

1492 AND THE LOSS OF AMAZONIAN CROP GENETIC RESOURCES.

I. THE RELATION BETWEEN DOMESTICATION AND HUMAN POPULATION DECLINE.^{1, 2}

CHARLES R. CLEMENT

Clement, C.R. (*Instituto Nacional de Pesquisas da Amazônia, Cx. Postal 478, 69011-970 Manaus, AM, Brasil*). 1492 AND THE LOSS OF AMAZONIAN CROP GENETIC RESOURCES. I. THE RELATION BETWEEN DOMESTICATION AND HUMAN POPULATION DECLINE. *Economic Botany* 53(2):188-202. 1999. *There may have been 4-5 million people in Amazonia at the time of European contact. These people cultivated or managed at least 138 plant species in 1492. Many of these crop genetic resources were human artifacts that required human intervention for their maintenance, i.e., they were in an advanced state of domestication. Consequently, there was a relationship between the decline of Amazonian Amerindian populations and the loss of their crop genetic heritage after contact. This relationship was influenced by the crop's degree of domestication, its life history, the degree of landscape domestication where it was grown, the number of human societies that used it, and its importance to these societies. Amazonian crop genetic erosion probably reflects an order of magnitude loss and the losses continue today.*

1492 e a perda dos recursos genéticos da Amazônia. I. A relação entre domesticação e o declínio das populações humanas. *A Amazônia poderia ter tido de 4 a 5 milhões de habitantes quando os Europeus chegaram. Estes povos cultivaram ou manejaram pelo menos 138 espécies vegetais em 1492. Muitos destes recursos genéticos eram artefatos humanos que requeriam a intervenção humana para sua manutenção, ou seja, estavam num estado avançado de domesticação. Conseqüentemente, existiu uma relação entre o declínio das populações indígenas da Amazônia e a perda de seus recursos genéticos após o contato. Esta relação foi influenciada pelo grau de domesticação do cultivo, sua história de vida, o grau de domesticação da paisagem em que foi cultivada, o número de sociedades indígenas que o utilizou, e sua importância a estas sociedades. A erosão dos recursos genéticos indígenas da Amazônia provavelmente reflete uma perda de um ordem de magnitude e as perdas continuam hoje.*

Key Words: Amazonia, landscape domestication, crop domestication, pre-Columbian demography, European contact, genetic erosion.

The crop genetic resources of the Neotropics are extremely rich and varied. They represent one of the greatest pre-Columbian Amerindian achievements and continue to benefit humans around the world (Harlan 1992:235). At least 257 species were cultivated in the Americas when Columbus arrived in 1492 (León 1992), several of which are staples today in various parts of the world, e.g., maize (*Zea mays*), potato (*Solanum tuberosum*), and cassava (*Manihot esculenta*). Many of these crop genetic resources are human artifacts and depend upon humans for their continued existence. During the centuries immediately after European contact, human populations in the Americas were drastically reduced, with as many as 90-95% of the people killed by European diseases or resisting the conqueror's attempts to enslave them (Denevan 1992b; Dobyns 1966). Amazonia occupies half of South America but, because of lack of data, is often neglected when discussing American crop origins and

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² Dedicated to the memory of Paulo Sodero Martins, 1941-1997, fellow student, researcher and professor of South American crop domestication, origins and biogeography.

diversity, while attention is focused on the better studied Andes (Pearsall 1992). In this paper, I hypothesize that this lack of attention is not due to a paucity of indigenous crop plants in pre-Columbian times, but is partially the result of the post-Columbian demographic collapse in the Amazon basin and the adjacent lowlands in northern South America. A companion paper discusses the biogeography of crop diversity at contact.

American prehistory is now the subject of ample debate generated by new, sometimes controversial research findings. Genetic analyses (e.g., Bonatto & Salzano 1997a, b) suggest human arrival in the Americas well before 12,000 years before present (BP), the date most widely accepted until recently (Cavalli-Sforza et al. 1994). The earliest humans in South America are now thought to have been broad-spectrum hunter-gatherers (Dillehay et al. 1992), and occupied parts of Amazonia very early (Roosevelt et al. 1996). The oldest pottery yet reported was recently found along the eastern reaches of the Amazon River, dated to 7-8,000 BP (Roosevelt et al. 1991). Pottery is generally associated with a shift to sedentary lifestyles (Meggers 1988), necessary for intensive agricultural development. In the millennium before contact, some human societies built earthworks in various parts of lowland northern South America. These earthworks were designed to control water for crop production (Denevan 1966; Denevan and Zucchi 1978), or as habitation mounds (Roosevelt 1993), suggesting high local human population densities or long gestation periods or efficient societal organization to supply the labor for their construction.

When Francisco de Orellana descended the Amazon River in 1542, he reported high population densities along the Amazon River floodplains, the *várzeas* (Carvajal 1894; Denevan 1992b), although the reliability of this report is questioned (Galloway 1992 and Gheerbrant 1992, cited by Meggers 1993-5). Denevan (1992a) emphasizes, however, that “high” is relative to other parts of Amazonia, not to the Andes, MesoAmerica or some Caribbean islands. Given the long occupation and the possibility of advanced societies (Roosevelt 1993), one would expect to find a rich crop genetic heritage, as occurs in other areas with long occupation and/or advanced societies (Harlan 1992:52; Hawkes 1983:67; Vavilov 1992a, b).

A rich crop genetic heritage and associated crop management practices were probably major instruments for “the remarkable success of the indigenous population in enhancing the subsistence potential of one of the world’s most unpredictable and ecologically complex regions...” (Meggers 1992a:38). In this paper I hypothesize that a significant portion of this heritage was lost when the indigenous human populations were nearly eradicated. Due to the lack of physical evidence, i.e., the crop genetic diversity itself, this paper defines landscape and plant domestication and relates them to genetic erosion when human populations disappear; lists the crop species probably present at contact and categorizes them with respect to their degree of domestication; and reviews estimates of Amerindian population density at contact and the extent of population decline suffered by these peoples. The synthesis of this information provides an order of magnitude estimate of the post-contact collapse of Amazonian crop genetic resources.

LANDSCAPE AND PLANT DOMESTICATION

Clear definitions of domestication are essential to understanding the rapid loss of crop genetic resources in Amazonia after European contact. Domestication of a plant or animal species is a co-evolutionary process, so one expects to find plant or animal populations that exhibit various degrees of domestication (Harlan 1992:64). Domestication of the biotic and abiotic landscape is a cultural process, where human knowledge about the consequences of environmental manipulation accumulates and becomes more comprehensive over time (Harris 1989). Consequently, it is important to define both plant and landscape domestication

and some categories within each that are important for the present discussion. As Harris (1989) emphasizes, domestication is a continuum of human investment in selection and environmental manipulation, so its subcategories are merely constructs that imperfectly reflect the real world. It is also important to remember that indigenous peoples frequently practice(d) all forms of landscape domestication at the same time (Harris 1989; Rindos 1984:153) and that they do not always distinguish domesticated from wild plants the way I do here (V.M. Patiño, pers. com., 1994).

