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NOBLE SEEDS: SACHA INCHI FROM AMAZONIA TO THE CARIBBEAN BASIN?

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1. Introduction

Sacha inchi (*Plukenetia volubilis*) is a perennial vine native to tropical America, which is notable for the high oil and protein content of its seeds. Both this oil and protein are of great benefit to human health, particularly for young and elderly persons. Several species of the genus *Plukenetia* were described for Mexico, Costa Rica and Suriname in the 1960s.[1] However, its wide dissemination within and outside of Peru came two decades later and it adapted in small farms oriented to ecological production. The cultivation and processing of Sacha inchi, mostly in edible oil, may help slow the advance of the agricultural frontier and improve the income of farmers, despite possible phytosanitary and marketing problems.

This chapter presents an overview of Sacha inchi production and commercial practices, its potential and the factors that limit the expansion of its cultivation and consumption in the Caribbean Basin. In the following sections, the economic and social context is described, followed by a brief analysis of its nutritional properties. The factors that influence the dissemination process are discussed with a view to potential integration into cropping patterns and consumption in Central America and the Caribbean. The discussion concludes with several issues that deserve to be developed in the agenda for academic research and pilot practices in the public policies of this region.

2. Economic and social context in Peru

Sacha inchi or 'Inca peanut' has been known and consumed for thousands of years, as evidenced by clay pots in the shape of its fruit from pre-Inca times, over three thousand years ago. Traditionally it is an ingredient of several indigenous dishes in the Peruvian Amazon. Despite having been classified by Carolus Linnaeus in 1753, interest in the crop emerged very recently, following a study by Cornell University in 1980 (Huamani and Flores, 2009). Sacha inchi farming was recorded in Peru, first in Pichanaqui (Junín) and Pasco, later in the north, particularly in San Martin, where in the middle of the last decade about 160 farmers already grew it (Saavedra, undated).

The change in the productive structure of Sacha inchi started from 2006 onwards in San Martín, with the execution of a cooperation programme involving four key players. In the first place, primary producers were activated, basically farmers with crop areas of 1.8 hectares on average, mainly planted with coffee (41%). They gradually increased their areas of Sacha inchi to almost 0.5 ha (25%) of their cultivated areas (Perú Biodiverso, 2013). In the course of the period until 2013, the number of farmers increased, reaching about 1,060 producers organized in 48 committees.

The second group of actors consisted of processing and trading companies. Starting with one in 2006, to which another nine were gradually added, with presence in the production areas and in Lima, where shelled seeds are processed into bottled oil or bulk oil for wholesale. A third participant was formed by public authorities in Peru, including the National Agricultural Research Institute (INIA), with an interest in field trials and post-harvest practices, as part of an alliance of research centres (CIED, 2008). In the case of the San Martin programme, starting in 2007, the Regional Government committed to allocating human resources for an investment exceeding USD 2 million for a public investment programme. Typically, public support at the regional level has been through demonstration plots, training workshops, internships and support to the certification process. In the fourth place, several cooperating agencies - in this case from Germany (GIZ) and Switzerland (SECO) - joined forces through various programmes, with the objective of strengthening the production and marketing structure (Perú Biodiverso, 2013).

San Martín in Peru is one of the six regions where Sacha inchi is grown, but the evolution of production in each of them is unknown. Also at the national level the gradual ascent of the subsector can be inferred only indirectly. It is estimated that the area planted with Sacha inchi has expanded to 2,000 hectares nationwide, and the number of producers has surpassed 4,000. In the five years to 2013, production has doubled, illustrating the export boom. Since 2004, the last year with no export, the Peruvian Ministry of Foreign Trade reports a steady increase in sales of processed Sacha inchi (oil and meal), exceeding 200 tons since 2012.[2]

In the Andean countries today, the number of Sacha inchi producers is still less than 6,000, with a total area of 2,750 hectares between Peru, Colombia, Ecuador and Bolivia. In these countries, the crop is promoted through research in areas with the greatest potential, training for prospective producers and promotion of consumption as an ingredient in the local diet (Bethancourt, MAGAP, 2012; La Razón, 2013). The support is channelled through the Ministries of Agriculture and trading firms interested in processing and selling abroad, mostly with the participation of Chinese and North American companies.

