Forests, Trees and Livelihoods, 2006, Vol. 16, pp. 85–101
1472-8028 $10

THE CULTIVATION OF CAMU CAMU (*MYRCIARIA DUBIA*): A TREE PLANTING PROGRAMME IN THE PERUVIAN AMAZON

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ABSTRACT

New initiatives in agroforestry are giving increasing importance to the domestication of indigenous trees whose products traditionally have been gathered from the forest, in order to achieve substantial increases in the quantity and quality of produce through cultivation. These efforts seek to enhance rural livelihoods by generating cash income through the sale of agroforestry tree products. *Myrciaria dubia* (camu camu) is a small tree of riparian habitats, native to Amazonia. Its fruits have increasing commercial potential in local, regional and international markets due to their high Vitamin C content. The government of Peru has been promoting the cultivation of the tree in support of a new export industry and to increase rural incomes. This paper examines: (i) the initial processes of domestication for *M. dubia*, (ii) new forms of land use and farmer experimentation with this species in floodplain agroforestry systems, (iii) the environmental implications of this new practice, and (iv) the influence of extension agencies, markets and recent challenges facing small farmers in northeastern Peru.

Key words: domestication, extension and adoption services, floodplain agroforestry, native fruits, planting stock, rural livelihoods.

INTRODUCTION

The domestication of indigenous trees is viewed as a sustainable development pathway by which farmers, buyers, and processors in the Amazon region enhance their livelihoods and alleviate poverty (Paitán 1997, Salo and Torres 1998). Domestication of indigenous trees can also help to avoid the boom and bust economy that typically occurs when products are harvested from the wild (Clement 1993, Prance 1994). However, if farmers are to adopt these species widely as new crops, they must have access to superior genetic stock in order to maximize the benefits obtained from their cultivation (Leakey and Simons 1998). In addition, ways must be found to avoid the deforestation (Wunder 2001) and the pests and diseases commonly associated with the expansion of agriculture (Clement 1993). These concerns are pertinent to *Myrciaria dubia*

H.B.K. McVaugh (Myrtaceae), commonly known as ‘camu camu’, which has recently become a widely cultivated fruit tree across floodplain environments of the Peruvian Amazon.

Camu camu is a small tree native to wetlands of the Amazon basin, whose nutritious fruit was first sold in Iquitos as one of a multitude of non-timber forest products (NTFPs) extracted from the wild. The tree is an important component of riparian vegetation in Peru and Brazil, and is especially abundant in Peruvian black water river systems. The fruit is a round berry about 2–3 cm in diameter and the pulp contains 2.7–2.8g of ascorbic acid per 100 g. This extremely high vitamin C content (30 times that of an orange) has generated interest in national consumption and the export of products such as beverage concentrate and vitamins. The tree is also highly productive, with some studies of wild populations estimating fruit production at 9000 to 12,000kg per hectare, with the potential to generate exceptional economic returns (Calzada 1980, Peters and Hammond 1990, Zapata and Dufour 1993).

Camu camu planting in Peru started in earnest in 1996 when Government-funded “reforestation” projects were implemented by state and private institutions under the Programa Nacional de Camu Camu (PNCC) for export to Japan. The PNCC initially aimed to plant 10,000 hectares of camu camu with 10,000 rural smallholders living along the floodplains to supplement wild harvesting and raise household incomes. Meanwhile, Peru created incentives for both private industry and non-profit extension organizations to collaborate with the PNCC (Riva 2001, Pinedo-Vasquez and Pinedo-Panduro 2002). Camu camu was therefore being promoted on the otherwise risky floodplains of the Peruvian Amazon as a flood-resistant, highly productive tree crop for agroforestry projects as a way to improve rural incomes and standards of living.

There was much to learn about the domestication of *M. dubia* as an agricultural crop in farmer’s fields (Riva and Gonzales 1997). Floodplain communities in the Peruvian Amazon have a history of resisting external pressures, including agricultural programmes, and choosing to adapt to circumstances in their own, unique ways (Pinedo 2002). Government reports have provided useful information about initial farmer response to programmes promoting the cultivation of NTFPs, but the information is limited in scope (de Jong *et al*. 2000). Consequently, there is a need to understand local variations in agroforestry practices in Amazonia (Smith *et al*. 1998) and to evaluate farmers’ reactions to planting camu camu. Interestingly, the early adoption of camu camu in pilot projects appears to have been more common where farmers were encouraged to combine the government-initiated protocols with their own complex local agricultural practices (Villachica 1996, IIAP 2001, Pinedo-Vasquez and Pinedo-Panduro 2002), but little information exists on either the domestication process of camu camu, or how it was adopted by farmers as projects extended into northeastern Peru.