Plant Domestication is a co-evolutionary process by which human selection on the phenotypes of promoted, managed or cultivated plant populations results in changes in the population's genotypes that make them more useful to humans and better adapted to human intervention in the landscape. As Darwin (1882) pointed out, human selection may be either unconscious or directed (Heiser 1988). For plant domestication to take place, however, there must be selection and management to cause differential reproduction and survival, contrary to Rindos' (1984:154) definition that includes co-evolution without human selection. The degree of change in the targeted population can vary:

1. **Wild:** A naturally evolved population whose genotypes and phenotypes have not been modified by human intervention.
2. **Incidentally Co-Evolved:** A population that volunteers and adapts in a human disturbed environment, possibly undergoing genetic change, but without human selection. This definition corresponds approximately to Rindos' (1984:154) "incidental domestication." Many weeds are examples of incidentally co-evolved species, which can also enter the domestication process if humans start to select for their useful traits and start to manage or cultivate them (Harlan 1992:90).
3. **Incipiently Domesticated:** A population that has been modified by human selection and intervention (at the very least being promoted), but whose average phenotype is still within the range of variation found in the wild population for the trait(s) subject to selection. The variance of this average is probably smaller than that of the original wild population, however, as selection has started to reduce genetic variability. This definition corresponds roughly to Rindos' (1984:158) "specialized domestication."
4. **Semi-Domesticated:** A population that is significantly modified by human selection and intervention (at the very least being managed) so that the average phenotype may diverge from the range of variation found in the wild population for the trait(s) subject to selection. The variance of this phenotypic average may be larger than that of the wild population, because the phenotypic variation now includes both types that are common in the wild population and types that are novel. Underlying genetic variability [e.g., isozyme variation (Doebly 1989)], however, continues to decrease because fewer individuals meet the selection criteria and are therefore included in the next generation. The plants retain sufficient ecological adaptability to survive in the wild if human intervention ceases, but the phenotypic variation selected for by humans will gradually disappear in the natural environment.
5. **Domesticated:** A plant population similar to (4) but whose ecological adaptability has been reduced to the point that it can only survive in human-created environments, specifically in cultivated landscapes (Harlan 1992:64). Genetic variability is generally less than in (4) because of increased selection pressure and loss of ecological adaptation. If human intervention ceases, the population dies out in short order, depending upon its life history, stature and the type of vegetation that invades the abandoned area. In clonally propagated crops, a single genotype may be the domesticate, but also is lost soon after it is abandoned.

5a. **Landrace**: A domesticated (or occasionally semi-domesticated) population selected in a cultivated landscape within a restricted geographical region with high phenotypic variability and relatively high genetic variability.

5b. **Modern Cultivar**: A highly selected and modified plant population or clone adapted exclusively to intensive monocultures with much reduced phenotypic and genetic variabilities.

Landscape Domestication is a conscious process by which human manipulation of the landscape results in changes in landscape ecology and in the demographics of its plant and animal populations, resulting in a landscape more productive and congenial for humans (Chase 1989; Harris 1989; Yen 1989). The intensity of manipulation may vary widely:

1. **Pristine**: A landscape in which humans have not manipulated plant or animal populations. It is unlikely that there was much pristine landscape in Amazonia at contact, nor is there today (Balée 1989; Denevan 1992c; Smith 1995).

2. **Promoted**: In this category desirable plant populations and individuals are encouraged through minimal forest clearance and expansion of the forest fringes (Groube 1989). Even though there may have been a low level of human intervention, the biotic components of this landscape may remain modified long after humans have abandoned the area.

3. **Managed**: In this category the abundance and diversity of food and other useful plant populations may be further encouraged through partial forest clearance, expansion of the forest fringes, transplanting of desirable individual plants or planting of individual seeds, addition of amendments to enhance plant growth, and reduction of competition from non-useful plants (Alcorn 1989; Anderson and Posey 1989; Groube 1989). Groube (1989) further divides this class into “forest management” and “forest gardens.” Again, the biotic components of this landscape may also remain long after humans have abandoned the area and may account for several of Balée’s (1989) anthropogenic forest types, e.g., some palm, bamboo, liana forests, and forest islands.

4. **Cultivated**: This category involves the complete transformation of the biotic landscape to favor the growth of one or a few selected food plants and other useful populations, through forest clearance and burning, localized or extensive tillage, seedbed preparation, weeding, pruning, manuring, mulching, and watering in any combination (Harlan 1992:64). The biotic components of this very artificial landscape do not survive long after human abandonment because the changes that favor the growth of the human selected populations also favor the growth of weeds and the invasion of other secondary forest species; however, it takes a long time to return to a natural state. The abiotic transformations practiced in this landscape often survive for long periods, e.g., the earthworks in various parts of lowland northern South America, such as the Llanos de Mojos (Denevan 1966) or the Llanos del Orinoco (Denevan and Zucchi 1978).

4a. **Swidden/Fallow**: This category is the combination of classes (4) and (3), in that order. The swidden is a cultivated landscape, which yields well for a few years but becomes progressively more difficult to weed and tend as soil fertility decreases. Useful weeds and volunteer or transplanted shrubs and trees are managed at progressively lower intensities until a managed secondary forest results (the fallow) (Denevan and Padoch 1987). This is the most visible sequence of indigenous landscape domestication in Amazonia today (Roosevelt 1989), but may have been less prevalent before the introduction of metal axes (Denevan 1992d). The managed fallow remains long after humans have abandoned it and may account for several of Balée’s (1989) anthropogenic forest types, e.g., Brazil nut (*Bertholletia excelsa*), bacuri (*Platonia insignis*), cacao (*Theobroma cacao*), and pequi (*Caryocar brasiliense*) forests [see also Friel (1978)].

4b. **Monoculture:** This is a cultivated landscape dominated by only one food plant or other useful populations. Species quasi-monocultures [e.g., initially dominated by cassava or maize] are common in new swiddens on the *terra firme* (the non-flooded surfaces of Amazonia) and on the *várzeas* (Roosevelt 1989), and probably existed before contact also.

The phrasing of the above definitions attests to my belief that there is a strong relationship between landscape and plant domestication in the Americas. Wiersum (1997), in fact, defined “co-domestication” of crops and landscapes, which may be the best view of this relationship. There are, however, examples of advanced landscape domestication, verging upon cultivation, without domesticated plants, such as by the Australian Aborigines (e.g., Chase 1989). Furthermore, wild plants can be cultivated without being domesticated (Harlan 1992:64). The inverse is not true, however: domesticated plants, as defined above, cannot be abandoned in unmanipulated landscapes because they have lost their ecological adaptations to natural environments (Harlan 1992:64).

Consequently, when Amazonian landscapes modified by humans were abandoned after European contact, the domesticated plant populations that occurred in them either died out, suffered their own population (and genetic) contraction, or regressed to the wild genotype while also becoming rarer. These changes depended upon the degree of population domestication and life history (herbaceous annuals and semi-perennials; woody perennial shrubs and trees) of the species in question. The time frames are conjectural, but may be estimated based upon life histories (Table 1). Little research has been done on this subject, but the shorter time frames are subject to testing through observation of swidden abandonment. One example is the pejibaye (*Bactris gasipaes*), a domesticated palm, that stops fruiting in second-growth forest when the canopy closes over the palm’s crown 10-15 years after abandonment, thus effectively eliminating the population’s long-term survival (Clement 1990).

Table 1. The sequence of crop genetic erosion (in years after abandonment) in Amazonia depended upon degree of domestication and crop life history and stature.

	anual	semi-perennial	perennial
full domesticate	1-3	2-10	10-30
semi-domesticate	2-10	5-20	20-100
incipiente domesticate	5+	10+	300+

CROP GENETIC RESOURCES OF AMAZONIA

León’s (1992) list of cultivated American crops was assessed to identify those that were probably in Amazonia at contact. Some Andean crops are included, if they commonly occur below 1000 m above sea level and if there is evidence that they were grown in the lowlands, although their distribution in the lowlands was generally limited. Patiño’s (1963, 1964) analysis of the early Spanish chronicles from northern South America provided the major key for this assessment. Neither source, however, deals specifically with incipiently domesticated crops. For this category, Balée (1988, 1989), Cavalcante (1991), Frikel (1978) and Lévi-Strauss (1950) were useful. A preliminary and somewhat subjective [for lack of data and occasional difficulty of distinguishing wild from incipiently domesticated crops (Lévi-Strauss 1950)] listing of domesticated, semi-domesticated and incipiently domesticated crops is presented in Appendices 1, 2 and 3, respectively.