Production of Sacha inchi oil in all Andean countries combined, is still at a level below 300 MT, to supply both domestic and export demand. Both segments are growing rapidly and reflect the global trend of demand for vegetable oils, with the largest increase in developing countries. There, an increase of about 30% in the consumption of vegetable oils is expected by 2023, attributed to both population growth and higher per capita consumption (OECD-FAO, 2013).

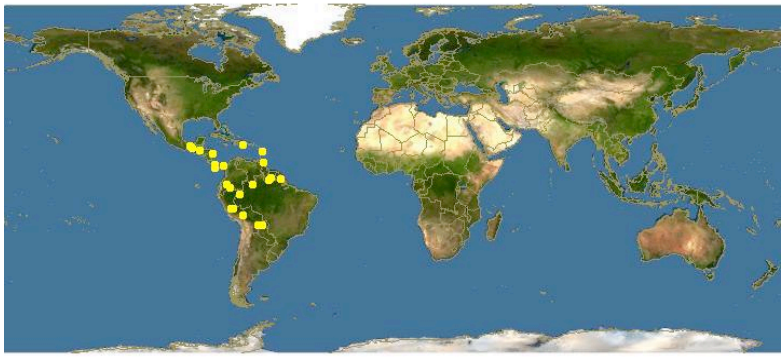
However, the Sacha inchi oil segment - for its 'gourmet' association' - is far superior in the international market and has a better prospect for expansion. The European market, to which it originally did not have access, has been opening since the Food Safety Authority of Ireland

(FSAI) at the end of 2012, notified[3] the services of the European Commission[4] of its criterion of functional equivalence between the oils of *P. volubilis* and flax (*Linum usitatissimum* L.). The consumption of flaxseed oil is not banned in the EU and hence the procedure to recognize the product under the Novel Food Regulation[5] could be avoided. It is expected that this flexibility will push forward the production of Sacha inchi and the marketing of its products.[6]

3. Plukenetia in Mesoamerica and the Caribbean Basin

The product known as Sacha inchi has become a cash crop in the Amazon basin, however, this is not the only region where the species *Plukenetia volubilis* is found. In fact, it appears in the records and drawings of early European botanists who passed through the Caribbean, among them Charles Plumier, who included it in his publication after his third trip to the French West Indies (now Haiti, Martinique and Guadeloupe) in 1703 and named it after the contemporary botanist Leonard Plukenet.

Figure 1. Occurrence of Plukenetia volubilis.



Source: Encyclopedia of Life

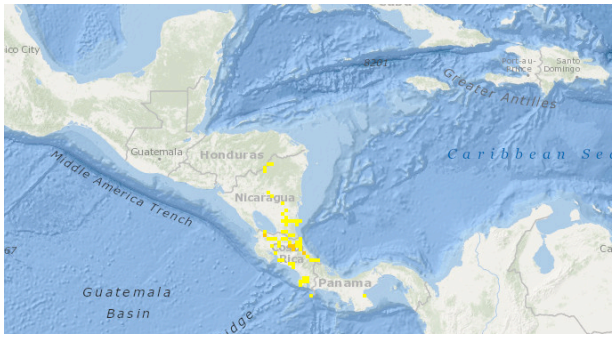
Of the 19 species distinguished within the genus *Plukenetia*, six are considered native to the Caribbean Basin.[7] Among them, the species *P. stipellata*, very similar to *P. volubilis*, is endemic in Mesoamerica, with intermediate variations in Venezuela and Colombia. The species *P. penninervia* occurs in dry to moist areas from southern Mexico to Venezuela. In Mayan culture, *P. penninervia* was known as "itch much", meaning toad's tendon.[8] Among the occurrences of *P. volubilis* shown in Figure 1, some probably correspond to specimens that at present would be classified as different species.

In the Isthmus, the consumption of *Plukenetia* seed is uncommon to sporadic. Several factors contribute to the absence of the genus in the production and consumption pattern of the Caribbean Basin. First, in Central America, no studies have been found on the composition and productive potential of the seed, as was done in Peru in the decade of the seventies. The lack of public interest contrasts with the approach followed in China by the Academy of Sciences, which started pilot plantings in 2006 with *P. volubilis* specimens, brought from Peru to the south of the People's Republic (CAS, 2008).

