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Risk coping strategies in tropical forests: floods, illnesses, and resource extraction

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ABSTRACT. This paper examines coping strategies in response to covariate flood shocks and idiosyncratic health shocks among riverine peasant households in the Amazonian tropical forests. An assessment of coping strategies reveals that although precautionary

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savings (food stock and livestock) are important for both types of shocks, *ex post* labor supply responses in the form of upland cropping and resource extraction (fishing and non-timber forest product gathering) are more common to cope with the flood shock depending on local environments. A bivariate probit model examines what factors shape households' adoption decisions of gathering and fishing as a coping strategy. The analysis reveals an important insurance role of non-timber forest product gathering for the asset poor who have limited options for coping with flood risk. Targeted interventions and programs for the poor to promote sustainable forest resource use are discussed.

1. Introduction

Researchers commonly argue that the rural poor – with limited assets and opportunities – tend to rely more on common property resources not only for income and sustenance but also for risk coping to smooth consumption after income shocks (Jodha, 1986; Dasgupta, 1993). As such, the environment provides the poor with natural insurance as part of 'the subsidy from nature' (Hecht *et al.*, 1988). Indeed, environmental assets may be the only 'wealth' the poor have at their disposal to combine with their labor, especially in locations where wage labor opportunities are limited.[1] This link between asset poverty and resource extraction as insurance may be very significant in tropical forests where the livelihoods of the poor often depend on the extraction of biological resources in a biodiverse yet fragile environment (Coomes and Barham, 1997; Byron and Arnold, 1999; Arnold and Perez, 2001; Wunder, 2001). While many recent empirical studies explore small-scale resource extraction among rural households (e.g., Gunatilake *et al.*, 1993; Godoy *et al.*, 1995; Reddy and Chakaravarty, 1999; Cavendish, 2000; Coomes *et al.*, forthcoming), very little research to date explicitly examines forest peoples' coping strategies and the role of resource extraction as insurance.[2]

This paper examines coping strategies among riverine peasant households living in and around Peru's Pacaya-Samiria National Reserve (PSNR), one of the largest protected areas in Amazonia. Using unique household data of shock history, we first construct a complete list of

[1] Development economists have explored a variety of risk coping strategies among rural households, such as precautionary savings (Paxon, 1992; Udry, 1995; Alderman, 1996; Behrman *et al.*, 1997; Fafchamps *et al.*, 1998), credit and remittance (Lucas and Stark, 1985; Rosenzweig, 1988; Stark and Lucas, 1988; Udry, 1990; Foster and Rosenzweig, 2001), market labor supply (Kanwar, 1995; Kochar, 1999; Rose, 2001), and mutual insurance (Fafchamps, 1992; Townsend, 1994; Udry, 1994; Fafchamps and Lund, forthcoming).

[2] As an exception, Pattanayak and Sills (2001) show a positive correlation between labor supply for forest product gathering and agricultural production risk among peasant households in the Brazilian Amazon. McSweeney (forthcoming) examines relationships between forest product extraction and unexpected illness as well as crop shortfalls among Amerindians of eastern Honduras. Howe (2002) explores the role of savings, labor supply, and credit and remittance in coping with health shock among Amerindians in the Bolivian Amazon, but he offers no discussion of resource extraction. Howe's study is based on the same data as Godoy *et al.* (1998) who also explore coping strategies among Amerindians without touching on resource extraction.

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household responses used to cope with a large covariate flood shock and idiosyncratic health shocks. Although flood cycles sustain the high productivity of lowland agriculture in Amazonia, through annual deposition of fertile alluvium, occasional high and long-duration floods cause massive crop failure in the region (Barrow, 1985; Goulding *et al.*, 1996).[3] Distinct from more arid regions like Sub-Saharan Africa where periodic drought is the greatest environmental shock, such unusual large floods often constitute a significant covariate shock in tropical lowlands even though the severity of the latter risk may be smaller than that of the former (Binswanger and McIntire, 1987). Do households go to the forest to smooth consumption after large floods? The types of needs associated with an illness shock are different, involving an emergent cash demand for medical expense as well as a decline of labor force, especially in the case of adult sickness. Cash tends to be one of the scarcest assets traditional forest people hold. How do they fill their emergency cash needs? Our descriptive analysis reveals that gathering of non-timber forest products (NTFPs) and fishing are the major coping strategies following flood shocks. What determines the coping strategy choice between gathering and fishing is a second issue examined in the paper. In particular, is asset poverty associated with resource extraction as insurance?

In the PSNR, unlike many other locales in tropical uplands, deforestation is not a primary threat. Indeed, essentially no colonization occurs in the area, less than 1 per cent of the forest area of the reserve has been transformed into agricultural land, and logging which is illegal in the reserve is very uncommon. Instead, species degradation and biodiversity loss caused by local resource extraction are the primary environmental concerns in the PSNR. This occurs not only directly through hunting and aquatic extraction (e.g., the Amazon river turtle, *Podocnemis expansa*; paiche, *Arapaima gigas*; various aquarium species) but also indirectly through NTFP gathering because certain NTFPs are important food sources (e.g., fruit, nuts, vegetation) for terrestrial and aquatic species. In our eight sample villages, the harvest of Moriche palm fruit (*Mauritia flexuosa*) and of heart of palm (*Euterpe precatoria*), for example, which typically entails the felling of the palm and hence their removal as a food source for local fauna, represents the loss of about 2,600–4,000 and almost 22,000 palms per year, respectively (Coomes *et al.*, forthcoming). Contrarily, fishing is widely viewed as being relatively sustainable because of the region's abundant fish stocks.

The paper is organized as follows. The next section describes the study area and households' livelihoods and asset holdings. Section 3 provides a descriptive analysis of household responses to flood and health shocks across different environments. Section 4 develops an econometric model of household coping strategy choice. Section 5 presents the estimation results, and section 6 concludes.

[3] Related with global climate change, El Niño, and upstream deforestation, the trend of the occurrence and magnitude of high floods on the Amazon River is a controversial issue among natural scientists (Gentry, 1980; Nordin and Meade, 1982; Sternberg, 1987; Costa and Foley, 1999).