There were probably at least 138 crops, in 44 botanical families, cultivated, managed or promoted in Amazonia at contact. This is about 50% of the total for the Americas. Among the 52 domesticates, 14 are fruit or nut trees or woody vines (27%); among the 41 semi-domesticates, 35 are trees or woody vines (87%); and among the 45 incipiently domesticated species, all but one are fruit and nut trees. Overall, 68% of these Amazonian crops are trees or woody perennials. In an ecosystem characterized by forest, a predominance of tree crops is not surprising. This predominance may be an artifact of abandonment, however, as domesticated annuals are expected to disappear more rapidly than perennials (Table 1).

How many crops are not on these lists? Certainly a considerable number, but there is no way of determining how many. *A priori*, I had expected the list of domesticates (Appendix 1) to be shorter than that of the semi-domesticates (Appendix 2) and much shorter than that of the incipient domesticates (Appendix 3), because only about 200 of the 3000 crops used by humans worldwide were domesticated (Hawkes 1983:6). While some species may be misplaced, there is certainly a lack of less derived species on these lists.

That some have disappeared since contact can be shown, however. Carvajal (1894:56) commented that, at one point between the Madeira and Tapajós Rivers they “found a lot of maize, and also a lot of oats, with which the Indians made bread” (my translation). As Patiño (1964:99) wrote, “we don’t know what ‘oats’ this species was.” It is not cultivated among the Amerindians and Amazonian peasants anywhere in Amazonia today. At the mouth of the Amazon River, recent archeological excavations have yielded large quantities of a rice-like grass (*Leersia hexandra*) (Roosevelt 1991:25), which may have been the ‘oats’ mentioned by Carvajal. She mentions early records of apparent *Leersia* cultivation on Marajó Island shortly after the arrival of the Portuguese, but there is not enough information to determine if it was domesticated to any degree (hence its placement in Appendix 3), although Roosevelt’s analysis is not yet complete. Another possibility is *Oryza glumaepatula*, found along várzea lake margins at high density (P. S. Martins, pers. com., 1995), although the early Spanish and Portuguese explorers would probably have recognized it as ‘rice,’ rather than as ‘oats.’

Species diversity is only one aspect of crop genetic diversity, the other is infra-specific diversity. This is where genetic erosion was probably most serious, but it is also the most difficult to quantify. Each indigenous society and village probably valued crops somewhat differently, depending upon local preferences and the genetic variability available to them. Consequently, the selection and propagation effort devoted to each may have been different. For example, *Heliconia hirsuta* is a minor root crop found among a few indigenous societies in Colombian Amazonia today. Very little variability has been observed in the modern populations. How much existed at contact will never be known. The South American sapota (*Quararibea cordata*) is a similar story. At the opposite extreme is cassava, whose variability is continuing to be amplified today. Among the inhabitants of the Vaupés River, NW Amazonia, for example, nearly 100 distinct cultivars of bitter and sweet cassava were recorded at one village (Chernela 1983). Ethnobotanists frequently record 20-50 cultivars per village in western Amazonia and slightly lower numbers elsewhere. A complex system of landraces of pejibaye exists in Amazonia, with most genetic diversity in the northwest (Clement 1988; Mora Urpí 1992). Many major crops and widespread minor crops should show patterns of genetic diversity similar to that of cassava and pejibaye if they were intensively cultivated and selected in numerous areas with different microecological variation and biotic pressures.

As with species diversity, there exists some evidence that infra-specific diversity has disappeared since contact. Patiño (1964:147-148) mentions that the maize that existed along the Amazon River at contact has been replaced by coastal Brazilian maize during recent centuries. Goodman’s (1976) map of the distribution of South American “Coroico” maizes

includes part of the middle Solimões and western Amazon Rivers and regions to the south, but does not extend up or down river to areas where maize was reported by Carvajal (1894) and other chroniclers [see Patiño (1964)]. Amazonian maize is poorly known today (M.M. Goodman, pers. com., 1994), because of lack of comprehensive collections.

ESTIMATES OF POST-CONTACT AMAZONIAN POPULATION LOSS

Gaspar de Carvajal (1894), the chronicler of the first European descent of the Amazon River in 1542, reported dense Amerindian populations along the Amazonian *várzeas* and adjacent *terra firme*. By the time European naturalists arrived in the region 200-300 years later, these populations had disappeared and Carvajal's account was discredited. The subject of Amazonian population density and associated level of cultural complexity is hotly contested today (Meggers 1993-5)

Meggers (1992b) offered the lowest recent estimate (1.5-2 million people in the Amazon Basin proper), based upon an average density of 0.3 persons/km². Meggers based her estimate on the *terra firme*'s low carrying capacity and the riskiness of *várzea* cultivation. At the other extreme is Myers (1988), who estimated 10 million in the Upper Amazon alone (essentially Amazonian Peru and Ecuador, and far western Brazil). Extrapolated to the rest of Amazonia, this suggests more than 30 million, or more than 4 persons/km², higher than the modern population.

Denevan (1996) recently lowered his earlier estimates (1992a, b) of 5-6 million in the Amazon Basin proper and 6-8 in lowland northern South America to 3-5 in the Basin and 5-7 in northern South America. His 1992 analyses included then current hypotheses of carrying capacity and pre-historic subsistence and agricultural technologies used in the various Amazonian ecosystems, and allowed for severe decline from disease and slavery, while cautiously accepting early historical accounts. His 1996 analysis emphasized the patchiness of human distributions, caused both by the patchiness of environments, especially suitable bluffs along the major rivers (Denevan 1992d), and by possible buffer zones between the larger societies, especially along the main rivers. Denevan provided estimates for each of Amazonia's various ecosystems. Amongst the most important were the *várzeas*, with estimated densities of up to 10 persons/km², possibly locally to 28 persons/km² on the Solimões and the Amazon Rivers; of 2 persons/km² in the Llanos de Mojos but possibly 28 persons/km² around the earthworks; of 9.5 persons/km² along the Brazilian coast south of Amazonia; of 0.3 persons/km² in the *terra firme* interfluvial forests; and 0.5 persons/km² overall.

Areas with high population densities are most important when considering crop genetic diversity. To support such densities, social organization must be more elaborate than at low density. As a corollary, agricultural and other subsistence technologies must be intensified (Roosevelt 1991:5, 1993), although they may be less sustainable. The intensification implies greater crop genetic diversity, because the intensified agricultural systems must be able to withstand pest and disease pressures. The relationship between diversity and agricultural intensification in pre-modern tropical and sub-tropical societies is essential to understanding why so much crop genetic diversity is found in this geographic area. Pre-modern societies in the tropics had few means of controlling pest and disease outbreaks other than genetic diversity, intercropping and swidden rotation (Altieri 1995:112-113), except in the floodplains where the annual flood cycle acts to reduce pest and disease populations in most years, just as winter cold or annual drought acts to reduce these populations in temperate regions.

In general, advanced agricultural societies accumulate crop genetic resources, both creating and importing them, as part of their agricultural intensification. This is the major

reason that several of Vavilov's (1992a, b) centers of crop genetic diversity are related to complex societies (Hawkes 1983:67), e.g., in the Americas, the Inca and pre-Inca civilizations are associated with the Peru/Bolivia center, and the Maya and Aztec civilizations with the MesoAmerican center. As paleoethnobotanical research expands in South America, the longest lists of crops are from areas where good conditions exist for archaeological artifact preservation and where complex societies with high population densities and advanced agricultural technologies existed (Pearsall 1992). In Amazonia, areas with higher population density in the pre-Columbian period should also exhibit a rich crop genetic heritage but the poor environment for archaeological preservation and lack of research effort have not yielded much information to date. Consequently living biological evidence is critical, but there are few clear patterns in Amazonian crop biogeography today, except in NW Amazonia (Clement 1989). The lack of clear patterns suggests that the loss of the Amazonian Amerindian population affected the crop genetic heritage severely.

