

Foraging for Development: A Comparison of Food Insecurity, Production, and Risk among Farmers, Forest Foragers, and Marine Foragers in Southwestern Madagascar

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International programs for combating food insecurity including the recent FAO “How to Feed the World in 2050: High-level Expert Forum” promote agricultural intensification among the main solutions to global hunger. We argue here that hunting and gathering on land and at sea will often result in less food insecurity than farming. In southwestern Madagascar, questionnaire data find farmers more food insecure than neighboring forest foragers and marine foragers. Production data show that farmers produce a greater quantity of food energy, but foragers sell their goods for higher prices resulting in comparable market-valued incomes among all three subsistence modes. A stochastic model finds farming portfolios an order of magnitude more risky (lower z -scores) than foraging portfolios, except when foraging portfolios have low means. This is because farmers experience only three to five harvests per year while foragers may experience 365 harvests. As farmers await future harvests of uncertain quantity, they are more likely than foragers to depend on formal and informal credit. The stochastic model shows that diversification, mixing foraging with farming, can only reduce the risks of farming under limited conditions. We conclude that pressuring foragers to become farmers will increase rather than diminish regional food insecurity.

Key words: food insecurity, risk, hunter-gatherers, coastal economies, agriculture, Madagascar

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Introduction

The World Bank's 2008 Development Report entitled “Agriculture for Development” promotes international investment in agricultural production and market infrastructure to improve food security, reduce rural poverty, and manage natural resources in the Global South (World Bank 2007). The FAO's (2009a) “How to Feed the World by 2050: High-level Expert Forum” recently concluded that improved agricultural technology, agricultural institutions, and agricultural infrastructure will be needed to achieve the estimated 70 to 100 percent increase in global food production necessary to feed a population that is expected to grow from 6.8 billion to 9.1 billion over the next 40 years. Belying these arguments are two assumptions, which we question here: that all rural people are farmers, or should be; and that increasing food production is equivalent to improving food security.

We offer an alternative to “Agriculture for Development,” which we call “Foraging for Development.” Our objective is not to contradict the logic of agricultural intensification, that greater technological and material inputs can

increase food production. Rather, we present evidence that a complementary strategy for reducing food insecurity is to allow those who live by hunting, gathering, and fishing of wild terrestrial and marine resources to continue their way of life without pressures to transition to agriculture.

Key to our argument is that increasing food *quantity* will not necessarily reduce food insecurity, for reasons related to food *quality*, production risk, and number of harvests per year. Food insecurity, as evaluated with the USDA food insecurity module, is defined as experiences of anxiety about food supply (Pérez-Escamilla et al. 2004). Farmers with high yields may be more anxious about their food supply than foragers with lower yields, because agriculture generates low nutritional and market value with high production risk, few harvests per year, a long delay between planting and harvest, and as a result, high dependency on formal and informal credit. Foraging, by contrast, yields foods of high nutritional and market value, low risk, frequent (sometimes daily) harvests, and little dependence on credit.

We develop our argument using a variety of forms of data collected among Masikoro farmers, Mikea hunter-gatherer-bricoleurs (foragers who opportunistically farm, herd, fish, and retail), and Vezo coastal fishermen-gatherers of southwestern Madagascar. We begin with some intriguing results from questionnaire data, which demonstrate that Masikoro, Mikea, and Vezo generate statistically similar incomes (market-valued production), but that Masikoro farmers are significantly more food insecure than their foraging Mikea and Vezo neighbors. Second, production data support the received wisdom that agriculture produces more food per unit labor than foraging. But, when these data are converted to market value, they suggest why farmers and foragers have similar market-valued incomes despite farmers' greater production: wild foods fetch higher prices, perhaps due to their rarity and superior flavor and nutrition. Third, a simple mathematical simulation shows that agriculture is an order of magnitude more risky than foraging as evaluated with the *z*-score model, because farmers have one to five harvests per year while foragers have 365 potential harvests. The model also shows that farmers find it difficult to reduce risk by adding foraging to their portfolio under a wide variety of conditions, for too much mean income must be sacrificed for marginal improvements in risk protection. We conclude by discussing the limitations and external validity of these findings.

The Western world often dismisses hunting and gathering as primitive and inefficient, in large part due to lingering 19th century prejudice. Early anthropologists like Tylor (1871) and Morgan (1964) voiced the common interpretation of their day, that hunter-gatherers are living relicts of prehistoric populations, "savages" lacking the technological sophistication to progress to more advanced stages of barbarism and civilization. In the 20th century, anthropologists have shown this discourse on social evolution to be a politically motivated justification for colonialism, assimilation, and genocide (Barnard 1999; Schrire 1984). Ethnographers who have lived with hunter-gatherers have

discovered that many are knowledgeable about agriculture, but choose not to rely on it (Lee 1979; Tucker 2003, 2006; Turnbull 1963). Many foragers have farmers and herders as ancestors, including at least some Kalahari San (Wilmssen 1989), some Okiek foragers of East Africa (Blackburn 1996), 18th and 19th century Lakota Sioux of the central United States (Layton, Foley, and Williams 1991), and the Mikea foragers described in this study (Tucker 2003). Human skeletal remains from archaeological sites with both pre-agricultural and agricultural horizons demonstrate that prehistoric farmers typically had worse nutrition and dental health, poorer growth, more anemia and infectious diseases, heavier workloads, and shorter lives than foragers (Cohen and Armelagos 1984; Larsen 1995), leaving Diamond (1987:95) to conclude that agriculture was "the worst mistake in the history of the human race."

