
Brief Communication

The Invasive Shrub *Piper aduncum* and Rural Livelihoods in the Finschhafen Area of Papua New Guinea

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Bioinvasion is recognized as an important component of the global loss of species and habitats. Some have argued that bioinvasion is a greater threat than the greenhouse effect, industrial pollution or ozone depletion (Mack *et al.*, 2001). An understanding of the causes and spread of a bioinvasive species is needed to assess its economic and ecological impacts.

INTRODUCTION

In Papua New Guinea the shrub *Piper aduncum* (L) has invaded the humid lowlands and locally dominates the fallow vegetation, mainly in Morobe and Madang Provinces. It is not known when or how *Piper aduncum* arrived in Papua New Guinea, but it is likely that seeds were introduced by accident from Papua (Irian Jaya) or perhaps from Fiji, where it was introduced in the 1920s (Hartemink, 2001). The botanist Mary Clemens first observed *Piper aduncum* (hereafter referred to as piper) in 1935 near the Heldsbach mission station near Finschhafen in Morobe Province. It was not very widespread by the early 1970s and is not listed in the standard text

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on New Guinea vegetation (Paijmans, 1976). However, by the late 1990s piper was very common in the lowlands of Morobe and Madang Provinces, and was observed in the Central Highlands above 2,000 m a.s.l. (Rogers and Hartemink, 2000) and on the island of Bougainville (Waterhouse, 2003). Causes for its rapid spread remain unclear but evidence suggest that areas of rich in native plant species and with high soil fertility, may be especially susceptible (Stohlgren *et al.*, 1999). Leps *et al.* (2002) suggest that the successful invasion of *Piper aduncum* in Papua New Guinea is due to its having a large native geographic range, the ability to aggressively colonize disturbed habitats such as fallow gardens, a short juvenile period, and relatively small seeds that are produced in large quantities every year. Recent research has also shown that the aggressive invasion of *Piper aduncum* in early fallow succession vegetation is not explained by a competitive advantage resulting from a low herbivore load (Novotny *et al.*, 2003).

The invasion of piper appears to be similar to the spread of *Chromolaena odorata* in Asia and parts of West Africa (McFadyen and Skarratt, 1996) and to the invasion of *Miconia calvescens* in the Society islands of the Pacific where it was introduced as an ornamental but is now a major pest (Meyer, 1996) some times nicknamed the “green cancer” (Stone, 1999).

Piper is a shrub or low tree with alternate leaves and spiky flowers and fruits. It occasionally reaches a height of 7–8 m, and has very small seeds, which are mostly dispersed by the wind, fruit bats, and birds (Bonaccorso *et al.*, 2002; Kidd, 1997). It occurs in Mexico, Central America, Surinam, Cuba, Southern Florida, Trinidad and Tobago, and Jamaica and is very common in Costa Rica on open or partly shaded sites (Burger, 1971). Piper is also found on Hawaii, Fiji, Vanuatu, and the Solomon Islands.

Some agronomic research on piper has focussed on biomass and nutrient accumulation (Hartemink, 2001, 2004), leaf litter dynamics (Hartemink and O’Sullivan, 2001), and the effects on soils and crops (Hartemink, 2003a,b). Virtually nothing is known of the socioeconomic effects of its invasion and how it affects the livelihoods of rural people. Studies in South America have shown that extracts of piper are used as folk medicine. The species is mentioned in several ethnopharmacological databases, and has antifungal and antibacterial compounds (Nair and Burke, 1990). In their survey of Morobe Province of Papua New Guinea, Holdsworth and Damas (1986) noted that new *Piper aduncum* leaves are crushed and rubbed into fresh cuts.

This study explores how piper affects rural livelihoods in the Finschhafen area in Papua New Guinea near where piper was first observed in the 1930s (Bourke *et al.*, 2002). The study involved qualitative fieldwork in three villages. Observations in people’s fields and interviews with men

and women were used to (1) find out how people use piper; and (2) find out what impacts piper has on their livelihood. In total 27 in-depth interviews were held, combined with a similar number of field observations. Fieldwork was conducted between July and November 2003 by Thomas Siges, who comes from the area, as part of his graduate study at Wageningen University, The Netherlands. Alfred Hartemink initiated the research and supervised it jointly with Paul Hebinck. Bryant Allen was involved in the write-up of the results and discussion.