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Table 1. *Income share by village in a normal flood year, 1996*

Sample means (n = 87)	*V1 Lowland Mixed* %	*V2 Lowland Fishing* %	*V3 Lowland Ag.* %	*V4 Upland Ag.* %	*ALL* %
Agriculture	54	8	68	54	50
Fishing	19	89	21	33	35
Gathering	24	0	4	6	8
Hunting	4	0	5	6	5
Aquatic extraction	0	3	1	2	1
Total income[a]	5,052	8,244	4,985	3,093	4,577

Note: [a]Total income is in 1996 Peruvian Sol (US$1 = S/. 2.6).

2. Study area, livelihoods, and asset holdings

The PSNR is situated in northeastern Peru, between the Marañón and Ucayali Rivers that join to form the Amazon River, some 110 kilometers southwest of the city of Iquitos. Extending over two million hectares of wetland, the reserve is dominated by seasonally or permanently inundated forest (Bayley *et al.*, 1991; Rodríguez *et al.*, 1995). Over 170 communities are found in and around the reserve, comprised largely of mestizo peasants (known locally as *ribereños*) who make their living from shifting cultivation, floodplain agriculture, fishing, hunting and NTFP gathering (Takasaki *et al.*, 2001).

Socio-economic survey data were gathered from 300 peasant households in eight villages in the PSNR area, four along the Marañón River and four along the Ucayali River, over a 16-month period, beginning in early 1996.[4] Each year flood-waters rise and fall over a range of 8–10 metres, demarcating the seasons and determining both the availability of food and the area of habitat available for fauna. In 1993, on the Marañón River, an unusually high and long-duration flood occurred unlike along the Ucayali River. To examine this environmental shock, the paper focuses on 95 households with complete data in the four villages on the Marañón River.

The average sectoral or sub-sectoral income share in our Marañón sample for 1996 is shown in table 1, a year that brought a normal annual flood. Agriculture and fishing are the principal activities, with income shares of 50 per cent and 35 per cent, respectively; the balance is accounted for by other extractive activities, of which NTFP gathering is the most important,

[4] Village selection was purposive, rather than random, in order to capture in a cost-effective manner the regional diversity in environmental conditions and resource use activity. In addition, we sought to avoid communities where environmental NGOs had been working so as to minimize possible ‘distortions’ in resource use behaviour due to ongoing or previous conservation-development initiatives. Based on a rapid rural appraisal wealth ranking effort, households were chosen according to a stratified sampling strategy designed to over-sample wealthier households who, by their relatively small numbers, were likely to have been overlooked by random sampling (Takasaki *et al.*, 2000).

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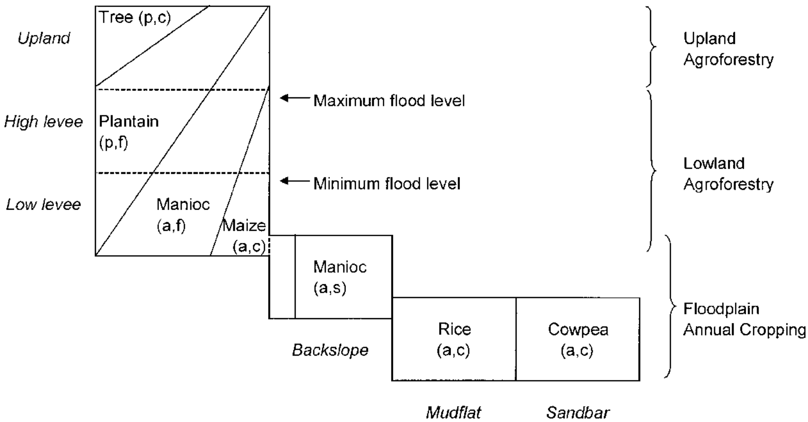

Figure 1. *Land types, agricultural strategies, and crop choice*
Notes: p: perennial crop, a: annual crop, f: food crop, c: cash crop.

while hunting and aquatic extraction contribute little to income. Table 1 also shows striking across-village differences in livelihood choices: Village 2 (V2) is fishing-oriented (about 90 per cent of income from fishing); Villages 1, 3, and 4 (V1, 3, 4) are agricultural-oriented (over 50 per cent of income from agriculture); and activity choice in V1 is the most mixed, with gathering accounting for nearly a quarter of income.

Livelihood heterogeneity across villages is largely a function of local environmental endowments, especially the availability of prime agricultural land. Forested land and natural resources such as fish and wildlife are essentially open access to local residents in the PSNR area. Once cleared, land is held by usufruct (i.e., without title), privately used, and transferred principally along kin group lines.

Flood vulnerability varies across land types: upland is never flooded, high levee is flooded only by high floods in some years (e.g., 1993), low levee and backslope are flooded each year, and mudflats and sandbars appear only for a limited time during the low-water season. Correspondingly, land types largely shape agricultural strategies and crop choices, especially given the very rudimentary technologies used by farmers in the area (figure 1). In upland agroforestry, plantain and manioc (main food crops) are planted first, followed by tree crops; at any moment in the crop rotation the plot may be left in fallow. Lowland agroforestry sequences on the high and low levees depend on soil conditions determined by the annual flood; manioc (as well as maize to a lesser extent) is cropped annually, whereas plantain (a perennial) may be harvested over several seasons. Although plantain tends to be cultivated on higher land than manioc and maize in order to survive floods during the low-water season, massive destruction of the plants can occur under periodic high floods that inundate the plant stem over an extended period (Bergman, 1980). On the levee backslope, mudflats, and sandbars, farmers annually crop manioc (as well as maize and watermelon to a lesser extent), rice, and cowpea, respectively, during the limited low-water period. A typical portfolio for households in the PSNR includes food

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Table 2. *Asset holdings and demographics by village in a high flood year, 1993*

