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# Tsimane' Horticulture

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Chapter 6

# Tsimane' Horticulture

***Summary***: *Aims*: *i]* Panel (2002-2010) and cross-sectional (2008) data from separate places are used to describe Tsimane' horticulture, focusing on anticipatory steps to safeguard crops from mishaps. I describe changes in the number of plots tilled and crops sown, including hardy crops that withstand neglect and adversity. *ii]* I probe the role of household size and composition in horticulture by reweighing *a)* Boserup's idea that population pressure causes field expansion followed intensification and *b)* Chayanov's idea that the household consumer/worker ratio affects horticulture. I control for market contact and use lag predictors when testing hypotheses. *Methods*: We collected data at the household level from one household head. Relying on one person led to inaccuracies. We found digit heaping around multiples of 5 and 10 when reporting areas and crop amounts. Findings from the panel and cross-sectional samples differed, backing the point made in Chapter 5 about the need to ensure that findings from data collected in different places concur. *Descriptive findings*: Tsimane' horticulture is in equilibrium yet changing. Some aspects (e.g., number of fields) barely changed, but yields and sales of rice (the main crop) fell, as did the chance of leaving lands idle. Tsimane' are upgrading swidden cultivation by adopting commercial inputs (e.g., chainsaws, chemical herbicides). *Specialization*: Tsimane' are becoming specialized horticulturists and forgoing customary steps to shield crops from mishaps. They plant in one plot, mostly with rice. In new swidden, the area with rice overshadows the area with other crops. The number of minor crops sown has fallen. Modest diversification nevertheless correlates with a higher real value of food consumption. *Demography*: Tsimane' are simultaneously expanding and intensifying farming. Deforestation and household size correlated positively, supporting Boserup's idea that in places with ample land, the first retort to population pressure consists in enlarging fields. With the uncasing of autarkic societies, however, only households with some types of people could adopt commercial inputs. Contrary to Chayanov's belief, the household dependency ratio did not predict farm outcomes, but having girls, for instance, predicted chainsaw use. Household size explained why households enlarged fields (Boserup), but some types of people in the household explained why only some households could also intensify (Chayanov). Thus, we see simultaneous signs of both horticultural expansion from household size and intensification from household composition.

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We like to portray the Tsimane' as a hunting and gathering society and, though true, the rendering misses the point the Tsimane' have been accomplished horticulturists since at least the early twentieth century. The size, assortment, and opulence of their fields everywhere in evidence, together with the eagerness of Tsimane' to embrace new crops from outsiders so struck the Swedish anthropologist Erland Nordenskiöld during his 1904-1914 sojourn to South America that he ranked the Tsimane' as one of the best horticulturists he had seen in the Bolivian lowlands. He compared the Tsimane' with nine other Indian societies that had kept "most, or a great deal of their original civilization" and found that the Tsimane' grew a panoply of crops that few other groups grew, such as pineapples, earthnuts, squash, cacao, rice, coffee, onions, and peas (Nordenskiöld, 1979 [orig. 1924], pp. 34-35).

An early study on household consumption by our research team showed that horticulture still plays a noticeable role in the household economy of the Tsimane'. During five consecutive quarters during 1999-2000, the team monitored goods entering all households in two villages along the Maniqui River. On a day chosen at random each quarter, a researcher sat in the compound of a house from 7am until 6pm in the villages of San Antonio near the town of San Borja. Another researcher did the same in the village of Yaranda, farther upriver. Researchers identified, weighed, and ascertained the provenience of any good brought into the house. From the forest, Tsimane' brought firewood, fish, game, and wild plants. From towns, they brought marketware, and from farms they brought crops, animals, and animal products. Researchers found that in the two villages farm goods accounted for 36% and 44% of the value of goods entering a household (Reyes-García, 2001, pp. 39, 77)[i]. During two quarters, the value of goods from farms (52%) surpassed the value of goods from the forest (42%) or from the market (6%) (Byron, 2003, p. 138)[ii].

Besides describing Tsimane' horticulture, I have three loftier, more analytical, hitched goals for the chapter. First, I want to reweigh Ester Boserup's (1965) influential hypothesis that population pressure at first ignites the expansion of farmlands into craggier, poorer soils, and that -- once new land gains have reached a ceiling, with no more dregs of land left – population pressure pushes tillers to deepen farming by trimming the fallow and putting more time, farmhands, and chemicals on sessile parcels.

As a second goal, I want to examine the role of markets in the population-horticulture nexus. Markets modulate the link between population and horticulture (Binswanger-Mkhize & Savastano, 2017; Netting, 1993, pp. 288-294). Even if one hews to Boserup's line that population growth changes the way people farm, one would still need to look at the hands of markets and towns in horticultural change. By reducing expenses, nearness to towns and partaking in markets make it easier for tillers not only to buy fertilizers, pesticides, and tools, but also to visit clinics to assuage illness, with ripple effects on mortality and population growth. If markets and towns attract people to buy tools, seeds, and chemicals for farming while seeking health services, then leaving out towns and market will yield an inaccurate reading of how population swelling shapes horticulture[iii]. With the longitudinal information at hand, we are well placed to face the challenge and to be slightly surer about what is cause and what effect. Access to repeated annual measures from the same households about their horticultural performance, their demography, their proximity to towns, lets us eye how past demography bears on later horticultural manners, while controlling for a household's dealing with the market.

As a third goal I want to describe the customary actions Tsimane' put in place now to safeguard their crops from tomorrow's mishaps. Like other assailable rural dwellers, Tsimane' bestrew fields, grow many crops and varieties of the same crop in a plot, and stagger planting[iv], all in anticipation of pests, diseases, and floods that could harm one plot but not another (Morduch, 1995; Sawada & Takasaki, 2017, pp. 5-6). I examine changes in the number of plots tilled, in the number of crops grown, and in the penchant to cultivate manioc and plantains, two hardy crops that withstand human neglect and nature's sieges. To these crops Tsimane' can turn after misfortune's crosses ruin other crops. I test how far precautionary steps safeguard the value of food consumption. Of course, Tsimane' can shield food intake from nature's wrackful batters in other ways besides taking preventive steps in their parcels. Other ways happen after fortune's spite ruin a plot, and include scrimping, thieving, and reliance on hock, migration, wage labor, remittances, and the evergetism of neighbors. I examine those topics in other chapters.

**A sketch of the slash-and-burn (swidden) horticultural cycle**

Extending from May until September, the dry season heralds the start of the slash-and-burn swidden cycle (Chapter 5; Figures 5.5.a and 5.5.b). During these months, households cut trees, shrubs, and brambles from fallow forest and from old-growth forests in a radius of less than two kilometers from the village (Pérez-Llorente et al., 2013; Ringhofer, 2010, p. 139)[v]. Some households opt out of clearing forest because adults get sick or leave the village, and the households lack the means to hire workers to fill the gap. From the forest, households clear one to two plots covering a total surface of one hectare. Tree trunks in old-growth forests being wider and their wood denser than tree trunks in younger fallow forests (Piland, 1991, p. 78), old-growth forests exact more work and need earlier clearing than fallow forests, but pay off by having fewer weeds and higher crop yields (Ringhofer, 2010, p. 139). Adult men hew the largest trees, adult women and children mow the smaller vegetation. Adults take the lead readying parcels and, through their toil, establish silent property rights to parcels. For clearing, the ruck rely on cutlasses and axes, but better-off households, or households without woodsmen hire help and use chainsaws. After clearing, households wait until the remains dry from the hot sun of the dry season before setting the waste ablaze. Sere vegetation and fallen tree trunks do not burn well if too wet, so tillers try to burn the debris before October, the onset of continuous rainy weather.

Using digging sticks (dibbles) that they fashion or buy, Tsimane' put in primary and minor crops, some annuals, some perennials, some to eat, some to sell. The chief annual crops are rice and maize[vi], the chief perennial crop includes plantains, with manioc, a tuber, straddling the annual-perennial dichotomy because some varieties can survive underground for more than a year before they spoil. Rice and plantains occupy most of a cleared parcel, probably because Tsimane' use them as their premier cash crops (Zycherman, 2013). In a plot, planters mix rows of plantains, rice, and maize, but refrain from too much intercropping or adding too many crops (Piland, 1991, p. 73). Grown in smaller patches, often contracted to the edge of newly-cleared fields, sit minor crops like peanuts, sweet potatoes, pineapples, sugar cane, fruit trees, and cacao (Reyes-García, 2001, p. 79; Vadez & Fernández-Llamazare, 2014, p. 156). Tsimane' roll out planting, with manioc and plantains going in first toward the end of the dry season, followed by maize and rice going in at the start of the rainy season (Vadez & Fernández-Llamazare, 2014, p. 152). Farmers subdue ruderal weeds with cutlasses, but prefer more and more to spray chemical herbicides on rice fields to kill weeds.

The harvests of rice and maize take place at the height of the rainy season, between January and March. After the harvest, the plot is planted again during the dry season for at least one more year (Vadez et al., 2008). People use a plot for two to three continual years before allowing it to go back to wilderness, but not without first putting in plants for later use. In plots that they had used to grow food crops and that are scheduled to rest, Tsimane’ plait in medicinal plants, fruit and lumber trees, and other vegetation, which they later use for food or to carve out canoes or to fashion utensils. Huanca (1999) studied the fate of retired fields among the Tsimane’ of the Sécure River, and found that they used the fields sporadically for the first five years, but thereafter came back to them steadily to take out the plants they had purposefully added.

Claims to land overlap, with the government, national parks, loggers, ranchers, highlanders, and Tsimane' voicing their right to use the same land (Godoy et al., 1998; Paneque-Gálvez et al., 2013; Piland, 1991, pp. 6-7, 44-45; Reyes-García et al., 2011; 2012). In practice, villagers have unfettered rights to use the village commons. Any Tsimane' can use the forest, rivers, riparian lands, tarns, and oxbow lakes that environ a village to grow crops, fish, homestead, cut lumber, raise swine and cattle, or stalk the woods for wildlife. Held as a common asset, land cannot be sold or rented to anyone, but Tsimane’ subscribe to a light Lockean view of land entitlement: land worked, land owned, even if there is not enough "left for others because of his enclosure for himself" (Locke, 1798, p. 30). A cleared parcel of forest belongs to the one who lead the clearing -- even if kin helped -- and a fallow forest belongs to the one who last farmed it. Unlike Medieval European peasants, Tsimane' have not started enclosing their fields for daily horticulture, but in villages with slim forest pickings one begins to spot pounds to pen in swine and cattle so they do not trample on the crops of neighbors. At any time, a household manages fields carved out from old-growth forests and fallow forests, the youngest fields with rice, the oldest with plantains, and the ones in between with maize or manioc (Piland, 1991, p. 74). The fields cleared by a household from a fallow forest can be a field a household used in the past, a forgotten field left by another household so long ago it is now available for use to anyone, or a field surrendered by a household that left the village forever.

**Reported data on horticulture and its quality**

The information collected on horticulture refers to the entire household rather than to individuals in the household, and for good reasons. Individuals might take the lead fixing a plot, but all in the household aid with farming, all combine their harvest, and all have the right to eat from the family larder. Partnership in work and the pooling of the harvest vindicate my viewing horticulture as a household business.

Since surveys happened during the dry season (May-September) when households were clearing forests, we could not ask about current forest clearing or about the current horticultural cycle. Instead, we asked about the farming cycle in the previous year. In the surveys, we asked about the number and the area of plots cleared from the forest, and about the use of chainsaws, herbicides, dibbles, and hired labor. For the main crops -- maize, rice, plantains, and manioc -- we asked about the amount harvested, lost, and sold, and -- having finished with the main crops -- we asked about other crops sown. For the descriptive analysis ("Tsimane' horticulture in numbers") of the next section I rely mostly on clean information from the annual longitudinal study (2002-2010) and from the baseline survey (2008) of the randomized control trial, but to test Boserup I use only data from the longitudinal study for reasons that I outline later (p. 21).

During the surveys we addressed queries about horticulture to the male head of the household. If a household did not have a male head, we asked the female head instead. We chose the husband because we thought that a wife and a husband were equally knowledgeable about the farming deeds of their household. Since spouses farmed in consent, we assumed that they would agree on their answers about horticulture. More pragmatically, relying on one spouse to answer questions about the horticultural activities of the household shortened the burden of the survey. The belief that spouses could substitute as informants would hold if couples decided and toiled in concord in all farm chores. In truth, wife and husband do cooperate, but they spend more time in some plots, crops, and activities than in others, and so know more about some things than other things. For instance, if, after clearing a forest plot, a husband left the village to work in a logging camp and the wife stayed in the village, stuck with weeding and harvesting, then the wife would end up knowing more about the amount of crop losses, harvested, bartered, and sold than the husband. Divergence in reported answers could stem for other reasons. For instance, even if spouses conjoin in farming and put in a common pantry what each had harvested for all to share, they would still know more about the crops from the parcels under their stewardship. We find some circumstantial backing for the hunch that relying on the husband to provide answers about horticulture for the whole household might have blemished the data. Three examples follow.

First, consider a study done during 2011-2012 among Tsimane' spouses in an area known as Territorio Indígena Multiétnico, next to the fieldwork sites of the longitudinal study and the randomized control trial. In the 2011-2012 study, we asked Tsimane' couples in 116 households to tell us who decided how much forest their household had cleared the previous year. Eighteen percent said the wife decided, 62.4% said the husband decided, 16.7% said spouses decided jointly, and 2.3% said that another person decided[vii]. Thus, husbands took part in 79.1% (62.4%+16.7%) of the decisions of how much forest to clear, meaning that in asking husbands about horticulture we were probably tapping an unreliable witness 21% of the time.

Next, and on a related point, think about the accuracy of reported answers about the amount of forest area cleared for horticulture. In a study done during September-November, 1999, among all 25 households in the village of Yaranda along the Maniqui River, researchers measured the 36 plots households had cleared earlier that year (Vadez et al., 2003). A few months later, during May-June 2000, researchers asked the male head of the household to report the total area cleared by the entire household in 1999, and the area of each parcel he had cleared. Researchers also asked other adults in the household to assess the area of plots cleared by each of the other household member in 1999. People's estimate of field size matched the field size measured by researchers, but custodians of a plot gave more accurate estimates of the plot size than other household members. The male head underestimated the total area of forest cleared by his household, probably because he forgot to include forest patches cleared by other people in his household. If the wont to underestimate forest area cleared extends beyond the village of Yaranda, the study period (1999-2000), and other outcomes besides deforestation, then we will find ourselves with data of questionable value to describe Tsimane' horticulture.

Last, consider the sale of crops, one of the chief ways by which Tsimane' forge links with the economy outside the village. When gathering information on crop sales, we decided to have the husband tell us how much rice, maize, manioc, and plantains the household had sold from the last harvest. The approach works well if the crops grew in the parcels managed by the husband, but it works less well if the crops grew in the parcels managed by others in the household. During the 2004 survey of the longitudinal study, we asked the wife and the husband who decided on the sale of crops, animals, and animal products. Forty-eight percent of the women said that they decided and 26% said they decided jointly with the husband, while 40% of the men said that they decided, and 35% said that they decided jointly with the wife (Godoy et al., 2006,

p. 1521). If these figures match reality, they imply that sometimes a respondent did not know how much of the harvest the household had sold.

In sum, the assumption that the female and the male head of a household could substitute with accuracy and reliability for each other when answering questions about household horticultural rested on loose grounds. Trusting one spouse to tally what the entire household had done in the fields muddied the data we gleaned, but how much we cannot tell.

**Tsimane' horticulture in numbers**

Using information from the longitudinal study and from the baseline of the randomized control trial, in this section I go over summary statistics and growth rates for horticultural inputs and outputs. I show separate summary statistics for each study because measures from the two studies differed (p. 17). When estimating growth rates, I combine the two studies, but control for the study. As seen later, households sometimes did not clear forest, plant a crop, spray herbicides, or hire workers. When this happens, one cannot tell whether one should score growth rates of horticultural inputs and outputs for all households, or only for households with a positive value; for safety, I do both. All three steps – showing separate statistics for each study, controlling for the study when estimating growth rates, and computing separate growth rates for the entire sample and only for households reporting positive values – add transparency to the narrative and confidence in the results. As the chapter unfurls, I show summary statistics sequentially starting with Table 6.1 and Figure 6.1a, but I put all the growth rates of the descriptive analysis in Table 6.7.

<u>Number of plots cleared from the forest</u>. Figures 6.1a-6.1b and Table 6.1 show trends over time in the number of plots cleared from the forest. During 2002-2010, most households (94%) cleared at least one plot from the forest (Figure 6.1a). Table 6.1 (section A) and Figure 6.1a show that in the two studies combined, 54% of households cleared only one plot, 29% cleared two plots, 7% cleared three plots, and 3% cleared four or more plots. Table 6.1 (section B) and Figure 6.1b show that the mean number of plots cleared from the forest spanned a narrow range, from 1.3 plots in 2008 and 2009 to 1.5 plots in 2002, 2005, and 2006, reaching 1.9 plots in 2003. The standard deviation (SD) also covered a thin band (0.7 to 0.8 plots), peaking at 1.2 plots per household in 2003. Table 6.1 (section B) shows that during the nine years of the studies, the mean number of plots cleared by households in the two studies reached 1.4, and the median reached one plot (SD=0.8 plots).

Insert Figures 6.1a-6.1b and Table 6.1

Table 6.7 (section A) relies on the combined sample from the two studies and shows that the number of forest plots cleared by households fell by 1.7% or 2.2% each year. The lower estimate (1.7% per year) includes all households even if they did not clear forest (n=2,700), whereas the higher estimate (2.2% per year) comes from the smaller sample of households clearing some forest (n=2,542). Even though the growth rates are statistically significant, their sizes are insubstantial. With these growth rates, a household would clear 17-22% fewer plots after a decade, but since households cleared only 1 to 1.4 plots each year, having 17-22% fewer plots would leave households in the future with roughly the same number of plots they have now. The number and growth rates of plots show that households, on average, are locked into clearing 1-2 forest plots each year.

Type of forest cleared. Figures 6.2a-6.3a and Table 6.2 show that in the two studies, 32.7% of households did not clear fallow forest and 53.1% of households did not clear old-growth forest. Whether from the shortage of old-growth forest near the village, from lack of time, from a dearth of household workers, or from the greater ease of clearing young forests, households chose to cut fallow forests more than to cut old-growth forests.