In genetic terms, domestication is accelerated and human-induced evolution (Leakey and Tchoundjeu 2001), however, the critical feature of domestication is how humans use it to improve their crops by growing selected planting stock (Nabhan *et al*. 2000). The most immediately apparent change under domestication is in morphological characters such as shape, size, and color, particularly in the part of the plant used by humans (Pickersgill and Heiser 1976), as seen in indigenous fruits in West Africa (Leakey *et al*. 2004). In the study area, the fruits of many useful tree species (e.g., *Bactris gasipaes*, *Poraqueiba sericea, Theobroma bicolor*, *Crescentia cujete*, *Pouteria caimito*, and *Inga* spp.) exhibit these effects as farmers have selected planting stock from wild and semi-domesticated tree species and exchanged this genetic material with others. Camu camu, however, was not a component of the traditional agroforestry systems of the region. The very tart fruit was rarely consumed, and until the promotion of camu camu as an edible fruit in the 1970s, there was no significant market for this NTFP. In specific localities it was traditionally used as fish bait, and as a source of high quality firewood (Penn 2004).[1]

Following government recommendations, seeds from the processing factories were used to produce seedlings in nurseries located in the participating communities. This quick and low cost method promoted by PNCC presumably maintained genetic diversity in the planted camu camu as the seeds came from widely dispersed patches of wild camu camu located throughout the Peruvian Amazon and therefore probably minimized the risks of pest and disease attacks (IIAP 2001). In this way, it appears that the initial extensive cultivation of camu camu by the PNCC may have promoted the genetic diversity in camu camu fields, not by traditional human selection, but from the mixing of seeds at processing plants and their redistribution to farmers. This was, however, done in the absence of any genetic selection. Such propagation reflects a degree of domestication commonly referred to as incipient domestication (Sauer 1993, Clement 1999), an important step in the diffusion process of this species in Peru.

STUDY AREA

During 2000–2003, a regional study was conducted with diverse groups of small farmers in 39 communities in four areas of the Peruvian Amazon that had been exposed to the PNCC (Penn 2004). Twenty-eight of these communities were cultivating *M. dubia*, while the others had contributed to the PNCC through their collection of planting stock and interaction with extension agencies. Their locations ranged from Putumayo River in the north,[2] to the Ucayali floodplain near Pucallpa in the south, in fairly evenly spaced clusters about 100–200 km apart in a line running roughly north-south. These communities were mostly small villages with less than 400 residents scattered along the floodplain and where it meets the uplands. Most of the local inhabitants were “ribereños”, a quasi-ethnic group of mestizo people of mixed Amerindian and European

[1]*M. dubia* should not be confused with the larger tree forms of *Myrciaria*, often called camu camu, which were cultivated in the region. They usually occur spontaneously and are then protected.
[2]Two of the communities were located in Colombia.

descent who live along watercourses. Ribereños, like Amazonian Indians, have a great knowledge of forest plants, agroforestry techniques, and hunting and fishing methods (Padoch and de Jong 1987, Chibnik 1991). Farming is the most important economic activity in the region (Chibnik 1994, Coomes 1995). Much of the land used for agriculture in the floodplain consists of old river levee fragments of alluvial soil called "restingas," which may or may not flood on an annual basis. Annual precipitation in the study area is 1700–2800mm, and mean monthly temperatures are 26–28°C (Riva and Gonzales 1997, SENHAMI 1997).

Data were collected from 89 camu camu fields (66% of the fields in these communities) belonging to farmers living in the 28 communities that were cultivating camu camu. Measurements made with the assistance of farmers included:

- the area of the individual fields;
- the spacing between planted camu camu trees;
- occurrence, density and diversity of other crops and
- the incidence of pests and diseases in $10m^2$ plots.

Farmers reported on the field histories, and field surveys were supplemented by interviews with farmer households and groups of community members. The interviews focused on demographic data, local incomes and land-use practices, as well as their decisions for adopting or not adopting the new tree crop.

EFFECTS OF MARKET ACCESS ON CAMU CAMU CULTIVATION

The effects of market access on camu camu cultivation across the region were studied in 89 fields from contrasting locations and floodplain landscapes across the Peruvian Amazon. Forty-six (52%) of these were located within one days travel time from Iquitos, and 43 fields (48%) were located well outside of this area and subject to different market forces (demand). Typically, camu camu farmers grow important annual crops such as manioc, fruits and vegetables between the trees. The Iquitos area is distinct because it is subject to the particular market forces from this large urban center that have important effects on the market-oriented agroforestry systems managed by ribereños (Padoch 1988a, Coomes and Burt 1997). Iquitos is well known for its exceptional diversity of fruits, especially from wild and semi-domesticated trees (Padoch 1988b, Vásquez and Gentry 1989). The design of this study thus allows a test of fields under characteristic "Iquitos market conditions" against the other group of fields outside the influence of Iquitos markets.