Dobyns (1966) estimated that 90-95% of the Neotropical population was lost within 100-200 years after contact. Disease was the principal agent (Dobyns 1966), but missionization, slavery and warfare contributed importantly (Hemming 1978). In Amazonia, this meant a collapse from 3-5 million to a low of about 200,000. Today there are perhaps 500,000 Amerindians in lowland northern South America (Denevan 1992b), often organized in small bands and restricted to the *terra firme*, with relatively simple agricultural and subsistence technologies. Many are already extensively acculturated. How then did this human population collapse effect crop genetic resources?

THE CONSEQUENCES OF POPULATION DECLINE

Although individual farmers are responsible for selecting and propagating crops, the village is the unit of interest because it identifies a domesticated plant population. Farmers within a village exchange germplasm and influence each others' preferences and planting strategies. There is probably less exchange between villages than within, and less still between villages of different language groups (cf Chernela 1987), because there is simply less contact in general. Myths of crop origins in Amazonia, for example, sometimes acknowledge the prowess of a farmer for stealing germplasm from a neighboring society (J. Chernela, pers. com., 1986), which would not be necessary if there was easy exchange. Consequently, the fate of the village determined the fate of its crop genetic resources during the post-contact population collapse.

The larger indigenous Amazonian societies consisted of numerous villages. Those that dominated the *várzeas* may have had many large and numerous small villages, while those restricted to the *terra firme* may have had only small villages. It is possible that the 90-95% population decline resulted in an equal loss of village units, although village members would attempt to escape from disease epidemics or slave raids, rather than stay and die (Denevan 1992a).

Loss in human numbers was quickly reflected in a loss of crop diversity at the village site as the forest reclaimed the landscape (Table 1). Balée (1992) presented the example of the Guajá of eastern Amazonia, who regressed from village horticulturalists to nomadic hunter-gatherers that depend upon the fallows of other societies or managed forests left by predecessors. In the process of regression, their repertory of crops diminished rapidly to only a few crops with short life histories.

Given the extent of population loss, I feel that it is reasonable to hypothesize that 70-80% of the pre-contact village groups either disappeared completely, or were severely reduced and then absorbed by other groups, or regressed to a non-agricultural state. The major *várzea* societies, such as the Omagua on the Solimões River, disappeared almost completely

(Roosevelt 1993). It is this low level of human survival in such important areas as the Omagua that is responsible for the tantalizing hints of a richer crop genetic past.

Although there is no direct evidence of how the loss of the human population was reflected in the loss of genetic resources, a synthesis of the information and ideas presented here permits an order of magnitude estimate. Genetic erosion after contact depended not only upon population decline but upon the degree of domestication of each crop, its life history, the agroecosystem in which it was cultivated or managed, and the number of crops maintained by each human society. I think that it is safe to assume that the Amazonian crop genetic heritage at contact was at least an order of magnitude greater than it is today. Unfortunately, even its current magnitude is poorly known for most crops, the partial exceptions being *Bactris gasipaes*, *Elaeis oleifera*, *Hevea brasiliensis* and *Theobroma cacao*, because they were extensively prospected during the early 1980s by Brazilian institutions.

MODERN CROP GENETIC EROSION

After the post-contact decline of Amazonian Amerindians, their populations stabilized and then expanded again, to about 500,000 today (Denevan 1992b). The number of societies continues to decline, however (Burger 1987; Clay 1990). During this century, the acculturation of the remaining Amerindians has accelerated, caused by the immigration of northeastern Brazilians to tap rubber during the late 19th century boom, the attempts by governments to occupy the region after World War II through directed colonization, and the spontaneous colonization that accompanied various infrastructure projects of the 1960-90 period (Hecht and Cockburn 1990).

After the Brazilian revolution of 1964, the government decided that Amazonia must be occupied by 'Brazilians.' This was and remains an issue of 'national security' (Hecht and Cockburn 1990:104-141). The first major initiative was the Trans-Amazon highway system, which started the era of reliance on roads, rather than Amazonia's extensive network of navigable rivers. This highway system made its strongest impact on eastern and southern Amazonia. In central Amazonia, the creation of the Free Zone of Manaus in 1967 had the greatest impact, as financial resources were funneled towards establishing industries in Manaus, rather than supporting trade between the hinterlands and the city. As traders stopped working, the interior of this vast region was essentially abandoned by government, and peasants started to migrate to Manaus and other urban centers. The 1970s saw the initiation of other large infrastructure projects, such as the Tucuruí Hydroelectric Dam, the encouragement of cattle pasture expansion, and the definition of PoloAmazonia's development targets. In the 1980s, Rondônia and Acre were opened by paving the Cuiabá-Porto Velho highway. By the late 1980s, Amazonia had become a focus of world attention because of the fires that accompanied deforestation (Hecht and Cockburn 1990:52-54). All these initiatives resulted in localized extinction of biodiversity and continued acculturation of the original Amazonians and their descendents.

Other modern Amazonian nations have followed roughly similar trajectories, with similar results. In Bolivia, Colombia, Ecuador and Peru, the poorer populations of the Andes were often encouraged to settle in the Amazonian lowlands, and governments are providing at least a part of the infrastructure necessary to further the migration. Peru and Ecuador have struck oil on the eastern slopes of the Andes and the boom has accelerated migration to those regions. In these areas, biodiversity, Amerindian cultures and crop genetic resources are disappearing rapidly, as occurs in numerous other parts of the world when modern societies displace indigenous and folk societies (Smith et al. 1992).

The late 1970s and 1980s also saw the first attempts at systematic evaluation of a few of Amazonia's crop genetic resources. Coordinated by the Brazilian National Center for Genetic

Resources (CENARGEN), important collections of *Bactris gasipaes*, *Elaeis oleifera*, and *Hevea brasiliensis* were made. Collections of *Theobroma cacao* were made by the National Cacao Board (CEPLAC). Both the National Research Institute for Amazonia (INPA) and the Center for Agricultural Research in the Humid Tropics (CPATU) made casual collections of dozens of other species (Clement 1991; Clement, Müller and Chávez Flores 1982).

Nonetheless, the germplasm saved is minuscule in comparison with the presumed erosion of the crop genetic resources of Amazonia and their wild populations and relatives caused by modern 'development.' In sum, the erosion of Amazonian crop genetic resources is presumed to have continued during the premodern and modern eras and appears to be accelerating as deforestation and acculturation proceed.

What trends are likely? Most Amazonian governments sponsor, or acquiesce to, acculturation of their Amazonian Amerindian populations, either as a conscious policy or by lack of action to protect the Amerindians from unwanted, forced contact with colonists (Treece 1990). Colombia, Ecuador and Venezuela are partial exceptions. Although several countries protect the rights of their indigenous populations on paper, few protect these rights on the ground. Recent efforts in Brazil, sponsored by the World Bank and the G-7, are aimed at changing this reality but it is still too early to measure their impact. Given the rapid expansion of non-indigenous populations, also demanding rights, land and government support, trends are unlikely to change enough to make a difference, unless governments alter their policies and enforce them.

Deforestation proceeds, although it slowed somewhat in the early 1990 due to an economic recession in many countries (Fearnside 1993). Strong systemic forces drive deforestation in Amazonia (Barbosa 1993) and are unlikely to change direction soon, although some popular movements are working to promote change. Some countries, such as Brazil, are reviewing government policies that favor deforestation, but social pressures to deforest are as yet unabated. Increasing poverty, combined with the still rapid population growth, are the major social pressures. Continued deforestation inevitably results in loss of biodiversity and associated crop genetic resources, many of which occur in formerly managed forests, now abandoned by their Amerindian creators (Smith and Schultes 1990; Smith et al. 1992).