Sample means	*V1 Lowland Mixed*	*V2 Lowland Fishing*	*V3 Lowland Ag.*	*V4 Upland Ag.*	*ALL*
Asset holdings:					
Cultivated land (ha):					
Upland	0.00	0.00	0.05	0.47	0.21
High levee	0.06	0.00	0.63	1.04	0.59
Low levee/Backslope	0.38	0.43	1.01	0.27	0.47
Mudflat	0.58	0.00	1.06	0.57	0.57
Sandbar	0.24	0.00	0.00	0.20	0.13
Total	1.25	0.43	2.76	2.54	1.97
Number of total plots	3.9	1.4	3.5	2.8	2.9
Large fishing net holdings (0/1)	5%	69%	32%	27%	31%
Demographic factors:					
Number of adults	3.3	3.1	3.6	3.8	3.5
Age of household head	46	40	46	49	46
Number of observations	19	16	19	41	95

crops on low levee and backslope (which are locally abundant), along with a combination of cash crops (especially rice) on fertile mudflats and/or food crops on secure upland and relatively secure high levee (both of which are locally scarce).[5]

As shown in table 2, households in the sample held an average of 2 hectares of cultivated land in 1993, a high flood year (see Takasaki *et al.*, 2001 for similar across-village variations of total land holdings including uncultivated land such as fallow). High levee, low levee/backslope, and mudflat constituted the three major types of land held, with 30 per cent, 24 per cent, and 29 per cent shares, respectively, of the mean land portfolio; the balance accounted for by upland and sandbars (in our data, low levee and backslope cannot be distinguished). Striking across-village variations of land portfolios are apparent. Households in V3 and V4 have larger mean land holdings than the others, and households in V2 have less land and fewer plots (on both cultivated and uncultivated lands) than the households in the other villages. Differences in land portfolios are especially evident in terms of locally scarce land types: upland holdings are common (but not uniform) only in V4 (the only village located on upland in the sample); high levee is common only in V3 and V4; and large mudflats occur in V3 whereas no mudflats exist in V2. These heterogeneous land portfolios across the villages give rise to distinct crop choice patterns. In particular, plantain cultivation on low levee in upland V4 is less common than in lowland V1–3

[5] Thus, depending on the availability of land types, farmers' land use involves trade-offs between low-risk–low-return upland agriculture and high-risk–high-return lowland agriculture and between food cropping on upland/levees and cash cropping on floodplains. Within the same type of high or low levee, farmers' crop choice between plantain and manioc also involves risk–return calculations.

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(the proportions of plantain cultivation on low levee plots are 90 per cent, 62 per cent, 60 per cent, and 33 per cent in V1–4, respectively).

A comparison of tables 1 and 2 clearly shows the correspondence between livelihood choice and land holdings; land-poor V2 is fishing oriented and land-rich V3 and V4 are agricultural oriented, while in land-middle V1 activity choice is more mixed. This correspondence is also explained by other local environmental endowments: V2 is located on an oxbow lake with rich fish stock and V1 has good access to rich Moriche palm stands. This correspondence is reflected in across-village differences in the holdings of fishing nets (that are privately owned);[6] large fishing net holdings are very common in V2 but there are almost none in V1. Contrarily, two demographic variables, number of adults and age of household head, show no strong across-village variations.

3. Coping strategies in response to flood and health shocks

All households in the Marañón portion of the sample ($n = 95$) experienced a high and long-duration flood as a covariate shock in 1993.[7] In our survey, each household head in the sample was asked to identify the *three* biggest flood shocks he/she had experienced over time. Although we did not ask households to rank these shocks in terms of severity, this subjective measure is comparable with the subjective risk ranking measure used by Smith *et al.* (2001) to examine risk assessment among East African pastoralists. Over 80 per cent of households reported the 1993 flood as one of the biggest three flood shocks (table 3). In this instrument older households may tend to underreport this specific flood simply because their time horizon of shock history is longer than that of younger households. This time horizon bias is formally treated in the econometric analysis below.[8]

With no hydrological data at a village level, we cannot compare the magnitude of the 1993 flood across the villages. However, V2–4 are located in relatively close proximity to each other, while V1 is situated further upstream. Our data show that only V1 experienced associated land slumps in 1993 and that, as a result, most households in V1 were forced to relocate their homes. These observations suggest that the magnitude and impacts of the flood were probably larger in V1 than they were in V2–4. At the village level, we anticipate that flood vulnerability is strongly shaped by variations

[6] Fish is the primary source of protein in the local diet and most households participate in subsistence fishing using rudimentary equipment (poles, hooks, canoes, etc.). More commercially oriented fishers employ boats with engines and larger, more sophisticated fishing nets.

[7] While hydrological data on the Amazon River can be obtained for Iquitos, no such data are available on the Marañón River in the PSNR region and thus across-time comparisons of flood levels are also not possible. Nonetheless, the unusually large flood of 1993 is well known in the region.

[8] This potential bias seems to be rather uniform across the villages as suggested by the similar average ages of household head. Since the reported high floods can include those experienced in former villages where households used to live, the time horizon can be captured by age.

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Table 3. *Flood shock and coping strategies by village*

(*n* = 95)	*V1 Lowland Mixed* %	*V2 Lowland Fishing* %	*V3 Lowland Ag.* %	*V4 Upland Ag.* %	*ALL* %
Shock vulnerability	95	75	79	80	82
Coping strategies					
Precautionary savings:					
Food stock	6	33	20	3	12
Livestock	33	8	7	12	15
Financial assets	17	0	0	3	5
Labor supply:					
Upland cropping	0	0	0	61	26
Fishing	39	83	47	27	42
Gathering	44	8	40	6	22
Hunting	11	0	0	3	4
Wage labor	11	0	20	9	10
Other:					
Formal credit	0	0	0	0	0
Informal credit	0	0	0	0	0
Migration	0	17	0	9	6
Mutual insurance	11	0	0	0	3

in the average land portfolios. In table 3, flood vulnerability was rather uniform across V2–4, and as expected V1 was relatively more vulnerable than the others. Interestingly, households in V4 also reported vulnerability to the flood shock of 1993 in similar proportions to households in V2 and V3, despite the availability of secure upland.[9]

Respondents were asked about household coping strategies in an open-ended question, which permitted them to provide multiple coping responses (we did not ask households to rank or value those strategies). Table 3 reports the adoption rate of 12 different coping strategies specified by households along the Marañón River who reported having been vulnerable to the 1993 flood ($n = 78$). These 12 strategies are grouped into three categories: *precautionary savings*, *labor supply*, and *other*.