Species diversity and planting density

The multitude of fruits sold in Iquitos markets originate primarily from upland rather than the floodplain agroforestry systems (Hiraoka 1986, Denevan and Padoch 1988, Coomes and Burt 1997). The survey in this study showed that the camu camu fields close to Iquitos had 3-fold greater crop diversity and higher planting density for camu camu trees than the other group of fields. In the group of Iquitos area fields, 27 tree crops, especially fruit trees, were cultivated (Table 1), while in the other group of fields only 4 tree crops (capirona [*Calycophyllum* spp.], huito [*Genipa americana*], *Carica papaya*, and andiroba [*Carapa* spp.] were grown with camu camu. 14 fields in the Iquitos area had fruit trees (e.g., 8 with shimbillo [*Inga* spp.], 5 with charichuelo [*Rheedia* spp.], 3 with aguaje [*Mauritia flexuosa*]) 11 of which contained more than 1 species; in contrast only 2 of the more distant fields contained any of the 4 species detailed above. This reflects the greater importance of fruit crops in camu camu fields located close to the markets of Iquitos, and suggests that economically important tree fruits may be more common in floodplain agroforestry systems of this area than was previously assumed. Moreover, farmers have started to cultivate camu camu with the commonly marketed fruit crops they have traditionally grown on the floodplain when responding to the demands of the PNCC to grow camu camu. The adaptability of farmers is also illustrated by their preference for cultivating manioc, maize, cucumber, beans and tomatoes with camu camu in the locations close to Pucallpa and other towns along the Ucayali River where market preferences differ from those of Iquitos.

At least 55 different crops were being cultivated in association with camu camu but none of them were present in even half the fields surveyed (Table 1). The two most popular crops were manioc and maize, both important subsistence and commercial crops, followed by fruits such as watermelon, cocona [*Solanum sessiliflorum*], and shimbillo [*Inga* spp.]. The fields near Iquitos had greater overall crop diversity than the other fields (50 vs. 23), including a greater number of tree species (27 vs. 4), and fruit crops (20 vs. 7). Up to 10 crops per field were cultivated in association with camu camu, but 34% of these fields consisted solely of camu camu trees (Figure 1). Three or more crops were found in 36% of fields. Sweet potato, a crop highly recommended by extensionists, was not found in any field.

Contrary to the recommendations of extensionists, farmers discovered that they could utilize camu camu trees to support climbing plants such as cucumbers, beans, and caihua (*Cyclanthera pedata*). Smaller annual crops such as tomatoes, peppers and cocona (*S. sessiliflorum*) were preferred as the trees increased in size. Conversely, space-demanding semi-perennials such as bananas and sugar cane became relatively rare, and usually occupied gaps where camu camu was absent. Tree crops other than camu camu were usually scattered at low densities within fields or near field edges. Spontaneous crops were relatively uncommon and generally small in stature (e.g., pichana [*Sida* spp.], mullaca [*Physalis angulata*], jergon sacha [*Dracontium loretense*]).

TABLE 1

Crops cultivated in association with camu camu in the floodplains of the Amazon, Tahuayo, Ucayali and Putumayo Rivers in the Peruvian Amazon in 2002–3.
* Indicates species which were usually spontaneous in fields.

Vernacular name	Scientific name	Main product	No. of fields	Iquitos fields	Other fields
Camu camu	*Myrciaria dubia*	Fruit	89	46	43
Yuca	*Manihot esculenta*	Root	30	9	21
Maíz	*Zea mays*	Grain	22	7	15
Sandia, sandília	*Citrullus lanatus*	Fruit	12	4	8
Cocona	*Solanum sessiliflorum*	Fruit	11	9	2
Capirona	*Calycophyllum spp.*	Fuelwood	9	2	7
Shimbillo	*Inga spp.*	Fruit	8	8	0
Pepino	*Cucumis anguria*	Vegetable	7	2	5
Frijol	*Phaseolus spp.*	Bean	6	2	4
Plátanos	*Musa spp.*	Fruit	6	6	0
Papaya	*Carica papaya*	Fruit	6	5	1
Caihua	*Cyclanthera pedata*	Vegetable	5	3	2
Melon, melon dulce	*Cucumis melo*	Fruit	5	2	3
Charichuelo*	*Rheedia spp.*	Fruit	5	5	0
Chiclayo	*Vigna unguiculata*	Bean	4	3	1
Tomate	*Solanum lycopersicum*	Vegetable	4	3	1
Guava	*Inga edulis*	Fruit	4	4	0
Ají	*Capsicum spp.*	Condiment	3	2	1
Aguaje	*Mauritia flexuosa*	Fruit	3	3	0
Caña	*Saccharum officinarum*	Juice	3	2	1
Huito*	*Genipa americana*	Fruit	3	2	1
Huingo	*Crescentia cujete*	Crafts	3	3	0
Bijáo*	*Ischnosiphon spp.*	Wrapper	3	3	0
Sacha culantro	*Eryngium foetidum*	Condiment	2	1	1
Zapallo	*Cucurbita spp.*	Vegetable	2	0	2
Mullaca*	*Physalis angulata*	Fruit	2	1	1
Jergon sacha*	*Dracontium loretense*	Medicine	2	2	0
Maní	*Arachis hypogaea*	Legume	2	2	0
Shahuinto	*Myrciaria spp.*	Fruit	2	2	0
Parinari, supay ocote	*Couepia subcordata*	Fruit	2	2	0
Cedro*	*Cedrela spp.*	Wood	2	2	0
Amacísa	*Erythrina spp.*	Medicine	2	2	0
Huasaí	*Euterpe precatoria*	Palm heart	2	2	0
Vino huayo*	*Coccoloba sp.*	Fish bait	2	2	0
Albaca, sacha albaca	*Lantana camara*	Medicine	1	1	0
Malva	*Malva sp.*	Medicine	1	1	0
Topa*	*Ochroma spp.*	Wood	1	1	0
Piña	*Ananas comosus*	Fruit	1	0	1
Andiroba	*Carapa sp.*	Wood	1	0	1
Lagarto caspi*	*Callyophyllum sp.*	Wood	1	0	1
Shiringilla*	*Micrandra sp.*	Fish bait	1	0	1
Tamara*	*Crataeva sp.*	Fish bait	1	1	0
Pichana	*Sida sp.*	Brooms	1	1	0