Ex situ collections of most tropical crop genetic resources are inadequate, poorly maintained, and poorly financed because of low government priority and conflicting economic demands throughout the Third World (Fowler and Mooney 1990:201-222; Harlan 1992:239-243). Even some Brazilian collections made in the 1980s are in danger of being lost, either by institutional apathy and budgetary restrictions (e.g., *B. gasipaes*) or by biotic pressures (e.g., *H. brasiliensis*). Only a few *in situ* genetic reserves exist on the ground; these are focused on forest species (E. Lleras, pers. com., 1990), few of which are even incipiently domesticated. Current trends suggest that central government budgets for genetic resource conservation will continue to shrink in Amazonia, although some international efforts are expanding (e.g., the Pilot Program for the Conservation of the Brazilian Rain Forest, financed by the World Bank, the G-7, and the government of Brazil, and the Global Environment Facility (World Bank, UNDP, UNEP) has initiated a new *in situ* program with CENARGEN).

One promising new trend is an international (and national in some countries) interest in exotic foods and natural sources of some industrial products, especially from Amazonia (Clay 1996:v-x; Smith et al. 1992:448-460). This interest has the potential of stimulating plantations in Amazonia to supply the emerging demand, but must overcome a series of limitations in order to compete internationally (Clement 1997). Given the fragility of most regional institutions and the likelihood of continually smaller institutional budgets as

Amazonian countries adapt to increased globalization, reverting the trends towards increased genetic erosion will require not only the development of numerous 'new crops' but a new focus by Amazonian research institutions - participatory plant improvement and community conservation of genetic resources (Engels 1995).

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LITERATURE CITED

- Alcorn, J. B. 1989. Process as resource: the traditional agricultural ideology of Bora and Huastec resource management and its implications for research. Pages 63-77 in D. A. Posey, and W. Balée, eds. Resource management in Amazonia: indigenous and folk strategies. *Advances in Economic Botany 7*. New York Botanical Garden, New York.
- Altieri, M. A. 1995. *Agroecology: The science of sustainable agriculture*. 2nd ed. Westview Press, Boulder, CO.
- Anderson, A. B., and D. A. Posey. 1989. Management of a tropical scrub savanna by the Gorotire Kayapó of Brazil. Pages 159-173 in D. A. Posey, and W. Balée, eds. Resource management in Amazonia: indigenous and folk strategies. *Advances in Economic Botany 7*. New York Botanical Garden, New York.
- Balée, W. 1988. Indigenous adaptation to Amazonian palm forests. *Principes* 32:47-54.
- . 1989. The culture of Amazonian forests. Pages 1-21 in D. A. Posey, and W. Balée, eds. Resource management in Amazonia: indigenous and folk strategies. *Advances in Economic Botany 7*. New York Botanical Garden, New York.
- . 1992. People of the fallow: a historical ecology of foraging in lowland South America. Pages 35-57 in K. H. Redford, and C. Padoch, eds. *Conservation of Neotropical Forests - Working from traditional resource use*. Columbia University Press, New York.
- Barbosa, L. C. 1993. The world-system and the destruction of the Brazilian Amazon rain forest. *Review (Fernand Braudel Center)* 16:215-240.
- Bonato, S. L., and F. M. Salzano. 1997a. A single and early migration for the peopling of the Americas supported by mitochondrial DNA sequence data. *Proc. Natl. Acad. Sci.* 94:1866-1871.
- , and F. M. Salzano. 1997b. Diversity and age of the four major mtDNA haplogroups, and their implications for the peopling of the New World. *Am. J. Hum. Genet.* 61:1413-1423.
- Brücher, H. 1989. *Useful plants of neotropical origin and their wild relatives*. Springer-Verlag, Berlin.
- Bruhns, K. O. 1994. *Ancient South America*. Cambridge University Press, Cambridge.
- Burger, J. 1987. *Report from the frontier: the state of the world's indigenous peoples*. Cultural Survival/Zed Press, London.
- Carvajal, G. de. 1894. *Descubrimiento del río de las Amazonas*. Imprenta de E. Rasco, Sevilla, Spain.
- Cavalcante, P. B. 1991. *Frutas Comestíveis da Amazônia*. 5th ed. Edições CEJUP/Museu Paraense Emilio Goeldi, Belém, Pará.
- Cavalli-Sforza, L. L., A. Piazza, and P. Menozzi. 1994. *History and geography of human genes*. Princeton Univ. Press, Princeton.
- Chase, A. K. 1989. Domestication and domiculture in northern Australia: a social perspective. Pages 42-54 in D. R. Harris, and G. C. Hillman, eds. *Foraging and Farming: The evolution of plant exploitation*. Unwin Hyman, London.
- Chernela, J. M. 1983. *Hierarchy and economy among the Kotiria (Uanano) speaking peoples of the northwest Amazon*. Ph.D. Dissertation, Columbia University, New York.
- . 1987. Os cultivares de mandioca na área do Uaupés (Tukâno). Pages 151-158 in B. G. Ribeiro, ed. *Suma etnológica brasileira. 1. Etnobiologia*. FINEP, Petrópolis, RJ, Brasil.
- Clay, J. W. 1990. Indigenous peoples - the miner's canary for the twentieth century. Pages 106-117 in S. Head, and R. Heinzman, eds. *Lessons of the Rainforest*. Sierra Club Books, San Francisco.
- . 1996. *Generating income and conserving resources: 20 lessons from the field*. World Wildlife Fund Publ., Baltimore, MD.