The defense of foraging that we offer here is significant for the over five million terrestrial foragers that inhabit the world today (according to a cautious estimate by Hitchcock and Biesele 2000:5), as well as the millions of fishermen and coastal gatherers. The Western world has long pushed foragers to convert to farming, using such tactics as boarding schools (Lomawaima 1993) and the policy of *terra nullius* (land belonging to no one) (Banner 2005). More recently, environmental conservation projects have evicted foragers from "natural" areas, arguing that they are a hindrance to conservation goals (Chapin 2004). Development projects and national governments typically follow pro-agrarian agendas (World Bank 2007); the FAO's (2009b) "State of Food Insecurity in the World" report does not mention foraging, hunting, gathering, fishing (or herding) at all.

Our defense of foraging may also be significant for the Mikea foragers of Madagascar discussed in this study. As plans emerge to convert the Mikea Forest where they live into a national park, many Mikea are feeling pressured to leave the forest and become full-time farmers. To be clear, Madagascar National Parks (MNP) is permitting Mikea to live within the planned park. A World Bank study declared Mikea an indigenous people (World Bank / ONE 2003) who have special rights to live within protected areas and parks according to a Malagasy law entitled *Code de Gestion des Aires Protégées*. Among the park's stated goals is to protect the cultural identity and economic sustainability of Mikea communities (Government of Madagascar 2007). Yet current plans would restrict Mikea to living within a limited number of *zones d'occupations contrôlés* (controlled occupation zones) and foraging only within *zones d'utilisations contrôlés* (controlled utilization zones), the locations and extents of which have not yet been officially decided. It is also unclear whether Mikea will be permitted to continue their traditional bricolage of activities. Uncertain about their future freedoms, many Mikea are leaving the forest to adopt Masikoro lifeways. Among our arguments here is that the transition to a Masikoro lifeway may be a transition to *greater* food insecurity. The freedom to hunt and gather reduces food insecurity for Mikea and also for neighboring peoples.

Ethnographic Background

Between the cities of Toliara and Morombe in southwest-ern Madagascar is the dense, dry, deciduous Mikea Forest (*Alamikea*), bordered to the east by savanna and to the west by the dunes, beaches, reefs, and mangroves of the Mozambique Channel. While “ethnic” identity is flexible and negotiated, within most villages people share a village-wide concept of their ethnicity. Generally speaking, Masikoro identity is rooted in savanna agropastoralism, Mikea identity is based on forest residence and hunting and gathering subsistence, and Vezo consider themselves to be people of the sea (Astuti 1995; Tucker 2003; Yount, Tsiazonera, and Tucker 2001).

The Masikoro ethnonym may have originally referred to the vassals of the pre-colonial Andrevola and Maroseragna kings (Tucker 2003; Yount, Tsiazonera, and Tucker 2001). Since French colonization, Masikoro have primarily been cultivators of rice (*Oryza sativa*), maize (*Zea mays*), manioc (*Manihot esculenta*), sweet potatoes (*Ipomoea batatas*), and butterbeans (*Phaseolus lunatus*). Previously, some Masikoro produced cash crops for export, including butterbeans in 1950s-1970s, cotton from the 1960s until 2007, and maize grown (usually illegally) in swidden fields in the Mikea Forest from the 1980s until 2002. The Masikoro farmers in the study region produce almost entirely for home consumption and sale in weekly village marketplaces. These farmers use negligible fertilizer, herbicide, pesticide, machinery, or improved seed and rarely hire labor.

Mikea oral history suggests that the Mikea ethnonym originally described those who avoided domination by the precolonial kings by living in the Mikea Forest. Mikea explain their identity with reference to forest life and foraging for wild ovy tubers (*Dioscorea acuminata*), honey, tenrecs (African hedgehogs *Echinops telfairi* and *Tenrec ecaudatus*), lemurs (*Microcebus murinus*, *Chierogaleus medius*), and freshwater fish, including several species of tilapia (*Paratilapia* spp.) and the invasive snakehead fish (*Channa striata*). But Mikea oral history is replete with references to pasture territories, maize and manioc fields, rice paddies, and markets, suggesting that Mikea have always been bricoleurs with diversified economic portfolios (Tucker 2003). The Mikea communities in this study were highly impacted by export markets for wild silk in the 1920s-1970s and swidden maize in the 1980s-2002, but currently produce for home consumption or local sale. They continue to get the majority of their calories from maize, grown either legally in old swiddens or illegally in newly chopped and burned fields. They sell wild foods and sometimes maize and manioc to their Masikoro and Vezo neighbors in village marketplaces.

Vezo oral history suggests that Vezo were originally those who evaded the Andrevola and Maroseragna kings by sailing away to sea in their outrigger canoes (Astuti 1995). The Vezo communities in this study were once diversified coastal sea turtle hunters, fishermen, reef flat gatherers, and farmers of maize, manioc, sweet potatoes, and watermelon. In the 1980s, Madagascar liberalized marine product exportation, resulting

in a series of market booms for seaweed, seashells, shark fin, finfish, octopus (*Octopus cyanea*), and sea cucumbers (*Holothuria* spp., *Sticopus* spp.) among other products. The Vezo we studied refer to themselves as “sea-Vezo” (*Vezone-driake*), in contrast to Vezo coastal farmers, the “mud-Vezo” (*Vezonepotake*). Sea-Vezo are specialized net and line fishermen and reef flat gatherers who sell the majority of their take to exporters. They purchase food at informal marketplaces created by Masikoro, Mikea, and mud-Vezo retailers.