continued

Table 1 continued

Vernacular name	Scientific name	Main product	No. of fields	Iquitos fields	Other fields
Biscocho huayo*	*?*	Nut	1	1	0
Sinamillo, bacabillo	*Oenocarpus sp.*	Fruit	1	1	0
Guayába	*Psidium guajava*	Fruit	1	1	0
Caimito	*Pouteria caimito*	Fruit	1	1	0
Uvilla	*Poourouma cecropiifolia*	Fruit	1	1	0
Pijuayo	*Bactris gasipaes*	Fruit	1	1	0
Arazá, guayaba brasilera	*Eugenia stipitata*	Fruit	1	1	0
Punga	*Pseudobombax sp.*	Wood	1	1	0
Pashaco blanco*	*Parkia sp.*	Wood	1	1	0
Palometa huayo*	*Alchornea sp.*	Fish bait	1	1	0
Cuchillo vaina*	*?*	Medicine	1	1	0
Uvos	*Spondias mombin*	Fruit	1	1	0

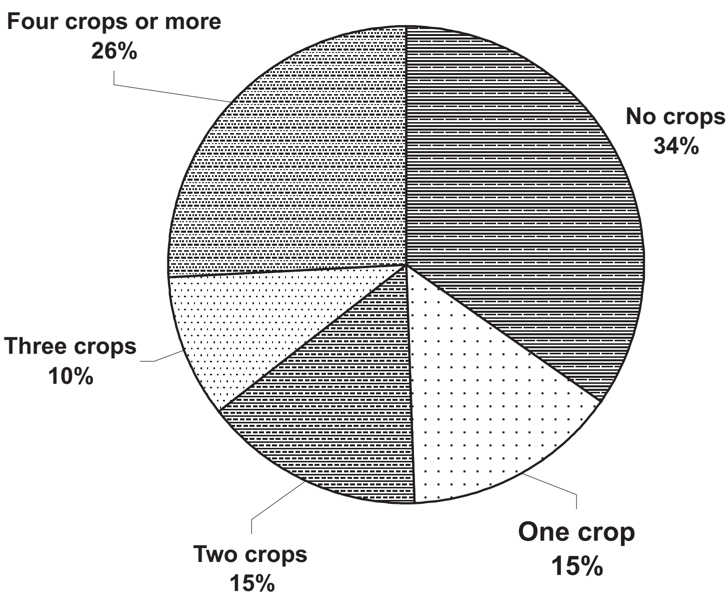

Figure 1. Number of crops cultivated in fields with camu camu in the floodplains of the Amazon, Tahuayo, Ucayali and Putumayo Rivers in the Peruvian Amazon in 2002–3

Just over half of the camu camu fields of five or more years old still contained multiple crops. The absence of any correlation between field age and crop diversity ($r^2 = 0.168$), indicates that crop diversity in these fields does not decrease over time Most farmers (66%) are cultivating camu camu as part of a sustained mixed agroforestry system and not as monocultural orchards (Nebel 2001). A lack of seeds, a common problem for floodplain farmers in the region

(Penn 2004), was given as the main reason why high value crops such as vegetables and melons were not intercropped with camu camu.

Small farmers plant trees in extension projects if the costs are minimal and their subsistence crops are not affected (Park 1997). The trees were, however, usually planted at a spacing of 3 × 3m, as recommended by PNCC so that they could be intercropped with manioc. In contrast, camu camu spaced 2 × 3m, as recommended for maximum camu camu yield (IIAP 2001) mitigated against other crops. Farmers recognized that for 2–3 years manioc was compatible with camu camu, but then competition would reduce yields. They explained that they would prefer to grow camu camu at wider spacing (4 or 5m between trees) and intercrop manioc, maize and melons in the fertile soils between the trees on a permanent basis. Most farmers wanted to maintain their production of annual staple food crops on these relatively high value floodplain lands. On their own initiative, a few farmers had experimented with small (< .25 ha), more densely planted plots trying to mimic the natural spacing of young camu camu in the wild.