STUDY AREA

The fieldwork for this study was conducted in three villages in Pindiu area in Finschhafen District of Papua New Guinea: Sanangac (147°31' E, 6°31'S), Sanzeng (147°31' E, 6°31'S), and Tongucboc (147°31' E, 6°31'S). They were chosen because piper is very common in the area (Bourke *et al.*, 2002), and the first author can speak the indigenous language and, as a local, could quickly gain acceptance.

Sanangac and Sanzeng villages (ca. 730 m a.s.l.) are about 2km apart whereas Tongucboc (995 m a.s.l.) is about 3 km south of Sanzeng. The topography in the study area includes the flat valley of Doi, which extends from the Sanzeng River to the periphery of Sanangac village, and which is viewed as good agricultural land. Tongucboc village is in hillier terrain. The three villages have reasonable access to the district center, Finschhafen, and are located in the same agroecological zone. They have similar agricultural systems. Construction of soil retention barriers on cultivated slopes is characteristic for the Pindiu area (Bourke *et al.*, 2002). The region has a population density of about 26 people km⁻² on land used for agriculture, including land in fallow.

The Villages

The villages differ only slightly from each other in terms of rural livelihoods, and the timing and the degree of the spread of piper is not exactly known. Because the three villages are in a similar agroecological zone it is possible to compare the use of and reactions to piper, and to make an assessment of the factors that may account for differences among the villages in these matters.

The farmers in the three villages live at different distances from the primary forest. Common to the three villages is clan ownership of land. Families are given usufruct rights to land for individual use and clan leaders, who are also the family heads, administer these rights. Piper and its by-products

are considered both a private and an open-access resource. If piper grows in people's fields (cultivated and fallow) it belongs to them; if it grows in the forest, anyone can use it.

Land use intensity in the area is low (Ruthenberg's $R = 25$) (Ruthenberg, 1980) and differs slightly among the three villages. Two agricultural subsystems were observed. In the first, which occupied most of the area, new gardens are cleared annually from low woody regrowth fallows, between four and six years old. All vegetation is cut down and burned. The most important crop is sweet potato (*Ipomoea batatas*) but sometimes taro (*Colocasia esculenta*) is planted first and sweet potato is a second planting. Chinese taro (*Xanthosoma sagittifolium*) is cultivated around the edges of gardens. Land is tilled and sweet potato is planted in 30 cm high mounds formed from topsoil. In the second subsystem, which occupies about 20% of the area, gardens are cleared from tall woody regrowth fallows over 15 years old. Fallow vegetation is cut down and usually burned. Chinese taro and bananas are planted. Although only one planting is made, Chinese taro and bananas continue to produce harvests for over three years. These gardens are not tilled (Bourke *et al.*, 2002). This pattern of land use means that about 80% of the cultivated land is cleared, burned, and cultivated every six years and about 20% every 15–20 years. The first subsystem is gradually spreading at the expense of the longer-cycle second subsystem. Fallow regrowth is largely a result of natural processes and is not interfered with by humans.

Village houses are similar in all three villages and are constructed from local materials. Houses accommodate one family with five to six members. The houses are small, rectangular and single-roomed, and are built on wooden posts, about one meter above the ground. In Sanangac and Sanzeng villages, apart from the posts, most of the wood used for house building is piper. In Tongucboc native wood predominates.

Sanangac Village

Sanangac has a population of about 300 people but only 150 people lived there permanently in 2003; the rest had migrated to urban areas or had moved to newly settled rural areas. The village had 30 houses surrounding a central open space used for community gatherings. Bank, postal services, and schools are about a one-hour walk from the village at Pindiu government station. The deteriorated gravel road that connects Pindiu to Finschhafen passes near the village enabling government and other public passenger vehicles to provide goods and services to the village in dry weather. In wet weather, the village is difficult to reach by road.