Precautionary savings include the use of *food stock*, *livestock*, and *financial assets* (no households liquidated productive capital such as land and fishing nets). While a very limited number of households used financial assets to cope with the flood shock, food stock use, especially manioc flour, and the disposition of small livestock like chicken (no cattle or buffalo) were employed, respectively, by 12 per cent and 15 per cent of households

[9] This may be an artifact of the line of questioning which asked about the three biggest floods. Because the magnitude of crop loss and other impacts of the flood were not measured, it could well be that the severity of the 1993 flood was much less in V4 than in the other villages which have no or little upland.

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Table 4. *Correlation between coping strategies for flood shock*

(n = 78)	*Upland cropping*	*Fishing*	*Gathering*	*Savings*
Upland cropping		−0.325***	−0.239**	−0.315***
Fishing			0.114	−0.042
Gathering				−0.001
Savings				

Notes: *: significant at 10%, **: significant at 5%, ***: significant at 1%.

in the sample. As might be expected, the food stock option was more common in the lowland V1–3 than V4 with upland fields. Food stock use was common especially in V2, where manioc cultivation is their primary crop in large part because they have only low levee/backslope available for cultivation. Livestock disposition was the most common in V1, the village that experienced land slumps.

The labor supply strategy consists of *upland cropping*, *resource extraction*, and *wage labor*. Upland cropping entails own-farm labor efforts for households with access to higher lands (uplands and probably some high levees) that were not flooded and thus could support food production. This is the most straightforward response to crop loss from floods on the lowland, and the *ex ante* and *ex post* insurance role of upland is well discussed in the Amazonian literature (Meggers, 1971; Hiraoka, 1985; Eden, 1990; Denevan, 1996). Reflecting the sharp contrast between upland and lowland environments, over 60 per cent of households in upland V4 employed upland cropping as insurance while no households in lowland V1–3 could employ this strategy.[10] The substitutive relationship of upland cropping with resource extraction (mainly gathering and fishing as discussed shortly) and with precautionary savings is very clear from their statistically significant negative correlations (table 4). Indeed, most households who employed upland cropping used neither resource extraction nor precautionary savings. This suggests that upland cropping is probably the most preferred strategy among households to cope with flood shocks. Put differently, a major household decision is how to cope with flood shocks when upland cropping options are not available.

Three extractive activities – *fishing*, *gathering*, and *hunting* – are associated with the labor supply strategy with adoption rates of 42 per cent, 22 per cent, and 4 per cent, respectively (distinct from upland cropping; table 4 shows no evidence of correlations among gathering, fishing, and precautionary savings). Fishing is the most common strategy among all of the 12 strategies, and gathering is also common. Contrarily, the use of hunting as a coping strategy is very rare perhaps because of its high skill

[10] Although situated on lowland, some households in V3 also hold upland fields across the Marañón River but they are too far away to be used as insurance.

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requirements and risk.[11] The same logic applies to aquatic extraction that was not employed as a coping strategy by any of the households. In general, fishing is also a risky activity, but it is less risky than hunting and aquatic extraction in the PSNR because of the region's abundant fish stocks.[12] Lower risks in NTFP gathering (because of the non-mobility of the fruits, palm hearts, and other products) as well as the easier access afforded by canoes during the high-water season generally make gathering an attractive coping strategy.[13] These findings suggest that as far as resource extraction as insurance is concerned, the indirect effect of NTFP gathering on species degradation and biodiversity loss in the PSNR is more significant than the direct effect of hunting and aquatic extraction, even though the latter direct effect is substantial when we consider production levels (Coomes *et al.*, forthcoming).

It should not be surprising then that the type of extractive activity pursued in response to floods varies significantly across villages. Fishing as a coping strategy is very common (over 80 per cent of households) in V2, but it is relatively less common in the other villages (under 30 per cent in V4 and under 50 per cent in V1 and V3). Whereas gathering as a coping strategy is relatively common (40 per cent or more) in V1 and V3, it is almost non-existent (less than 10 per cent) in V2 and V4. Contrarily, our production data in 1993 show that while gathering is very rare in V2, it is not uncommon in V4 (over 40 per cent participation). Indeed, the access to forest product resources is rather similar across V2–4 that are located in relative proximity to each other. Thus, with rich fish stocks nearby, households in V2 (with large fishing nets) strongly preferred fishing to gathering,[14] while households in V4 – with their preferred upland cropping option – also did not adopt gathering as a coping strategy. Wage labor, the remaining way to use family labor as a coping strategy, is uncommon in the PSNR area where wage opportunities are very limited.

The other coping strategies include *formal credit*, *informal credit*, *migration* (as temporal resettlement to escape from floods), and *mutual insurance*. No households in the sample used credit as a coping strategy, and migration and mutual insurance were relatively rare events across these villages. Our data show no direct evidence of remittances as a coping strategy.

[11] This does not mean that hunting itself is an uncommon activity as our production data shown that 26 per cent of households in the sample participated in hunting. The infrequency of hunting as a coping strategy even though its productivity is improved during the high-water season, when wildlife is concentrated on the reduced non-inundated lands, suggests the high risk involved in hunting.

[12] This assertion is supported by the relatively uniform high adoption of fishing as a coping strategy across the villages despite its diminished productivity during the high-water season due to dispersal of the fish stock in the floodplain forest.

[13] Adjustment of food intake can be also an important coping strategy. Food adjustment in tropical forests includes the consumption of 'hunger food' in forests (e.g., bread fruit tree), which is captured by gathering in our data, although it is not common.

[14] Income sharing which is common among commercial fishermen in V2 also promotes fishing as a coping strategy (Baland and Platteau, 1996).

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To sum up, the choice of coping strategy is strongly shaped by local environments. In particular, gathering plays a major role only in villages without rich fish stocks or upland nearby as alternative insurance. Although both fishing and precautionary savings (food stock or livestock) are observed in all villages, their relative importance varies across the villages. It seems that resource extraction options in the PSNR allow households to rely less on other self- and mutual insurance options than are common in other rural areas.[15] The descriptive results also suggest the significant heterogeneity in coping strategy choice across households within the same village, which becomes the focus of the econometric analysis in the following sections. Before that inquiry, we briefly examine coping strategies associated with idiosyncratic health shocks.