Insert Figures 6.2a and 6.3a and Table 6.2

Area of forest cleared by forest type. When answering questions about land area, Tsimane' answered in units known as tareas, 10 of which comprise a hectare.

Data quality. Figures 6.2b and 6.3b show that when answering questions about the size of parcels cleared from forests, respondents in either study rounded answers around multiples of five and 10. Typically, households said that they had cleared 5, 10, 15, or 20 tareas of fallow forest (Figure 6.2b) and 10, 15, or 20 tareas of old-growth forest (Figure 6.3b).

Insert Figures 6.2b and 6.3b

Findings. During 2002-2010, a household in the merged samples cleared an average of 5.4 tareas and a median of five tareas of fallow forest, and a slightly lower average of old-growth forest (4.9 tareas) (Table 6.2). Each year a household cleared a total of 10.3 tareas of fallow forest plus old-growth forest (SD=7.5 tareas), equivalent to one hectare. Starting in 2006 we asked households if they had left idle some of the land they had deforested. In the bottom row of Table 6.2 we see that -- depending on the year -- between 3.5% (2009) and 15.3% (2007) of households said they had left idle some deforested land. From 2006 until 2010, an average of 7.7% of households in the longitudinal study and 9.9% of households in both studies combined left idle some area of recently cleared forest (Table 6.2). The period 2006-2010 saw a yearly decline of 2.1% in the chance of leaving idle some of the land cleared from the forest (Table 6.7, section I.B). Together, these statistics suggest that Tsimane' do not overestimate the amount of land they need to farm and, more importantly, that they are more likely to use all the land they deforest, a finding auguring Boserup.

In Figures 6.2c and 6.3c I show box plots of the yearly area cleared from fallow forest and from old-growth forests for the two studies jointly, but drop households that had not cleared forest. Three features stand out. First, we find anomalies, such as one very high value of fallow forest cleared in 2008 and one very high value of old-growth forest cleared in 2002. Second, we find much variation in the area cleared of either forest type. Third, for both types of forests we see a yearly increase in the expanse of forest cleared. The last point gets support from the statistics of Table 6.7 (section II.B). Every year saw households clear 1.6% more fallow forest, 4.1% more old-growth forest, and 1.7% more total forest[viii]. One should read with care the third finding. When we include all households -- even if they did not clear forest (Table 6.7, section I.B) -- we find no coherent change in the area cleared from old-growth forest or from all forest. Instead, we find a significant yearly decline of 2.8% in the area cleared from fallow forests, a result jarring with earlier results showing greater clearance of all forest types. From the descriptive preamble arises an inconclusive portrait of changes in deforestation, but later, in the conclusion to the chapter (p. 27), when we return to the topic, we will see clearer evidence that households are clearing a larger aggregate area of fields from the forest.

Insert Figures 6.2c-6.3c

Area planted with the leading annual crops: Rice, maize, manioc, and plantains. We asked household heads to tell us the area they had planted with each of the four leading crops. For rice, household heads reported the area in tareas, as they did for the area of forest cleared. We did not adjust the estimate of area sown with rice to acknowledge the practice of sowing rice with other crops in the same plot. For other crops, surveyors computed the area grown. Since rows of maize are mixed with rice, we assumed that in plots with maize and rice grown together, the area under maize cultivation would approach 20% of the total surface area of the plot. Because it was easier for them to tally, household heads reported the number of plantains and manioc plants they had put in the previous year, rather than the area planted with either crop. To convert the number of plants to an estimate of area sown, we assumed that 100 plantains or 400 manioc plants sown alone, without other crops in the same parcel, would each fit into one tarea (0.1 hectare).

Data quality. Because of the approach used to estimate the areas cultivated with manioc, plantains, and maize, we cannot tell if the measurement errors in these crops came from the respondent, the surveyor, or both. Owing to the imputation techniques used, there are probably more mistakes with the measures of area and yields of manioc, plantains, and maize than with the measures of area and yields of rice.

I begin by assessing the amount of rounding error. To underscore the amount of rounding error I created histograms of the yearly area planted with rice, maize, manioc, and plantains for households that had planted at least one tarea of the crop (Figures 6.4a-6.4d). To unclutter the histograms of area planted with rice, manioc, and plantains, I dropped a few large values[ix].

Insert Figures 6.4a-6.4d

The histograms in Figures 6.4a, 6.4b, and 6.4d show that respondents rounded estimates of the area planted with rice (Figure 6.4a), maize (Figure 6.4b), and plantains (Figure 6.4d) to multiples of five and 10, much as they did when reporting the area cleared from fallow forest or from old-growth forest (p. 17). Rounding errors did not show up in estimates of the area planted with manioc (Figure 6.4c).

Besides rounding errors, we also find outliers, which I show in the box plots of Figures 6.5a-6.5d. To make the box plots I did not drop observations. Figures 6.5a-6.5d show high values in the reported areas planted with manioc in 2002 and 2009 (Figure 6.5c), in the reported area planted with plantains in 2004 (Figure 6.5d), and in the reported areas planted with rice (Figure 6.5a) and maize (Figure 6.5b) in 2008.

Insert Figures 6.5a-6.5d

Findings. Table 6.3 contains yearly summary statistics for the areas planted with the four crops. The table shows that rice and plantains ranked higher than maize or than manioc when judged by two criteria. First, if we use the share of people who did not grow a crop as a proxy for the crop's importance we see that few households -- only 7.8% and 16% -- did not grow rice or plantains, whereas many households -- 49.1% and 46.8% -- did not grow manioc or maize. Second, if instead we use the area planted to judge prominence, we arrive at the same conclusion. Because not all households grew rice, plantains, maize, or manioc, the median value of the area tilled for a crop is more telling than the average value. During the study period, the average household in the two studies combined tilled a median of eight tareas of rice and two tareas of plantains, but only 0.4 tareas of maize and 0.1 tareas of manioc. Both criteria -- whether a household planted a crop and the area planted with a crop-- point to rice and plantains as the vanguard crops.

Insert Table 6.3

I next examine changes in the areas under each of the four crops, but only for households growing the crops. I begin by examining the probability of eschewing the crop. Table 6.7 (section I.C) shows that each year saw a 1.3%, 2.5%, and 2.3% higher probability of not planting maize, manioc, or plantains, but the passing of time did not affect the probability of planting rice. One could read the statistics as showing less diversification and, by default, growing specialization in rice cultivation.

Time trends in the area planted -- rather than in the probability of not planting a crop -- show blurry results. Some trends do emerge, but only when estimated numerically, as shown in Table 6.7 (section II.D), not when viewed graphically, as in Figures 6.5a-5d. Figure 6.5a shows a mild yearly increase in the area planted with rice (1.6%), most likely from the higher values in 2009 and 2010. The box plot of the area planted with maize (Figure 6.5b) shows a dip in 2007, but no large or statistically significant change from 2002 until 2010. The area planted with manioc grew by 5.8% per year, pulled up by the higher values of 2009 and 2010 (Figure 6.5c). Figure 6.5d shows a drop in the area under plantains. Among households growing plantains, the area planted shrank by 7.7% per year, a result driven by the larger area under plantains cultivation in the early years of the study (2002-2003).

As before, uncertainties about changes in time arise when using the full sample of households even if they did not grow a crop. If we compare growth rates between households that grew the crops and households that did not grow the crops (Table 6.7, section D), we find only one understandable result. Depending on the sample used, the area under plantains fell by 7.7% or 9.2% per year.

I draw five conclusions about yearly changes in the cultivation of the leading crops. First, tillers are shedding crop diversity. As shown by the probability of growing a crop, tillers seem less inclined to grow maize, manioc, and plantains and, by default, are left with rice covering their fields. Second, Tsimane' show less and less interest in plantains. Each year saw a 2.3% rise in the probability of foregoing plantains cultivation (Table 6.7, section I.C) and -- complementing this retrenchment -- each year also saw a 7.7% or a 9.2% shrinkage in the area with new plantains (Table 6.7, section D). Third, with maize, as with plantains, we see diminution. The probability of growing maize fell by 1.3% per year (Table 6.7, section I.C), as did the area under maize cultivation, but the amount of shrinking varied by the sample. If we estimate the trend with all households, the area under maize cultivation fell by 3.6% per year (Table 6.7, section I.D), but if we estimate the trend restricting ourselves to households that grew some maize, the area under maize cultivation still fell, but fell by the inappreciable amount of 0.8% per year (Table 6.7, section II.D). Fourth, the probability of growing manioc declined by 2.5% per year, and the area grown with manioc also declined -- by 3.9% per year (Table 6.7, section I.C) -- but among households growing manioc land under new manioc rose by 5.8% per year (section I.D). Last, unlike the other major crops, the area under rice cultivation remained steady in time. Through time, neither the probability of growing rice, 0.1% per year (Table 6.7, section I.C), nor the area under rice cultivation among all households showed significant change (Table 6.7, section I.D). Indeed, the land area under rice cultivation rose by 1.6% per year among households growing rice (Table 6.7, section II.D). In sum, the casting away of maize, manioc, and plantains cultivation is leaving tillers alone with rice as their staple of choice.

Minor annual crops in farmlands. I use the word minor not as a solecism, but as a synonym for secondary, implying that the crops occupy less farmlands than rice, plantains, manioc, or maize. The cultivation of minor crops in farmlands (as opposed to forests) speaks to a pining for dietary variety and to the need to safeguard food consumption when cardinal crops fail. But there are other reasons for growing non-staple crops. For instance, Rosinger (2015) found that Tsimane' put in fast-growing fruit trees like papayas in their fields to have an ever-handy source of packaged water to relieve thirst when working away from home. Others have found that Tsimane' grow plants for medicines or rituals, but we do not know if they grow them in forests or in farmlands (Reyes-García et al., 2001; Reyes-García, 2001). In this section, I concentrate on annual minor crops grown in farmlands, not in forests.

Information on minor crops came from the longitudinal study and relied on two prompts. In 2004, we started asking if households grew any of the following crops: yams (*ahipa*), onions, peanuts, and sweet potatoes. The next year, we added open-ended questions about three other crops that households grew. The second prompt produced a total of 54 additional crops beyond the four major crops discussed in the previous section, and the four minor crops just mentioned. Tsimane' rarely grew most of the 54 crops, but four crops -- binca (a tuber), pigeon pea, pineapples, and watermelons -- accounted for at least 5% of the observations, and it is these that we dissect here. Thus, the analysis of this section centers on a total of eight minor crops: yams, onions, peanuts, sweet potatoes, binca, pigeon pea, pineapples, and watermelons.

Data quality. We gathered less information on minor crops than on major crops. We did not collect data on minor crops in the randomized control trial, and even in the longitudinal study we started collecting data on minor crops in 2004. We did not ask about the area planted with a minor crop, or about the amount reaped, lost, or sold, as we did with the leading crops. Restricted data means that we are crippled in the scope of the analysis. We can only describe the share of households growing a minor crop, and, for the analysis of change in time, we can only speak to the chance of growing a minor crop.

Table 6.4 (section A) shows that for yams, onions, peanuts, and sweet potatoes -- the four minor annual crops that we consistently trolled in the yearly surveys -- there was reasonable year-to-year change. But information on minor crops from open-ended questions show odd blots. For instance, section B of Table 6.4 shows that the share of households growing watermelons ranged from a high of 32.8% in 2006 to a low of 1.6% two years later, which seems unreasonable. The share of households growing binca went from a low of 0.3% in 2006 to a high of 15.3% in 2010, and wild swings also appear with the cultivation of pigeon pea.

Insert Table 6.4

Findings. Broken down by importance, minor crops fell into three types (Table 6.4). Sweet potatoes and yams topped the list, with 41.3% and 33.9% of households growing the crops, followed by 20.4-24.1% of households growing pineapples, onions, and peanuts. Pigeon pea, binca, and watermelons rounded out the list, with only 8.3-13.5% of households cultivating these crops. Figure 6.6a shows that among the two leading minor crops, sweet potatoes towered over yams every year in the share of households growing the crops, while onions and peanuts traded places as the least two popular minor crops.

Insert Figure 6.6a

If we leave out the four lesser crops just discussed -- sweet potatoes, yams, peanuts, and onions -- and instead pay attention to the minor crops named by households in response to open-ended questions, we find that households did not add much crop variety to their fields. Recall that each year after asking them if they had planted yams, onions, peanuts, or sweet potatoes in their recently cleared forest plots, we prompted respondents to name up to three other minor crops they had planted in these plots. Figure 6.6b shows that 61.53% of households did not grow another crop, and 22.44% grew only one more minor crop. A mere 16% of households added two or more minor crops. When we combine all the information we see that most household grew just five crops, two staples (rice and plantains), three minor crops (yams, peanuts, pineapples), and not much else.

Insert Figure 6.6b

Two conclusions flow, one about substance, one about methods. On substance, one could say that the figures belie the impression that the Tsimane' want to increase crop diversity in their fields. Great diversifiers of farmland husbandry they are not. On substance, one could say that the figures show shortcomings in the way of gathering data. If people got tired of answering questions about the four main crops and about the four minor crops, then they could have lightened the burden of the survey on themselves by telling us that they did not grow other minor crops when we prompted them to answer open-ended questions. The penchant to deny growing other minor crops would have been stronger if they felt that naming other crops was a foyer to more questions about these crops, such as the area planted with the crops, the harvest of the minor crops, losses, sales, and the like.

Among the four minor crops households named most often in answers to open-ended questions, pineapples and watermelons led the way. Figure 6.6c and Table 6.4 (section B) show that more households grew these two crops than other crops almost every year, perhaps because they used them as a source of water in the field. The cultivation of binca and pigeon pea varied in time (Figure 6.6c-6.6d). In the early years of the study (2006-2007) the share of households growing pigeon pea eclipsed the share of households growing binca, but the two crops switched rank during the last two years of the study (2009-2010).

Insert Figures 6.6c-6.6d

Table 6.7 (section I.E) shows an unmistakable tide to homogenize horticulture. Other than the chance of growing binca, the chance of growing other minor crops fell, often significantly. Each year saw a 0.9-4.3% lower probability of growing a minor crop. In the last row of section I.E, I show the probability of growing any minor crop, by which I mean not just yams, peanuts, sweet potatoes, and onions, but also any minor crop named in answer to open-ended questions. The probability is telling. During 2004-2010, each year witness a 4.9% decline in the probability of growing any minor crop. Figure 6.6e sheds light on the fall. The figure shows a break in 2007 in the share of households growing a minor crop, from 79.6% in the early years of the study (2004-2006) to 60.6% in the later years of the study (2008-2010). A drop of 20 percentage points in seven years could reflect the growing role of other ways to strengthen food security or dietary diversity beyond the ones available in one's croplands. Other ways could come from fallow forests or from home gardens. Unfortunately, we do not have information to say anything about willful changes in crop diversity in fallow forests or in cottage gardens. Changes in the cultivation of minor crops in croplands might not march in rank with changes in crop diversity in fallow forests (Guèze et al., 2015) or in dooryard gardens (Díaz-Reviriego et al., 2016). If one included the array of crops from fallow forests and from dooryard gardens, the shoal of crops available to a household could well stay the same or even rise despite fewer minor crops grown in farmlands.

Insert Figure 6.6e

In short, Tsimane' farmlands have few crops, and a tendency to have ever fewer crops. Besides the staples of rice, plantains, maize, and manioc, Tsimane' put in only sweet potatoes and yams, with a sprinkling of pineapples and watermelons. The monolithic menu might be peppered with foods from dooryard gardens, fallow forests, neighbors, or markets, but it shows a troubling lack of concern for variety, an improvident mindset, and a jejune diet.

Inputs for swidden horticulture: Tools, seeds, chemical herbicides, and farmhands. Besides skills and knowledge of local hydrology, soils, plant, topography, and animals (Reyes-García et al., 2011), swidden horticulture requires a package of tools, workers, and seeds. The package can have a mix of local and commercial ingredients. In an idealized local-to-commercial continuum, the local ingredients include wooden digging sticks, family labor, local seeds; the commercial ingredients include purchased inputs and farmhands. Packages in the middle of the continuum have a mix of ingredients from the extremes. Our survey probed the use of commercial inputs more than the use of local inputs. Of tools, we asked about the use of chainsaws to cut forests, commercial dibbles to plant, and chemical herbicides to grow rice. Of labor, we inquired about hired workers (farmhands). Of seeds, we asked tillers if they had bought or used their own seeds during the previous growing season. Since the use of commercial inputs stands for farm deepening, plotting their use lets us test Boserup's hypothesis that population swelling deepens farming. I next describe the inputs used for swidden horticulture which we scanned in the surveys.

Chainsaws. Loggers, missionaries, ranchers, and road workers brought the first chainsaws to the Tsimane'. An expensive luxury, chainsaws are seldom seen. In the villages of the longitudinal study and in the baseline survey of the randomized controlled trial, 63.29% of villages in a year lacked a chainsaw and 24.68% of villages had but one (Figure 6.7). During the surveys, we asked if households had used a chainsaw to clear forest, not if they owned, borrowed, or rented one, so we do not know how households got the chainsaws that they used. Most households likely borrowed one, but we cannot tell from whom. Only men use chainsaws, to clear either fallow forest or old-growth forest in equable likelihood[x], but enterprising men also use chainsaws to cut lumber for sale.

Insert Figure 6.7

Commercial dibbles. Since pre-Hispanic days, native Amazonians and their Andean neighbors have used wooden digging sticks to plant and dig up tubers (Denevan, 2001, p.

247). The up-graded version of the pole, the commercial dibble, came to the Tsimane' during the early 1990s (Godoy et al., 1998, pp. 355-356), or perhaps earlier (Vadez et al., 2008, p. 386). Like the local digging stick, commercial dibbles are wooden, but thicker, with an iron beak and a receptacle for seeds at one end, and handles that release the seeds at the other. The tiller begins by thrusting the metal beak into the ground to open a hole, then moves the handles so seeds can fall into the hole. Tsimane' use commercial dibbles to sow rice and maize. Available in towns, inexpensive, and easy to fix, commercial dibbles find their way to most households. Remiss, we did not query people on how farmers got their dibbles.