Questionnaire Data: Farmers, Foragers, and Fishers Have Similar Incomes While Farmers Have Higher Food Insecurity

The inspiration for this paper came from two intriguing findings from questionnaire data collected by the first author and a field team from the Université de Toliara, Madagascar: Masikoro, Mikea, and Vezo appear to have statistically similar incomes while Masikoro have higher food insecurity.

Over the course of four seasons in 2007-2008, we evaluated food insecurity, income, and other variables in two Masikoro, three Mikea, and two Vezo communities. We sampled exhaustively, recruiting nearly all adults in the seven field sites ($N=550$). Some participants were absent in some seasons. To deal with these missing values, the analyses here are based on a subsample of 312 cases for which we have complete income and food insecurity data for the latter three seasons of the study. The subsample, consisting of 155 Masikoro, 54 Mikea, and 103 Vezo, is statistically similar to the main data set.¹ As the main dataset includes almost all adult residents in the seven field sites, the subsample is representative.

Following Ellis (2000:10-11), we define income as the market value of all production, whether for home consumption or for the market. We define five income sectors: agriculture, forest foraging, marine foraging, livestock sales, and retailing and wage labor.² Every three months, we asked participants to recall all the activities they practiced in each sector and to estimate the frequency and gain of each activity. Participants reported gains in oxcartloads, basketloads, buckets, bundles, and kilograms. These were converted to a common currency, market value, and summed to get the income score (calculated over the latter three seasons of the study, thus, nine months). Income scores refer to individual men and women rather than households.

Table 1 summarizes income scores for the three ethnicities and the seven field sites. The frequency distributions of income scores are highly positively skewed, meaning that there are many more people with low incomes than high incomes. Given the skewed distributions, we report medians, minima, and maxima rather than mean and standard deviation and contrast subgroups using nonparametric statistics. Median incomes for Masikoro, Mikea, and Vezo were in the range of 500,000 MGA (\$286) to 1,000,000 MGA (\$572) over nine months. A few prosperous shopkeepers claimed income up to 58,000,000 MGA (\$33,143), while some elderly individuals reported incomes of 0.

Table 1. Summary of Income Data From Questionnaire, Based on Three Seasons (Nine Months) of Informant Recall

Ethnicity Village	N adults	Income (Malagasy Ariary)			Sources of Income (Percent of Total)				
		Median	Minimum	Maximum	Agriculture	Forest foraging	Marine foraging	Livestock sales	Retailing
Masikoro	155	672,500	0	40,800,000	64.9	8.9	0.3	24.4	1.5
Andranodehoke	62	639,813	0	40,800,000	58.9	21.6	0.8	16.7	2.0
Tsilokarivo	93	697,500	30,000	25,700,000	68.8	0.4	0	29.6	1.2
Mikea	54	782,485	112,273	11,000,000	45.3	31.7	0.3	17.2	5.5
Belo	11	688,213	241,239	5,172,500	36.4	47.4	0	4.1	12.1
Antsognobe	17	664,543	112,273	3,344,992	45.1	35.0	0	16.8	3.1
Ankililale	26	1,053,199	180,705	11,000,000	49.2	23.0	0.6	22.9	4.3
Vezo	103	578,000	0	58,000,000	2.8	0	84.2	11.7	1.3
Bevohitse	67	502,000	30,000	11,800,000	0.7	0	84.2	14.6	0.5
Beangolo	36	872,000	0	58,100,000	6.5	0	84.3	6.4	2.8

Table 1 also reports the sources of income by sector. Masikoro at the village of Tsilokarivo gain the majority of their income from agriculture (69%) and livestock sales (30%), while Masikoro at Andranodehoke gain income from farming (59%), forest foraging (22%), and livestock (17%). Mikea are the most diversified, but get most of their income from agriculture (45%) and forest foraging (32%). Vezo are specialist marine foragers, gaining 84 percent of their income from the sea.

Income was statistically similar among Masikoro, Mikea, and Vezo (Kuskall-Wallis rank sum test, $\chi^2=2.485$, $df=2$, $p=0.289$). To control for possible demographic differences in the three samples, Table 2 presents a linear regression model in which log income is predicted by sex, household size, and dummy variables for Masikoro, Mikea, and Vezo. Because income is transformed by its natural logarithm,³ the coefficients may be read as percent change. Being male predicts 110 percent greater income. Household size has little influence. Being Ma-

sikoro or Vezo rather than Mikea does not significantly predict income. Deleting outliers (incomes greater than 5,000,000 MGA) (\$2,857) does not change the results.

Food insecurity was evaluated with a modified version of the USDA food insecurity module consisting of 11 likert-scored questions asking how frequently the household experienced symptoms of food shortage or anxiety about running out of food (Pérez-Escamilla et al. 2004). The food insecurity score is an average of three seasonal measurements.

We were intrigued to find that farming Masikoro were significantly more food insecure than their forager-bricoleur Mikea neighbors (Wilcoxon rank-sum test, $z=2.602$, $p=0.009$), or their coastal foraging Vezo neighbors ($z=4.134$, $p=0.000$), while Mikea and Vezo expressed similar degrees of food insecurity ($z=-0.262$, $p=0.793$). Table 3 presents a linear regression model in which log food insecurity is predicted by sex, household size, and dummy variables for Masikoro, Mikea, and Vezo. Being male predicts 19 percent greater food

Table 2. Regression Model Predicting Log Income by Demographic Variables and Ethnicity Dummy Variables (N=312; Adjusted R²=0.158)

	Coefficient	Standard error	t	p
male	1.108	0.146	7.57	0.000
household size	0.040	0.025	1.56	0.119
Masikoro	-0.238	0.204	-1.17	0.244
Mikea	(reference)			
Vezo	-0.260	0.220	-1.18	0.240
Constant	12.905	0.225	57.24	0.000