- Clement, C. R. 1988. Domestication of the pejibaye palm (*Bactris gasipaes*): past and present. Pages 155-174 in M. J. Balick, ed. *The Palm - Tree of Life. Advances in Economic Botany 6*. New York Botanical Garden, New York.
- . 1989. A center of crop genetic diversity in western Amazonia. *BioScience* 39:624-631.
- . 1990. Regeneração natural de pupunha (*Bactris gasipaes*). *Acta Amazonica* 20:399-404.
- . 1991. Amazonian fruits: neglected, threatened and potentially rich resources require urgent attention. *Diversity* 7:56-59.
- . 1997. Environmental impacts of, and biological and socio-economic limitations on new crop development in Brazilian Amazonia. Pages in press in J. Smartt, and N. N. Haq, eds. *Domestication, Production and Utilization of New Crops: Practical Approaches*. International Centre for Underutilised Crops, University of Southampton, Southampton, England, UK.
- Clement, C. R., C. H. Müller, and W. B. Chávez Flores. 1982. Recursos genéticos de espécies frutíferas nativas da Amazônia Brasileira. *Acta Amazonica* 12:677-695.
- Darwin, C. 1882. *The variation of animals and plants under domestication*. 2nd ed. Vol. I & II. John Murray, London.
- Denevan, W. M. 1966. *The aboriginal cultural geography of the Llanos de Mojos de Bolivia*. Ibero-Americana no. 48. University of California Press, Berkeley.
- . 1992a. The aboriginal population of Amazonia. Pages 205-234 in W. M. Denevan, ed. *The native population of the Americas in 1492*. University of Wisconsin Press, Madison, Wisconsin.
- . 1992b. Native American populations in 1492: recent research and a revised hemispheric estimate. Pages xvii-xxxvii in W. M. Denevan, ed. *The native population of the Americas in 1492*. University of Wisconsin Press, Madison, Wisconsin.
- . 1992c. The pristine myth: the landscape of the Americas in 1492. *Annals of the Association of American Geographers* 82:369-385.
- . 1992d. Stone vs metal axes: The ambiguity of shifting cultivation in prehistoric America. *J. Steward Anthropology Society* 2(1/2):153-165.
- . 1996. A bluff model of riverine settlement in prehistoric Amazonia. *Annals Association American Geographers* 86(4):654-681.
- Denevan, W. M., and C. Padoch. 1987. Introduction: The Bora agroforestry project. Pages 1-7 in W. M. Denevan, and C. Padoch, eds. *Swidden-fallow agroforestry in the Peruvian Amazon*. *Advances in Economic Botany 5*. New York Botanical Garden, New York.
- Denevan, W. M., and A. Zucchi. 1978. Ridged field excavations in the central Orinoco Llanos. Pages 235-246 in D. L. Browman, ed. *Advances in Andean archeology*. Mouton, The Hague.
- Dillehay, T. D., G. Ardila Calderón, G. Politis, and M. C. M. C. Beltrao. 1992. Earliest hunters and gatherers of South America. *Journal of World Prehistory* 6:145-204.
- Dobyns, H. F. 1966. Estimating aboriginal American populations: an appraisal of techniques with a new hemispheric estimate. *Current Anthropology* 7:395-416.
- Doebly, J. 1989. Isozymic evidence and the evolution of crop plants. Pages 165-191 in D. E. Soltis, and P. S. Soltis, eds. *Isozymes in plant biology*. Dioscorides Press, Portland, OR.
- Engels, J. M. M., ed. 1995. *In situ* conservation and sustainable use of plant genetic resources for food and agriculture in developing countries. Report of a DSE/ATSAF/IPGRI workshop, 2-4 May 1995, Bonn-Röttgen, Germany. International Plant Genetic Resources Institute (IPGRI), German Foundation for International Development (DSE), Rome, Italy.
- Fearnside, P. M. 1993. Deforestation in Brazilian Amazonia: The effect of population and land tenure. *Ambio* 22:537-545.
- Fowler, C., and P. Mooney. 1990. *Shattering: Food, politics, and the loss of genetic diversity*. University of Arizona Press, Tucson.
- Frikel, P. 1978. Áreas de arboricultura pre-agrícola na Amazônia: notas preliminares. *Revista Antropológica* 21:45-52.
- Galloway, P. 1992. The unexamined habitus; direct historical analogy and the archaeology of the text. Pages 178-195 in J. C. Gardin, and C. S. Peebles, eds. *Representations in Archaeology*. Univ. Indiana Press, Blomington.
- Gheerbrant, A. 1992. *The Amazon; Past, present, and future*. Harry N. Abrams, New York.
- Goodman, M. M. 1976. Maize, *Zea mays* (Graminae-Maydeae). Pages 128-136 in N. W. Simmonds, ed. *Evolution of Crop Plants*. Longman, London.
- Groube, L. 1989. The taming of the rain forests: a model for Late Pleistocene forest exploitation in New Guinea. Pages 292-304 in D. R. Harris, and G. C. Hillman, eds. *Foraging and Farming: The evolution of plant exploitation*. Unwin Hyman, London.
- Harlan, J. R. 1992. *Crops and Man*. 2nd ed. American Society of Agronomy/Crop Science Society of America, Madison, Wisconsin.

- Harris, D. R. 1989. An evolutionary continuum of people-plant interaction. Pages 11-26 in D. R. Harris, and G. C. Hillman, eds. *Foraging and Farming: The evolution of plant exploitation*. Unwin Hyman, London.
- Hawkes, J. G. 1983. *The diversity of crop plants*. Harvard University Press, Cambridge, Massachusetts.
- Hecht, S., and A. Cockburn. 1990. *The fate of the forest: Developers, destroyers and defenders of the Amazon*. Harper Perennial, New York.
- Heiser, C. B. 1988. Aspects of unconscious selection and the evolution of domesticated plants. *Euphytica* 37:77-81.
- Hemming, J. 1978. *Red gold: The conquest of the Brazilian Indians*. Harvard University Press, Cambridge.
- León, J. 1987. *Botánica de los cultivos tropicales*. Instituto Interamericano para la Cooperación Agrícola - IICA, San José, Costa Rica.
- . 1992. Los recursos fitogenéticos del Nuevo Mundo. Pages 3-22 in J. E. Hernández Bermejo, and J. León, eds. *Cultivos marginados: otra perspectiva de 1492*. Food and Agriculture Organization (FAO)/Jardín Botánico de Córdoba, Rome, Italy.
- Lévi-Strauss, C. 1950. The use of wild plants in tropical South America. Pages 465-486 in J. H. Steward, ed. *Handbook of South American Indians*. Smithsonian Institution, Bureau of American Ethnology, Washington, DC.
- Meggers, B. J. 1988. The prehistory of Amazonia. Pages 53-62 in J. S. Denslow, and C. Padoch, eds. *People of the tropical rain forest*. Univ. California Press, Berkeley.
- . 1992a. Amazonia: Real or counterfeit paradise? *Review of Archaeology* 13:25-40.
- . 1992b. Prehistoric population density in the Amazon basin. Pages 197-206 in J. W. Verano, and D. H. Ubelaker, eds. *Disease and demography in the Americas*. Smithsonian Institution Press, Washington, DC.
- . 1993-5. Amazonia on the eve of European contact: Ethnohistorical, ecological, and anthropological perspectives. *Revista de Arqueología Americana* 8:91-115.
- Mora Urpí, J. 1992. Pejibaye (*Bactris gasipaes*). Pages 209-220 in J. E. Hernández Bermejo, and J. León, eds. *Cultivos marginados: otra perspectiva de 1492*. Food and Agriculture Organization - FAO/Jardín Botánico de Córdoba (España), Rome.
- Myers, T. P. 1988. El efecto de las pestes sobre las poblaciones de la Amazonia alta. *Amazonía Peruana* 8:61-81.
- Patiño, V. M. 1963. *Plantas cultivadas y animales domésticos en América Equinoccial*. Tomo I. Frutales. Imprenta Departamental, Cali, Colombia.
- . 1964. *Plantas cultivadas y animales domésticos en América Equinoccial*. Tomo II. Plantas alimenticias. Imprenta Departamental, Cali, Colombia.
- Pearsall, D. M. 1992. The origins of plant cultivation in South America. Pages 173-206 in C. W. Cowan, and P. J. Watson, eds. *The origins of agriculture - An international perspective*. Smithsonian Institution Press, Washington, DC.
- Pickersgill, B., and J. Heiser CB. 1977. Origins and distribution of plants domesticated in the New World Tropics. Pages 803-836 in C. A. Reed, ed. *Origins of Agriculture*. Mouton Publ., The Hague.
- Rindos, D. 1984. *The origins of agriculture: An evolutionary perspective*. Academic Press, San Diego, CA.
- Roosevelt, A. C. 1989. Resource management in Amazonia before the conquest: beyond ethnographic projection. Pages 30-62 in D. A. Posey, and W. Balée, eds. *Resource management in Amazonia: indigenous and folk strategies*. New York Botanical Garden, New York.
- . 1991. *Moundbuilders of the Amazon: Geophysical Archaeology on Marajó Island, Brazil*. Academic Press, San Diego.
- . 1993. The rise and fall of the Amazon Chiefdoms. *L'Homme* 33:255-283.
- , ed. 1994. *Amazonian indians from prehistory to the present - anthropological perspectives*. University of Arizona Press, Tucson.
- Roosevelt, A. C., R. A. Housley, M. I. da Silveira, S. Maranca, and R. Johnson. 1991. Eighth millennium pottery from a prehistoric shell midden in the Brazilian Amazon. *Science* 254:1621-1624.
- Roosevelt, A. C., M. Lima da Costa, C. Lopes Machado, M. Michab, N. Mercier, H. Valladas, J. Feathers, W. Barnett, M. Imazio da Silveira, A. Henderson, J. Sliva, B. Chernoff, D. S. Reese, J. A. Holman, N. Toth, and K. Schick. 1996. Paleoindian cave dwellers in the Amazon: The peopling of the Americas. *Science* 272:373-384.
- Schultes, R. E. 1984. Amazonian cultigens and their northward and westward migrations in pre-Columbian times. Pages 19-38 in D. Stone, ed. *Pre-Columbian plant migration*. Harvard University Press, Cambridge, MA.
- Schultes, R. E., and A. Hofmann. 1979. *Plants of the Gods: origins of hallucinogenic use*. Alfred van der Marck Ed., New York.
- Smith, N. J. H. 1995. Human-induced landscape changes in Amazonia and implications for development. Pages 221-251 in B. L. Turner II, A. Gómez Sal, F. González Bernáldez, and F. di Castri, eds. *Global land use*