Chemical herbicides. The first use of chemical herbicides dates to the same time as the first use of commercial dibbles, the early 1990s (Godoy et al., 1998). Weeds thrive in cleared fields of tropical rainforests, the more so as the duration of fallow shrinks. Chemical herbicides trim the growing grind of manual weeding farmers face from tilling old fields more often and facing more weeds each time they return (Jakovac et al., 2016).

Indeed, not just chemical herbicides, but also chainsaws and commercial dibbles redeem time. During 2001-2002, Vadez et al. (2008, p. 389) did focus groups with adult women and men in 18 villages, asking them to assess how long it took them to grow one hectare of rice -- from forest clearing to harvest -- using the old and the new tilling package, with its chainsaws, commercial dibbles, and chemical herbicides. Groups had to agree before vouchsafing answers, but when they could not agree, researchers wrote the average answer of the group. Vadez and his co-workers found that an adult spent a total of 102 or 49 days using the old or the new tilling package. Chainsaws erased 23 days of work to cut forest, commercial dibbles lessened sowing time from 12 days to two days, and chemical herbicides lowered weeding time from 23 days to two days. Thus, a household with the new tilling package would free up 53 work days for use in other things besides rice cultivation.

Farmhands. We canvassed people on how much they had spent to hire workers. Tsimane' pay in cash or in kind, using piece-rate or a daily wage, sometimes with meals and drinks added. To avoid errors from poor recall when measuring the amount spent to hire workers, and to sidestep the recondite crochets used to impute monetary values to viands, in-kind payments, and lagniappes, I overlook the wage bill and scrutinize instead the coarser binary outcome of whether a household hired workers.

Unlike metal tools and chemical herbicides, which save time, farmhands bring less patent gains to an employer and raise a puzzle. The practice of course redresses a worker shortfall in the household. Tales told by the Tsimane' say that households with farmhands are richer, anxious to clear forest before the advent of the rainy season, but have no workers, or only sick ones, and so have to hire workers to fill the gap. We found partial support for the tales. Richer households were indeed more likely to hire workers, but the number or the health of adult women or men in the households did not predict whether a household would use farmhands[xi]. Even if the tales explained why households hired workers, hiring presents a puzzle, a puzzle without a clear answer. Why would households not ask extended kin for help to amend the shortfall of household laborers? In an inbred, inward-looking, small-scale village economy where everyone is related to everyone else, villagers should be able to ask almost anyone for help in times of need. One would think. But if every household needs workers during the same window of the farming cycle, those needs will remain unfulfilled unless needy households can bribe their unwilling or unknown kindred with cash. In the past, possibly, households helped those in need, and, in mutual exchange, later received help from those whom they had helped, all as part of a long chain of prestations. At present, households that choose not to bother kin for help in the fields and that opt instead to use farmhands are either households with elderly people and money from government pensions (Chapter 5) to hire workers, or wealthier households that for some reason are drained of able-bodied adults, most likely because those adults went to work outside the village. If I am right, then the use of farmhands could be telegraphing changes in the village economy and the fraying of the old social integument.

Seeds. We asked households where they had found the rice and maize seeds for their latest planting, but we did not ask them if they had used commercial (high-yielding) seeds, or local seeds. Because they raise yields and income, and raise the demand for schooling, commercial seeds flag a modernizing countryside (Foster & Rosenzweig, 1996), but commercial seeds have made sluggish inroads among the Tsimane'. The randomized control trial of 2008-2009 sheds cultural and economic light into the lethargy, but only for rice seeds (Chapter 4). As a consolation prize to households in the control group, we gave each household six kilograms of commercial, high-yielding rice seeds from the department of Santa Cruz. After the study ended, in February 2011, we did focus groups and informal interviews with household heads and asked them how they felt about the edible rice harvested from the commercial seeds we had given them. People told us that they disliked the harvest from the new seeds for a mesh of reasons. The covered rice kernels, dark and hard, splintered as threshers pounded them to remove the hull. Households did worse in the market and at home with the rice harvest. In the market, they said, broken and dark kernels fetched a lower price than whole white kernels. At home, they groused, cooking hard grains took longer, used more firewood, and, in the end, left them with boiled rice that did not taste as good as boiled rice harvested from local seeds.

Data quality. The scope of information on horticultural inputs varies. We have no data on labor for sowing, weeding, or harvesting, and no data on the amount of seeds sown. Information on chemical herbicides comes from the early years (2003-2004) and the last year (2010) of the longitudinal study, was not collected in the randomized control, and refers to chemicals used only to grow rice. Other than some ingredients to grow rice, such as commercial dibbles or chemical herbicides, we have no yearly data on inputs for the other crops.

Because people could answer questions about horticultural inputs with a "yes" or a "no", answers about inputs did not beget rounding errors. With the information gleaned, all we can do is assess if the share of households using an input changed in a tenable way during the study. Table 6.5 shows some data blemishes. For example, in section A we see that the share of households using chainsaws in the longitudinal study more than doubled in a short time, from 6.3% in 2008 to 15.6-16.3% in 2009-2010, and a similar jump happened with the share of households hiring workers from 2007 to 2009; during these three years, the share rose from 11.4% to 20.6%. The share of households that relied on gifts of maize seeds or that borrowed maize seeds tripled in two years, from 6.1% in 2002 to 18.5% in 2003, and the share of households borrowing maize seeds almost tripled from 6.5% in 2003 to 17.2% the next year (section B). The number of households supplying data on maize seeds remained stable, but fell from 167 households in 2003 to 116 households in 2004. These peaks and troughs reflect a commingling of truth and mistakes in measurement.

Insert Table 6.5

Findings. Tsimane' have embraced different facets of modern farming. At one extreme, only 9.5-10% of households relied on chainsaws to cut forest, but at the other extreme, 83.6-85.3% of households relied on commercial dibbles to sow (Table 6.5, section A). In between the endpoints we find 16.5-17.8% of households using farmhands and 25.6% using chemical herbicides to grow rice. From most to least popular methods, dibbles outstripped chemical herbicides, chemical herbicides farmhands, and farmhands chainsaws. Three-quarters of the households (74-76%) set aside some of the rice and maize harvested from the previous year for use as seeds in the next planting cycle, with the remaining households borrowing or buying seeds, or planting with seeds received as a gift.

A look at changes in the inputs used shows selective upgrading in the way Tsimane' practice horticulture. During 2003-2010, the chances of using chainsaws and commercial dibbles rose by 1.2% and 1% each year (Table 6.7, section F). Table 6.5 (section A) shows that the share of households spraying chemical herbicides on rice plantings doubled from 18.88% during 2003-2004 to 36.90% during 2010. But next to these telltale signs of development one find lingering tokens of the old. The passage of time showed no change in the probability of hiring farm workers, and a 1% per year increase in the probability that a household would turn to its latest harvest to find maize seeds for the next planting (Table 6.7, section I.F).

In horticulture, the Tsimane' come across as choosy, earthly modernizers, leveraging foreign technologies like chainsaws or commercial dibbles that save them time, and aloof to those that do not bring them ponderable gains, like farmhands or commercial seeds. Some horticultural intensification is taking place, but we cannot tell whether this comes from more people, the market economy, or the cross-breeding of the two.

<u>Harvest, yields per tarea, storage, and sale: Rice and maize</u>. The four outcomes discussed here -- harvest, yields per <u>tarea</u>, storage, and the sale of rice and maize -- speak to matters beyond horticulture. The harvest of staples is a blunt measure of the food available to a rural household. Large, fast, year-to-year changes in the harvest mirror changes in the growing milieu, such as floods or crop injuries from pests and diseases. Trends in yields tell us about soil richness, duration of fallow, and new ways of farming. If Tsimane' wish to have the same amount of food but face falling yields, they will have to clear more forest and, in doing so, lessen the biological diversity of their forests (Guèze, 2011, pp. 5-6). Crop storage tells us about a hoary safety net used by households to cope with environmental distemperatures (Rosenzweig & Wolpin, 1993; Winterhalder, Puleston, & Ross, 2015). And the share of a foison sold tells us about a household's ties to the market economy, with all the blessings and curses that markets might bring.

Among the major crops, I discuss only rice and maize, not manioc or plantains. We have no data on the harvest or sale of manioc or plantains, and for good reasons. As annual or as biannual crops, rice and maize have periodic, circumscribed harvest times. A salient happening because it arrives once or twice a year, the harvests of rice and maize stick out in people's mind, so one can ask growers to say how much rice or maize they harvested, sold, or lost. Which is not to say that answers are free of mistakes, as we shall see. Manioc and plantains differ. As crops that dribble into the household unsteadily through the year, manioc and plantains make it hard to figure out how much of the crops households harvested, sold, or lost during the 12 months before the interview. Asking household heads how much manioc or plantains their household had gleaned, sold, or lost would have burdened them with having to remember many old episodes, only to yield noisy answers. Which is a pity because manioc and plantains, rugged and unfazed by environmental insults and human disregard, provide households with food during lean seasons and misfortunes.

When discussing rice or maize, I restrict myself to households that had sown the crops. Households sometimes sold more rice or maize than what they reported harvesting, or said that they had sold rice or maize even if they had not sowed the crops. These oddities happened when households sold inventories more than one-year old, or when they sold crops for other households. My stricture barely lessens the sample size, and makes the analysis cleaner[xii].

When gathering information, surveyors remained faithful to the way Tsimane' reported the amounts of rice or maize, or the areas tilled with these crops. Amounts of maize, Tsimane' reported in mancornas, one of which weighs 2.1 kilograms. Quantities of rice, they reported in arrobas, one of which weighs 11.5 kilograms[xiii]. Areas they expressed in tareas, 10 of which make up a hectare. For rice, I express yields as arrobas per tarea, and for maize I express yields as mancornas per tarea.

Data quality. Figures 6.8a-6.8c show that, as usual, respondents rounded answers about quantities to numbers ending in zero and five. Digit heaping happened when reporting the amounts of rice harvested (Figure 6.8a), sold (Figure 6.8b), or stored (Figure 6.8c). Rounding errors also happened when reporting the amounts of maize harvested (Figure 6.8d) and stored (Figure 6.8f), but not when reporting the amount of maize sold (Figure 6.8e)

Insert Figures 6.8a-6.8c (rice) and Figures 6.8d-6.8f (maize)

Table 6.6 shows sharp dogleg bends in quantities during 2008-2009 of the longitudinal study. The share of households not growing rice tripled from 0.8% to 3.4%, median rice yields fell by 37% from eight to five arrobas per tarea, the median amount of maize and rice harvested fell by 40% and 30%, and the share of households not selling rice or maize doubled, from 9.6% to 23.8% for rice and from 37% to 60.4% for maize. Among household in the longitudinal study, the median amount of stored rice doubled between 2004 and 2005, and then fell by 50% between 2006 and 2007. Data from the baseline survey of the randomized control trial shows one striking difference from data of the longitudinal study. In the randomized control trial, 16.29% of households did not grow rice and 24.84% did not grow maize. In contrast, during the longitudinal study far fewer households abstained from growing the crops. On average, in the longitudinal study 1.9% of households did not grow rice and 6.5% did not grow maize. Whether the contrasts between the two studies reflect differences in growing conditions, surveyor quality, or both we cannot tell. At least in some aspects of horticulture, households in the randomized control trial and in the longitudinal study differed.

Insert Table 6.6

Findings. The statistics in Table 6.6 refer to households planting rice or maize, even if they had lost the harvest and said they had no rice or maize when we interviewed them. Since some of these households did not harvest rice or maize, had none in storage at the time of the interview, or did not sell the crops, I focus on median values when describing findings. To analyze changes, I use the full sample of households even if they had values of zero for the outcome, but I also use the smaller sample of households with positive values for the outcomes (Table 6.7, sections I-II).

Table 6.6 shows that most households grew rice. Only 1.98% of households in the longitudinal study and 16.2% of households in the baseline survey of the randomized control trial did not grow rice. In the combined sample of the two studies, an average of 5% of households did not grow rice. The finding buttressed the idea that rice anchors Tsimane' horticulture. In a year, the average household producing rice reaped 50 arrobas of rice, but the variation was much larger in the randomized controlled trial (SD =113.8 arrobas) than in the longitudinal study (62.7 arrobas). The median crop yield for the two studies combined reached 7.1-7.5 arrobas per tarea, but was lower (5.7 arrobas per tarea) and more variable (SD=10.3 arrobas per tarea) in the sample from the randomized control trial than in the sample from the longitudinal study (median=7.5 arrobas per tarea; SD=5.2 arrobas per tarea).

Over a quarter of the sample (27.3%) from the randomized control trial and 11.5% of the yearly sample from the longitudinal study had no rice in storage by the time of the yearly interview. Remember that the rice harvest took place during the rainy season, between January and March, and that the surveys took place during the dry season, between May and August (p. 3). Our figures for the combined samples show that 5-6 months after the yearly rice harvest, 11.5-15% of households that had sown rice had none in stowage. Households had a median of 9-10 arrobas left by the time of the survey. Since the median rice harvest of a household reached 50 arrobas, the rice inventory shows that households had 18% of the harvest left to carry them over from the dry season when we interviewed them until the next rice harvest, 5-6 months in the future. From spoilage, theft, consumption, sale, or gifting, households had lost or done away with 80% of the rice harvest during the first half of the year so that by mid-year they had 20% of the harvest left to tie them over for the second half of the year. Whether the thin stock shows improvidence, poor management, or too much reliance on rice sales to make ends meet we cannot say. By mid-year, 15.9% of households in the longitudinal study and 18.4% of households in the randomized control trial had not sold rice. Those who sold, sold an average of 30-40% of their rice harvest.

Fewer households grew maize than rice. For example, 1,617 households in the longitudinal study grew rice, but only half as many (868) grew maize. The difference also appears in the randomized control trial; 442 households grew rice, compared with 310 households growing maize. The median yearly maize harvest of a household in the longitudinal study, 29 mancornas, was higher than the median yearly maize harvest of a household in the randomized control trial, 20 mancornas, and so were maize yields. In the randomized control trial, median maize yields reached 13.1 mancornas per tarea, compared with a yearly median of 20 mancornas per tarea in the longitudinal study. By the time of the survey, households in the randomized control trial had four mancornas of maize in storage, equivalent to 25% of what they had harvested. In contrast, households in the longitudinal study had three mancornas in storage, equivalent to 10% of their median yearly harvest. Of households that grew maize in either of the two studies, 43% had not sold maize, higher than the share of households that had not sold rice (longitudinal=15.9%; randomized control trial=18.4%). And of households that sold maize, households in the longitudinal study sold a yearly median of 20% of their harvest whereas households in the randomized control trial sold half as much (10%).

Before turning to the analysis of change, I highlight differences between the two studies. Households in the longitudinal study farmed more than households in the randomized control trial, and showed less variability. For example, Table 6.6 shows that among households sowing rice or maize, more households in the longitudinal study harvested either staple. Households in the longitudinal study had larger yearly median harvests and larger yearly median yields of rice and maize than households in the randomized control trial. The variability in the harvest and in the yields of rice and in the variability of maize yields were larger among households in the randomized control trial than among households in the longitudinal study. The differences vindicate the remark made earlier about the need to present separate summary statistics for each study, and to control for the type of study when reckoning growth rates.

Figures 6.9a-6.9d show box plots of trends in time for rice, Figures 6.9e-6.9h show box plots of trends in time for maize, and Table 6.7 (section G) has estimates of annual growth rates for the outcomes of Table 6.6 and Figures 6.9a-h[xiv].

Figure 6.9a shows no change in the amount of rice harvested, and the statistics of Table 6.7 buttress the figural analysis. Each year saw a one-percent shrinkage in the amount of rice harvested by households (Table 6.7, section G). In contrast, Figures 6.9b-6.9d show a significant decline in rice yields and in the share of rice sold, and a significant increase in the amount of rice in storage. Depending on the sample used for the analysis, yields fell by 3.2% per year (Table 6.7, section II.G) or by 2.3% per year (Table 6.7, section I.G). Figure 6.9b suggests that the yield decline in rice from 2004 until 2010 reflects the higher yields of 2005 and the lower yields of 2009. During 2004-2010, the amount of rice stored rose by 6.7% per year or by 8% per year (Table 6.7, sections I.G. and II.G), and Figure 6.9c suggests that the results reflect the lower amounts of stored rice during 2004 and 2007, compared with the higher amounts of stored rice during 2008-2010. Last, Figure 6.9d shows a drop in the share of the rice harvest sold. The share fell by 2.3% per year in the full sample, and by 4.6% per year in the smaller sample restricted to households that had sold some rice (Table 6.7, sections I.G and II.G).

Compared with rice cultivation, maize cultivation shows dimmer changes. The harvested amounts of maize fell by 7.2% per year in the full sample (Table 6.7, section I.G) and by 3.7% per year in the sample limited to households harvesting some maize (Table 6.7, section II.G). The decline came from the slightly higher values in the first two years of the study (2004-2005) compared with the values in some of the later years, such as 2008-2009. Figure 6.9f shows a fall in maize yields, and Table 6.7 (section I.G) supports the visual analysis by showing that yields shrunk by 5.9% per year, but the conclusion only applies to the full sample of households, not to the sample of households harvesting some maize, however small the amount of the harvest. The smaller sample shows a non-significant decline in yields of 3.1% per year. The same uncertainty about change found when examining the amounts of maize harvested or maize yields reappears when examining the amount of maize in storage. Figure 6.9g shows rises and falls in the amounts of maize inventories, with a nadir in 2009, producing an overall yearly decline of 4.7% in the full sample of households (Table 6.7, section I.G), but a wisp of change (+0.50% per year) in the smaller sample of households harvesting some maize (Table 6.7, section II.G). Last, Figure 6.9h shows that the median share of the maize harvest sold fell in time, but in a jagged fashion. Among all household, the share of maize sold declined by 2.8% per year (Table 6.7, section I.G), but if we examine only households selling some maize, the share rose by 3.7% per year (Table 6.7., section II.G).