Table 3. Regression Model Predicting Log Food Insecurity by Demographic Variables and Ethnicity Dummy Variables (N=312; Adjusted R²=0.113)

	Coefficient	Standard error	t	p
male	0.194	0.038	5.17	0.000
household size	0.014	0.007	2.25	0.025
Masikoro	0.156	0.052	2.99	0.003
Mikea	(reference)			
Vezo	0.055	0.057	0.97	0.333
Constant	2.228	0.058	38.51	0.000

Table 4. Agricultural and Foraging Production Data

Product	N	Mean harvest kg/ha	sd harvest kg/ha	Energy kcal/kg	Price MGA/kg	Labor req. days/ha ^a
Maize ^b	246	931	517	3640 ^g	383	44
Manioc ^c	435	3696	2739	1240 ^g	122	175
Rice ^c	161	235	1318	3630 ^g	723	109
Butterbeans ^d	242	812	788	3350 ^g	812	63

Product	N	Mean CPUE kg/day	sd CPUE kg/day	Energy kcal/kg	Price MGA/kg	Seasonality
Ovy tubers ^b	162	9.57	5.20	1167 ^h	508	dry seasons
Honey ^b	45	5.78	5.68	3110 ^g	750	rainy season
Tilapia ^b	140	1.85	3.27	1320 ^h	1000	year round
Snakehead fish ^b	33	1.58	0.91	1237 ^h	1745	year round
Marine finfish ^{e,f}	275	2.16	3.65	1158 ⁱ	1000	year round
Octopus ^e	2739	3.19	2.73	1640 ^j	1000	springtide
Sea cucumbers ^b	23	2.83	2.97	(not eaten)	2000	springtide
Crabs ^b	84	3.48	4.68	407 ^j	407	year round

Sources:

a. Ottino, Lavondès, and Trouchaud (1960).

b. Data collected by Tucker and Tsimitamby, with a research team from Université de Toliara, Madagascar, 1997-2008.

c. Dandoy (1972); Hoerner (1986)

d. Hoerner (1986); Ottino (1963)

e. Data collected by Blue Ventures Conservation, 2005-2009.

f. Data collected by Iida, 1996-1998.

g. Wu Leung (1968)

h. Samples collected by Tucker and Tsimitamby, analyzed at the Centre National de Recherche sur l'Environnement, Antananarivo.

i. Average of 40 ocean fish listed in Pennington (1998).

j. www.nutritiondata.com

insecurity, while household size again has a negligible effect. Being Masikoro significantly predicts 17 percent greater food insecurity than being Mikea, while being Vezo predicts no more food insecurity than being Mikea.

Not only do these two findings contradict received wisdom about the superiority of farming over foraging, they also seem to pose a paradox. If farmers and foragers are, on average, producing equivalent incomes, why do farmers feel greater anxiety about their food supply?

Production Data: Farmers Produce More Food Per Unit Labor

Next, we test the received wisdom that farmers produce a greater quantity of food per unit labor than do foragers, using agricultural and foraging production data summarized in Table 4. The first two authors measured production in 246 maize fields in 1998-1999 (Tucker 2007). The other values in Table 4 are from published studies (Dandoy 1972; Hoerner 1986; Ottino 1963). The Table also displays labor requirements per hectare, from Ottino, Lavondès, and Trouchaud (1960), plus the caloric values of crops (Wu Leung 1968) and their market prices.

Although some of these published agricultural datasets are decades old, there are at least three reasons to suspect that yields have not changed much over this time. Our field measures of maize and rice yields match those from Hoerner in 1986. Diachronic production data by Ottino (1963), Dandoy (1972), and Hoerner (1986) show no changes in average yield over 10 to 24 year periods. Agricultural technology has not changed over this period, with most labor still performed with handheld or ox-drawn tools and almost no use of fertilizer, pesticide, or improved seed.

Table 4 also presents data for terrestrial and marine foraging activities, with productivity expressed as catch per unit effort (CPUE) in kg/forager/day. These data were collected by the authors with an activity log that recorded individuals' time spent foraging and the weight of their catch (Gough et al. 2009; Humber et al. 2006; Iida 2005, 2008; Tucker 2001, 2007).

In this dataset, labor is quantified in days, with no assumptions about the number of hours worked within the day. We assume that workdays vary in length due to weather, rest breaks, and other activities that demand the worker's time. Because this variation is largely beyond the individual's control, the figures here represent averages of daily labor accomplishments.

Table 5. Average energy and cash production from seven agricultural portfolios (top) and 14 foraging portfolios (bottom), where each portfolio is an allocation of 100 percent of the year's labor (365 days) to a different suite of activities. (Note that three maize crops and two rice crops are possible per year; RS=rainy season, EDS=early dry season, LDS=late dry season).

