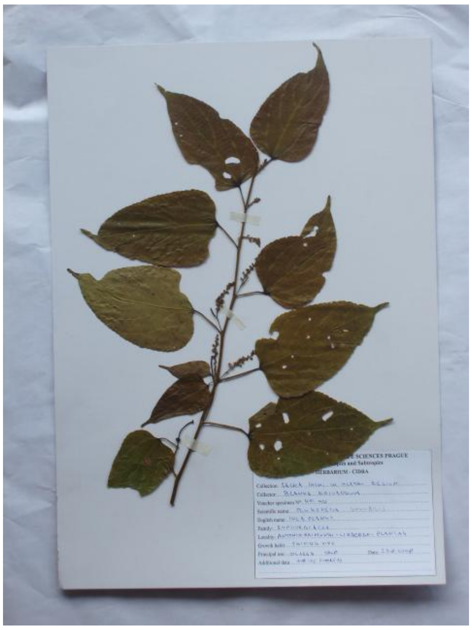
Plant sample DE 1.1



Plant sample DE 1.2



Plant sample DE 1.3



Plant sample DE 1.4