Insert Table 6.7

In sum, rice undergirds Tsimane' horticulture. It covered the biggest area of new swiddens. Most households grew it, and, by mid-year, most had eaten a hefty share of the harvest, had a paltry amount left to tie them over until the next harvest, and had sold much of what they had reaped. Compared with the number of households growing or selling rice, fewer households grew or sold maize, and when they sold maize they sold a smaller share of the harvest. In the randomized control trial, households sold a median of 40% of their rice harvest but only 10% of their maize harvest, and in the longitudinal study, households each year sold a median of 20% of their maize harvest, and 40% of their rice harvest. Trends in time show a significant, notable drop in yields, in storage, and in sales of rice, and a light drop in the yearly amount of rice harvested. Beyond the decline in the maize harvest, nothing clear shows up from the graphical or from the numerical analyses of change in the yields, storage, or in the sale of maize.

## A test of Boserup's hypothesis, with a foray into Chayanov

Motivation. Because of its elegance, simplicity, lucency, and role as an antidote to Malthusian and neo-Malthusian doom, Boserup's vulgate hypothesis has lured acolytes from many fields (Pacheco-Cobos et al., 2015; Turner & Fischer-Kowalski, 2010). One might wonder about the worth of testing the hypothesis in a place with unproven carrying capacity and much land where, as household size grows, people need only step outside their homes to reach fresh woodlands for farming. Population growth should swell farmlands, not deepen investments in old fields. We should not find Boserupian intensification in the Amazon (Netting, 1993, pp. 274-275). True, where it not for loggers, cattle ranchers, and highland homesteaders moving in and chipping away at the Tsimane' homeland (p. 4). The unwelcomed guests kindle Boserupian-type land stresses, with Tsimane' pouring more toil and money into an ever-shrinking niche.

But there is another reason for testing Boserup's hypothesis in the Amazon. Boserup is only a small step away from a hallowed anthropological concern about how household demography – not population swelling – shapes horticulture in secluded settings. Immortalized in anthropology and in neighboring fields by the Russian agricultural economist Alexander V. Chayanov (1966), the idea is that the number of girls and boys, of women and men, and, more germane, the ratio of consumers to producers in a household might foretell the horticultural practices of a household. The demographic makeup of a household, Chayanov thought, should shape household horticulture when households are shackled by time, credit, money, and wealth -- when they cannot rely on the rest of the world to overcome these manacles (Benjamin, 1992; LaFave & Thomas, 2016)[xv]. To paraphrase the economist Dwayne Benjamin, the number of daughters of baroness Hochschild should not affect her winery production, but the number of daughters of a poor peasant will. As the ratio of consumers to producers in a household changes over a household's lifecycle, so should farm drudgery. Independent at first, a newly-joined couple will only need to worry about feeding themselves, but as offspring arrive and the clutch expands, adults need to toil harder until dependents segue into workers or leave the house. When households are stuck with their own workers for any work, with their own land for any farming, with their own cash for any purchases, when they cannot grab from the world beyond the village, then changes in the ratio of consumers to producers in a household should affect not only drudgery, but also how and how much household can farm. Households with a high ratio of consumers to producers should show a velleity to bring into their households new ways of farming that save time. Since Tsimane' are secluded, poor, and unschooled, and face day-to-day hurdles in making a living, one should see links between the inner demography of their households and how they farm.

Thus, in this section I want to accomplish three aims: *(1)* test Boserup's hypothesis that population pressure deepens horticulture, *(2)* test Chayanov's hypothesis that the demographic makeup of a household affects horticulture, and *(3)* test whether socioeconomic hindrances faced by households act upon the demographic composition of a household to affect the horticultural practices of a household. To expand on point *(3)*: If the inside demographic composition of a household affects horticulture most starkly when households cannot lean on the rest of the world to borrow or hire workers, and when grown-ups in the household have too many dependents under their care, then the grind in the fields and the inducements to bring in new technologies to ease drudgery should be most striking among archly destitute households.

Approach. Except for how I treat the size and composition of a household, I follow the same approach when testing Boserup and Chayanov (Appendix A). I first test Boserup and then Chayanov.

*Boserup*. In testing Boserup's hypothesis, I examine the link between household size measured with a head count and three sets of outcomes: *(a)* six commercial inputs (chainsaws, dibble, chemical herbicides, purchased seeds, farmhands), *(b)* idle deforested area, and *(c)* rice and maize yields. Commercial inputs and idle deforested area stand for horticultural intensification. If Boserup is right, then large or crescent households should be more willing to use commercial inputs, and be less willing to leave alone recently cleared plots in the forest. When the size of a household increases but field size does not, pouring commercial inputs into circumscribed fields should raise crop yields.

Since dealings with the market and nearness to town affect household size and the way people farm (p. 2), I control for the effects of nearness to town and dealing with the market. To control for dealings with the market, I include the monetary value of commercial assets purchased in stores[xvi]. To control for nearness to town I use a technical device that peels off any feature of a household that did not change during the study, but which could affect horticulture and household size[xvii]. The device lets me strip away not only the role that distance from household to town could play in the population-horticulture nexus, but also the role of other fixed traits of a household, such as role models, generational makeup of a household, stocks of traditional knowledge, long-run indicators of good health (e.g., adult height), and marks of place, such as elevation and soil quality (Pacheco-Cobos et al., 2015). .

At least two other things besides dealing with the market and nearness to town could change the effect that household size has on horticulture: Schooling and signature features of a year. By building reading, writing, and language skills, and the ability to deal with socio-economic changes, schooling makes it easier for adults to embrace new, foreign ways of husbandry to lighten the grind of work and intensity farming (Foster & Rosenzweig, 1996) while, at the same time, changing attitudes and knowledge about fertility and health and, thus, household size. Schooling I equate with the median completed grades of schooling attained by adults in a household at the time of the survey. Each year brings memorable events: a flood, high crop prices, low wages, epidemics, and the like. Like adult schooling, signature features of a year affect crop yields, migration, and fertility, with cascading effects on household size.

*Chayanov*. To test Chayanov's hypothesis, I drop the measure of household size used to test Boserup's hypothesis, and replace it with the number of girls, boys, women, and men in the household. In this way I can see the type of person in the household that best predicts horticultural outcomes. To remain faithful to Chayanov, I also assess if the ratio of dependents to adult workers predicts outcomes better than a separate head count of girls, boys, women, and men. I define an adult as someone 16 years of age or older because this is the age when Tsimane' marry and set up an independent household (Chapter 5).

To test the hypotheses, I confine myself to the nine-year longitudinal study because it allows me to see trends, compute growth rates, and remove signature features of a year that could tarnish results. Besides technical advantages, longitudinal information lets me estimate how time's flow -- independent of household demographics or confounders -- changes horticulture.

Findings.

Boserup. I first present visual and statistical analyses of the relation between horticultural outcomes and household size, without controlling for confounders. Figures 6.10a-6.10i and Table 6.8 show the results and three findings. First, the relation between household size and horticultural outcomes are small, hard to see, equivocal, and statistically insignificant. Second, of the two significant relations, neither confirmed Boserup's hypothesis. One more person in the household increased by 1.7 percentage points the chance that a household would leave idle recently cleared plots in the forest, suggesting that larger households worked fields with less intensity, a result that contraverts a stanchion of Boserup's thinking. One more person in the household reduced by 1.3 percentage points the chance that a household would buy rice seeds, a finding again running counter to Boserup.

Insert Table 6.8 and Figures 6.10a-6.10i

Table 6.9 contains a reprise of Table 6.8, but with controls for the median schooling of adults in the household, household wealth in commercial physical assets, and the year of the survey. Table 6.9 foregrounds three findings. First, household size both increased and decreased horticultural intensification. One more person in the household increased by 3.2 percentage points the chance that a household would use chemical herbicides, but it also increased by 1.7 percentage points the chance that a household would leave idle recently cleared forest plots. Once again, the two variables of household size and idle land correlated in the wrong way, for one would have thought that with an increase in household size, households would be less likely to leave dormant cleared plots. Second, dealings with the market captured in the variable for commercial wealth, predicted the use of chainsaws and nothing else. Although statistically significant, the effects of commercial wealth on the use of chainsaws was negligible. An increase of 1000 bolivianos in commercial wealth increased the chances of using chainsaws 1.1 percentage points. Since the median and mean wealth in commercial physical assets owned by a household reached 1,924 and 2,590 bolivianos (SD=2,406) (Appendix A, Table A.3), an increase of 1,000 bolivianos in commercial wealth would represent a 38-52% increase in asset wealth; for this sizeable increase in asset wealth, the chance of using a chainsaw would rise by a trifling amount. Last, as we saw in the descriptive analysis of Table 6.7, we see again in Table 6.9 that from 2002 until 2010 tillers worked with more ardor. Once we control for household size, commercial wealth, and for the median schooling of adults in the household, the passage of a year was associated with a 2.3 percentage-point lower chance of leaving free recently cleared forest plots and with a 1.3 percentage-point lower chance of hiring workers. As noted (p. 13), one could read the trend of using fewer farmhands in two ways. One could read it as a way of cutting ties with the labor market, but one could also read it as a way of deepening crop husbandry. Some say that hired rural workers are more likely to shirk job duties, putting less effort into farming than kin who own and who have more at stake in the success of the family farm (Bharadwaj, 2015; Chowdhury, 2013; Foster & Rosenzweig, 1996). If they are right, then one could interpret the tendency to hire fewer outsiders as a way of strengthening farming by relying on trusted kin. Thus, we see some horticultural intensification in time, but we can rule out the explanation that trends of intensification in time, however spotty, stemmed from the number of people in the household, from dealings with the market, from adult schooling, or from fixed traits of the household because we controlled for this noise.

Insert Table 6.9

In Table 6.10 I re-do the analysis of Table 6.9, but I control for signature features of each year. Table 6.10 shows that household size predicted four of the nine outcomes, but sometimes the predictions ran counter to Boserup's prediction. Enlarging the size of a household by one person raised the chances of using a commercial dibble and chemical herbicides by 1.4 and 3.2 percentage points, and raised maize yields by 2 mancornas/tarea, all findings buttressing Boserup's hypothesis. But as household size rose, households were less likely to buy maize seeds. Increasing the size of a household by one person lowered by 1.5 percentage points the chance of buying maize seeds.

Insert Table 6.10

If we put aside household size and assess horticultural trends in time, we find a somewhat cleaner view of intensification. After controlling for household size, each year saw a 1.9-1.8 percentage-point lower chance of using farmhands and leaving forest plots idle. In addition, rice yields rose by 0.25 arrobas/tarea each year, equivalent to a 3.6% yearly increase. The growth rates move in logical partnership: more use of reliable family workers with less land left dormant on one side, and higher rice yields on the other side.

In sum, Table 6.10 uncovers some backing for Boserup's hypothesis. While household size correctly predicted three of the nine outcomes (commercial dibbles, chemical herbicides, maize yields), it did not predict five of the other outcomes, and it predicted an effect on maize seeds that ran counter to Boserup's hypothesis. Nevertheless, an analysis of trends in time controlling for household size, dealings with the market, along with other confounders, such as signature features of the year, showed tighter evidence of horticultural redoubling. Trends in time showed some of the things Boserup stressed -- higher rice yields, shorter fallow, with a shift away from farmhands to more reliable family workers. But this happened despite household size.

In Tables 6.11-6.12 I assess if the effects of household size on horticulture differed by the wealth of the household or by the schooling of adults in the household. As household size increases, wealthier or more schooled households might find it easier to deepen farming. For the assessment, I interacted household size with the total asset wealth of the household (Table 6.11) or with the median schooling of adults in the household (Table 6.12). I found no evidence that household wealth acted upon household size to shape horticultural outcomes in different ways for wealthy and for poor households, or that the yearly rate of change in horticultural outcomes differed by household wealth (Table 6.11). Table 6.12 shows that adult schooling did not interact with household size to shape horticultural outcomes, or that the yearly growth rate in horticultural outcomes differed by the median schooling of adults in the household (Table 6.12). Thus, asset wealth and schooling, two variables likely to upend the socioeconomic hurdles faced by households, did not change the effect of household size on horticultural outcomes, or the growth rate of horticultural outcomes.

Insert Tables 6.11-6.12

Before turning to Chayanov, I examine one more feature of Boserup's hypothesis. Boserup believed that population load deepened farming only when households could not enlarge fields. Expansion first, deepening later. Until now the analysis has focused on intensification. But what if Tsimane' are at the early stages of demographic take off, replying to population pressure by enlarging fields? To answer the query, in Table 6.13 I re-do the analysis of Tables 6.8-6.10, but use the total area of forest cleared by a household as an outcome. If the Tsimane' still have copious farmlands, then one should see larger households cutting more forest to farm because they have more workers, more mouths to feed, or both. Table 6.13 provides hazy support for this reading. In Table 6.13 I use all households in the sample, including the 5.1% of households (n=73) that had not cut forest and find that one more person in a household caused the amount of forest cut by a household to rise by 0.13 tareas (~3%), but results were statistically weak. If I drop the households that did not cut forest, then results become clearer. For brevity, I do not report those results, but they showed that with the slightly smaller sample, one more person in the household made the household clear 2.8% to 3.1% more forest. Although statistically significant, the effect size was modest[xviii]. The average household had 5.9 people (Appendix A, Table A.3), so doubling household size -- an unlikely happening -- would cause deforestation to increase by 18%.

Insert Table 6.13

Together, the shards of evidence provide some backing for Boserup's hypothesis, but not in its canonical form. Larger households cut more forest to farm, with households using more commercial inputs over the years. Household enlarged their fields while deepening farming, both happening irrespective of the number of people in the household, dealings with the market, or nearness to towns. Field expansion and farm deepening happened at the time same time, but they were not mandated by demographics.

Chayanov. To test Chayanov, I redid Tables 6.9-6.10, but dropped household size, putting instead the number of girls, boys, women, and men in the household. I do this because I first wanted to find out which group best foretold horticultural intensification, before weighing the effects of the consumer/worker ratio on farming. When creating the homologous two new tables (6.14-6.15), I controlled for the same confounders (Table 6.14) that I used before, and sweep away the effect of signature features of the year (Table 6.15) using the same approach I used when testing Boserup's hypothesis,

Insert Tables 6.14-6.15

Tables 6.14 and 6.15 both produce essentially the same findings. First, of the four age-sex demographic groups, the number of boys predicted most horticultural outcomes. Having one more boy increased by 3.4 to 3.8 percentage points the chance that a household would leave idle new plots cleared from the forest, lowered by 4.4 to 4.7 percentage points the chance of relying on farmhands, and lowered by 2.9 to 3.2 percentage points the chance of buying maize seeds. Second, in a household the number of adult men or girls each only predicted one outcome. Having an additional girl increased by 1.9 percentage points the chance of using a chainsaw, while having one more adult man lowered by 3.9 to 4 percentage points the chance of buying rice seeds. Third, the number of adult women did not predict any outcome.

In the bottom of Tables 6.14-6.15 I show the results of tests to assess if, in a household, the effects of demography on horticulture differed after lumping groups. I wanted to see if the bevy of females versus the bevy of males, or the number of adults versus the number of children foreshadowed outcomes better than treating girls, women, boys, and men as separate groups. The number of females and males in a household predicted equally well the outcomes, as did the number of adults and children. From this I conclude that the effects of inner household demography on horticulture are clearest when treating the demographic groups separately, not when lumping them.

Chayanov cared about the dependency ratio or the ratio of consumers to workers, not about the separate number of girls, women, boys, or men in a household, so in Table 6.16 I assess how far the dependency ratio affected horticulture. To make Table 6.16, I took out the number of girls, boys, women, and men of Table 6.15, and put instead the dependency ratio. Table 6.16 shows that, with one exception, the dependency ratio did not predict any outcome. Holding constant the number of adult workers, an increase of one dependent lowered by 4.5 percentage points the chances of buying maize seeds.

Insert Table 6.16

One problem with Tables 6.15-6.16 is that in them I defined a worker or a dependent as someone above or below a single age: 16 years. In Table 6.17 I re-do the analysis of Table 6.16, but define an adult as anyone 13 years of age or older. This seems reasonable since Tsimane' girls and boy reach puberty at 12-14 years of age (Chapter 5). The new definition of adult and dependent reflects a biological more than a sociological concept of an adult or a dependent. The analysis in Table 6.17 with the new age boundary produces the same empty findings we saw in Table 6.16. An additional young dependent lowered even further the chances of buying maize seeds from 4.5 (Table 6.16) to 6.1 percentage points, but it also now lowered by 3.8 percentage points the chances of using a chainsaw.

Insert Table 6.17

One could lean on Tables 6.16-6.17 to reject the letter of Chayanov's hypothesis, but when viewed along with Tables 6.14-6.15, one begins to see some backing for his way of thinking. The inner demography of a household predicted horticultural practices, as he upheld, but it was not the ratio of consumers to producers that brought about the effects, as he thought, but the actual number of girls, boys, or men in the households that did so. It is as though Chayanov is leading one to search inside the right box, but at the wrong place inside that box.

**Discussion and conclusion**

I close the chapter by coming back to its aims (p. 2) and appraising how far we have come in reaching them. I split the finale into five parts: (a) lessons about methods to gather data, (b) descriptive findings, (c) horticultural specialization and customary field safeguards, (d) the effects of population growth and household demography on horticulture, and (e) the confounding role of markets in the chain from population to horticulture.

Lessons about methods to gather data. Following the same people in a household through time allows one to lag the size or composition of a household when assessing the effects of demography on horticulture, and thus be sure about the direction of causality, with all the rote caveats to the claim. Such information lets us see how the size or composition of a household in the past shaped the later forms of horticulture. We feel comfortable with the origin and end-point of the causal arrow, but uneasy with its size. If some things affected at the same time past demography and current horticulture, then past demography might still disclose a flawed conclusion. The use of yearly measures from the same household allows one to rein in some of this additional stubborn noise. Even if longitudinal data does not let one draw an unarguable arrow from demography to horticulture, it at least lets one see trends in time, a nearly hopeless endeavor with cross-sectional information gleaned once.

As in Chapter 5, here too we see mistakes in the approach to data gathering, and mistakes everywhere in the measure of variables. To start, it matters who you query. We should have tested the assumption that spouses could replace each other as trustworthy suppliers of horticultural information. They might have. However, the fact that one spouse often thought of itself as the chief decision maker in matters horticultural even when the other spouse thought otherwise makes one wonder whether, in truth, respondents knew well what they were talking about. We have no way of knowing if our assumption that spouses could replace each other as reliable purveyors of horticultural information matched reality, but with hindsight we should have checked and corrected answers on the spot when spouses disagreed. Another problem was choppy data gathering. Every year we should have prowled for data on commercial inputs and tillage of all major and leading minor crops. Instead of having a solid block of data, we ended up with a punctured one. We consistently measured some variables every year, as it should be, but collected syncopated data on other variables.