- change - A perspective from the Columbian Encounter. Consejo Superior de Investigaciones Científicas, Madrid.
- Smith, N. J. H., and R. E. Schultes. 1990. Deforestation and shrinking crop gene-pools in Amazonia. *Environmental Conservation* 17:227-234.
- Smith, N. J. H., J. T. Williams, D. L. Plucknett, and J. P. Talbot. 1992. *Tropical forests and their crops*. Cornell University Press, Ithaca, NY.
- Treese, D. 1990. Indigenous peoples in Brazilian Amazonia and the expansion of the economic frontier. Pages 264-288 *in* D. Goodman, and A. Hall, eds. *The future of Amazonia - Destruction or sustainable development*. MacMillan, London.
- Vavilov, N. I. 1992a. On the origin of cultivated plants (First published in 1926 in *Novoye v Agronomii* (News in Agronomy)). Pages 14-21 *in* V. F. Dorofeyev, ed. *Origin and geography of cultivated plants*. Cambridge University Press, Cambridge.
- . 1992b. Universal centers of a wealth of types (genes) of cultivated plants (First published in 1927 in *Izd. Gos. In-ta, opyt. agr.* (Pub. National Institutes of Experimental Agriculture) 5(5)). Pages 144-157 *in* V. F. Dorofeyev, ed. *Origin and geography of cultivated plants*. Cambridge University Press, Cambridge.
- Wiersum, K. F. 1997. From natural forest to tree crops, co-domestication of forests and tree species, an overview. *Netherlands Journal of Agricultural Sciences* 45:425-438.
- Yen, D. E. 1989. The domestication of environment. Pages 55-75 *in* D. R. Harris, and G. C. Hillman, eds. *Foraging and Farming: The evolution of plant exploitation*. Unwin Hyman, London.

Appendix 1. Probably domesticated crops grown in Amazonia at contact (Brücher 1989; León 1987, 1992; Patiño 1963, 1964; Pearsall 1992; Pickersgill and Heiser 1977; Schultes 1984; Schultes and Hofmann 1979).

Species	Family	Probable origin	Uses
<i>Annona muricata</i> L.	Anonaceae	N. S. America	fruit
<i>Rollinia mucosa</i> (Jacq.) Baillón	“	Amazonia	fruit
<i>Xanthosoma brasiliense</i> Engler	Araceae	N. S. America	vegetable
<i>X. sagittifolium</i> (L.) Schott	“	N. S. America	root
<i>Crescentia cujete</i> L.	Bignoniaceae	N. S. America	tree gourd
<i>Bixa orellana</i> L.	Bixaceae	S. W. Amazonia	colorant
<i>Ananas comosus</i> (L.) Merrill.	Bromeliaceae	Brazil/Paraguay	fruit
<i>A. erectifolius</i> L.B. Smith	“	Amazonia	fiber
<i>Neoglaziovia variegata</i> Mez.	“	N. S. America	fiber
<i>Canna edulis</i> Ker.	Cannaceae	Andes/W Amaz	root
<i>Carica papaya</i> L.	Caricaceae	MesoAmerica	fruit
<i>Eupatorium ayapana</i> Vent.	Compositae	Amazonia	condiment
<i>Spilanthes acmella</i> (L.) Murr.	“	Amazonia	condiment
<i>S. oleracea</i> Jacq.	“	Amazonia	condiment
<i>Ipomoea batatas</i> (L.) Lam.	Convolvulaceae	N. S. America	root
<i>Cucurbita maxima</i> Duch.	Cucurbitaceae	E. Bolivia	vegetable
<i>C. moschata</i> Duch. ex. Poir.	“	MesoAmerica	vegetable
<i>Cyclanthera pedata</i> Schrad.	“	N. S. America	vegetable
<i>Lagenaria siceraria</i> Standl.	“	Africa	gourd
<i>Sicana odorifera</i> (Vell.) Naud.	“	Brazil/Paraguay	vegetable
<i>Cyperus</i> sp.	Cyperaceae	Amazonia?	condiment
<i>Dioscorea trifida</i> L. f.	Dioscoreaceae	Guianas	root
<i>Erythroxylum coca</i> Lam.	Erythroxylaceae	Central Andes	stimulant
<i>Manihot esculenta</i> Crantz	Euphorbiaceae	N. S. America	root
<i>Zea mays</i> L.	Gramineae	MesoAmerica	cereal
<i>Poraqueiba paraensis</i> Ducke	Icacinaceae	E. Amazonia	fruit,oil
<i>P. sericea</i> Tul.	“	W. Amazonia	fruit,oil

Appendix 1 (continued). Probably domesticated crops grown in Amazonia at contact.

Species	Family	Probable origin	Uses
<i>Persea americana</i> Mill.	Lauraceae	MesoAmerica	fruit
<i>Arachis hypogaea</i> L.	Leg. Papilionoidae	Brazil/Paraguay	seed
<i>Canavalia ensiformis</i> (L.) DC	“	N. S. America	seed
<i>C. plagioperma</i> Piper	“	MesoAmerica	seed
<i>Phaseolus lunatus</i> L.	“	N. S. America	seed
<i>P. vulgaris</i> L.	“	N. S. America	seed
<i>Pachyrhizus tuberosus</i> Spreng.	“	W. Amazonia	root
<i>Gossypium barbadense</i> L.	Malvaceae	N. S. America	fiber
<i>G. hirsutum</i> L.	“	MesoAmerica	fiber
<i>Calathea allouia</i> (Aubl.) Lindl.	Marantaceae	Amazonia	root
<i>Maranta arundinacea</i> L.	“	N. S. America	root
<i>Bactris gasipaes</i> Kunth	Palmae	S. W. Amazonia	fruit
<i>Passiflora edulis</i> Sims	Passifloraceae	N. S. America	fruit
<i>P. quadrangularis</i> L.	“	N. S. America	fruit
<i>Genipa americana</i> L.	Rubiaceae	N. S. America	colorant
<i>Paullinia cupana</i> Kunth	Sapindaceae	C. Amazonia	stimulant
<i>Pouteria caimito</i> Radlk.	Sapotaceae	Amazonia	fruit
<i>Brugmansia insignis</i> Lockwood	Solanaceae	W. Amazonia	drug
<i>B. suaveolens</i> Bercht. & Presl.	“	W. Amazonia	drug
<i>Capsicum baccatum</i> L.	“	Bolivia	condiment
<i>C. chinense</i> Jacq.	“	W. Amazonia	condiment
<i>Nicotiana rustica</i> L.	“	N. S. America	stimulant
<i>N. tabacum</i> L.	“	N. S. America	stimulant
<i>Solanum sessiliflorum</i> Dunal	“	W. Amazonia	fruit
<i>Cissus gongyloides</i> Burch.	Vitaceae	Amazonia	vegetable

Appendix 2. Probably semi-domesticated crops grown in Amazonia at contact (Brücher 1989; León 1987, 1992; Patiño 1963, 1964; Pickersgill and Heiser 1977; Schultes and Hofmann 1979).