Portfolio #	Percent of annual labor budget allocated								Total energy production (kcal)	Total cash production (MGA)
	Maize, RS	Maize, EDS	Maize, LDS	Manioc	Rice, RS	Rice, LDS	Butter beans	Remainder		
1	32	38	18		1			11	24,326,860	2,576,163
2	32		27		1		32	8	21,537,447	4,616,312
3		40			40			20	17,138,947	2,405,448
4	12	35			35		13	5	20,509,642	3,623,331
5	26	29			14	1	25	5	21,592,256	4,313,809
6	23		17	50	1			9	16,024,691	1,669,864
7	23	1		50	1		23	2	15,483,731	3,288,386
	Ovy tubers	Honey	Snake-head fish	Tilapia	Finfish (marine)	Octopus	Sea cucumbers*	Crabs		
8	75	25							4,700,801	1,727,603
9	75		25						3,327,853	1,583,521
10	50		50						2,396,524	1,391,358
11	38	25	38						3,462,773	1,453,272
12	50	25	25						3,859,473	1,535,440
13	25	25	25	25					3,062,662	1,260,447
14	50	17	17	16					3,421,602	1,433,009
15					100				913,593	788,940
16					61	39			1,302,520	935,661
17					41	39		20	1,184,626	881,338
18					61		39		557,291	1,438,501
19					41		39	20	439,398	1,384,178
20					61	20	19		939,460	1,180,634
21					41	20	19	20	821,566	1,126,311

*Sea cucumbers are not eaten by Malagasy people, but fetch a high price when sold to exporters. Portfolios that allocate time to sea cucumber harvesting have low caloric gains but high monetary gains.

According to the values in Tables 4, if a whole year of labor (365 days) could be spent cultivating maize, this would result in an 8.30 hectare field yielding 28,429,482 kcal. A similar year spent farming manioc would result in a 2.09 hectare field yielding 10,286,048 kcal. In contrast, a year spent digging wild ovy tubers (*Discorea acuminata*) yields less than half as many Calories, 4,076,389 kcal; a year spent fishing at sea yields an average of only 1,292,976 kcal; and a year of octopus collection provides 1,909,534 kcal. Farming appears to be much more productive than foraging.

These simple calculations ignore many facets of the real world. Next, we consider seasonal labor scheduling. It is not possible to spend an entire 365 days cultivating maize, for one hectare of rainy season maize requires 24 days of labor in the late dry season and 76 days during the rainy season (Ottino, Lavondès, and Trouchaud 1960). Based on these figures, the largest field one can reasonably cultivate is 2.65 hectares, using up 117 days of the year, leaving a remainder of 248

days to spend on other activities. Ottino and co-authors supply comparable seasonal labor requirements for other crops.

There are also seasonal constraints on the scheduling of foraging labor, as explained in the final column of Table 4. Wild ovy tuber foraging is limited to the nine-month dry seasons, for tubers are rotten and regenerating during the three-month rainy season. By contrast, honey is primarily harvested during the three-month rainy season. On the coast, octopus and sea cucumber are primarily harvested during springtides, which occur for four to five days every two weeks.

These seasonal constraints mean that farmers and foragers will typically invest in a portfolio of activities rather than in a single activity. Table 5 displays seven agricultural portfolios, seven forest foraging portfolios, and seven marine foraging portfolios that respect the seasonal limits just described. Each portfolio is as an allocation of 100 percent of the 365 potential labor days in a year to a series of activities (assuming every day is spent working). These portfolios

were generated by allocating the maximum possible time to the highest-yielding activities, then adding as much time as possible to other activities in descending order of mean production. In some cases, we then lowered investment in the top ranked activities to allow greater diversification into lower ranked activities. Agricultural portfolios include a small remainder of unallocated days, for the seasonal constraints make it difficult to schedule all 365 days in productive labor.

The penultimate column in Table 5 displays the expected production of food energy from each portfolio. Agricultural portfolios average 19.5 million kcal per year, while forest foraging portfolios average 3.4 million kcal and marine foraging averages 0.9 million kcal per year. Agriculture appears 5.7 to 21.7 times more productive than foraging.

The final column in Table 5 translates annual food production into market value. Because wild foods have higher prices than cultivated foods, agricultural and foraging portfolios provide similar payoffs. Agricultural portfolios still produce more (averaging 3.2 million MGA) (\$1,920) than foraging portfolios (averaging 1.5 million MGA) (\$900), but the difference is less severe with agriculture 2.1 to 2.9 times more profitable. This may explain the comparable market-valued incomes from the analyses of the questionnaire data. Wild foods probably fetch higher prices because of their superior flavor and nutrition and because marketplaces are seldom saturated with wild tubers, honey, and fish.

Mathematical Simulation: Farmers Face Greater Production Risk Than Foragers

Next, we examine the production risk of farming and foraging by converting the previous calculations into a stochastic simulation. The simulation, programmed in Excel 2004 for Macintosh Visual Basic Macros, allows the user to input a portfolio of foraging and farming activities by allocating 100 percent of the year's labor to a suite of farming and foraging activities. For each agricultural activity, the model generates a random harvest value from a standard-normal distribution with mean and standard deviation from the production data in Table 4. For each day spent foraging, the model generates a random CPUE value from a normal distribution with mean and standard deviation from Table 4. The calculation is iterated 1,000 times with different random harvest and CPUE values in each iteration. The model outputs the mean and standard deviation for the portfolio calculated over the 1,000 iterations.

From the mean and standard deviation (*sd*) we can calculate a measure of risk protection, *z*. The *z*-score is the number of standard deviates that exceed a household's minimum subsistence requirements, R_{min} , calculated as $z = (\text{mean} - R_{min})/sd$ (Winterhalder, Lu, and Tucker 1999). Higher *z*-scores indicate less risk. While we lack a good measure for R_{min} , as long as our analytical goals are limited to comparing the relative riskiness of different portfolios, it is sufficient that R_{min} be reasonable but not exact, for no matter what R_{min} value is used, portfolio risk will be ranked in the same

relative order. We choose the arbitrary but reasonable value of 2,500 kcal per day, or 912,500 kcal/year; or 800 MGA/day (\$0.48) (292,000 MGA/year) (\$167), equivalent to three cups of rice per day.