Errors reappear, and of these two types deserve attention. Rounding errors, so well documented when reviewing demography in Chapter 5, resurface with many horticultural measures. The leaning to round answers to multiples of five and 10 appeared everywhere. The bias turned up when reporting area of forest cleared, the area cultivated with rice, maize, and plantains, and when reporting the amount of rice and maize harvested or stored. A second type of ubiquitous error had to do with sporadic, outlandish values. We saw them in such things as the number of forest plots cleared, the area of fallow or of old-growth forest cleared, the area sown with major crops, and it follows that we saw them with crop yields too. Some outlandish measures could mirror reality, but other could reflect carelessness. The outlandish measures contributed to the hazy trends in time for some horticultural outcomes. In retrospect, we should have taken two steps to lower rounding errors and bizarre values during the survey. To avoid rounding errors we should have had interviewers record answers to at least one decimal point. In addition, interviewers should have carried the survey from the previous year to check how current answers compared with past answers. The old survey would have allowed surveyors to spot oddities during the survey and ask for clarifications before closing the interview.

The last lesson on methods has to do with samples. Some variables had many zeros. For example, ~55% of households had not cut old-growth forest, ~30% had not cut fallow forest, ~ 50% had not planted maize or manioc, and 60-80% of households had not cultivated minor crops like onions, peanuts, or sweet potatoes. When this happens, one must choose how to analyze the information, and whether to include those reporting zero. To avoid taking sides, I showed results with both samples when presenting growth rates (Table 6.7). Most of the time the two samples yielded the same conclusions, but not always. For example, Table 6.7 shows that the amount of fallow forest cut, tillage under manioc, and maize sales all rose for the smaller sample of households that cut fallow forest, planted manioc, or sold rice, but fell when using the sample for all households even if they had done none of these things. Last, findings from the yearly longitudinal sample (2002-2010) and from the cross-sectional sample (2008) differed, backing the point made in Chapter 5 about the need to ensure that findings from data collected in one place mesh with findings from data collected in another place. The approach allowed us to see that Tsimane' vary in their horticultural manners. Those along the Maniqui River followed in the longitudinal study were more invested in horticulture than their peers surveyed in the baseline of the randomized controlled trial.

*Descriptive findings*. During the nine years of the 2002-2010 longitudinal study, rice formed the bedrock of Tsimane' swiddens, and its sale -- as we shall see in a later chapter -- one of the chief ways by which Tsimane' earned cash. For annual planting, woodsmen preferred fallow forests over old-growth forests, mowed a greater area of the former than of the latter, and cleared a total of one hectare of forest, fallow and old-growth combined.

Table 6.7 shows that during 2002-2010 Tsimane' horticulture was in balance, meaning that the amount of some inputs and outputs did not change. The number of plots cleared barely changed. Except for the area under plantains (which fell), the area sown with rice, maize, and manioc did not differ much between years. Growth rates of tillage areas varied by the sample analyzed. Tillers almost always liked to use seeds from their latest harvest rather than to buy seeds in the market. The harvest, yields, storage, and sale of maize showed no consistent or significant change from year to year. Although these null, equivocal findings could reflect noise from mistakes in measurement, they could also reflect veritable stasis in crop husbandry.

Yet in this equipoise we see gestures of change that, when taken together, show a people treading water, trying to deal with countervailing forces. On one side of the ledger we see caustic decay in yields and sales or rice, and more rice in storage. But on the other side -- perhaps to overbear their struggle with an unsteady rice economy -- we see tillers squeezing their land by being less likely to leave alone plots of cleared forest, mowing 2.3% more forest each year, and upgrading swiddens by relying on chainsaws, commercial dibbles, and chemical herbicides. We cannot say whether falling rice yields makes tillers work harder and invest more in their fields, or the other way around. But irrespective of what is cause and what effect, we see a people in a horticultural treadmill, at least with their rice endeavors.

*Horticultural specialization and customary field safeguards*. The Tsimane' are becoming specialized horticulturists and forgoing customary steps to shield their crops from nature's broils. For example, each year during 2002-2010 they farmed in only one or two plots, the number falling, albeit slightly by 1.7% to 2.2% per year. In new swiddens, the area allocated to rice overshadowed the areas allocated to maize, plantains, or manioc. Over time, Tsimane' grew fewer minor crops. No, the Tsimane’ do not live up to Nordenskiöld’s flattering portrait of avid diversifiers; no, they do not use many plots; no, they do not grow many crops. Each year they planted one hectare, mostly in one place, put in a handful of crops, relied on rice for food and cash, and in haste finished all the rice they had harvested[xix]. A flood can unravel all their plantings since their farming has so few sinews: one plot, one place, one crop, one harvest, with little else.

Why so strange a system? Three overlapping answers come to mind. A gentle clime and topography blunts the pointed need to diversify horticulture, one could muse. Dapple horticulture makes sense when one has an archipelago of distinct nearby ecological niches at one’s disposal, but this does not happen in the flat homeland of the Tsimane’. The soil, topography, altitude, and vegetation of my field look like those of my neighbor, or those of people in the next village. Walk 1000 meters down a village in the steep Andean hillside and you enter a new world. Walk 1000 meters downriver a Tsimane’ village and you will not know if you are in the same place, or out of it. Another explanation for weak diversification stresses the viewpoint of the judge. One could say that great diversifiers the Tsimane’ are, but across subsistence buckets, not within them. After all, as anglers, hunters, tillers, foragers, and laborers they fish, hunt, pick, and, to this, they add as a necessary avocation some horticulture, with wage labor and the sale of farm and forest crops thrown in. They shield themselves by having many subsistence buckets, not by having one variegated bucket. Measuring diversification hinges on how far back one stands, on how many subsistence buckets one chooses to see in the portfolio. If this analytical viewpoint is right, then Tsimane' can afford to be plain farmers and shortsighted consumers of their crops because they have other cushions to fall back on. One could extend the reasoning by saying that sharing between households in a village or between villagers and outsiders weakens the need to grow many crops or varieties of a crop in scattered plots because kin, village confreres, the state, and charitable outsiders will step in during hungry periods. All this could explain why households do not shield staples by diversifying what, where, and how they grow them.

But there is a more maverick story worth entertaining. Suppose that, contra orthodoxy, horticultural diversification did not bring glaring gains to households, perhaps for some of the reasons just mentioned? To assess the claim, examine Table 6.18, where I show the best indicators of horticultural diversification we have -- number of plots used along with the total number of crops sown -- and their effect on the inflation-adjusted (real) value of food consumption. One can see that diversification boosts the real monetary value of food consumption. Each additional major crop grown raised the real value of food consumption by 3.6% while each additional minor crop raised it by 4-4.2%, and this happened after taking away the annoying noise from fixed aspects of the year, such as food prices, or fixed attributes of the place or household, such as distance to the nearest town or market. The number of plots tell a null story, no doubt because there was not much variation in plot scattering, most households clearing only one field from the forest (Table 6.1).

Insert Table 6.18

This leads to a tempered coda about diversification. The Tsimane' of the Maniqui River practice modest horticultural diversification, at least when compared to legendary diversifiers in the Andean highlands, with their myriad of plots strewn in the mountains, each plot filled with a cornucopia of tubers or when compared to Medieval smallholders before the enclosure movement (Godoy, 1991) . The Tsimane' rank far below their Andean or Medieval peers, but their middling diversification nevertheless seems to bestow on them real gains in food consumption.

*<u>The effects of population pressure and household demography on horticulture</u>*. I find little backing for the exegeses of Boserup and Chayanov of why the burden of population or household demography changes horticulture. Instead, what I find with both authors is that the spirit of their approach survives. Households are cutting more forest while putting more effort into farming -- all this despite household size. At the same time as they enlarge fields, household are deepening farming. With farm deepening, some people in the household play a more pivotal role than others in horticulture, but the ratio of child dependents to adult workers plays almost no role, at least not among the Tsimane'. Farm deepening takes place and inward household demography matters in farm deepening, but not in the ways Boserup or Chayanov thought.

Elsewhere in the world, narrow backing for an orthodox interpretation of Boserup or Chayanov also appears. In Mesoamerica, Pacheco-Cobos et al. (2015) found weak support for the belief that population growth changed yields or fallow duration. In six African nations, Binswanger-Mkhize and Savastano (2017) found that fallow duration shrunk as population pressure rose, as Boserup predicted, but they also found that population pressure did not goad farmers to use more commercial inputs. Drawing on many worldwide sources, Birchenall (2016) saw no evidence to back up Boserup. In Sub-Saharan Africa, Jayne et al. (2014) found that rural people had other answers to population pressure besides pouring more effort and investments into their farms. Other answers included migration and having fewer bairns. Anthropological demographer Eugene Hammel (2005) found that the peaks of Chayanov's household dependency ratio got flatter if one included transfers between generations and households. Hammel did not estimate the effect of the dependency ratio on farming but his finding implies that transfers would lower the need to rely on family workers and thus lighten the effects of a high dependency ratio on the work load of young households.

As the human ecologist Robert Mc Netting (1993, pp. 306-310) pointed out, one should blend the insightful heuristics of Boserup with Chayanov to grasp horticultural change as traditional societies uncase. With trade opening and population growth, rural households at first feed new mouths by extending fields, while only some households can also intensify farming. The discussion around Table 6.13 (p. 22) suggests that the amount of forest razed for horticulture rises in tune with household size, a storyline bearing out Boserup's belief that in places with idle land, the first retort to population pressure consists in enlarging farmlands. Rub is that in enlarging farmlands, some households also deepened farming. Enlargement and deepening go together, not in sequent answers, one after the other. But why do only some households intensify farming? To answer the query, we leave Boserup and enter Chayanov. With the uncasing of autarkic societies, only households with some demographic traits can embrace commercial inputs while enlarging farmlands. In autarky, dependency ratios might shape horticulture, but once out of autarky only some people in the household do. Household size tells us why households enlarge farmlands (Boserup), but the presence of some types of people inside the household tells us why only some households can deepen farming while enlarging fields (Chayanov).

*The confounding role of markets in the chain from population to horticulture*. The hands of the market touch the way households farm and their size, so markets need a place when drawing a Boserupian arrow from population to horticulture (Pacheco-Cobos et al., 2015). But the need to acknowledge markets arises not only when testing Boserup. In Chayanov's scheme, autarkic poor households are stuck with a circumscribed labor pool composed of people inside their households. Stuck, the ratio of child dependents to adult workers shackles adults to how and how much they can farm. As households leave autarky they can hire workers and buy tools that ease work, thereby shaking off the manacles of household demography. Thus, with Chayanov, too, one needs to bring in markets for markets lift the burden of dependents.

We have already spoken about the effect of household size and composition on horticulture while controlling for markets. Missing still is a look at the straight arrow from markets to horticulture while controlling for demography. To explore the topic, we revisit previous tables, but fasten attention to the role of commercial wealth, our proxy for dealings with the market. Commercial wealth comprised the cash value of a basket of market goods like metal tools (e.g., axes), kitchenware (e.g., pots), and useful frills (e.g., radios) (Appendix B). After controlling for demography, whether in the form of household size or household composition, markets predicted the use of chunkier, expensive items like chainsaws and chemical herbicides, and, less strongly, the use of farmhands. Commercial wealth almost never predicted the use of store-bought dibbles, commercial seeds, crop yields, or idle land[xx]. From this we conclude cautiously that horticultural intensification picks up the coincident effects of dealing with the market, on one hand, and the presence of some types of people in the household, on the other[xxi].

When closeted rural societies step into the outside world, horticultural manners change for reasons we will never fully grasp because we have but a tangled skein. Horticultural change could arise from changes in population, in household makeup, in prices, in social networks, in local knowledge, in health, in weather, in migration, in colonization, and so on. In an experiment, one cold tweak some of the traits to see how horticulture changes. One could artificially change the price of farm inputs or crops, for instance, to see what moved on the farm. But experiments are unsuitable to gain a thorough grasp of how horticulture changes in the vulgar course of human history. And valid natural experiments to ferret out the effects of exogenous population shifts on horticulture among living people are rare (Diamond & Robinson, 2011; Kremer, 1993). If we add to the cobweb of causes, the panoply of errors that arise when measuring horticultural outcomes, as we have seen, we are left with thin empirics to draw conclusions about the causes of horticultural change, whether the causes be population size, population density, household demography, market contact, or any of the other hosts of predictors routinely invoked to explain horticultural change. These caveats aside, from the story and statistical analysis of this chapter we nonetheless see some signs of horticultural intensification, some growing out of household size, some out of the demographic makeup of the household, some out of dealings with the market, but we cannot tell whether any of these conclusions will survive the test of time.

Fig. 6.1a. Reported total number of forest plots cleared by household last year: Full sample: TAPS (2002-2010) and RCT (2008) compared

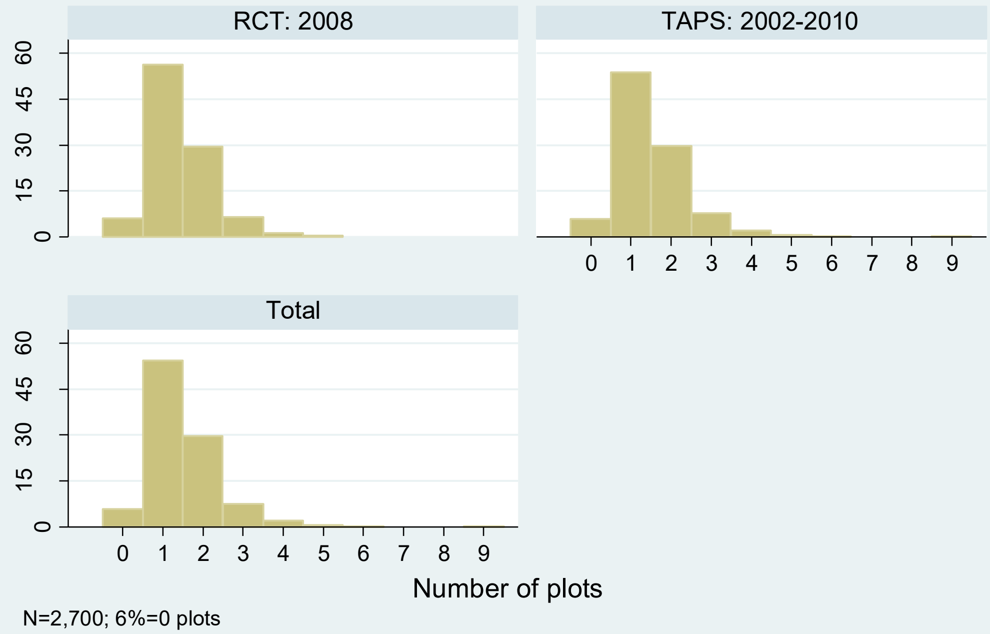



Fig. 6.1b. Reported total number of forest plots cleared by household last year: Full sample: TAPS (2002-2010) and RCT (2008) combined by survey year (N=2,700; 6%=0 plots)

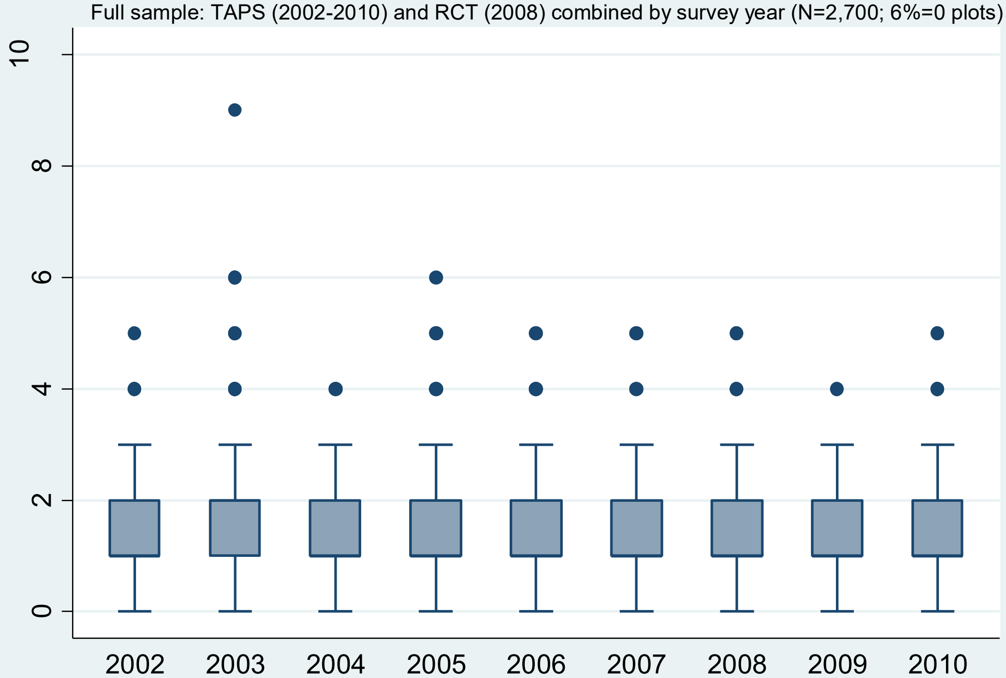


Fig. 6.2a. Area of fallow forest cleared by households last year:
Full sample: TAPS (2002-2010) and RCT (2008) compared