Forest dwellers in the Amazon basin suffer various major illnesses, including potentially fatal diseases and snake bites (Godoy *et al.*, 1998; Howe, 2002; McSweeney, forthcoming). We employed the same type of open-ended survey instrument to reveal the three most serious illnesses of household members experienced by each household over time and the corresponding coping strategies they employed. Table 5 shows the results of the *latest* health shock each household experienced in the current village over the last 20 years.[16] Thirty-six per cent of households experienced major illness, and illness shock vulnerability is rather uniform across the villages.[17]

Households' coping strategies for idiosyncratic health shocks are quite distinct from those for covariate flood shocks. The liquidation of small livestock (especially chicken) is the dominant strategy employed by more than half of the households to fill emergency cash needs for medical expense. The adoption of livestock disposition in V1 is more common than the others. This may reflect the fact that the only health post exists in V4, providing the residents in V2–4 that are located close to one another better access to medical service. The second most common strategy reported is mutual insurance (24 per cent) as might be expected for idiosyncratic shocks. Mutual insurance is especially significant in V1, the one with no proximate access to medical service.[18] Contrary to the case of flood shocks, households with a member seriously ill did not employ labor supply as

[15] The uncommonness of mutual insurance may be also explained by the widely held notion that mutual insurance under covariate shock is much less feasible than under idiosyncratic shocks.

[16] We focus on the *latest* shock to avoid multiple observations for the same household. To be consistent with the flood shock analysis, households who moved to the current village after 1993 were removed from the sample and health shocks experienced in former villages where households used to live were not included.

[17] Contrary to the specific flood shock, older households may tend to report more illnesses because of their longer time-horizon and physical condition. This potential bias also seems to be rather uniform across the villages.

[18] This finding is also consistent with our field observation that the communal bond in V1 is probably the strongest among the four villages. The following episode illustrates the significance of small livestock and mutual insurance to cope with health shocks. When one of the authors stayed in one of the sample villages on the Ucayali River, an old man was seriously injured by the attack of a cayman. His daughter-in-law took him in a boat, along with two live chickens, to seek care in

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Table 5. *Health shock and coping strategies by village*

(n = 105)	*V1 Lowland Mixed* %	*V2 Lowland Fishing* %	*V3 Lowland Ag.* %	*V4 Upland Ag.* %	*ALL* %
Shock vulnerability	35	39	42	33	36
Coping strategies					
Precautionary savings:					
Food stock	14	0	38	13	16
Livestock	86	57	50	44	55
Financial assets	0	14	25	6	11
Labor supply:					
Upland cropping	0	0	0	0	0
Fishing	0	43	13	6	13
Gathering	29	0	13	0	8
Hunting	0	0	0	0	0
Wage labor	0	0	0	25	11
Other:					
Formal credit	0	0	0	6	3
Informal credit	0	0	13	0	3
Migration	0	0	0	0	0
Mutual insurance	43	14	13	25	24

a coping strategy with much frequency partly because of a decline of labor force. No households in the upland V4 employed upland cropping as insurance, suggesting that food cropping on upland does not work to fill the emergency cash demand perhaps because of its relative weakness as a source of immediate cash due to high transactions cost to sell their produce in the urban market. Because resource extraction is an infrequently employed insurance option for health shocks, it has limited environmental impacts.

Overall, mutual insurance, which plays a minimal role in coping with covariate environmental shocks, plays a major role in coping with idiosyncratic health shocks, and the role of livestock as insurance is much greater for health shocks than flood shocks. Although one might expect livestock liquidation to play an important role as a form of self-insurance in coping with covariate shocks, it seems that this is more likely to be the case in areas like Sub-Saharan Africa with more limited resource extraction options.[19] The remaining analysis focuses on the determinants of coping strategy choice in response to a covariate flood shock.

a hospital in Iquitos. His son followed the next day after he collected cash from relatives and neighbors to help pay for the care.

[19] Another possible explanation is that the massive liquidation of livestock under the covariate shock in the region may have significantly lowered livestock market price (Fafchamps *et al.*, 1998). Our limited price data do not allow us to examine this hypothesis.

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4. Econometric model

After the high floods cause an income shock, households simultaneously decide whether to gather and/or fish to cope with the shock. Thus, unlike work by Kochar (1999) and Rose (2001), which use labor supply measures that aggregate before- and after-shock efforts, we estimate these two *ex post* labor supply decisions jointly.[20] Since we only have indicator variables for the use of each coping strategy, we use a discrete choice model framework. Specifically, we estimate the adoption of gathering and fishing (y_1 and y_2, respectively) using the following equations

$$y_1^* = S\beta_{11} + X\beta_{12} - u_1, \tag{1}$$

$$y_2^* = S\beta_{21} + X\beta_{22} - u_2, \tag{2}$$

where y_j^* ($j = 1, 2$) is a latent variable such that $y_j = 1$ (adopt) if $y_j^* \geq 0$ and $y_j = 0$ (not adopt) otherwise, S is flood shock, X is household and other village factors, β_{11}, β_{12}, β_{21} and β_{22} are coefficients, and u_1 and u_2 are error terms with variance equal to one. Equations (1) and (2) are similar to a labor supply equation estimated by Rose (2001) and can be derived from a non-farm labor supply model in a straightforward manner (Takasaki *et al.*, 2003).

A critical feature of our data is that information on the use of coping strategies is only available among households who reported having been vulnerable to the 1993 flood. As a result, estimation of (1) and (2) for this subsample may lead to selectivity bias because the subjective flood vulnerability may not be random, and unobservable factors (such as skills) may be correlated across the vulnerability and coping strategy equations. To control for this selection problem, we estimate the flood vulnerability using the following equation

$$I^* = S\beta_{31} + X\beta_{32} + H\beta_{33} - u_3, \tag{3}$$

where I^* is a latent variable such that $I = 1$ (vulnerable) if $I^* \geq 0$ and $I = 0$ (not vulnerable) otherwise, H is historical shock experience, which captures the potential time-horizon bias of our instrument, β_{31}, β_{32}, and β_{33} are coefficients, and u_3 is an error term with variance equal to one.[21] Equation (3)

[20] The adoption of upland cropping is not examined because this option is essentially available only in upland V4 and the estimation procedure discussed here cannot be applied to the limited observations there.