Table 6 displays the results of our simulations for the 21 portfolios introduced previously. Agriculture is an order of magnitude more risky than forest foraging. The *z* values for agricultural portfolios range from 1.91 to 2.89, while *z* values for forest foraging portfolios range from 13.57 to 33.59. Agriculture is also considerably more risky than marine foraging when marine foragers sell their catch in the market ($z=16.23$ to 19.53).

According to the logic of the *z*-score model, portfolios can have high risk for three reasons, corresponding to the model's three variables: high standard deviation, which explains the high risk of the agricultural portfolios; high R_{min} , related to household size and ratio of producers to consumers; and low mean, either approaching R_{min} or less than R_{min} . This final situation explains the high production risk associated with marine foraging valued for Calories. Partially, this is an artifact of using Calories as a currency for food value, as marine foods tend to be low in Calories and high in protein. Note that portfolios 18-20 include sea cucumber, which, because Vezo do not eat them but harvest them only for sale, gain no food value for the household.

Mathematical Simulation: Does Diversification Protect Farmers Against Risk?

In Table 1, we saw that at least some Masikoro farmers spend a considerable amount of time hunting and gathering. Andranodehoke residents gained 22 percent of their income from wild foods. Does adding foraging to an agricultural portfolio reduce the risk of the portfolio, and if so, at what cost to the mean? Because the "portfolios" in Table 1 consist of income scores while the portfolios in our simulation consist of labor allocation, we cannot simply plug the "real" portfolios into the model. Instead, we reran the first agricultural portfolio from Table 5 30 times. In each run, we added an additional two percent time allocated to ovy tuber foraging, subtracting time spent on maize and rice proportionally. The result was that as time spent foraging increases, the portfolio's mean diminishes linearly while *z* increases in a gradually accelerating manner. The rates of change are notably different if the portfolio is valued for Calories versus cash.

Valued for food energy, if farmers allocate 20 percent of their annual labor to ovy foraging, their mean drops 17 percent (from 23.8 million kcal to 19.7 million kcal) without affecting *z* at all (2.85). If they allocate 40 percent of their annual labor to ovy, they lose 36 percent of their mean (dropping to 15 million kcal) while *z* increases only 9 percent (to 3.12). At 60 percent time allocated to foraging, the mean has diminished 58 percent (to 10 million kcal), while *z* has only increased 13 percent (3.28). In short, when portfolios are valued by Calories, it costs a lot of mean to marginally improve risk protection; diversification is an ineffective way to reduce risk.

Table 6. Results of stochastic model of agricultural and foraging portfolios, demonstrating the comparative production risks of foraging versus farming (portfolios 1-21 are explained in Table 6). cv refers to the coefficient of variation (sd/mean). The z-score measure of risk protection is described in the text.

Portfolio	Food energy (kcal)			Market value (MGA)		
	Mean	cv	z	Mean	cv	z
Agricultural portfolios						
1	24,038,056	0.36	2.64	2,545,096	0.36	2.66
2	22,236,853	0.34	2.78	4,888,420	0.51	1.91
3	17,276,749	0.45	2.09	2,457,358	0.48	2.00
4	20,769,510	0.35	2.73	3,748,696	0.36	2.64
5	21,925,208	0.33	2.89	4,463,198	0.44	2.19
6	16,550,149	0.35	2.63	1,723,430	0.35	2.66
7	15,971,387	0.37	2.49	3,432,004	0.53	1.84
Forest foraging portfolios						
8	4,664,923	0.04	20.53	1,687,468	0.03	29.47
9	2,736,358	0.03	19.31	1,368,647	0.03	31.56
10	2,325,683	0.03	16.77	1,366,034	0.03	33.59
11	3,492,359	0.05	14.97	1,443,322	0.03	27.15
12	3,908,710	0.04	16.76	1,537,920	0.03	27.62
13	3,268,138	0.05	13.57	1,371,661	0.04	23.68
14	3,563,478	0.04	17.44	1,505,527	0.03	28.01
Marine foraging portfolios						
15	1,221,838	0.05	1.89	1,055,128	0.05	16.23
16	1,538,269	0.05	6.32	1,121,922	0.05	18.94
17	1,354,516	0.05	4.02	1,025,303	0.05	18.68
18	724,079	0.07	-7.69	1,679,989	0.05	18.50
19	571,856	0.07	-12.53	1,579,033	0.05	18.72
20	1,142,578	0.05	0.78	1,387,703	0.05	18.13
21	960,780	0.05	-2.64	1,294,230	0.05	19.56

Diversification is much more likely to reduce risk when production is sold in the market. At 20 percent time allocated to foraging, the mean drops 7 percent (from 2.5 to 2.4 million MGA) (\$1,500 to \$1,440) to while z increases 11 percent (from 2.90 to 3.26). At 40 percent time allocated to foraging, the mean diminishes 16 percent (to 2.1 million MGA) (\$1,260), while z increases 30 percent (to 4.22). At 60 percent time allocated to foraging, the mean diminishes 30 percent (to 1.8 million) while z has doubled (5.69).

Discussion: Risk, Delay, and Anxiety

The reason why the foraging portfolios we modeled are less risky than the agricultural portfolios is because foraging portfolios have a greater number of annual payoffs, and, thus, a lower standard deviation relative to mean (a lower coefficient of variation). Echoing the old wisdom not to put all of one's eggs in the same basket, Mehr and Cammack (1952) begin their textbook on insurance by stating that insurance consists of spreading one's investments over multiple "exposure units," each with a randomized fate independent of the other units. As our model assumes that each day is spent

working, the foraging portfolios have 365 "exposure units" per year while the agricultural portfolios have only two to five exposure units (harvests) per year.⁴ Greater insurance is offered by foraging, except when the portfolio mean is low relative to R_{min} , as is the case with marine foraging portfolios valued for Calories.