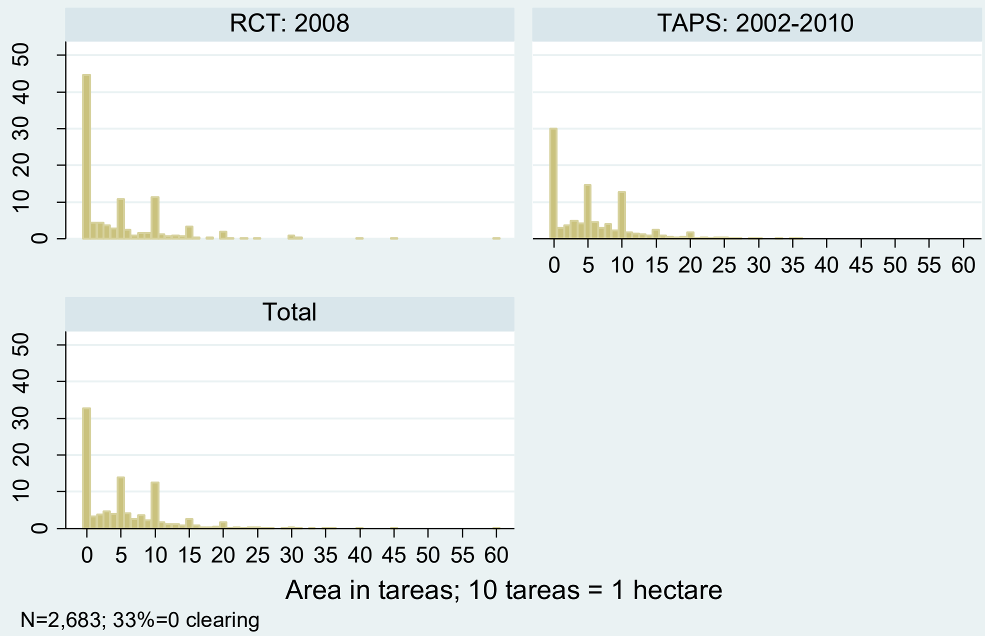



Fig. 6.2b. Area of fallow forest cleared by households last year:
Clearance>0: TAPS (2002-2010) and RCT (2008) compared

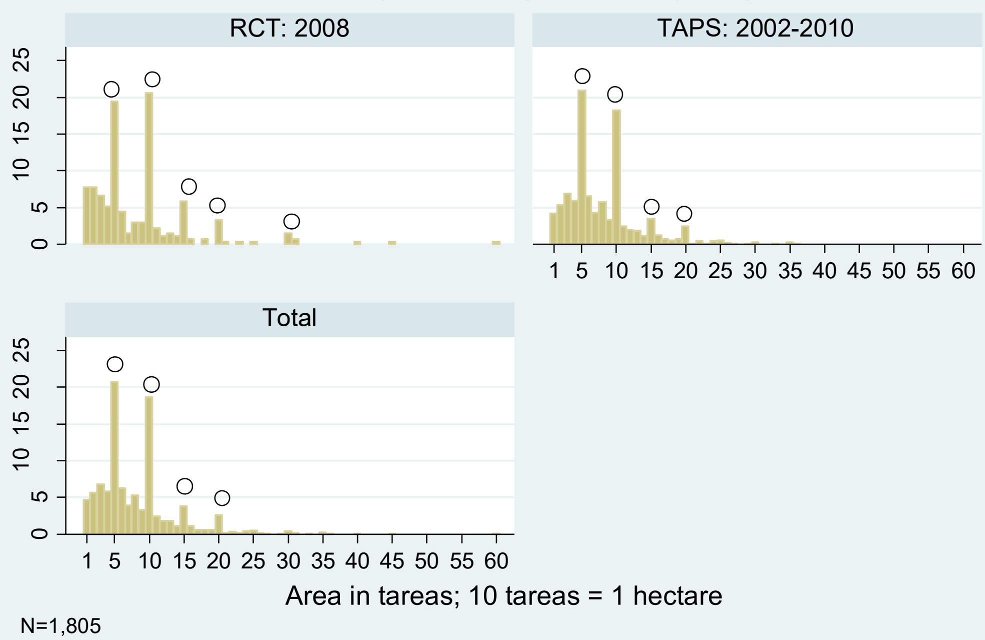


Fig. 6.2c. Area of fallow forest cleared by households last year:
Clearance>0: TAPS (2002-2010) and RCT (2008) combined by survey year (N=1,805)

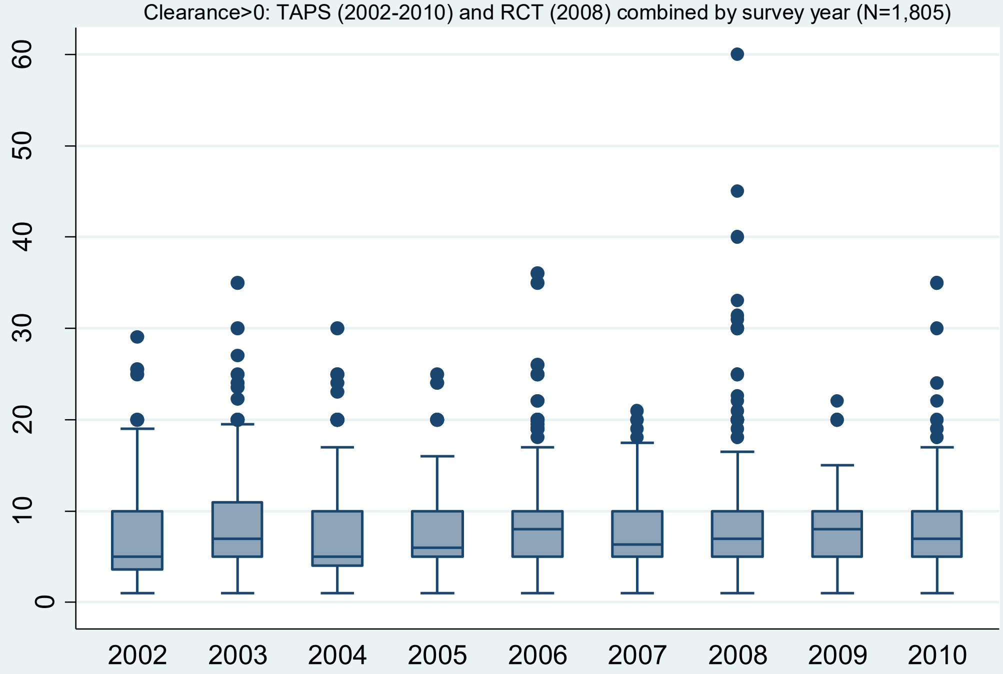


Fig. 6.3a. Area of old-growth forest cleared by households last year:
Full sample: TAPS (2002-2010) and RCT (2008) compared

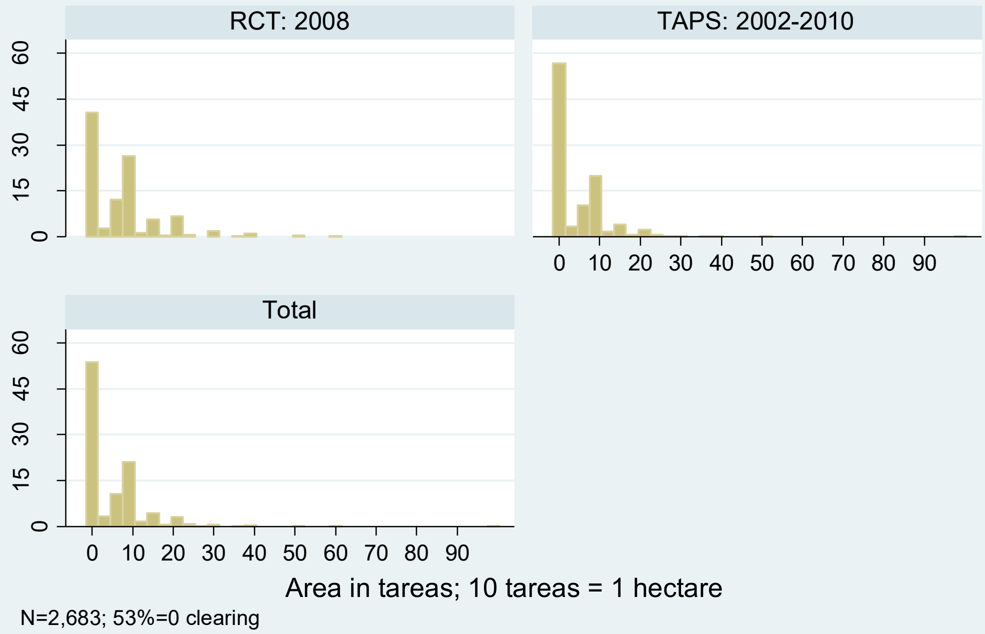
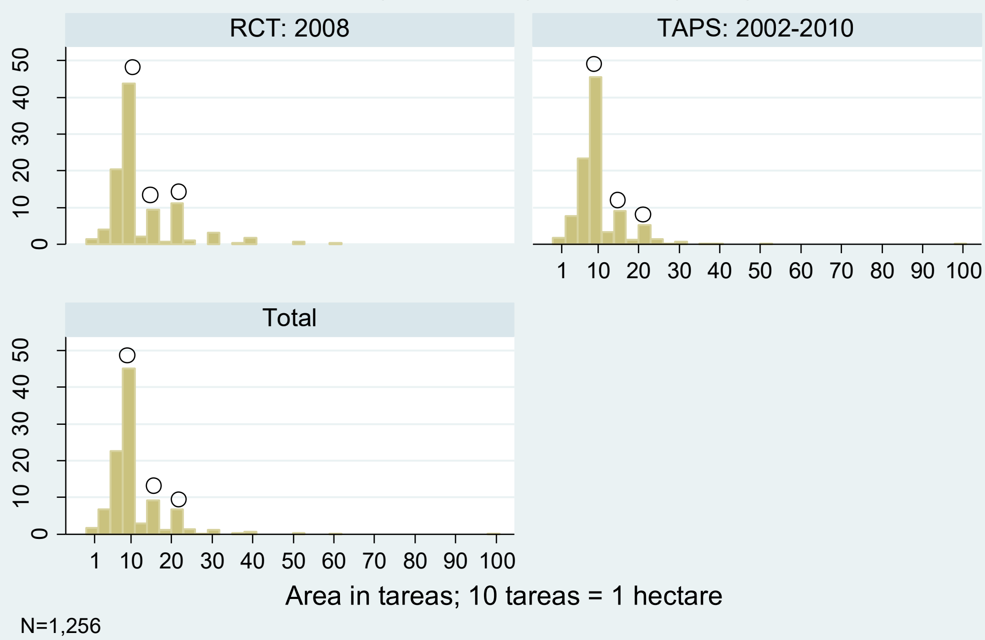



Fig. 6.3b. Area of old-growth forest cleared by households last year:
Clearance>0: TAPS (2002-2010) and RCT (2008) compared



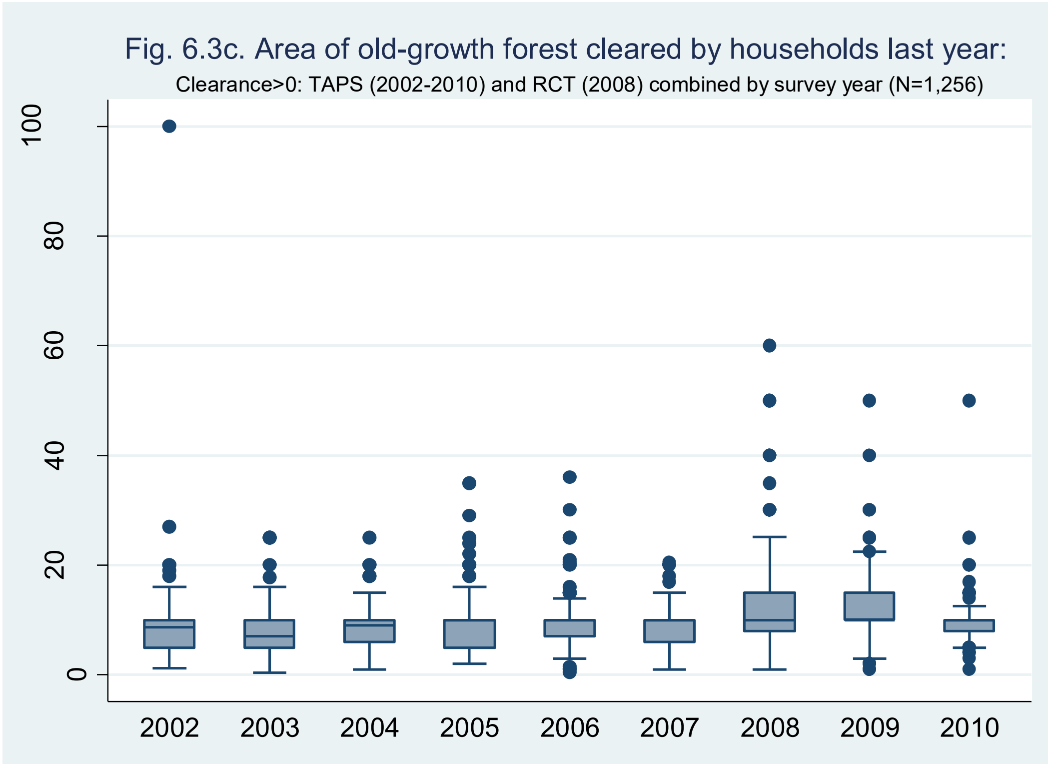


Fig. 6.3c. Area of old-growth forest cleared by households last year:
Clearance>0: TAPS (2002-2010) and RCT (2008) combined by survey year (N=1,256)
0
20
40
60
80
100
2002
2003
2004
2005
2006
2007
2008
2009
2010

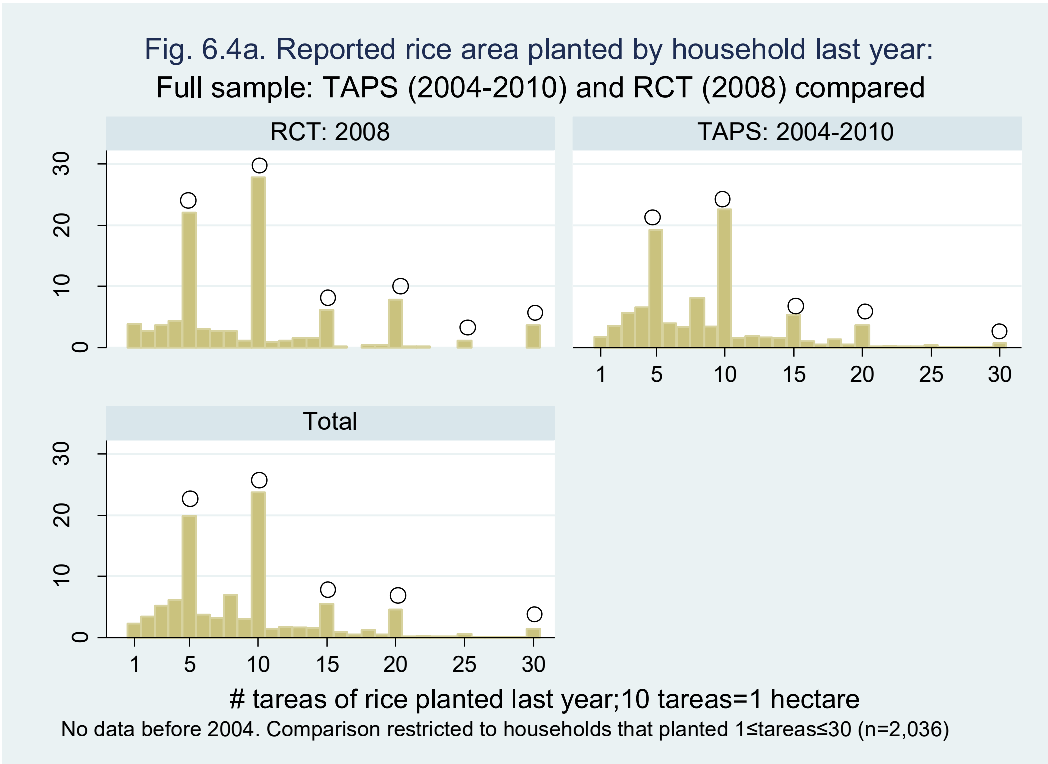


Fig. 6.4a. Reported rice area planted by household last year:
Full sample: TAPS (2004-2010) and RCT (2008) compared
RCT: 2008
TAPS: 2004-2010
Total
0
10
20
30
1
5
10
15
20
25
30
# tareas of rice planted last year;10 tareas=1 hectare
No data before 2004. Comparison restricted to households that planted 1≤tareas≤30 (n=2,036)