[21] Equation (3) is based on the following endogenous threshold model. We first hypothesize that each household reported having been vulnerable to the flood if its forecast error in *ex ante* income, or equivalently income from risky lowland agriculture assuming no risks in all other activities (upland cropping, fishing and gathering), d, was smaller or equal to some threshold level $\underline{d}$; i.e., $d \leq \underline{d}$. The threshold varies depending on household other secure *ex ante* income and historical shock experience; as the household earns more secure income in the shock year and experienced more income shocks in previous years, the threshold gets lower and thus the household is unlikely to report the 1993 floods as one of

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is estimated for all observations of our sample, and (1) and (2) are estimated for the self-selected subsample with $I = 1$. We assume that u_1, u_2 and u_3 are the multivariate normal with $\mathrm{Cov}(\rho_l, \rho_m) = \rho_{lm}$ where $l, m = 1, 2, 3$. The system of three discrete choice equations (1)–(3) is a censored multivariate probit model.

In previous empirical studies on risk-coping strategies, a main question has been whether the strategies examined in fact serve to cope with shock. Therefore, transitory income shocks are a critical explanatory variable. Some studies focus on covariate environmental shocks directly using rainfall measures, and others estimate transitory income or forecast error in income by combining rainfall measures with various attributes. Unfortunately, our PSNR data have neither significant spatial variations in flood shocks nor the rich panel data necessary to estimate transitory income or forecast error in income. What is feasible here is to capture the shock S using village dummy variables. These are, of course, crude measures because they also capture other village characteristics such as fish stock and forest stock that significantly shape the productivity of fishing and gathering, respectively. Nonetheless, our focus here is rather to see what household factors shape the household level choices of gathering and fishing as coping strategies. Specifically, we examine asset holdings, labor endowment, and lifecycle measures.

Asset holdings consist of productive capital for major livelihood activities, i.e., land holdings and fishing capital. Our land holdings variables focus on cultivated land where major crop failures on lowland and upland cropping as insurance occur. In the coping strategy equations (1) and (2), lowland holdings are captured by the size of aggregated cultivated lowland plots on all five types of land. In the shock vulnerability equation (3), to capture potentially distinct land portfolio effects, we treat lowland holdings in a more detailed manner. First, we disaggregate lowland holdings into high levee, low levee/backslope, and mudflat/sandbar. Second, the total number of both cultivated and uncultivated plots is added to capture potential diversification effects of *ex ante* risk management. We include uncultivated plots because total land portfolio holdings should affect household land use and crop choices. Third, to capture potentially different crop choices in the upland environment, we interact a dummy variable for the upland V4 with these four land variables. The remaining land asset is upland holdings that do not need to be interacted with the V4

the three biggest floods it has experienced. Regression equations for the forecast error in *ex ante* income and threshold are given by

$$d = X\gamma_{11} + S\gamma_{12} + \varepsilon_1,$$

$$\underline{d} = X\gamma_{21} + H\gamma_{22} + \varepsilon_2,$$

where γ_{11}, γ_{12}, γ_{21} and γ_{22} are coefficients, and ε_1 and ε_2 are error terms with $\mathrm{Var}(\varepsilon_1) = \sigma_1^2$, $\mathrm{Var}(\varepsilon_2) = \sigma_2^2$, and $\mathrm{Cov}(\varepsilon_1, \varepsilon_2) = \sigma_{12}$. In the estimable equation (3), $I^* = (\underline{d} - d)/\sigma$, $\beta_{31} = -\gamma_{12}/\sigma$, $\beta_{32} = (\gamma_{21} - \gamma_{11})/\sigma$, $\beta_{33} = \gamma_{22}/\sigma$, and $u_3 = (\varepsilon_1 - \varepsilon_2)/\sigma$, where $\sigma = \mathrm{Var}(\varepsilon_1 - \varepsilon_2) = \sigma_1^2 + \sigma_2^2 - \sigma_{12}$ (Maddala, 1983: 229).

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dummy because most upland exists only in V4.[22] Our data only allow us to use a dummy variable for large fishing net holdings to capture fishing capital.

Labor endowment is measured as the number of adults. Labor is the only factor required for NTFP gathering. Historical shock experience *H* is captured by the age of household head and the number of other flood shock experiences reported. Households that experienced more flood shocks are less likely to report having been vulnerable to the 1993 flood, and older households may be more likely to have experienced more flood shocks. We also use the age of household head to capture lifecycle effects.

Households' decisions to gather and to fish as coping strategies give rise to four regimes of labor supply, suggesting four different reduced forms for (1) and (2) (see Takasaki *et al.*, 2003 for theoretical analysis). Our limited sample size does not allow us to employ such an endogenous switching model in our multivariate probit framework, and thus we take a parsimonious approach. As shown in the descriptive statistics, households' labor supply decisions in V2 and V4 with rich fish stock and upland nearby, respectively, are quite distinct from those in V1 and V3 as the use of gathering as a coping strategy is almost non-existent in V2 and V4. Thus, only two regimes are relevant in V2 and V4, while all four regimes exist in V1 and V3. To capture these distinct patterns, we allow the coefficients of the large fishing net dummy, the number of adults, and the age of household head to vary across these two village groups by interacting them with the dummy variables for V1 and V3, and V2 and V4. Lowland holdings, whose impacts only come through *ex ante* income from risky lowland agriculture (Takasaki *et al.*, 2003), are not interacted with the village group dummies, and upland holdings do not need such interactions for the reason discussed above.