The lack of interest in the development of the Sacha inchi chain reflects the weakness of the oils sector in Caribbean Basin countries. Both the Caribbean and Mesoamerica are net importers of vegetable oil: their domestic consumption exceeds production - with the exception of palm oil,

whose production is concentrated in Guatemala, Honduras and Costa Rica - while consumption of vegetable oils has been increasing among the lower socioeconomic strata (MI, 2007). The position of vegetable oils has been gaining interest, in view of their importance in the healthy foods market, especially the segment of virgin oils, because of their substantial levels of antioxidants, vitamins such as E (Sayogo et al., 2007) and polyunsaturated fatty acids. In turn, the level of oil consumption depends largely on import volumes, both in the Caribbean (69%) and Central America (47%), more than any other segment of food products (IICA, 2012).

Figure 2. Occurrence of Plukenetia stipellata.



Source: Encyclopedia of Life.

On the other hand, the encouragement of consumption - more than production - of vegetable oils is inspired by a generic interest in food security, which is in the interest of small and medium-scale family agriculture (FAO, 2007 and INCAP, 2012). In this sector, the crop would be inserted as a diversification activity and with higher added value, both for nutrition and for the household economy. Despite their presence and potential in the Isthmus, *Plukenetia* species, either endemic (*P. stipellata*, see Figure 2.) or related (*P. volubilis*), have not attracted general interest. Their position remains marginal and shared with other nutritious foods that, with difficulty, are recognized in rural production development policies.[9]

The absence of commercial cultivation of *Plukenetia* in the Caribbean Basin also reflects the approach given to agroforestry practices in the region. The conservation of natural resources in Central America has often been based on monocultures like coffee, cocoa or - in Costa Rica - tree species such as teak, which usually result in disappointments. Multi-crop production methods that pursue variety and the adaptation of crops to changing ecosystems over the longer term, are rather scarce.[10]

In South America there seems to be a better prospect for the dissemination and organic integration of ancient crops like Sacha inchi in forested farms to take advantage of their resistance to toxic substances in the soil and their role in improving the composition of degraded soils.[11] This synergy between agroforestry production and the conservation of natural resources conservation has not yet materialized in Central America to the same extent.

4. Characteristics of Sacha inchi oil

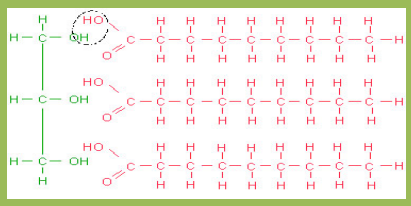
In the research of the Cornell University in 1980, Sacha inchi was identified as an important source of highly unsaturated oil, rich in 'omega-3 (ω-3) (linolenic) fatty acids. These fatty acids

are relatively rare in the plant kingdom, particularly in oils from common crops such as soybean, palm, peanut, rapeseed and sunflower.

Fatty acids, fats and oils

Oils and fats are 'triglycerides', i.e. glycerol molecules, with three carbon atoms (C), each having a hydroxyl group (OH) that binds to a fatty acid. The result is a molecule with three 'tails' of fatty acids. In two dimensions, the structural formula can be represented as follows:

Structure of a triglyceride



Glycerol 3 fatty acid molecules

By joining glycerol (green) with each of the three fatty acid molecules (red), one H atom and one OH group are removed, and a water molecule (H_2O) is released.