People in Sanangac are farmers but most have other income generating activities such as marketing and casual labor in town. Most families

cultivate 500 to 1,000 coffee (*Coffea arabica*) trees and up to 200 vanilla plants (*Vanilla fragrans*). Until recently, the sale of parchment coffee was the main source of income with supplementary incomes from local sales of peanuts (*Arachis hypogaea*), fresh vegetables, livestock, betel nut (*Areca catechu*), and rice. Recently, vanilla briefly replaced coffee as the biggest income earner when international prices boomed for three to four years, due to a failure of production in Madagascar.

People say piper first appeared in this area in the early 1950s and gradually spread until today it has colonized much of the fallow garden areas and in some places completely dominates the fallow vegetation. It was estimated that only 30% of the village land remains in primary forest with the remaining 70% under secondary forest vegetation or cultivation. Of this 70%, around 75% is cultivated and 25% is fallow. On much of the land cultivated since the 1970s, fallow vegetation is dominated by piper. A vanilla farmer described the changes as follows:

Our forefathers cut a lot of forest trees down to make gardens in the past. All the forest and its services are gone, together with the wild animals. We only see what forest is like from the pictures in the magazines or books. Piper has become our new environment.

Sanzeng Village

About 250 people live and work in Sanzeng village permanently; others live and work in the urban areas or have migrated to other villages. Sanzeng, like Sanangac, lies close to the gravel road that connects Pindiu to Finschhafen, but is closer to Pindiu. Access to services like banks, postal services and schools is similar to Sanangac, as are livelihoods, except that piper is sold as firewood to government officers in Pindiu.

People say that piper was first brought to Sanzeng from Timbulim on the coast in the 1950s. Fifty years later, piper occupies almost the entire land area of Sanzeng and has replaced almost all the previous secondary vegetation. At Sanzeng less than 10% of the land area is primary forest, which is restricted to the crests of the highest hills. Of the 90% of land area in use, about 70% of the area is fallow and 30% under cultivation.

Tongucboc Village

The village is smaller than the other two villages and has a population of 100. The population appears to be younger. There are 20 houses. A number of people have migrated to other parts of the district. Within the village

land, people are scattered in small hamlets leaving the main village with only eight houses. Banks, postal, and health services and schools are about two hours walk from the village.

Like Sanangac and Sanzeng, people grow coffee and peanuts as cash crops. Families own around 500 coffee trees. Many have recently planted vanilla. A few people keep pigs for sale and some make money from selling wild fowl eggs and hunted game. Two men make handles for tools from forest hardwoods and sell them at the local market. Betel nut is another source of income.

According to the villagers, piper was brought to this area in 1946 as an ornamental plant and as a source of firewood. Piper is currently seen in small patches as understory in gaps in the secondary forest. It was estimated that primary forest covers about 60% of the total land area, 30% is under fallow successions and about 10% is under cultivation. Fallow vegetation is dominated by piper. Clan leaders have imposed restrictions on felling primary forest and tall secondary forest; so all farmers cultivate lands in the secondary forest areas.

FIELDWORK AND DATA COLLECTION

The selection of informants followed a purposeful sampling technique, a procedure that is often used in exploratory investigations (Poate and Daplyn, 1993). Snowball sampling was also applied within each village. In Sanangac, older men were interviewed separately from their wives because women are supposed to keep silent when men communicate with visitors. In Sanzeng village, an open village meeting was held first and then people were questioned individually. In Tongucboc, many villagers spontaneously came and told stories about piper.

In each village, nine villagers were interviewed and some six to seven detailed field observations were made. In this way, various accounts were collected of people's views on piper, its history in their village, and whether and how they use it. Villagers were able to provide through these narratives, a map of the social consequences of the piper invasion and its present dominance.

An interview guide was prepared to make sure that in all the three villages similar topics were covered. The interview guide was pretested in three other villages in Finschhafen District (Torecko, Heldsbach, and Siki) by randomly interviewing 12 people. This pretesting phase also enabled us to trace part of the history of the introduction and spread of piper in Finschhafen and other districts. The interviews were conducted by the first author in the local language and Pidgin, which were used interchangeably

in everyday conversation. A tape recorder was not used but handwritten notes were typed up after the interviews.