5. Estimation results

We first test the independence of equations (1)–(3) in a multivariate probit framework, i.e., H_0: $\rho_{lm} = 0$ ($l, m = 1, 2, 3$), by using a Lagrange multiplier test developed by Kiefer (1982).[23] The test results reveal a sharp contrast. While there are no signs of dependence of the vulnerability equation with each of the two coping strategy equations, independence of gathering and fishing is strongly rejected ($p \leq 0.001$).[24] Accordingly, we estimate separately the vulnerability equation (3) by univariate probit analysis for the whole sample and the remaining coping equations (1) and (2) by a bivariate probit for the subsample.

[22] To use the upland holdings and V4 dummy variables together is unlikely to cause multicolinearity because a significant proportion of households in V4 do not hold upland fields.

[23] When we test the independence of (3) from (1) or (2), we use the subsample for the former because of censoring in the latter.

[24] LM test statistics are 13.098 (0.000), 0.014 (0.907) and 0.013 (0.909) for ρ_{12}, ρ_{13} and ρ_{23}, respectively, where p-values are in parentheses ($\chi_{(1)}$).

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Table 6. *Probit estimation results for flood vulnerability*

(n = 95)	*Coefficient*	*Slope*
Constant	2.87 (2.38)***	–
Cultivated upland (ha)	−0.94 (1.33)*	−0.17
Cultivated high levee (ha)	1.09 (1.14)	0.19
Cultivated low levee/backslope (ha)	0.27 (0.46)	0.05
Cultivated mudflat/sandbar (ha)	−0.14 (0.35)	−0.02
Total number of plots	0.67 (1.93)**	0.12
Cultivated high levee * V4 (ha)	−0.84 (0.80)	−0.15
Cultivated low levee/backslope * V4 (ha)	−1.29 (1.69)**	−0.23
Cultivated mudflat/sandbar * V4 (ha)	−0.22 (0.47)	−0.04
Total number of plots * V4	−0.11 (0.23)	−0.02
Large fishing net holdings (0/1)	0.07 (0.15)	0.01
Number of adults	0.09 (0.76)	0.02
Age of household head (10 years)	−0.61 (2.79)***	−0.11
Number of other flood shocks	0.01 (0.02)	0.00
Village 2 (0/1)	−1.06 (1.10)	−0.15
Village 3 (0/1)	−2.11 (1.83)**	−0.31
Village 4 (0/1)	0.38 (0.29)	0.04
Log-likelihood	−0.32	
Correct preditions (%)	0.83	

Notes: z-statistics are in parentheses.
*: significant at 10%, **: significant at 5%, ***: significant at 1%.

The results of the probit estimation of the shock vulnerability equation (3), including marginal effects, are presented in table 6.[25] As expected, secure upland has a negative and statistically significant impact on flood vulnerability; e.g., a one-hectare increase of upland holdings decreases the probability of being vulnerable to the flood shock by 17 per cent. Although in V1–3 high levee and low levee/backslope take expected positive signs, mudflat/sandbar and low levee/backslope in the upland V4 take negative signs, with only the low levee/backslope being statistically significant with an 18 per cent marginal effect per hectare. These findings weakly suggest that the loss of food crops especially plantain on high levee, low levee, and backslope is a major outcome associated with high-flood shocks (note that with secure upland, households in V4 cultivate less plantain on the low levee).[26] The number of total plots has a positive and statistically significant impact on the flood vulnerability (with a 12 per

[25] The sample average of the individual marginal effects is shown. The marginal effect for a binary independent variable, z, is given by: $\text{Prob}(y = 1 \mid x_*, z = 1) - \text{Prob}(y = 1 \mid x_*, z = 0)$, where x_* denotes all other explanatory variables in the model (Greene, 2000: 817).

[26] Put differently, cash cropping on mudflats and sandbars may be less vulnerable to big floods. This does not mean that floodplain agriculture is less risky; indeed, it is very risky even under normal floods (Chibnik, 1994). Our point is that unexpected crop loss due to unusual high floods is probably not so significant on floodplains

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Table 7. *Bivariate probit estimation results for coping strategies*

(n = 78)	Gathering coefficient	Slope	Fishing coefficient	Slope
Constant	0.63 (0.62)	–	1.31 (1.30)*	–
Cultivated upland (ha)	0.73 (0.83)	0.09	−1.14 (1.70)**	−0.22
Cultivated lowland (ha)	0.00 (0.04)	0.00	0.00 (0.05)	0.00
Large fishing net holdings in V1 and V3 (0/1)	−0.45 (0.65)	−0.04	0.39 (0.55)	0.03
Number of adults in V1 and V3	0.26 (1.73)**	0.03	−0.16 (1.07)	−0.03
Age of household head in V1 and V3 (10 years)	−0.38 (1.71)**	−0.05	−0.25 (1.26)	−0.05
Large fishing net holdings in V2 and V4 (0/1)	0.85 (1.04)	0.08	2.05 (2.44)***	0.10
Number of adults in V2 and V4	−1.04 (1.36)*	−0.13	−0.27 (1.13)	−0.05
Age of household head in V2 and V4 (10 years)	0.73 (1.15)	0.09	−0.59 (1.73)**	−0.11
Village 2 (0/1)	−2.66 (1.28)*	−0.20	2.05 (1.24)	0.10
Village 3 (0/1)	−0.10 (0.20)	−0.01	0.15 (0.28)	0.01
Village 4 (0/1)	−3.48 (1.50)*	−0.09	1.19 (0.76)	0.07
ρ_{12}	0.37 (1.47)*			
Log-likelihood	−0.81			
Correct preditions (%)	0.83		0.77	

Notes: z-statistics are in parentheses.
*: significant at 10%, **: significant at 5%, ***: significant at 1%.

cent marginal effect per plot). This suggests that *ex ante* risk management through plot diversification is not effective to reduce high-flood risks as this risk-decreasing effect is already captured by the secure upland variable. Thus, the number of plots rather seems to capture opposite risk-increasing scale effects (more vulnerable plots increase shock vulnerability). Lastly, the age of household head is negatively associated with the flood vulnerability with a statistical significance (a 1 per cent marginal effect per year) which is consistent with the time-horizon bias associated with our subjective measure.