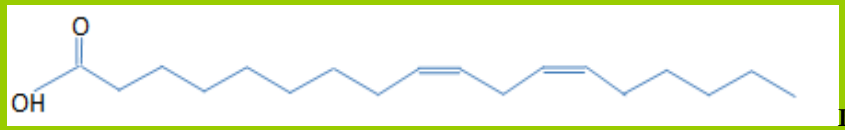
This, coupled with excessive consumption of oils in the current urban diet, has led to an imbalance. It has been estimated that the ratio of o ω-3: ω-6 fatty acids has changed from about 1:1 in the ancient diet of the human species[1] to 1:20 or 1:50 now. Many physiological problems are attributed to this imbalance.[1]

The main source of ω-3 fatty acids in the contemporary diet is wild fish from cold water oceans.[1] A terrestrial source would be most welcome, both for human health as well as to relieve the pressure on dwindling wild fish stocks. Recent research (Bethancourt, 2013), shows that Sacha inchi oil contains about 48% linolenic (ω-3) and 33% linoleic acid (ω-6). Both of these fatty acids are essential, meaning that the human body cannot synthesize them based on other molecules. Hence they must be consumed in food. The body uses them both directly and indirectly as they can be converted into other ω-3 and ω-6 fatty acids, which have effects on brain and hormonal functions, among others.

Omega 3 (□ -3)

Unsaturated fatty acids are characterized by the length of the carbon chain and the position of any double bonds. Omega (□), the last letter of the Greek alphabet, points to the end of the chain: the last carbon atom. Omega-3 fatty acids have the first unsaturation at the third carbon atom counting from the end of the tail. Similarly, □ -6 and □ -9 indicate that unsaturation occurs at the 6th and 9th carbon atom from the end of the chain respectively. This concept is illustrated in following examples, all with 18 carbon atoms in the chain:

Alpha-linolenic acid (□ -3)



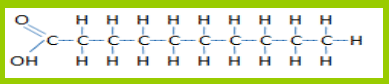
Linoleic acid (□ -6)

Most akin to Sacha inchi oil is flaxseed oil, which also contains a high percentage of ω-3 fatty acids, and is used in alternative medicine treatments. In the Andean countries, the refreshing drink of flaxseed is consumed accompanied by lime juice. However, Sacha inchi oil is more easily digested than flaxseed oil. It also contains a higher level of antioxidants, such as alpha-tocopherol (a form of vitamin E) and beta-carotene (precursor of vitamin A). Sacha inchi consumption is not subject to a maximum like flaxseed consumption, because the latter contains anti-nutrient substances (e.g. cyanogenic glycosides) which impose a limit on its daily consumption (Ganorkar et al., 2013). For Sacha inchi oil, the anti-nutrients saponins and tannins are the only ones reported so far, but in lower concentrations than in other oilseeds such as soybeans (Ruiz et al, 2013).

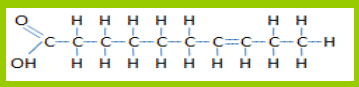
The healing properties attributed to consumption of Sacha inchi include functions in the circulation of oxygen in the blood and its transport to the tissues, the regulation of pressure on the eyes, ligaments and arteries, the alleviation of the ageing process, the regulation of sugar levels in the blood thereby decreasing the risk of diabetes, and the maintenance of the flexibility and strength of cell membranes. The beneficial effects of Sacha inchi oil materialize in various physical and mental processes (Rodriguez et al., 2010b).

Unsaturated

The tails of saturated fatty acids have two H (hydrogen) atoms for each C (carbon) atom. Fatty acid molecules that do not have two H atoms for each C atom are said to be unsaturated. In parts where H atoms are lacking, double bonds occur between neighbouring carbon atoms:



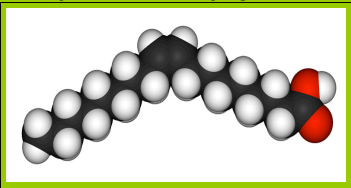
Saturated fatty acid



Unsaturated fatty acid

Seen in three dimensions, the unsaturated chains are folded on the double bond positions.

Three-dimensional representation of an unsaturated fatty acid



Oleic acid (□ -9)
Black: carbon (C)
White: Hydrogen (H)
Red: Oxygen (O)

Unsaturated fatty acids are bent wherever there are double bonds between carbon atoms. Therefore, triglycerides with unsaturated fatty acids have erratic shapes. They crystallize with difficulty and remain liquid at lower temperatures. We call them oils. The more unsaturation in the fatty acid tails, the more complex the molecule's structure, the more difficult it is to crystallize and the more liquid the oil. Fatty acids with multiple double bonds and the corresponding oils are called poly-unsaturated. More polyunsaturated fatty acids in triglycerides also make for more viscous oil.