THE USE OF PIPER

The villagers use piper in three ways: (i) in agriculture (farm use), (ii) in and around the house, and (iii) in medicinal applications, and each of these uses is described in this section. Villagers in the area have found different uses for all parts of the piper plant and in general they favor it. However, villagers also recognized negative aspects associated with the invasion of piper.

Farm Use

In agriculture the stems, the roots and the ashes from burned wood and leaves are the most valued parts of the piper tree. There is a difference in the use of piper by men and women (Table I). Men mostly use piper stems and roots while women tend to use the ashes as pesticide in the food gardens. Older people and women prefer the tree for fence construction or for other farm use because it is locally available and the wood is soft. Younger and more active men who are able to travel longer distances and carry heavier loads fetch harder wood from the forests. Each of the main uses is discussed briefly below.

Table I. Summary of the Main Uses of *Piper aduncum* in the Three Villages of the Finschhafen Area of Papua New Guinea

Plant part	Products or services	Users
Live trees	Shade for pigs	—
	Windbreaks	All
	Weed control	All
Mature Stems	Used as digging stick	Men
Stems and branches	Build soil retention structures	Men
Stems, stumps and branches	Staking crops	Men
Stems	Making new fences	Men
	Maintain fences	Men
	Used as pegs	Men
	Build chicken houses	Men
	Coffee and vanilla platforms	Men
	Handles for tools	Men and Woman
Roots	Makes soil tillage easier	All
Ashes	Pesticides	Women
	Fertiliser for the soil	Women

Making Soil Tillage Easier

Most villagers till the soil with hand tools before new crops are planted. Several steps usually precede tillage. A young farmer from Tongucboc explained the steps as follows:

The first thing before I select the land for my farm, I survey the area to see if the vegetation is covered by piper. Everyone in the village does that because the vegetation under piper is light and so it is easy to clear the place quickly with fewer difficulties. After all the vegetation is slashed, the last task is to fell the piper trees. Not all trees are cut down. I leave few trees standing which can be used later for the staking of yams or sugar cane. I just pollard them. Leaves and branches from the felled trees are stripped off and spread out equally and evenly around the garden and the piper stems are either grouped in upright positions against any remaining unfelled stems to dry or piled at the sides of the cleared area. The cleared area is left to dry for about three or four weeks depending on the weather. When it is dry I burn the dry vegetation starting from one end of the garden. I then wait at least a day before I rake the debris together and burn the rubbish in small heaps, known as "qago." ("Qago" is made out where specific crops like banana and yams will be planted in the ashes. Dry piper branches or stems and bamboos make good materials for "qago.") The soil is now ready for tillage, which is done with the help of my family members or by myself depending on the size of the clearing. I normally choose piper dominated areas for farming as the tree roots break up the soil and make it easier to till and also the roots of the trees are easier to remove than those trees from the jungle.

This account summarizes many farmers experience. People till the soil with hand tools like digging sticks, hoes, forks, and spades, so areas where the soil is lighter are preferred and the deeper rooting systems of secondary forest areas are avoided. Tillage is unusual in PNG shifting cultivation systems and its practice here may be an important factor in the rapid spread of piper. Piper enables women to prepare land for cultivation because it does not require the heavier work that it takes to clear local woody fallow species.

Soil Erosion Control

The majority of the respondents use piper stems to build soil retention structures that take the form of narrow terraces. Felled dry branches are cut to a length of 1–2 m and pushed into the soils in a fence-like pattern roughly along the contour. The structures are fastened with ropes to sustain the weight of the debris, such as soil, stones, roots, and branches. Men usually do this before the soil is tilled. Prior to the invasion of piper, cane and other grasses were planted on the contour.

Allen *et al.* (2002) describe migrants from Finschhafen District using piper to make terraces for subsistence sweet potato growing on the Sogeri Plateau, inland from Port Moresby. At Sogeri, piper stems that had been

pushed vertically into the soil along the front edge of the narrow terraces were striking, creating rows of piper trees across previously Imperata grass covered hillsides. Highlands migrants living nearby had not adopted this practice.