Location and size of fields

The PNCC protocols had recommended that camu camu should be planted in floodplain environments on the slight rise of low restingas ("restinga baja"). On these landforms, annual innundation helps maintain soil fertility and limits the development of weeds, pests, and diseases, minimizing labour requirements with less risk of submerging the fruits. The closely spaced planting arrangement aims to maximize camu camu productivity with less emphasis on associated annual crops. These floodplain fields were supposed to be one hectare in area and located well away from riversides, to avoid erosion or heavy sedimentation (IIAP 2001).

The PNCC was initiated in great haste and thus the assistance promised to farmers by government agencies and NGOs for labor-intensive activities, like site clearance, was in fact rarely delivered. Consequently, farmers wishing to cultivate camu camu were forced to use readily available or easily cleared lands, such as young fallows (Penn 2004). These were mostly the farmers with larger landholdings on the floodplains. Few (10%) of the camu camu fields were cut from mature forest, while more than half (57%) were started on non-forested lands that were already cultivated, and 27% were cut from young fallows less than five years old (Figure 2). A typical camu camu field was less than one-half hectare in area, much smaller than recommended by the extension workers (Table 2). In contrast to the hypothesis of Wunder (2001), who believes that the expansion of markets for NTFPs will cause extractors to clear natural forest, only 10% of fields were cut from mature forests. However, impacts on the floodplain landscapes presented here may only represent the initial impacts of a new boom in NTFP planting and more extensive clearing of mature forests may follow an expansion of camu camu cultivation.

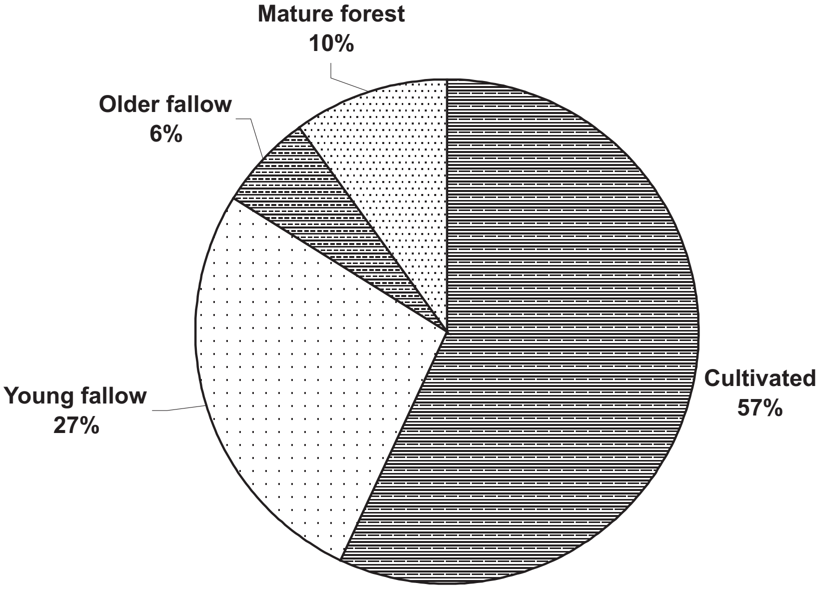

Figure 2. Lands used for camu camu cultivation in the floodplains of the Amazon, Tahuayo, Ucayali and Putumayo Rivers in the Peruvian Amazon in 2002–3

TABLE 2

Size of fields planted with camu camu in the floodplains of the Amazon, Tahuayo, Ucayali and Putumayo Rivers in the Peruvian Amazon in 2002–3.

Sample	All fields (n = 89)	Iquitos area (n = 46)	Non-Iquitos area (n = 43)
Mean field area (ha)	0.67	0.45	0.91
Median	0.45	0.31	1.00
Std. deviation	0.60	0.39	0.70
Range in field area	0.05–3.0	0.05–2.0	0.05–3.0

The Iquitos market area fields were significantly smaller in size and located closer to homes than the other group of fields. Two-thirds of the smallest fields (< 0.25ha) were in the Iquitos market area, with fields from outside that area being significantly larger ($p < 0.01$) (Table 2). In many cases, when the planting requirements of the PNCC could not be met, farmers were willing to experiment on a small scale, and often in their home gardens. Home gardens are a common place for Amazonian farmers to experiment with agroforestry (Smith 1996) and this smaller-scale approach to a new crop is an example of the step-wise nature of farmer experimentation with new techniques (Bunch 1989). About 20% of these farmers were not formal participants in the planting programmes, preferring to experiment without the constraints imposed by extension agencies.

A typical field in the remote areas was located 10 minutes away from the home, but near Iquitos fields were located significantly closer to the owner's home ($p < 0.01$) (Table 3). By investing their efforts in smaller fields located closer to their homes they also reduced the risk of theft, a major worry for farmers experimenting with new crops in this particular area.