Agriculture may engender more anxiety about food supply because farmers wait many months for just a few harvests, while for foragers, every day is potentially a harvest day. If a forager dedicates a day to digging wild tubers or collecting octopus on the reef, by the end of that day she generally brings home some quantity of fresh food to supply the daily needs of her household. By dusk of the same day, a farmer has little to show for her toil but sweat, aching muscles, and nagging uncertainty about the final fate of her fields (Tucker 2006).

On days without harvest, farm families feed themselves from stored foods, stored cash, the generosity of others, and off-farm income. Among Masikoro farmers, managing stored food and cash is very difficult; many run out of stores well before the next harvest. Following a year of low production, the farmer must carefully manage stores to meet both consumption needs

and need for seeds for the following year. Following a year of high production, a farmer with bountiful stores is targeted for favors by the less fortunate and by family members planning costly ceremonies, such as rites of *soronanake* (filiation), *savatse* (circumcision), and *soro* (invocations of ancestors). In Masikoro society, it is almost impossible to say no to a wide variety of claimants. Saying no exposes one to the risks of being called *matity* (stingy), the most common insult; and to accusations of having gained large stores through *vorike* (black magic) or *raty hevitse* (witchcraft). Particularly successful farmers are expected to throw a party called a *bilo* in which they redistribute some of their wealth to the community (Fieloux and Lombard 1987).

When stores run out, Masikoro farmers with immediate food needs often seek rice loans at interest to carry them through until the next harvest. At the village of Bekongo in 2006, the first author was told about a system in which a successful farmer lends 1,000 MGA (\$0.57) to the debtor in exchange for one daba (9.2 liter container) of paddy rice at harvest time. As a daba of rice is worth about 13,600 MGA (\$7.77), the interest rate over a 90-day growing season is 5,040 percent. Bekongo farmers complained that by harvest time they owed the majority of their production to creditors and had little to store for the next year. Even though it was harvest time, we saw farmers subsisting on fallback foods, boiled sweet potato greens and unripe fruit.

In addition to storage and credit, farmers meet immediate food needs from what agricultural economists call “off-farm income,” which includes foraging, herding, retailing, and wage labor. According to our simulation, adding foraging to an agricultural portfolio does make it less risky, at the cost of reduced mean. When foraged goods are valued calorically, a lot of mean must be sacrificed for a small marginal gain in risk protection. In order for Masikoro farmers, such as those at Andranodehoke, to reduce risk by foraging, they would have to sell the wild foods they capture. In the questionnaire data, the median percentage of wild foods sold by Andranodehoke farmers was 0 percent. Foraging does not appear to mitigate risk for these farmers. Instead, foraging may be a source of dietary diversity or a leisure activity (most of the foraging at Andranodehoke is freshwater fishing).

An explanation for why Mikea gain up to 40 percent of their income from maize agriculture is also suggested by our simulation results. Small investment in agriculture increases the mean productivity of the portfolio linearly, albeit adding increasing risk. Given a forager’s wealth of exposure units and high z scores, many Mikea are likely to sacrifice some safety for a greater mean.

Caveats and Limitations

Our thesis that foraging should be part of the solution to global food insecurity requires several caveats. First, hunter-gatherers and fishermen are hardly immune to food insecurity. Mikea tend to exhaust the wild tuber patches close to their homes within a few months of the beginning

of the dry season, after which they must travel increasing distances to find unharvested tuber patches. On the coast, Vezo often find that they cannot work at sea for days at a time, when winds are strong (especially the Antarctic wind called *tsiokantimo*), rains are heavy (as during cyclones), or seas are churned and dark; the result is periodic food shortages. Vezo women are particularly affected, as most of their foraging occurs during the 3 to 5 days of peak springtide during the 14-day springtide-neap tide cycle when the reef top is exposed. Women wait 10 to 12 days for the right tidal conditions to forage, but then if the winds are wrong or it is raining, they must wait through another lunar half cycle to go foraging. Vezo are also particularly vulnerable to market risk as they sell the majority of their catch to exporters or Masikoro traders and buy most of their food.

Our second caveat is that many foragers are actively interested in doing some cultivation. While the point of our article is to discourage development agencies from forcing foragers to become farmers, we also argue that development projects should not exclude foragers from adding agriculture to their portfolios. Mixing some agriculture with foraging increases the mean of the portfolio, albeit at the expense of risk protection.

A third caveat is that our data and models do not address wild resource management and the risks of overexploiting wild plant and animal populations. We have discussed the market value of wild foods without mentioning the “bushmeat” problem that threatens endangered species throughout much of rural Africa and Latin America (Apaza et al. 2002; Juste et al. 1995). Yet foraging may be no more damaging to wildlife than expanding farmland and rangeland. Just as farming must be managed by either indigenous or state institutions, so must foraging. But many foraging behaviors, such as wild tuber digging and honey collection, are easily sustainable. Among Mikea, ovy vines will grow new tubers each year as long as foragers leave the stem in the ground.

A limitation of our model is that it does not consider gendered division of labor, gendered differences in return rates, and household composition. Gendered division of labor places further constraints on household portfolio compositions. Men, women, children, and the elderly not only do different kinds of tasks, they also have different alternative uses for their time including housework, ceremonies, play, rest, etc., that influence the number of days available for work. Household size and composition affect the household’s minimum requirements and, thus, R_{min} . Behaviors that change a household’s R_{min} , such as sending children away to school or to live with relatives, could reduce risk.