Fences and Stakes

More than half of the people in Sanangac and Sanzeng said that piper stems were very useful for constructing fences to keep feral and domesticated pigs out of gardens. Both dry and newly cut piper stems were used. In Sanangac, farmers used dry stems in new and existing fences. Occasionally some piper plants would be left growing inside the fences to provide shade for domestic pigs that are sometimes allowed into gardens after the harvest; it was also mentioned that pigs eat piper. Piper stems were also used for staking sugar cane, pitpit (*Saccharum edule*), and bananas. Women and children collect the stakes for firewood after the crops have been harvested.

Digging Sticks and Tool Handles

Mature stems of piper are used as digging sticks to plant root crops like *Xanthosoma sp.* Fresh piper stems are used in stony soils, where farmers do not want to damage their iron tools, because they are heavier and stronger. Piper stems are used as handles for tools such as rakes, hoes, and spades in Sanangac and Sanzeng, but not in Tongucboc where two specialist craftsmen make all types of tool handles from forest hardwoods.

Other Uses

Piper stems are used as pegs for marking out new fields. This was observed in a newly developed cocoa plot at Heldsbach, near Finschhafen, and at Sanzeng, where piper was used as pegs and then as support for vanilla plants. Villagers near Heldsbach used piper stems to remove the husk from dry coconuts. They were also used in the construction of chicken houses and for building raised platforms for drying copra, vanilla and, coffee. Live trees were used for windbreaks.

Household Use

Various parts of the plants are used in and around the house particularly by women, who now prefer piper to other tree species.

Construction of Fences and Boundary Markers

Piper stems were used as small protective fences for flower gardens near houses to keep village chickens and children from trampling the flowers. Piper stems laid lengthwise along the ground served as markers to indicate the field boundaries shared between clan members or neighboring clans.

Poles and Rafters for Buildings

Stems of mature piper were widely used as framing for houses at Sanangac and Sanzeng but not at Tongucboc, where very few people used piper for building. Straight and mature piper stems were selected and felled and the desired portions were cut off and the bark removed. The stems were dried vertically for several days and were then transported to the construction sites. Men normally prepared the stems but woman and children helped carry them to the building site. There were disparities in the views in Sanangac on the usefulness of piper stems as house frames. Some men argued that piper rots easily compared to forest hardwood. Its use as framing is possibly related to its ability to resist ants and termites.

Uses as Fire Wood/Fire Stick

Cooking was done over an open fire, usually indoors. Firewood and its collection played an important role in daily life. Dry piper wood was preferred over indigenous trees by many people. A man summarized this as follows:

We prefer piper as it does not produce as much smoke inside the house, it cooks our food quickly and also it is a soft tree which women and children can chop and carry home. It is not heavy like other trees in the forest. If you walk long distances to the bush or distant gardens, you can carry a fire stick that will burn until you reach that place. We prefer piper wood for such characteristics.

Another man from Sanzeng village said:

Men and women like this tree as it is easy to chop with bush knives and to break with our hands. The trunk of the tree is usually straight and small and that is why women and children can easily chop and carry it. Once in a while, policemen and governments officials working at the station request us to bring firewood to them for cash, clothes or food.

Piper has become an important source for domestic firewood and as a source of cash or trade at Sanzeng because of its proximity to the government station at Pindiu.

Other Household Uses

Young leaves of the piper were used for cleaning household utensils together with ashes from the fireplace. Young leaves of piper were also placed at pit toilet houses. The leaves were picked a few days previously because fresh leaves are uncomfortable to use. In the past people used the leaves of a flowering plant for this purpose. These flowers were grown near the toilets and picked as needed. Not many villagers were keen to talk about this.

Medicinal Applications

Piper plant parts appear to have a number of medicinal properties and Table II below provides a summary of such uses in the three villages. Extracts from leaves, bark, and roots were reported to heal some sicknesses and diseases. A few villagers also indicated that a preparation from piper leaves will kill leeches and that leeches have almost disappeared from areas where piper has become dominant in the secondary forest. Treatment of cuts with piper was widely used, and a man explained this as follows:

One day I was planting taro and a sharp bamboo cut my foot. It was a deep cut and I lost much blood. I scraped the bark of piper and squeezed the sap on to the cut. The blood clotted very quickly. Later I dressed the cut with piper leaves. I did not visit the hospital. I waited about a month before the sore healed to an extent where I could walk around. At that point, I realized that piper is a good medicine.