Species	Family	Probable origin	Uses
<i>Anacardium occidentale</i> L.	Anacardiaceae	N. E. Brazil?	fruit, nut
<i>Spondias mombin</i> L.	“	N. S. America	fruit
<i>Annona montana</i> Macf.	Anonaceae	Amazonia	fruit
<i>A. reticulata</i> L.	“	MesoAmerica	fruit
<i>Macoubea witotorum</i> Schultes	Apocynaceae	W. Amazonia	fruit juice
<i>Thevetia peruvianum</i> Merr.	“	C. Andes	poison
<i>Ilex guayusa</i> Loes.	Aquifoliaceae	N. W. Amazonia	stimulant
<i>Mansoa alliacea</i> (Lam.) Gentry	Bignoniaceae	W. Amazonia	condiment
<i>Quararibea cordata</i> Vischer	Bombacaceae	W. Amazonia	fruit
<i>Couepia subcordata</i> Benth	Chrysobalanaceae	Amazonia	fruit
<i>Clibadium sylvestre</i> Baill.	Compositae	N. S. America	poison
<i>Dioscorea dodecaneura</i> Steud.	Dioscoreaceae	Amazonia	root
<i>Phyllanthus acuminatus</i> Vahl.	Euphorbiaceae	N. S. America	poison
<i>Mammea americana</i> L.	Guttiferae	Antilles	fruit
<i>Platonia insignis</i> Mart.	“	E. Amazonia	fruit,seed?
<i>Heliconia hirsuta</i> L. f.	Heliconiaceae	W. Amazonia	root
<i>Cassia leiandra</i> Benth.	Leg. Caesalpinoidae	Amazonia	fruit
<i>Anadenanthera peregrina</i> Speg.	Leg. Mimosoidae	N. S. America	drug
<i>Inga cinnamomea</i> Benth.	“	Amazonia	fruit
<i>I. edulis</i> Mart.	“	W. Amazonia	fruit
<i>I. feuillei</i> DC	“	W. Amazonia	fruit
<i>I. macrophylla</i> H.B.K.	“	W. Amazonia	fruit

Appendix 2 (continued). Probably semi-domesticated crops grown in Amazonia at contact.

Species	Family	Probable origin	Uses
<i>Lonchocarpus utilis</i> Smith	Leg. Papilionoidae	Amazonia	poison
<i>Banisteriopsis caapi</i> Morton	Malpigiaceae	W. Amazonia	drug
<i>B. inebrians</i> Morton	“	W. Amazonia	drug
<i>Bunchosia armeniaca</i> DC	“	Amazonia	fruit
<i>Byrsonima crassifolia</i> H.B.K.	“	MesoAmerica	fruit
<i>Maranta ruiziana</i> Korn.	Marantaceae	W. Amazonia	root
<i>Pourouma cecropiifolia</i> Mart.	Moraceae	W. Amazonia	fruit
<i>Eugenia stipitata</i> McVaugh	Myrtaceae	W. Amazonia	fruit
<i>Myrciaria cauliflora</i> McVaugh	“	S. Brazil	fruit
<i>Psidium guajava</i> L.	“	N. E. Brazil	fruit
<i>Astrocaryum aculeatum</i> Meyer	Palmae	W. Amazonia	fruit
<i>Talinum triangulare</i> Willd.	Portulacaceae	N. S. America	vegetable
<i>Borojoa sorbilis</i> Cuatr.	Rubiaceae	Amazonia	fruit
<i>Paullinia yoco</i> Schult. & Killip	Sapindaceae	W. Amazonia	stimulant
<i>Pouteria macrocarpa</i> Baehni	Sapotaceae	Amazonia	fruit
<i>P. macrophylla</i> (Lam.) Eyma.	“	Amazonia	fruit
<i>P. obovata</i> H.B.K.	“	C. Andes	fruit
<i>Theobroma bicolor</i> H. & B.	Sterculiaceae	W. Amazonia	fruit,seed
<i>T. cacao</i> L.	“	W. Amazonia	stimulant

Appendix 3. Some species with incipiently domesticated populations in Amazonia at contact (Balée 1988, 1989; Cavalcante 1991; León 1987, 1992; Lévi-Strauss 1950; Patiño 1963, 1964).

Species	Family	Probable origin	Uses
<i>Couma utilis</i> Muell.	Apocynaceae	Amazonia	fruit, latex
<i>Hancornia speciosa</i> Gomes	“	N. E. Brazil	fruit, latex
<i>Caryocar glabrum</i> (Aubl.) Pers.	Caryocaraceae	W. Amazonia	nut
<i>C. nuciferum</i> L.	“	N. S. America	nut
<i>C. villosum</i> (Aubl.) Pers.	“	C. Amazonia	fruit
<i>Chrysobalanus icaco</i> L.	Chrysobalanaceae	N. S. America	fruit
<i>Couepia bracteosa</i> Benth.	“	C. Amazonia	fruit
<i>C. edulis</i> Prance	“	Amazonia	nut
<i>C. longipendula</i> Pilger	“	Amazonia	nut
<i>Caryodendron orinocense</i> Karst.	Euphorbiaceae	W. Amazonia	nut
<i>Hevea</i> spp. (various)	“	Amazonia	seed, latex
<i>Leersia hexandra</i> Sw.	Graminae	E. Amazonia	seed
<i>Rheedia brasiliensis</i> Pl. & Tr.	Guttiferae	Amazonia	fruit
<i>R. macrophylla</i> Planch & Triana	“	Amazonia	fruit
<i>Bertholletia excelsa</i> H. & B.	Lecythidaceae	E. Amazonia	nut
<i>Lecythis pisonis</i> Camb.	“	Amazonia	nut
<i>Grias neubertii</i> MacBride	“	W. Amazonia	fruit
<i>G. peruviana</i> Miers	“	W. Amazonia	fruit
<i>Hymenaea courbaril</i> L.	Leg. Caesalpinioideae	Amazonia	starchy fruit
<i>Campsiandra comosa</i> Cowan	Leg. Mimosoidae	N. W. Amazonia	fruit
<i>Inga</i> spp. (numerous)	“	Amazonia	fruit
<i>Lonchocarpus nicou</i> (Aubl.) DC	Leg. Papilionoidae	Amazonia	poison
<i>Lonchocarpus urucu</i> Smith	“	Amazonia	poison

Appendix 3 (continued). Some species with incipiently domesticated populations in Amazonia at contact.

Species	Family	Probable origin	Uses
<i>Eugenia uniflora</i> L.	Myrtaceae	S. America	fruit
<i>Psidium acutangulum</i> DC	“	Amazonia	fruit
<i>P. guineensis</i> Sw.	“	N. S. America	fruit
<i>Acrocomia aculeata</i> (Jacq.) Lood	Palmae	E. Amazonia	oily fruit
<i>Astrocaryum murumuru</i> Mart.	“	E. Amazonia	oily fruit
<i>Elaeis oleifera</i> (H.B.K.) Cortés	“	N. S. America	oily fruit
<i>Euterpe oleracea</i> Mart.	“	E. Amazonia	oily fruit
<i>Jessenia bataua</i> (Mart.) Burret	“	N. S. America	oily fruit
<i>Mauritia flexuosa</i> L. f.	“	N. S. America	oily fruit
<i>Maximiliana maripa</i> Drude	“	E. Amazonia	oily fruit
<i>Oenocarpus bacaba</i> Mart.	“	Amazonia	oily fruit
<i>O. distichus</i> Mart.	“	E. Amazonia	oily fruit
<i>Alibertia edulis</i> A. Rich ex DC	Rubiaceae	Amazonia	fruit
<i>Melicoccus bijugatus</i> Jacq.	Sapindaceae	C. & N. S. America	fruit
<i>Talisia esculenta</i> Radlk.	“	W. Amazonia	fruit
<i>Manilkara huberi</i> (Huber) Standl.	Sapotaceae	Amazonia	fruit, latex
<i>Pouteria</i> spp. (numerous)	“	Amazonia	fruit
<i>Sterculia speciosa</i> K. Sch.	Sterculiaceae	Amazonia	fruit
<i>Theobroma grandiflorum</i> Schum.	“	E. Amazonia	fruit
<i>T. speciosum</i> Willd.	“	Amazonia	fruit
<i>T. subincanum</i> Mart.	“	Amazonia	fruit
<i>Erisma japura</i> Spruce	Vochysiaceae	N. W. Amazonia	fruit