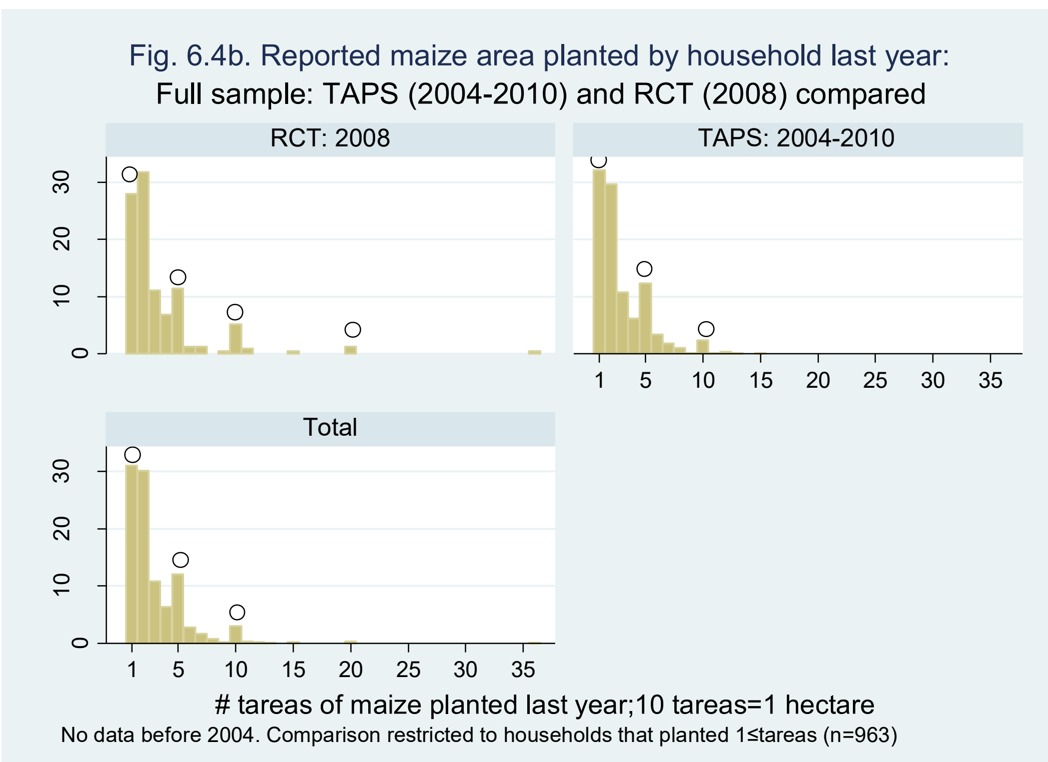
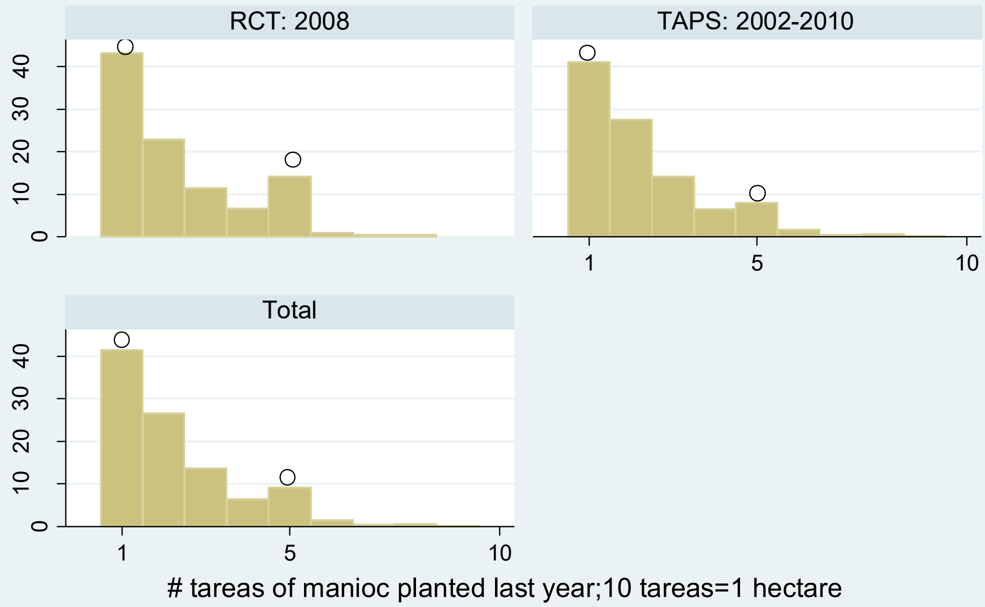


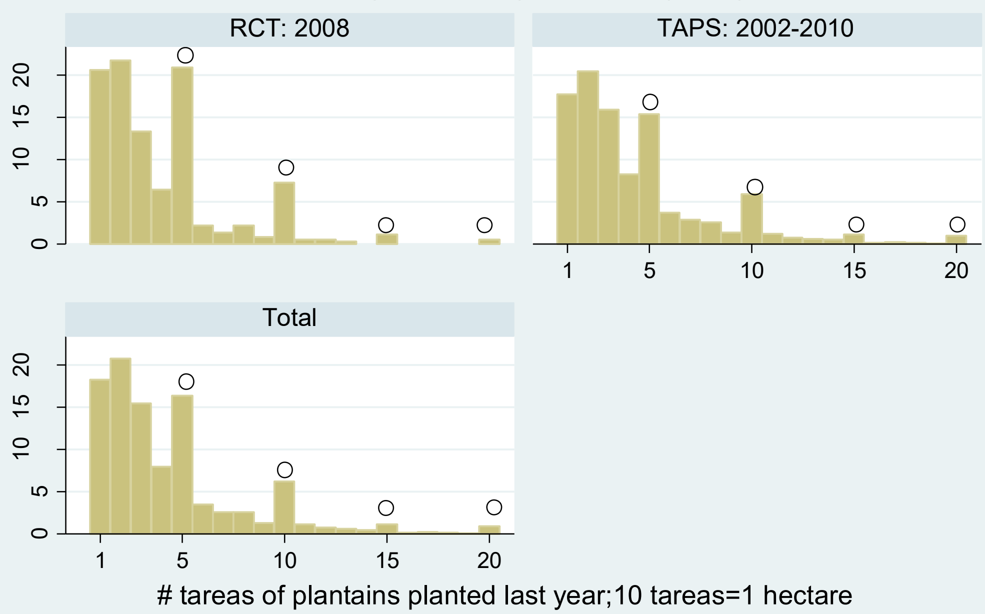
Fig. 6.4b. Reported maize area planted by household last year:
Full sample: TAPS (2004-2010) and RCT (2008) compared
RCT: 2008
TAPS: 2004-2010
Total
0
10
20
30
1
5
10
15
20
25
30
35
# tareas of maize planted last year;10 tareas=1 hectare
No data before 2004. Comparison restricted to households that planted 1≤tareas (n=963)

Fig. 6.4c. Reported manioc area planted by household last year:
Full sample: TAPS (2002-2010) and RCT (2008) compared



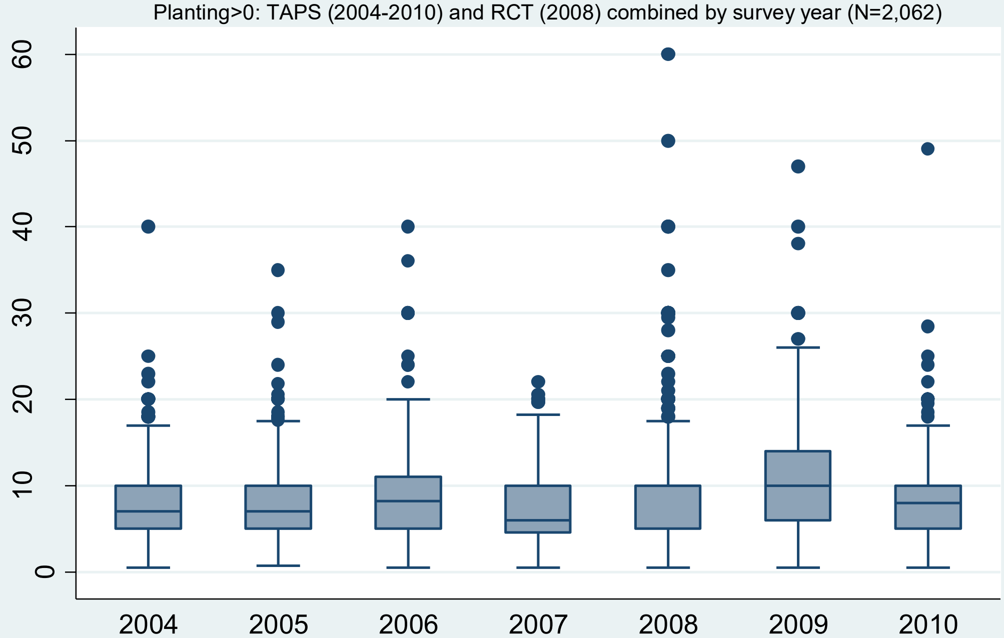

Comparison restricted to households that planted 1≤tareas1≤10 (n=1,125)

Fig. 6.4d. Reported plantains area planted by household last year:
Full sample: TAPS (2002-2010) and RCT (2008) compared



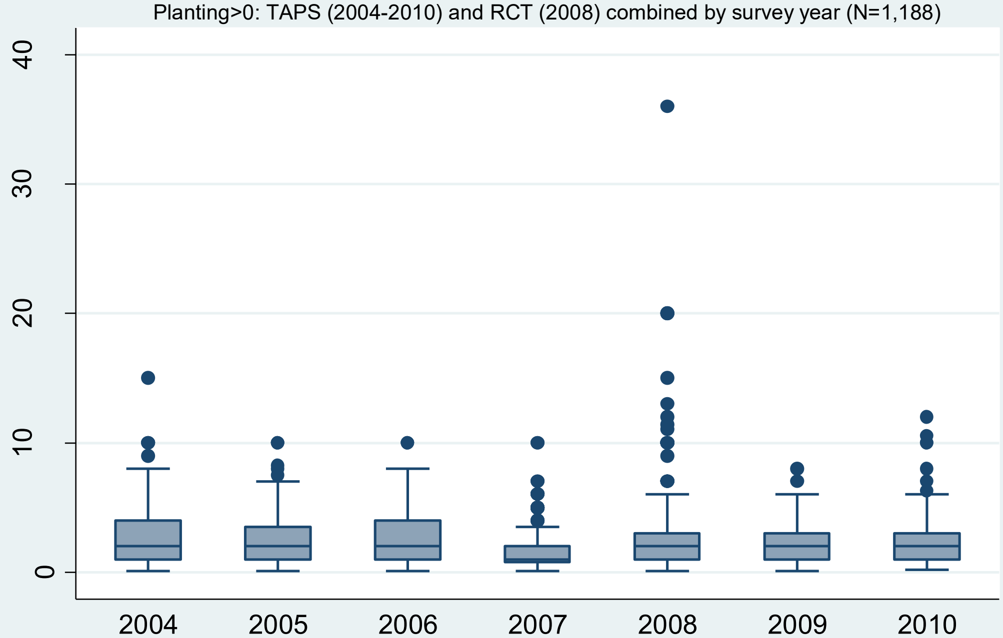

Comparison restricted to households that planted 1≤tareas≤20 (n=2,013)

Fig. 6.5a. Reported rice area planted by households last year:
Planting>0: TAPS (2004-2010) and RCT (2008) combined by survey year (N=2,062)




No data before 2004. Full sample (N=2,238), but 176 excluded because they did not plant

Fig. 6.5b. Reported maize area planted by households last year:
Planting>0: TAPS (2004-2010) and RCT (2008) combined by survey year (N=1,188)




No data before 2004. Full sample (N=2,237), but 1,049 excluded because they did not plant

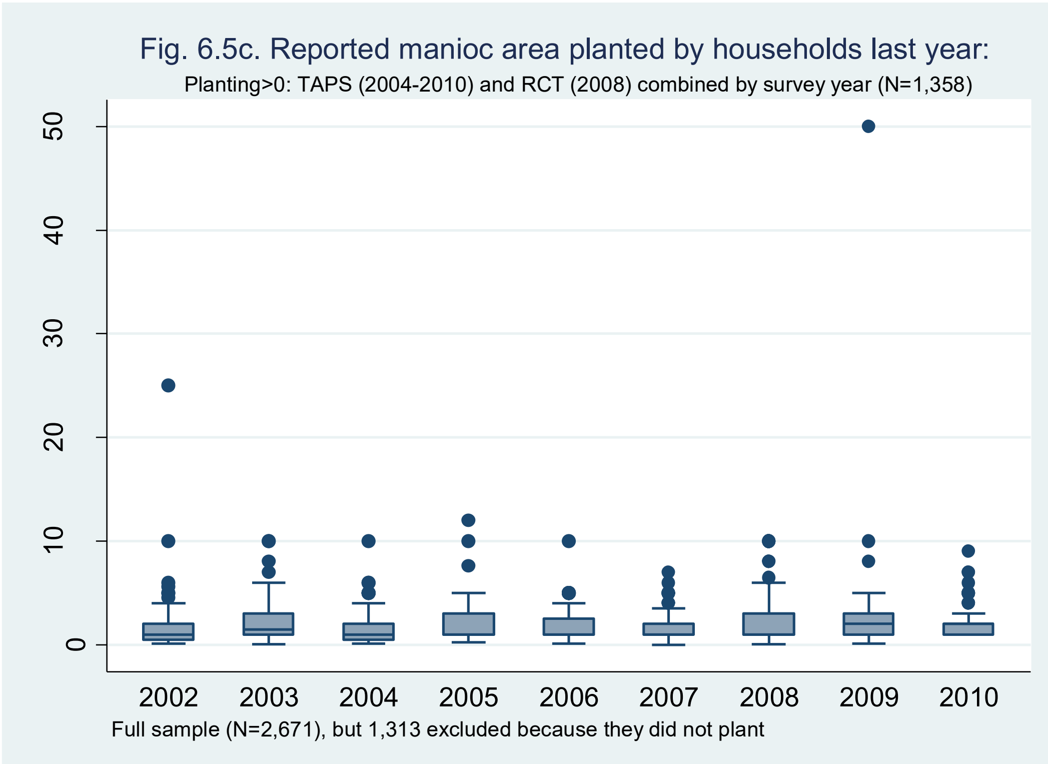


Fig. 6.5c. Reported manioc area planted by households last year:
Planting>0: TAPS (2004-2010) and RCT (2008) combined by survey year (N=1,358)
0
10
20
30
40
50
2002
2003
2004
2005
2006
2007
2008
2009
2010
Full sample (N=2,671), but 1,313 excluded because they did not plant

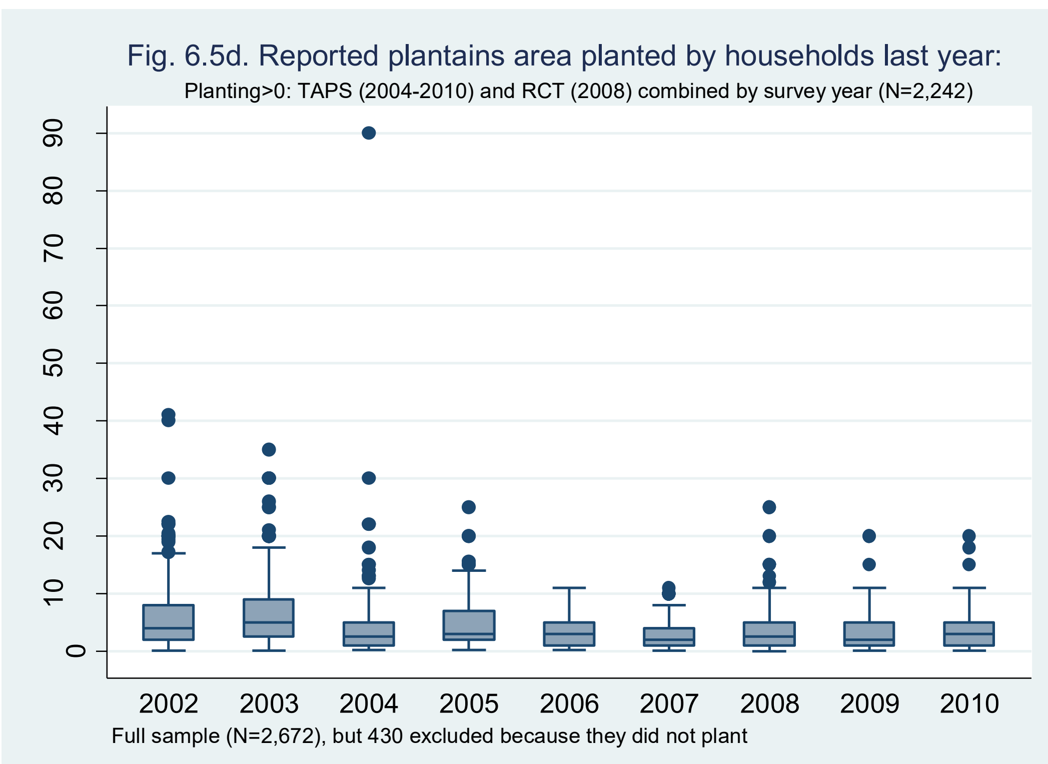


Fig. 6.5d. Reported plantains area planted by households last year:
Planting>0: TAPS (2004-2010) and RCT (2008) combined by survey year (N=2,242)
0
10
20
30
40
50
60
70
80
90
2002
2003
2004
2005
2006
2007
2008
2009
2010
Full sample (N=2,672), but 430 excluded because they did not plant

Fig. 6.6a. Percent of households growing minor crops by survey year: TAPS 2004-2010 - Yams, onions, peanuts, and sweet potatoes

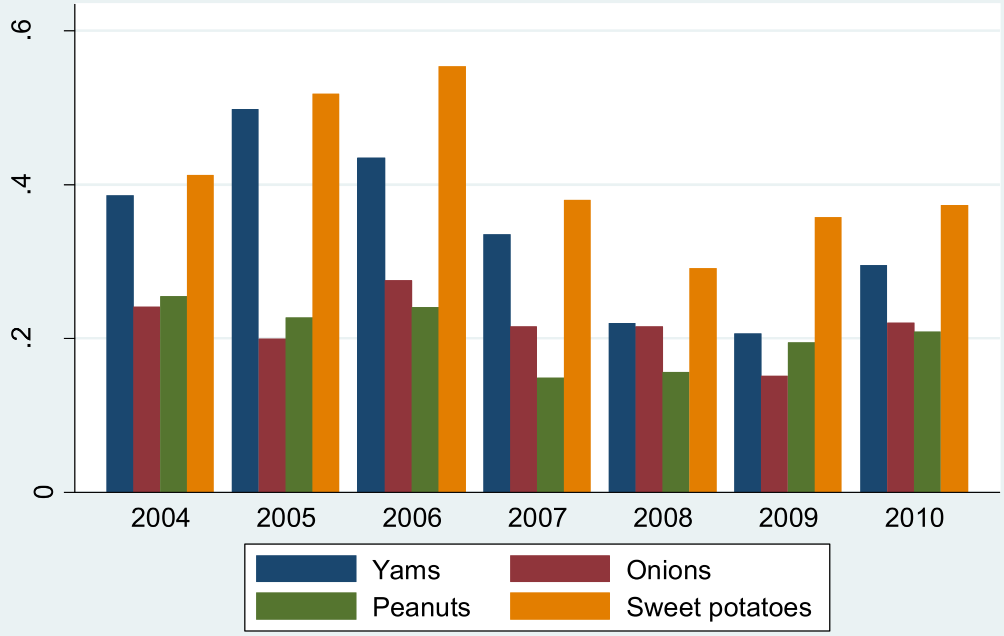
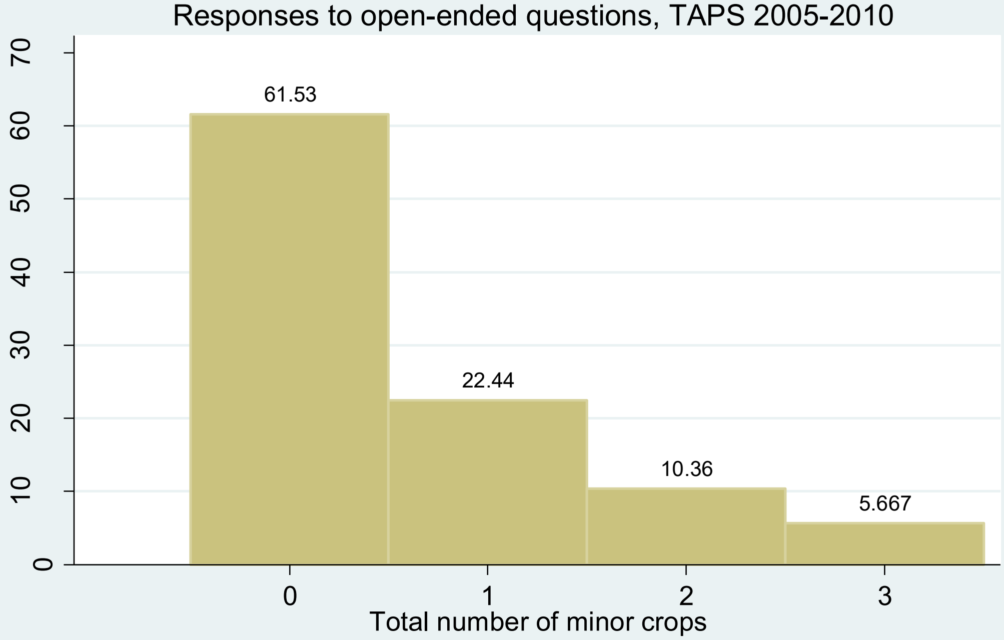