In the three villages, medicinal knowledge of piper is usually shared only with close family members or associates because the villagers are not sure whether piper medicine will work for others. Due to the prestige accorded modern medicine, discoveries such as medicinal uses of piper are regarded by villagers as relatively unimportant.

Table II. Plants Part and Medicinal Use of *Piper aduncum* in the Three Villages of the Finschhafen Area of Papua New Guinea

Plant parts used	Maladies
Extracts from fresh leaves, bark, and roots	New cuts to the body
Extracts from the bark and fruits	Tooth-ache
Extracts from fresh barks and roots	Diarrhoea
	Dysentery
	Cough
Fresh bark extracts used with lime	Fungal infections (grille)
Extracts from fresh leaves	Insect bites (centipedes, bees and leeches)
Extracts from the leaves	Dressing sore
Juice extracted from the fresh stem	Head-ache
Extracts from the fresh marks and leaves	Scabies
Extracts from the fresh roots	Stomach—ache (pain)

Most villagers have learned about the medicinal properties of piper by trial and error. A man from Sanangac used it for stomachache and when asked why he took the risk and tried it, he replied:

I have a dog and every time I passed through an area of piper she would eat the fallen fruits. When I first saw this I did not think about it but suddenly I witnessed some changes in my dog. You know when dogs are sick in the stomach they pass out bad smells from their anus. It is then that the dog ate the fallen piper fruits. After several observations on my dog, I got curious and tried it on myself by digging the roots of the plant and use its extracts to stop my stomachache. The relief was instant. I never have this problem anymore, but I have told nobody. I only told few family members about my discovery.

OTHER EFFECTS

There are several other aspects of the piper invasion that people reported during the interviews.

Loss of Forest and Timber Products

Forest products refer to timber and non-timber products that are collected from the primary and secondary forest. Some people expressed concern that products they were able to collect from the forest in the past are not available since the invasion of piper.

In Sanzeng and Sanangac villages, older people could compare the situation before and after the invasion of piper. They argue that the regeneration of the indigenous forest was disturbed by the fast growth of piper. As a result, useful trees for building houses disappeared. A particularly hard felt loss was trees used for making planks. Men also spoke of trees that were used for rafters, poles, posts, and other smaller parts of houses, which have been replaced by piper stems. In Tongucboc, a clan leader has made a rule that no forest tree can be cut unnecessarily. Although Tongucboc has a larger forested area than the other two villages, people there still expressed their concern at the decreasing supply of forest products. In Sanangac and Sanzeng the loss of some species has forced villagers to adopt woven bamboo for walls instead of planks.

Loss of Non-Timber Products From the Forest

Wild fowl eggs are another product no longer harvested from the secondary forest. Rattans that men collected for fastening fences and houses are also no long easily found. Both fowl eggs and rattans are absent

where piper dominates and have become scarce particularly in Sanzeng and Sanangac. Wild animals like cassowary, pigs, and other small animals do not live in piper dominated fallows. Older women reminisced about particular trees that sheltered mushrooms:

In the past Sanzeng was covered with secondary forest where we could harvest mushrooms like Kinge, Gulu, and Siula. Siula is still collected today but the others have disappeared. Today lots of young people do not know about these mushrooms.

Effects on Food Production

There were conflicting views on the effect of piper on food production. According to people at Sanangac and Tongucboc, root crops like Chinese taro are less productive than before. But at Sanzeng, people said that Chinese taro will yield well if some piper trees are left in the middle of the fields and occasionally coppiced to generate mulch for the crop. Taro (*Colocasia esculenta*) yields are said to have decreased in areas where piper has become dominant and some farmers have given up growing taro and local yam varieties. Other men said that before the invasion and dominance of piper, their staple diet consisted of Chinese taro (*Xanthosoma sagittifolium*), taro (*Colocasia esculenta*), yam (*Dioscorea spp*), and to a lesser extent sweet potatoes (*Ipomoea batatas*). Gradually, they have switched to sweet potato as a staple crop because it grows so well after a piper fallow. This change from taro to sweet potato has also been observed in many areas where piper is not dominant, so it may not be a consequence of the piper invasion at Finschhafen, but more a broader outcome of shorter fallows and lowered soil fertility (see, for example, Bourke, 1992).