Of the 89 fields surveyed, less than one-fifth (19%) of the fields were located on the recommended low restingas (Figure 3). Instead, nearly half (47%) were located in the lowest lands (bajeales) where seasonal floodwaters could easily cover the trees during the fruiting period. Most farmers felt that the trees would grow better in conditions that mimicked those of wild camu camu, rather than on the low 'restingas'. This is not surprising, as farmers in this region have a tradition of experimenting with the cultivation of wild species for markets (Denevan and Padoch 1988). About one-third (29%) of the fields were located directly on riversides, in danger of erosion or sediment damage. A typical field was located just 50 meters from the nearest river and over three-quarters (77%) of fields were located 150m or less from the edge of a river. In 75% of the fields the trees were planted at a distance of 3 × 3m. A typical field contained 1200 trees per hectare, quite close to the density recommended by PNCC of 1111 trees per hectare. Near Iquitos fields had a higher mean density of trees than the other fields.

GENETIC VARIATION AND IMPROVEMENT

When farmers planted camu camu they usually selected the largest, most vigorous plants from the local nurseries to transplant in their fields, even if they had not yet reached the prescribed height of 30cm. These seedlings tended to come from very ripe fruits and those with larger seeds. Farmers with access to wild camu camu also made use of wild seedlings. Just over half of camu camu fields surveyed in this study (56%) were managed by families with access to wild camu camu fruit, and 86% of their fields were at least partially stocked with wildings. For ease and convenience, extension agencies would often buy wildings; as in the case of obtaining seed from the factories, there was no selection of planting stock based on desirable traits such as productivity or

TABLE 3

Travel time from farmers' homes to camu camu fields in the floodplains of the Amazon, Tahuayo, Ucayali and Putumayo Rivers in the Peruvian Amazon in 2002–3.

Distance to homes	All fields (n = 89)	Iquitos area (n = 46)	Non-Iquitos area (n = 43)
Mean travel time (minutes)	11.8	6.9	17.1
Median travel time	10	5	15
Std. deviation	11.9	9.0	12.4
Range in time	1 to 50	1 to 50	1 to 45

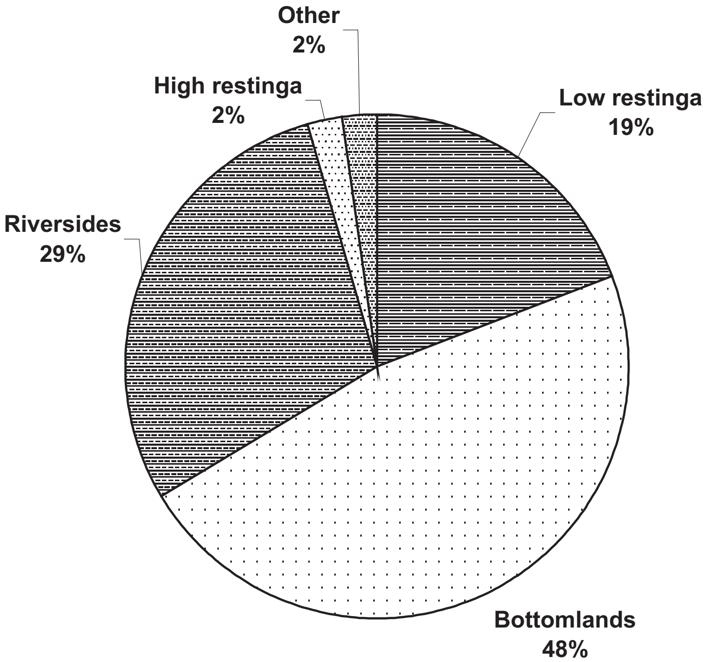

Figure 3. Landforms used for camu camu fields in the floodplains of the Amazon, Tahuayo, Ucayali, and Putumayo Rivers in the Peruvian Amazon in 2002–3

fruit quality. In this phase of camu camu domestication, there was no attempt to enhance the performance of the trees. These methods of acquiring planting stock are common in tree planting programmes in the Amazon region, where efforts focus on obtaining the quantities of planting stock needed as quickly as possible (Penn 2004). However, State agencies produced quantities of grafted planting stocks during 1995–97, in order to produce trees that would mature more quickly than those from seedlings (i.e., fruiting two years after planting). This was done without selecting either the rootstock or scion for any desirable traits, again foregoing the opportunity for crop improvement. Less than 10% of fields surveyed contained grafted stock, with most of these located where wild camu camu was absent or rare.