5. Plukenetia species, their cultivation and processing

The genus *Plukenetia* contains several edible species. In southern Nigeria and western Cameroon *P. conophora* ("African walnut")[12] occurs, of which the leaves, for their mineral elements, and the

seeds, believed to treat male infertility, are consumed. In Brazil, *P. serrata* (Ticazo-Mirim)[13] is used and grown. Until now, the genus has been relatively little studied and its taxonomy is in discussion. As such, *Plukenetia carolis-vegae*[14], *P. huayllabambana* (both from Peru) and *P. stipellata* (from Central America), which were previously considered as local varieties of *P. volubilis*, have been re-classified as distinct species and other ones are being proposed still. Rodriguez et al. (2010a), for example, proposed to separate a "variety" found in Cusco as a different species.

Even so, within the species *P. volubilis*, significant genetic variability has been observed in natural populations from different ecological conditions (e.g. different levels of elevation - see Corazón Guivin (2009), Reátegui & Arévalo (2012) and Rodríguez et al. (2010a)). The first commercial selections from different backgrounds already exist. Several seed houses now offer 'improved' seeds, [15] but commercial varieties, well documented in a wide range of agro-ecological environments, are not yet available. As in all new crop introductions, varieties from different sources will have to be tried in order to identify the ones that adapt best. To date no crop trials have been reported with a comparison of characteristics and performance between the different species across several countries.

Since the genus *Plukenetia* is cross-pollinating[16], a stand obtained from sexually produced seeds will always be heterogeneous. This is a disadvantage from an agricultural point of view, where uniformly performing plants are preferred. Ruiz-Solsol and Mesén (2010) obtained good results in promoting root growth in cuttings using auxins.[17] This allows the cloning of elite plants, helping to improve the yield.

Sacha inchi is a perennial crop that requires an initial investment to establish the tutors. On the other hand, it is planted at a relatively low density and – as opposed to many other perennial crops – develops rapidly and produces the first harvest within the year after planting. This is an advantage for small farmers.

The low planting density (typically in rows three meters apart) permits intercropping. The leaves and prunings of trees used as live tutors can contribute to the mineral nutrition of the crop. In its natural habitat, it occurs in low densities, within a diverse ecological environment. As a climber, it requires other crops (shrubs or trees) for support. If grown in monoculture at high density the likelihood of disease transmission from one plant to another equally susceptible plant of the same species increases. These characteristics are compatible with traditional production systems in small farms.

Since the earliest (mono-)culture attempts in Peru, a high vulnerability of Sacha inchi to nematodes was observed. Nematodes are microscopic worms that live in the soil, attack the roots and can even kill the plant. This problem has been studied in a wide variety of crops. If a large population of nematodes accumulates in a soil, farmers say the soil is "tired" and practice crop rotation. After a few years of fallow or under crops that do not host the nematode, the population is reduced and they can return to the original crop. This strategy, however, does not apply to a perennial crop like Sacha inchi.

Selection in natural populations has revealed more resistant variants, which can be grown as such or used as rootstocks for the grafting of other, more productive but susceptible varieties. This

way, a composite plant is obtained with the root system of a nematode-resistant variety or species but the aerial parts of a variety known for its productivity in the local conditions. On the other hand, nematode attacks usually occur in high temperature conditions, so they can also be controlled by selecting an appropriate climate for the crop. Similarly, larger nematode populations were observed in soils with poor drainage.

P. volubilis is native to the tropical rainforest. The plant survives drought periods up to a couple of months, but these cause disturbances in flowering, make the harvest seasonal and reduce productivity. As with many tropical perennial crops (e.g. oil palm and *Jatropha curcas*), under such conditions, optimal performance will only be obtained with irrigation. Temperatures above 35 °C also affect productivity, by causing the abortion of flowers and young fruits. Naturally, the plant occurs on the edges of forests. It supports shade, but definitely prefers full sunlight and any shade reduces its productivity (Cai, 2011).

Figure 3. Abundant fruit set (young and mature fruits) at Mastatal (Puriscal, Costa Rica)

The plant shown (Figure 3) descends from a variety introduced into Costa Rica from Peru in the 1990s. It develops easily, both on the Caribbean coast and in the Pacific, even without much agronomic intervention. Yields so far obtained appear satisfactory. At least one Central American company offers seeds and seedlings of selected materials, and moreover promises to buy the production.