Effects on Social or Community Life

The dispersion of the large village into smaller and more isolated hamlets has been indirectly associated with the spread of piper. Piper makes it easy to clear new areas to construct settlements and the establishment of small hamlets. In Sanangac, there were three such hamlets, Sanzeng and Tongucboc had two. These breakaway communities are usually made up of close family members. Elsewhere in PNG, fears of interfamily conflict and jealousies create pressures for large settlements to disperse. The introduction of piper appears to have facilitated a desire that was previously more difficult to satisfy because a small family unit did not have sufficient labor to clear well-developed secondary forest.

Impact on Bush-Spirit Sites

Several villagers expressed mixed feelings about the influence of piper on the existence of bush-spirits. These often malicious spirits lived in small waterholes in difficult to access areas in the forest. They are commonly mythically associated with the origins of humans and many domesticated plants and animals. People believe that they will get sick and die if they trespass in places where these spirits are said to live. A villager from Tongucboc explained how the introduction of piper had affected these human-spirit relationships:

That place called Wiri Sungurungu used to be a *masalai* [spirit] place. People would get sick and die if they went there. We would protect ourselves with magic and insert a piece of special vine in our hair when we went there. When piper took over, after people made gardens and disturbed the nearby forests, the spirits may have fled. Today even the children can go there without fear of being harmed.

People have long forgotten the special protective charms but they can still identify the special protective vines. These bush-spirit sites are an integral part of traditional knowledge systems. In Sanzeng and Sanangac village, most bush-spirit sites were reported to be rendered useless, but in Tongucboc, at least one bush-spirit site still exists. The influence of mission teaching, which discourages such beliefs, is not known.

DISCUSSION

Although piper had been in the study area less than 50 years, villagers used it in many different ways. In the three villages, the tree had significantly influenced livelihoods. Villagers appreciated the usefulness of piper although the uses differed slightly in the three villages (Table III), but also recognized some unfavorable aspects of its dominance. This discussion focuses on the main effects of piper on the livelihoods of rural people and how these effects were brought about. It should be stressed that there are particular aspects of the piper that raise concern, which makes it difficult to generalize about the generic usefulness of piper.

In part, villagers were forced to use piper because it had replaced indigenous trees in the fallow vegetation successions. It had direct effects on the soil and on successive crops after a fallow, but had also some indirect effects. In field experiments, it was observed that piper had significantly higher growth rates than other common fallow species in lowland Papua New Guinea (Hartemink, 2001, 2004). Several farmers mentioned that soils after piper fallows are easier to till and this is likely related to the fact that soils after piper fallows contain less moisture (Hartemink, 2003).

Table III. The Significance of *Piper aduncum* Uses in Three Villages in the Finsch-hafen Area in Papua New Guinea Based on the 9 Interviews/Village.

	Sanangac	Sanzeng	Tongucboc
Farm uses			
Digging stick	XXX	X	—
Making fences	XXX	XXX	XX
Stakes	XXX	XXX	XX
Pegs	XX	X	—
Tool handles	XX	XX	X
Soil retention structures	XXX	XXX	XXX
Shade	XX	XXX	X
Helps tillage	XXX	XXX	XX
Good fertilizer	XXX	XX	X
Burn debris	XXX	XXX	XXX
Weed control	XXX	X	X
Household uses			
Cleaning stains on cooking utensils	XXX	XXX	XXX
Temporary platforms for resting	X	X	X
Ashes used as insecticide	X	X	XX
Leaves used as toilet tissues	XXX	XXX	X
Walking stick	X	X	—
Fire stick	XXX	XXX	XXX
Fuel wood	XXX	XXX	XXX
Rafters for houses	XXX	XXX	X
Poles for buildings	XX	X	—
Cleaning stains on teeth	XX	X	XX
Plant support	XXX	XXX	XX
Sticks for flower bed fences	X	X	X
Making temporary ladders	XX	X	—
Services			
Attracts wild animals	XX	XXX	XX
Improves soil fertility	X	XX	X
Dries of waterlogged soils	X	X	X
Provides shades	XX	XXX	X
Chases away the leech	X	XX	X
Host to other useful plants	—	X	—
Good sweet potato yield in short fallow	XXX	XX	XX
Provides wind breaks	XX	XX	XX

X: Rarely used (3 or less of the 9 interviews).
 XX: Often used (4–6 of the 9 interviews).
 XXX: Very often used (7 or more of the 9 interviews).