External Validity

The foraging and farming portfolios presented here may not be generally representative of foragers and farmers throughout the world. Agricultural yields among Masikoro are possibly on the low end of the worldwide spectrum,

lower than those of farmers who have better access to water, improved seed, and inputs. Mikea foraging portfolios may also be on the low extreme, due to the lack of large game animals. Vezo, likewise, rarely catch large prey apart from the occasional sea turtle.

We expect that foragers throughout the world will typically have less anxiety about food than farmers when the following conditions are met: (1) when foraging provides many more payoffs per year than agriculture; (2) when foraging brings new food into the household on an almost daily basis while farmers have to wait for future, uncertain harvests; (3) when the first two conditions mean that foragers depend less upon stored foods and credit to meet their daily food needs; and (4) when farmers cannot reduce risk by practicing some foraging.

The conditions under which our model would predict greater risk for *foragers* rather than farmers include: (1) if forager's mean returns are low relative to minimum requirements, as is the case with Vezo portfolios valued calorically; (2) if payoffs are not normally distributed, as we have assumed them to be throughout this paper; if foraging returns are positively skewed while farming returns are negatively skewed; (3) if foraging activities are delayed return activities with few harvests, as with some hunting with traps and nets (what Woodburn (1980) called "delayed return foragers"); and (4) if farming permits constant harvesting, as in some manioc cropping regimes where tubers are excavated and stems replanted daily to meet family needs.⁵

Conclusion

Anthropologist Leslie White (1949) argued that societies advance as they learn more effective and efficient methods of capturing energy from the environment. Agriculture captures more energy per unit energy (labor) than foraging, and intensive agriculture captures more than does the low-input variety. We have argued here that more is not always better, if "better" refers to household food insecurity. Under a wide variety of conditions, farmers are likely to experience great anxiety about the food supply as they work towards just a few delayed and risky harvests of low-quality food.

We are not arguing that more of the world's population should be encouraged to become foragers. But allowing the over five million terrestrial foragers and many millions of fishermen to remain in their subsistence mode rather than encouraging them to move into farming may be more beneficial to regional food security. Allowing foragers to forage could be less destructive to natural environments that are not conducive to cultivation in the first place, and more beneficial for the foragers themselves, many of who see foraging as a central part of their cultural identity.

Notes

¹Chi-square tests and Wilcoxon rank-sum tests find the subset of 312 cases is statistically similar to the main dataset of 550 cases with

regards to sex ($X^2=0.077$, $df=1$, $p=0.782$), household size ($z=1.562$, $p=0.118$), material wealth ($z=-0.204$, $p=0.838$), social capital ($z=0.244$, $p=0.808$), and human capital ($z=-0.038$, $p=0.970$). The 155 Masikoro cases in the subsample are statistically similar to the 222 Masikoro in the main sample: sex ($X^2=0.136$, $df=1$, $p=0.712$), household size ($z=0.443$, $p=0.658$), material wealth ($z=-0.127$, $p=0.899$), social capital ($z=0.011$, $p=0.991$), and human capital ($z=0.271$, $p=0.787$). The 54 Mikea in the subsample are statistically similar to the 129 Mikea in the main sample: sex ($X^2=0.021$, $df=1$, $p=0.886$), household size ($z=-0.422$, $z=0.673$), material wealth ($z=0.723$, $p=0.470$), social capital ($z=0.574$, $p=0.566$), human capital ($z=0.418$, $p=0.676$). The 103 Vezo in the subsample are statistically similar to the 198 Vezo in the main sample: sex ($X^2=0.096$, $df=1$, $p=0.757$), material wealth ($z=-0.523$, $p=0.601$), social capital ($z=0.311$, $p=0.756$), human capital ($z=-0.353$, $p=0.724$). Vezo households were significantly larger in the subsample versus the main sample (6.59 versus 5.74 members; $z=2.224$, $p=0.026$).

²The retailing and wage labor sector does not include profits from the sale of products from other sectors. Retailing refers to purchasing products in one place to resell at a markup elsewhere, including itinerant trading and shop keeping.

³An arbitrary 1 was added to each income and food insecurity score to avoid zero values that have no natural logarithm.

⁴An anonymous reviewer suggested that agricultural harvests should not be treated as single outcomes, for harvesting occurs over a span of days each with its own rate of return. By this logic, our model should compare 365 days of foraging with N days of harvesting, rather than with one harvest per crop. This modification of the model would result in lower risk estimates for agricultural portfolios. We appreciate this insight, but disagree with its logic. Daily foraging returns are more or less independent outcomes, meaning that the outcome of tuber foraging on day N is independent of the outcome on day $N-1$ or day $N+1$. By contrast, the outcome of an agricultural harvest on day N is dependent on $N-1$ and on labor and other investments in the field during previous days. If a farmer harvests 1,000 kg on day 1 but awakes the next day to find the field destroyed by pests, she cannot then harvest 1,000 kg again on day 3 or 4. The quantity of production in a wild tuber patch or an agricultural field is a function of its cumulative exposure to inputs (soil nutrients, rainfall, sunlight, and for agriculture, labor, fertilizer, etc.) and its cumulative exposure to environmental hazards (pests, rot, previous harvesting, etc.). Each foraging day has an independent outcome because the forager may visit a new patch each day. Each day spent harvesting is part of a single outcome because the farmer is limited to her own field.

⁵While in the Neotropics manioc is often harvested and replanted continuously through the year, in 149 fields that we visited, all were planted in October-December and harvested on average 10.2 months later.

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