Little is known about genetic variability in camu camu. The leaves of wild *Myrciaria dubia* are typically 6cm wide and 10cm long, while the fruit is from 2–3cm in diameter (Peters and Hammond 1990, Villachica 1996, IIAP 2001). Evidence from this study in different parts of the Peruvian Amazon, however, suggests that the variation in the both leaves and fruit size are considerably greater. For example, along the Putumayo River, large stands of camu camu had leaves over 7cm wide and 14cm long and fruits over 4cm in diameter (Penn 2004). At the other extreme, some trees in fields near Iquitos had very small leaves, just 2.5 cm wide and 7.5 cm in length, while within the same field or close by in neighbouring fields, many trees of the same age were found with very large leaves (7.5 cm wide and 14.3cm long) This variation is perhaps not unexpected, given the mix of planting stock used in the PNCC plantings. Certainly some of the seeds in these fields near Iquitos may have originated in the Putumayo region of Peru and Colombia.

Variation in tree form was difficult to assess because farmers were pruning the trees to varying degrees. In general, unpruned trees exhibited more variation in stem diameter than in height. Some trees were quite narrow crowned, while others had more heavily branched architecture. Farmers indicated that they were still uncertain as to which form would ultimately produce more fruit.

The phenology of camu camu was also found to be quite variable. In northeastern Peru, wild camu camu usually fruits once per year, from November to March, with the peak season during December to February. This varies somewhat from year to year and by location, often contingent on the period when floodwaters drop (IIAP 2001). With cultivated camu camu, the fruiting period appears to be less seasonal, even in fields from a single source. Typically, flowers and fruits at all stages of development can be found on a single tree. Moreover, the trees commonly experienced two fruiting cycles within a period of six months. Near Pucallpa in the Ucayali floodplain, where *M. dubia* is not found in the wild, most fruiting occurred during August to October, with a smaller crop between January and April. In this area trees produced at least some fruit throughout the year, and some farmers reported that their biggest harvests were in April. Overall, farmers were concerned that the yields from the planted stock were not as high as from wild trees.

Leakey and Simons (1998) have suggested that the domestication of indigenous species provides an incentive for farmers to adopt them in agroforestry practices and that access to superior genetic stock is a requirement to maximize the benefits obtained from their cultivation. In this study, morphological variation was observed between trees within the same field on the floodplain. While soil conditions may cause some variation in growth and structure (Riva and Gonzales 1997), the variation observed in this study, especially the variation in fruit size is likely to have a genetic component. The farmers cultivating camu camu expressed a desire to improve their fruit yields as soon as they gained more knowledge and experience. However, it will be some time before the fruiting cycles are understood, as these fields have only recently come into production. The mixture of planting stock, and variation between trees in fruit and leaf size, phenology and fruiting will provide opportunities for selection, although it remains to be seen whether farmers can take advantage of this variation. Experience with indigenous trees elsewhere suggests that excessive variation deters large-scale buyers but the recognition of superior products is highly beneficial in the domestication process (Leakey *et al*. 2003; Tchoundjeu *et al*. this volume). This will no doubt lead to farmer innovation with the on-farm selection of planting stock based on productivity and fruit quality, whether in new fields, or to replace existing trees. Such efforts would complement current genetic selection programmes in Peru aimed at improving both productivity and vitamin C content (Pinedo 2002). It is clear therefore that camu camu is starting to become what Simons and Leakey (2004) have called an 'agroforestry tree product' (AFTP) through the integration of farmers own actions with the recommendations of government initiated planting programmes.

PESTS AND DISEASES

Sixty-four potential insect pests have been identified for camu camu (Delgado and Couturier 2002), while Peruvian researchers have identified four insects that are prevalent enough to cause significant economic damage to cultivated camu camu. These are common even in a low restinga environment where seasonal flooding is reported to control their populations (IIAP 2001). One of these (*Tuthillia cognata*) lays eggs in the leaves, two (*Conotracheius dubiae* and *Edessa* sp.) attack the fruit and the fourth is a shoot borer (*Xylosandrus compactus*). In this study, the four insects were found in over half (52%) of the camu camu fields. Farmers, however, did not consider any of them to be harmful to the trees. In fact, they considered the shoot borer to boost fruit yields, because new shoots would form after an attack by the insect.

Similarly, a leaf fungus (*Fumago* sp.), found in 34% of the fields, was not of concern to the farmers, as the trees lose most of their leaves anyway during seasonal floods. Altogether, these pests and diseases were found in 67 (75%) of the camu camu fields. Farmers were much more concerned by a parasitic climbing plant (*Moradendron* spp.) commonly called "suelda con suelda" or "mata palo" found in just 15% of the fields. Farmers considered this a problem because it could smother the trees and interfere with their development. While these pests and diseases were found in surveyed fields all across the region, they were most abundant in specific locations. A striking pattern was observed along the Ucayali River floodplain, where in an area characterized by decades of agricultural development pests were most common, but absent in nearby fields cut from mature forest (Penn 2004).