Some farmers indicated that crop yields are lower after piper fallows but that was not a universal observation and it is not supported by the limited data in the agronomic literature (Hartemink, 2003a,b). Yield decline and changes in cropping patterns (e.g., from taro and yam to sweet potato) is related to a range of factors affected by population increases and higher yields per unit area of sweet potato systems (Allen, 2001; Allen *et al.*, 1995). Thus there is some mismatch between what farmers observe and what has been concluded from experimental data. Such differences in perceptions

are not uncommon (Bouma, 1993). In this case the decline in yields (and crop switching) is caused by a shortening of fallow periods, which has coincided with the invasion of piper and people have blamed the more obvious change of fallow species in the landscape rather than the more insidious decline in soil fertility.

Villagers had also found several new uses for piper and its products so it became both a resource which they were to some extent forced to use, as well as one they chose to use. Examples of new uses are processed leaves and stems as medicines for various maladies. Although there is a small body of literature that indicates the usefulness of *Piper aduncum* for medicinal purposes (Maia *et al.*, 1998; Nair and Burke, 1990) and the species appears in various ethnopharmacological databases, it is interesting how people have discovered these uses, especially as they appear reluctant to tell non-family members about their discoveries.

Villagers have adapted to the changes brought about by piper to their natural environment. Issues of governance and institutional relations defining access to natural resources, which in many parts of the world restrict both use and access, do not occur in Papua New Guinea with regard to piper. In the study area, the tree has been defined as a common property resource that is freely accessible in fallow land. Nor do restrictive gender relations impinge on the use of piper and in some cases piper provided alternative sources of cash for women. These institutional dimensions of piper have contributed to the positive evaluation of the plant made by the villagers. Such a conclusion warrants the observation that piper has brought new opportunities for rural people in Papua New Guinea. There was some difference in the use and the appreciation of piper by men and women that is probably a consequence of household task related issues.

The invasion and dominance of piper has also had some negative effects on rural livelihoods in the study area. These are mainly related to the loss of primary forest and the replacement of indigenous secondary fallow vegetation successions with one dominated by piper. There is disintegration of social cohesion that people have associated with piper, the vanishing bush-spirit sites the disappearance of certain forest products, and the destruction of the primary forest although these changes would probably have occurred with or without piper. It is unlikely that piper was the primary cause of cultivated land reaching bush-spirit sites that were once deep in the primary forest. But piper has become associated with fallows and is forming a monospecific fallow succession, very different to the previous species rich, secondary forest successions that dominated these landscapes, so people associated with it the loss of the bush-spirit sites, rather than population pressure on land. The villagers in Sanangac and Sanzeng now

have limited access to products from the forest, and may feel compelled to accept and use piper in their place.

Other studies have argued for a negative interpretation of the impact of bioinvaders on people's livelihoods. McWilliam (2000) found that the invasive weed, *Chromolaena odorata*, challenged the ability of farmers in Timor to farm and ultimately prosper. Comparing the Timorese and Papua New Guinea cases highlights the difficulty of generalizing meaningfully about socioeconomic and agronomic impacts of bioinvasive plants. The effect of bioinvaders is clearly site-specific. Possible bioinvasive control programs in their turn need to take into account locally specific conditions.

The long-term impact of piper may be different from the short-term adaptation people have made. Careful monitoring of changes in the impact and the agronomic and livelihoods aspects of piper invasion and dominance is required. The specificity of the social and natural environment is important in assessing the impact of bioinvasive plants on people's lives and interdisciplinary research needs to explore the possible relations between the way the social and the natural interact and mutually transform each other. For such research, a situational perspective is required. The challenge for such interdisciplinary research is placing the human actor and the natural environment at the forefront of the analysis.

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