The results of the bivariate probit estimation of gathering and fishing coping equations (1) and (2) are presented in table 7. A strong positive correlation of the error terms ($\rho_{12} = 0.37$) suggests that unobservable factors like skills and knowledge or other outside options are positively correlated between gathering and fishing. The estimation results of explanatory variables are quite distinct across strategies and across villages.

In V2 and V4 where almost no use is made of gathering as a coping strategy, younger households with large fishing nets and less upland holdings are more likely to employ fishing. Secure upland cropping is the

that are flooded every year and cash cropping offers more cushion for the shock than food cropping under significant market imperfections.

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most preferred strategy to cope with flood shocks; in particular, a one-hectare increase of upland holdings reduces the probability of adopting fishing as a coping strategy by 22 per cent. Fishing net possession gives rise to a 10 per cent higher probability of using fishing as a coping strategy. Fishing is also a preferred activity for youth with sufficient physical abilities (a 1 per cent marginal effect per year) (Coomes *et al.*, forthcoming). Younger households also may need to rely on fishing as a coping strategy because they can hold fewer assets in the form of precautionary savings.

As might be expected, the estimation results in V1 and V3 where all four *ex post* labor regimes coexist are less clear. Households with a greater labor endowment are more likely to use gathering (which requires only labor) as a coping strategy. Younger households are also more likely to use gathering for the reasons discussed above, although the marginal effects of these two variables are rather small (3 per cent and 0.5 per cent, respectively). Households with large fishing nets are less likely to employ gathering as a coping strategy, but the result is not statistically significant. We recall, however, that almost no households hold large fishing nets in V1, where gathering is the most common coping strategy (tables 2 and 3). Contrarily, none of the coefficient estimates for V1 and V3 in the fishing regression is statistically significant. These limited results suggest that a better treatment of different regimes may be needed for V1 and V3.

In summary, gathering appears to be a vital form of natural insurance employed by the young poor that live in environments without upland or rich fish stocks. Our findings weakly suggest that gathering serves as an alternative insurance form for those for whom labor is the only endowment at their disposal. Thus, there seems to be a positive link between the adoption of NTFP gathering as insurance and asset poverty (not necessarily income or consumption) that is significantly shaped by local environments. Contrarily, fishing is preferred by young households with fishing nets and limited upland holdings, thereby showing a mixed poverty–environment relationship.

6. Conclusion

This paper examined resource extraction as a coping strategy among riverine peasant households in the Peruvian Amazon where species degradation and biodiversity loss are the primary environmental concerns. We first constructed a complete list of household responses used to cope with a large covariate flood shock and idiosyncratic health shocks. As in many other settings, the disposition of assets in the form of food stock (mainly manioc flour) and small livestock (mainly chickens) was found to be an important response to both types of shocks. In particular, livestock liquidation was the dominant strategy to cope with health shocks, followed by mutual insurance. However, for the covariate flood shock, *ex post* labor efforts in the form of upland cropping and resource extraction – fishing and NTFP gathering – were more common than precautionary savings, and resource extraction was particularly important for those without upland cropping options. Contrarily, hunting and aquatic extraction were rarely employed as a response to either type of shocks. Thus, flood shocks

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appear to exacerbate species degradation and biodiversity loss through the intensive use of forest resources that are a food source for local fauna, but the direct impacts of hunting and aquatic extraction are rather small.

We also jointly estimated household coping strategy choice of gathering and fishing using a bivariate probit model. It was shown that: (1) in environments with upland or rich fish stocks nearby as alternative insurance, gathering was almost non-existent and fishing was employed by young households with fishing nets but only limited upland holdings; and (2) in environments without upland or rich fish stocks nearby, gathering was used especially by young (and poor) households and those households with large labor endowments. Thus, clear links exist between asset poverty and NTFP gathering as insurance in certain locations.

These findings suggest the following hierarchy of labor supply responses to cope with flood shocks. Upland cropping is the most preferred response but available only for households who have upland access. Fishing comes next especially for those who hold large fishing capital and can attain relatively high returns. NTFP gathering, which requires only labor and attains secure but low returns, is a last resort probably combined with subsistence fishing using rudimentary equipment. Therefore, NTFP gathering is a unique means of insurance for the poor who have limited options for coping with flood risk. Put differently, the downward spiral of the poverty–environment link can be exacerbated by shocks, as they propel the poor to hit nature hard (Barrett and Arcese, 1998). Sustainable forest management is thus of great importance not only for environmental conservation but also for poverty alleviation.

Unsustainable gathering practices such as those observed in our study area require well-targeted interventions and programs for the poor. Our findings offer useful information about promising targets at both village and household levels (Coomes *et al.*, forthcoming). Generally speaking, they suggest that policies should be designed so as to promote *ex post* labor allocations to more sustainable activities. If resource extraction and precautionary savings have a substitutive relationship (which this paper did not formally examine), promotion of the accumulation of liquid assets would also be a promising approach. Specific programs might include: (1) improved access to 'right' productive capital, for example, through a work-to-own arrangement (e.g., fishing nets in our study area); and (2) contingent employment programs such as clearing land for future agricultural use and food stock accumulation (given that deforestation is not a major problem), building up small livestock raising enterprises, and improving access to social goods, such as education and health care. These programs would thus be used both to take pressure off the forest resources in the shock period and to reduce future reliance on vulnerable resources. Some of them, especially livestock and health support, would also help the poor cope with health shocks. The combination of these programs depends on local environments and household asset holdings that shape their relative importance.

We envision several fruitful lines for future research. First, although this paper focused on resource extraction as a coping strategy, a deeper understanding of its relationship to savings is crucial to better explicate

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the poverty–environment link and to shed new lights on possible win–win policies. We examine a multiple coping strategy choice between savings and resource extraction elsewhere (Takasaki *et al.*, 2003). Second, insufficient variation in environmental shocks and the lack of panel data prevented us from examining the impacts of shocks of differential severity on household coping strategy choice. The collection of this type of data would be highly demanding but is essential for a more comprehensive empirical analysis of responses to shocks. Third, although the paper focused on resource extraction as a labor supply strategy, the instrument and analysis we used can be applied to other types of labor supply responses. A good example is wage labor which is a common response in other rural areas like Sub-Saharan Africa (Barrett *et al.*, 2001).

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