Evidence from this study showed that like other new crops introduced into agricultural systems (Schroth *et al*. 2000), camu camu trees were hosts to species with potential to become pests and diseases, although there was broad agreement among farmers that floodwaters help to control them. Results of surveys from the Ucayali floodplain fields suggest and farmers agreed that these maladies are usually less common in fields cut from mature forests. Nevertheless, other Amazonian species (e.g., cacao and rubber) have experienced disease problems when widely cultivated (Smith *et al*. 1992). These risks are probably exacerbated when indigenous species are domesticated and grown in monocultures, or in mixtures with related species, such as camu camu and arazá (*Eugenia stipitata*) and guayába (*Psidium guajava*), other members of the Myrtaceae. Consequently, the focus of camu camu farmers on mixed species agroforestry plantings is probably highly desirable. The unknown reason for sudden die-back in wild patches of camu camu and its possible spread to cultivated plants, is of primary concern (Penn 2004).

ENVIRONMENTAL IMPLICATIONS OF CAMU CAMU CULTIVATION

The floodplain forests of Amazonia are threatened ecosystems that are especially important for fruit-eating fish (Araujo-Lima and Goulding 1997). Camu camu is one of the important fruits in the diet of commercially valuable fish, like "gamitana" (*Colossoma macropomum*). In camu camu fields, at least four tree species were protected to attract fish into flooded fields and for use as fish bait (Table 1). According to the farmers, the addition of camu camu has attracted more fish to their fields during flood season and, as in wild stands of camu camu, many farmers run gill nets in between the fruiting trees during periods of inundation. Near Pucallpa, farmers explained how camu camu cultivation has brought back tree farming to intensively cropped floodplain fields where the practice had almost disappeared during the last two decades. Although deforestation and environmental degradation are often blamed on farmers trying to escape from poverty (Wunder 2001), at least in this situation the cultivation of camu camu seems to have provided an alternative to deforestation (Current *et al*. 1995) for most participants in the programme, and these new agroforestry systems contribute to the conservation of biodiversity in agricultural landscapes (Schroth *et al*. 2004).

Assuming that fish, birds, and human activity may be dispersing the camu camu fruit, is there need for concern about the unintentional spread of economically valuable tree species as invasive weeds across extensively used landscapes (Unruh 1994), especially as the ecology of the species is poorly understood, even by ribereños. Perhaps this is less of an issue in areas where camu camu occurs in the wild, but it may be a potential problem around Pucallpa and along stretches of white water rivers such as the Amazon and the Ucayali where the species does not exist in the wild. To date, the evidence suggests that *M. dubia* does not spread spontaneously as easily as some other fruit trees of the floodplains such as *Rheedia*, *Genipa* or *Inga* species, but this should be monitored. Ecological concerns also arise from the proximity of wild camu camu to cultivated plants.

CONCLUSIONS

The spread of cultivation of camu camu in northeastern Peru was initiated through a top-down, rapidly imposed government programme. The fact that it has been fairly successful in specific locations is largely attributable to the innovative nature of the older and more experienced floodplain farmers ('ribereños'); who combined government protocols of the Programa Nacional de Camu Camu with local agricultural practices, planting unimproved but genetically diverse planting stock. These farmers preferred to plant the already cleared lowest lands rather than the recommended "restinga baja", and in smaller fields than envisioned by planners. Agroforestry with camu camu has become an alternative form of floodplain agriculture, returning tree cultivation to intensively cropped lands. The greatest crop diversity is found in areas located within one day's travel of

Iquitos where camu camu is cultivated in association with traditionally marketed crops, changing both cropping patterns on the floodplain and the biophysical environment. These changes seem to have also had beneficial impacts by providing additional habitat for some fish species.

Cultivated camu camu trees exhibit considerable variations in phenology and morphology, probably reflecting the diverse origins of the planting stock. Now that incipient domestication has occurred farmers have expressed their desire for the improvement of this crop and efforts to improve the productivity and Vitamin C content are underway. The identified morphological diversity underscores the importance of conducting a region-wide domestication programme that utilizes the full range of variation and seeks a better understanding of the species genetic attributes now that widespread commercialization is taking place. Lessons from this study suggest that if new tree crops are to be widely adopted by smallholders in the region, extension agencies must work closely with them in a sustained effort and on a smaller scale than the PNCC. If Peru is to capitalize on what has been achieved, national and international markets for the fruit and its products need to be developed.

ACKNOWLEDGEMENTS

The assistance of residents of the Tahuayo, Amazon, Ucayali, Putumayo, and Nanay Rivers is gratefully acknowledged. Special thanks go to colleagues and staff at IIAP-Iquitos, IIAP-Pucallpa, INIA-Iquitos, PNCC-Iquitos, PNCC-Pucallpa, INADE-Iquitos, INRENA-El Estrecho, and INPA-Manaus. Mario Pinedo, Jorge Soplin, Dennis Huayllahua and Pilar Diaz are acknowledged for their exceptional support and collaboration. Field research was generously funded by the Rainforest Conservation Fund (RCF) of Chicago, Illinois; the Dallas Zoological Society, and the Tropical Conservation and Development Program of the University of Florida.

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