The fruits of Sacha inchi are capsules, typically with four seeds, but may contain more. Even dry, they remain attached to the plant (Figure 4). This is an advantage: one round of harvest per month is enough. The seeds are easily separated from the dried fruits, so decapsulation can be

performed in the field. This reduces the carry-out weight by about 45% and the fruit residues can be used as an organic fertilizer in the plantation itself.

Figure 4 and 5. Ripe fruits (pictured with five and six seeds) and Seeds with a peeled kernel (white).

The commercial product is the dry seed. It features a hard shell that is difficult to remove. If done manually, the cost of shelling can be as much as half the market value, but it can also be done using simple machinery. The shell constitutes about half the weight of the seed. However, it is not recommended to shell the seeds before the final transformation since kernels exposed to oxygen in the air quickly turn rancid.

The kernel has a bitter taste when fresh, but similar to peanuts. It can be roasted for direct consumption and for preparing snacks and candies like nougats. It is also used in several traditional dishes. When pressed for oil, it is important not to allow the temperature to rise, as the highly unsaturated oil oxidizes easily. As a consequence, pressing efficiency is decreased, leaving a significant portion of the oil in the cake. Only with “cold” pressing is "extra virgin" oil obtained. After pressing, the only additional processing consists of letting impurities settle out for several days and possibly a filtering. Any additional refining treatment would deteriorate the quality of the oil. For this same reason, the oil must be protected from light (coloured glass bottles) and stored at moderate temperature.

Figure 6. Press and hand mill, ready to press oil and prepare sacha inchi butter at household scale**.**

Industrial scale processing for export (to the United States), requires *Hazard Analysis and Critical Control Points* (HACCP) certification (Chirinos et al., 2009). In addition, the production process - from planting to packaging the final product - can obtain organic certification, awarded by entities that mainly operate from the destination countries.
The cost of both types of certification is one factor that explains the high commercial margin between the value of the agricultural product (seed in shell) and oil in the retail market. This difference is huge as compared to common food oils such as palm- and soybean oil. However, the entire processing chain can be completed with simple manual equipment, and therefore can be performed at the local level or even at the farm itself.

6. Lessons learnt and conclusions

Production of Sacha inchi - or other species of the genus Plukenetia - and their derivatives, represents a major challenge for rural areas in the countries of the Caribbean Basin, for several reasons. First, contrary to the general image of Sacha inchi, the species is not exotic to the region, nor exclusive for the Andean countries, as it is fully integrated in the botanical map of the centre of the Americas.

Second, the seeds of Plukenetia species possess such favourable characteristics from a human health point of view that their cultivation and consumption are suitable in strategies to enrich and diversify food patterns.

Third, the content of the seeds offers - in the longer term - a substitute for such food sources (rich in essential fatty acids, especially sea fish) that become scarce due to over-exploitation.

Fourth, since their cultivation and processing are not technically complicated or demanding in capital investment, entry into the production chain is relatively easy for small producers. The chain can be developed by organizing small producers.

Last but not least, the production of Sacha inchi seems to generate more added value in less ecological space, anchored in the management of natural resources in rainy areas with temperate heat.

The promotion agenda of any production chain in the region first of all requires an agreement between the key stakeholders in the productive sectors. In this aspect, Central America and the Caribbean lag behind the Andean countries. Recognizing that the facets of research, technical extension and organization are triangularly linked, the development of an agenda depends on the ability to forge alliances in a way similar to development in Andean countries, particularly Peru. Public, private and foreign actors, joined together in a common strategy that, in less than a decade, allowed the development of a production chain that was virtually unknown previously.

In the case of the Central American and Caribbean countries, in a first step, cultivars will have to be identified and technological packages established that can be adapted to the reality of rural regions where the crop is to be disseminated. The most promising areas will have a cool climate and an even distribution of rainfall throughout the year. It can well be inserted into highland coffee farms, especially from a point of view of diversification of a crop exposed to rising

phytosanitary risks (leaf rust) and reduced viability in the face of climate change. Academic research centres are an essential part of this line of experimentation.

Experience with different species of *Plukenetia* shows that marketing is implemented after the supply. Both in Central America and in foreign markets, the small amounts that are produced in the start-up phase are very well received and are easily marketed at favourable prices in local farmer's markets. It is essential to first develop the domestic market to avoid swings in export markets, which with present-day communications media is more feasible than in past decades, as in the case of Peru. In addition, the population density in Central America (on average 80 hab./km^2) is more than triple that of Peru (23 hab./km^2), which facilitates the channelling of the raw material to urban areas.

As a perennial crop, sacha inchi can help stabilize the population and thus help reduce shifting cultivation and the advancement of the agricultural frontier into the interior of natural areas not spoiled until now. Its permanent dependence on water can help maintain awareness of the need to safeguard forest resources, whose presence is vital for future access to water sources. In addition, being a high-value product associated with a quasi-captive market of increasingly health-aware consumers, there is no need to pursue extremes of productivity. This is consistent with the non-specialized production pattern on small farms.

As for processing (extraction and packaging of oil), there is a big difference in added value between the agricultural product and the final product. Nevertheless, oil extraction does not require highly sophisticated facilities. This suggests envisaging the development of the value chain in the hands of the organized small producers themselves, either in organic farmers' trade associations or in local organizations (foundations, associations and indigenous communities), whose challenge it is to find a synergy between the development of value chains and the conservation of their natural environment.

Notes

1 Source: Global Biodiversity Information Facility, see http://eol.org/pages/1152376/maps.

2 León (2014) mentions exports of Sacha inchi oil of 300 MT in 2013, with a value of USD 3.5 million, and refers to sources that predict 800 MT for 2014. The main markets are the USA and Canada.

3 See http://ec.europa.eu/food/food/biotechnology/novelfood/notif_list_en.pdf#page=71 From 1997 to 2012, the sale of Sacha inchi oil was forbidden under the EU Novel Food Regulation .

4 Food Safety Authority of Ireland (undated), Substantial Equivalence Opinion - Inca Inchi Virgin Oil.

5 Regulation (EC) 258/97 of 27 January 1997 http://ec.europa.eu/food/food/biotechnology/novelfood/index_en.htm.

6 See Organic Wellness News, 6 February 2014. The import of Sacha inchi seeds remains subject to the tightest restrictions under the Novel Food Regulation.

7 Other species include Plukenetia verrucosa (a.o. in Trinidad), P. supraglandulosa (French Guyana and Amapá, Brazil, ref. Gillespie, 1993) and P. carabiasiae (Oaxaca, Mexico; Jiménez et al., 2000).

8 *Itch much* is used in the traditional craft of the Yucatán peninsula, where baskets are made of the wild vine (Arce and Armijo, 2011).

[9] A comparison can be made with amaranth (*Amaranthus cruentus*), a native of Middle America and only recently promoted in Central American agriculture (Benda Garcia, 2012). Amaranth is known as *kiwicha* in Peru (*A. caudatus*) and it is cultivated and marketed more widely along with quinoa, a nutritious Andean grain like amaranth. Both Peruvian products are enjoying ever greater acceptance outside of Peru (http://www.inkanatural.com/es/arti.asp?ref=amaranto).

[10] Long-term diversification practices are scarce but they do occur, e.g. in Belize: http://permaculture.com.au/tropical-permaculture-agroforestry-central-america/.

[11] In Colombia, successful Sacha inchi cropping is reported from areas affected by anti-coca toxic substances: http://www.unep.org/pdf/Tunza_9.1_Span_lr.pdf.

[12] http://florajournal.com/vol1issue3/aug2013/29.1.pdf

[13] http://www.colecionandofrutas.org/plukenetiaserrata.htm

[14] http://link.springer.com/article/10.1007%2Fs12231-013-9247-2#page-1

[15] For example: http://www.colbio.com/semillas/sacha-man%C3%AD/

[16] Although the flowers are hermaphroditic (with both male and female parts), the shedding of pollen does not occur at the time when female parts are receptive.

[17] Auxins are plant hormones which function as plant growth regulators.

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