Fig. 6.6b. Percent of households growing minor crops: Responses to open-ended questions, TAPS 2005-2010




N=1,747. Households list up to 3 minor crops. Yams, onions, peanuts, sweet potatoes excluded

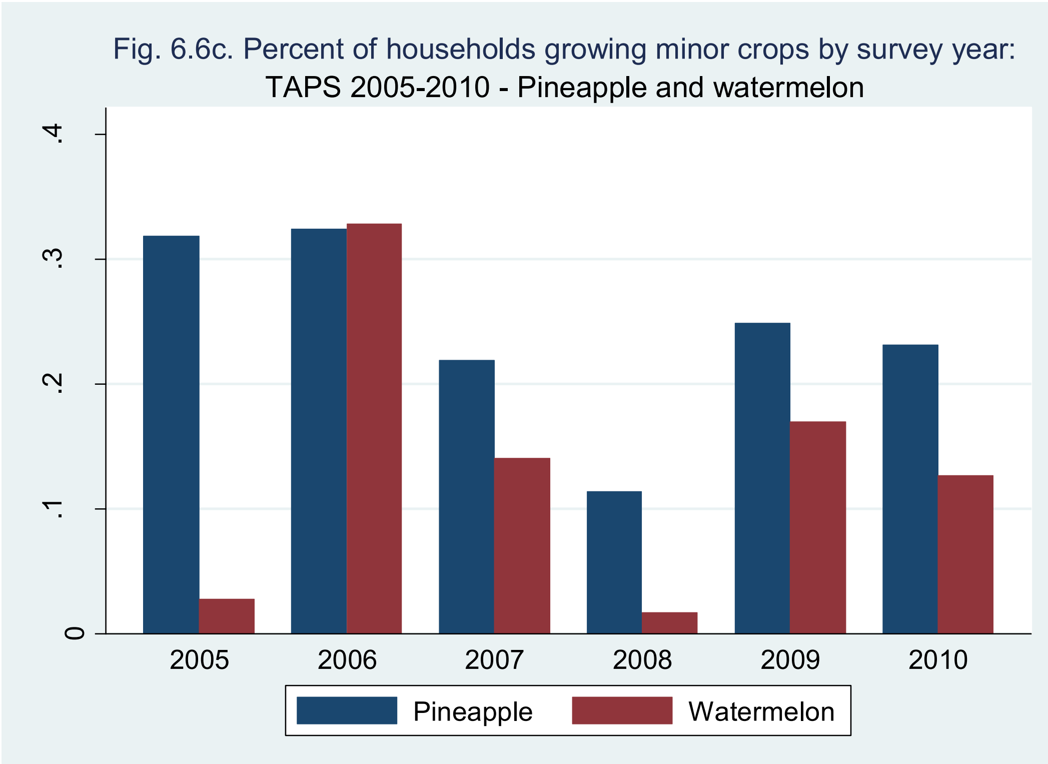


Fig. 6.6c. Percent of households growing minor crops by survey year:
TAPS 2005-2010 - Pineapple and watermelon
0
.1
.2
.3
.4
2005
2006
2007
2008
2009
2010
Pineapple
Watermelon

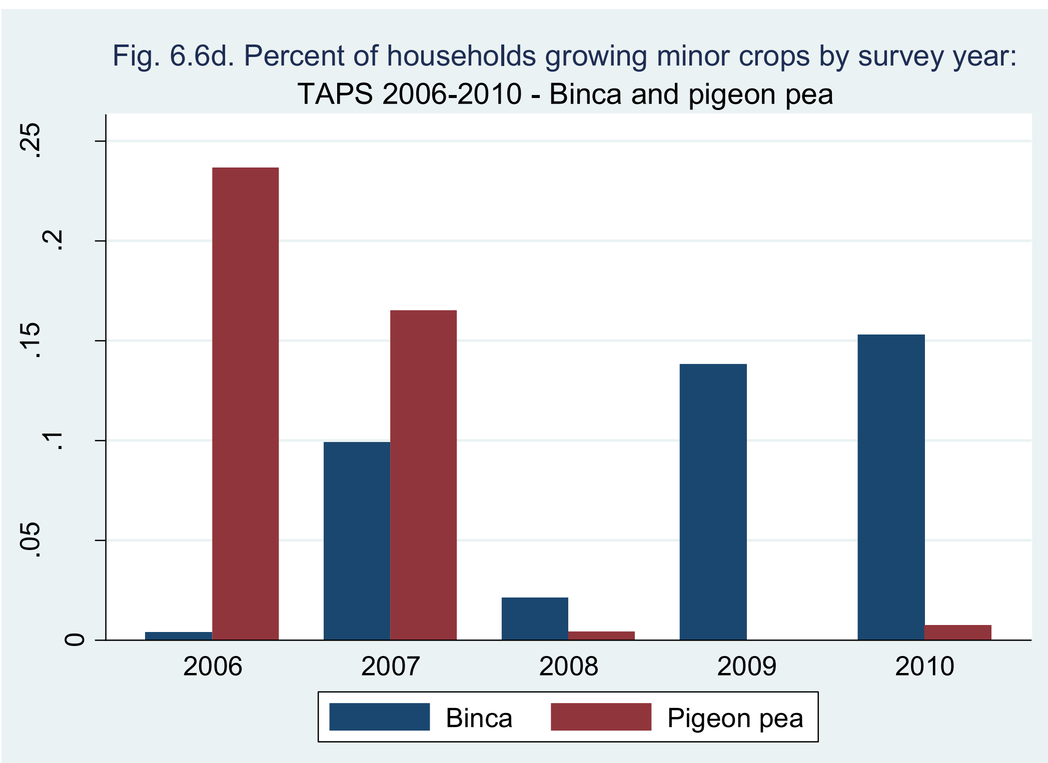


Fig. 6.6d. Percent of households growing minor crops by survey year:
TAPS 2006-2010 - Binca and pigeon pea
0
.05
.1
.15
.2
.25
2006
2007
2008
2009
2010
Binca
Pigeon pea

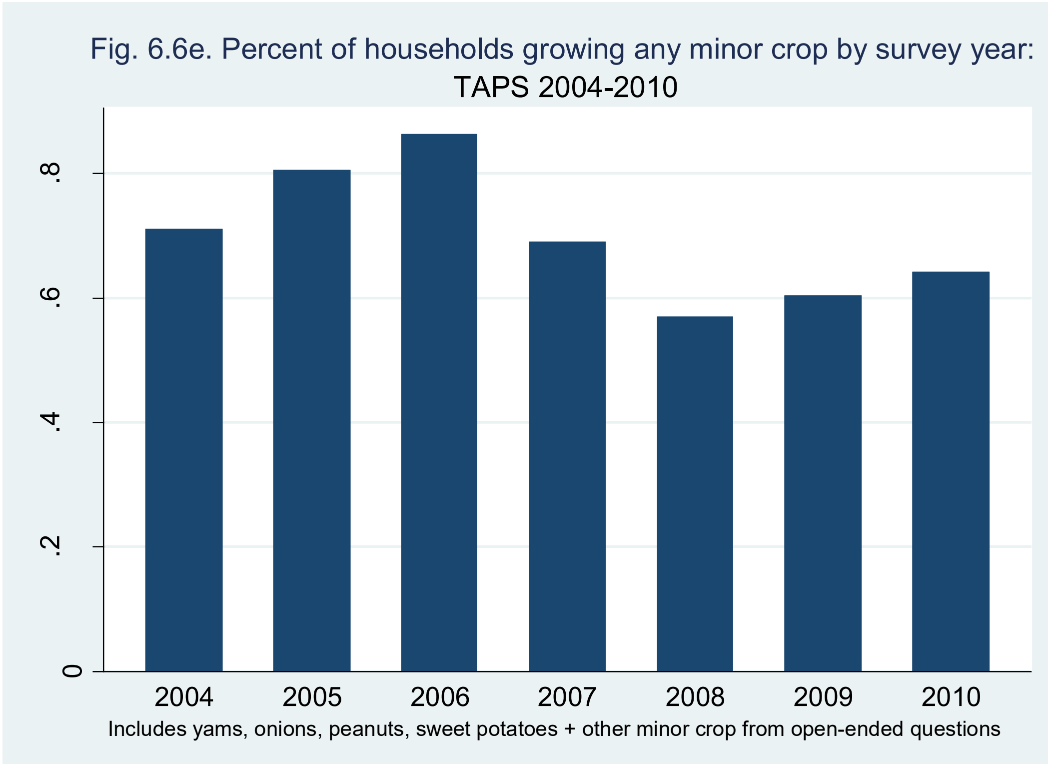


Fig. 6.6e. Percent of households growing any minor crop by survey year:
TAPS 2004-2010
0
.2
.4
.6
.8
2004
2005
2006
2007
2008
2009
2010
Includes yams, onions, peanuts, sweet potatoes + other minor crop from open-ended questions

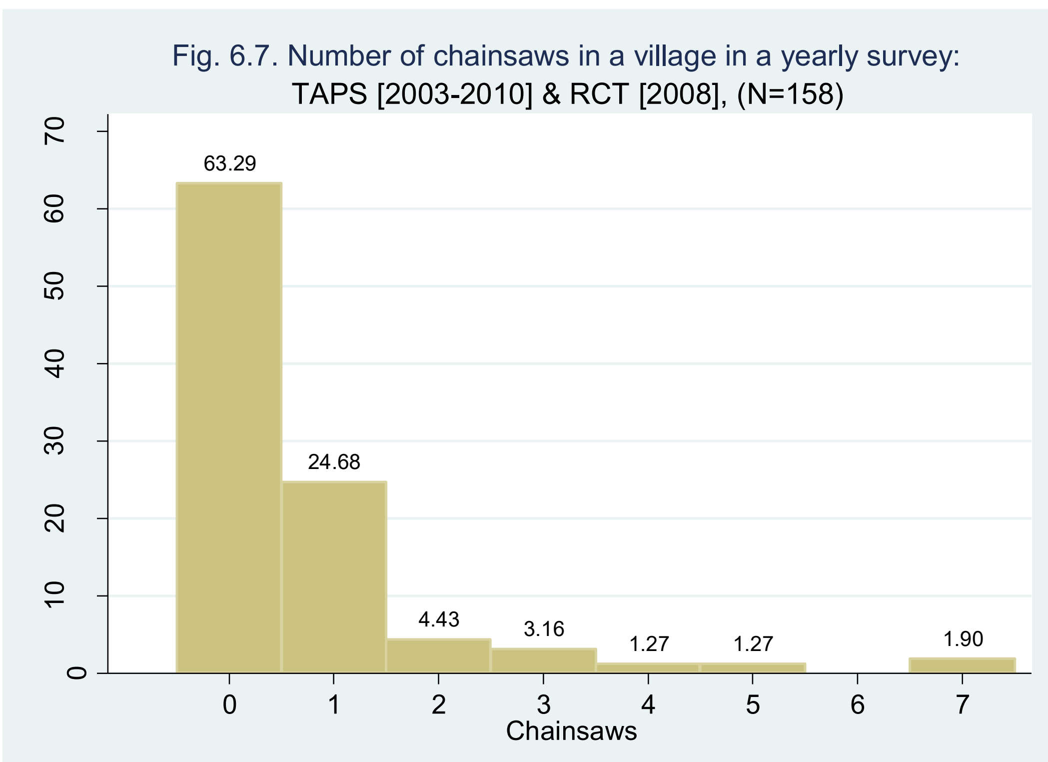


Fig. 6.7. Number of chainsaws in a village in a yearly survey:
TAPS [2003-2010] & RCT [2008], (N=158)
0
10
20
30
40
50
60
70
63.29
24.68
4.43
3.16
1.27
1.27
1.90
0
1
2
3
4
5
6
7
Chainsaws

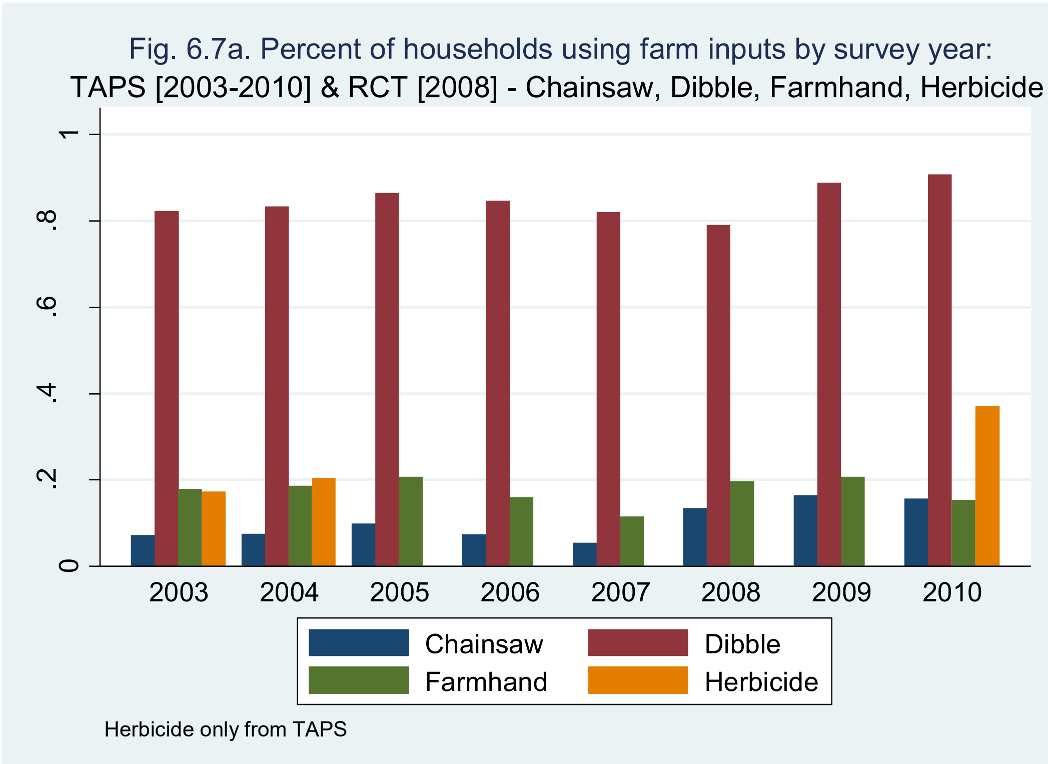
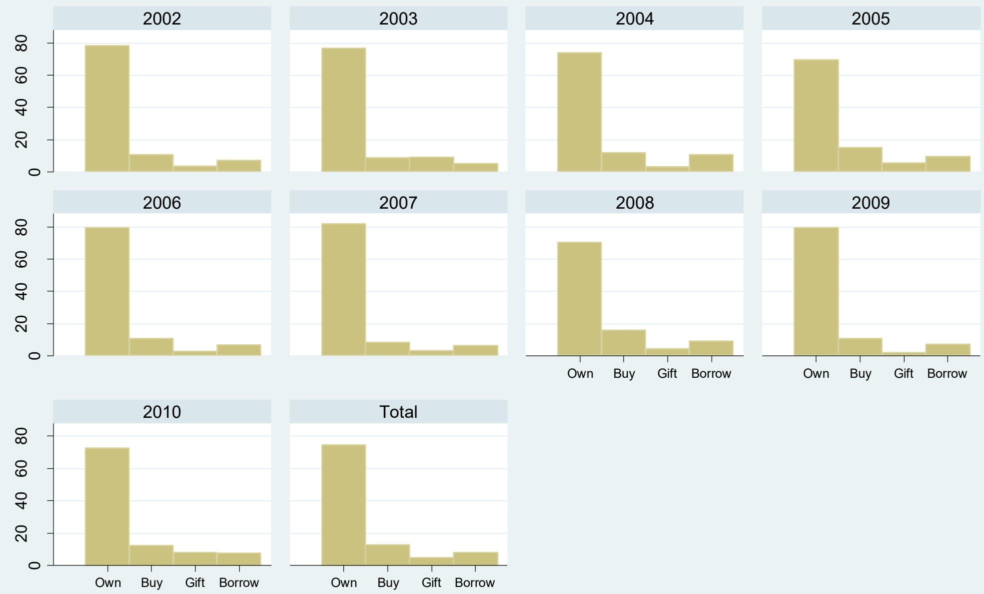


Fig. 6.7a. Percent of households using farm inputs by survey year:
TAPS [2003-2010] & RCT [2008] - Chainsaw, Dibble, Farmhand, Herbicide
0
.2
.4
.6
.8
1
2003
2004
2005
2006
2007
2008
2009
2010
Chainsaw
Dibble
Farmhand
Herbicide
Herbicide only from TAPS

Fig. 6.7b. Sources of rice seeds by survey year:

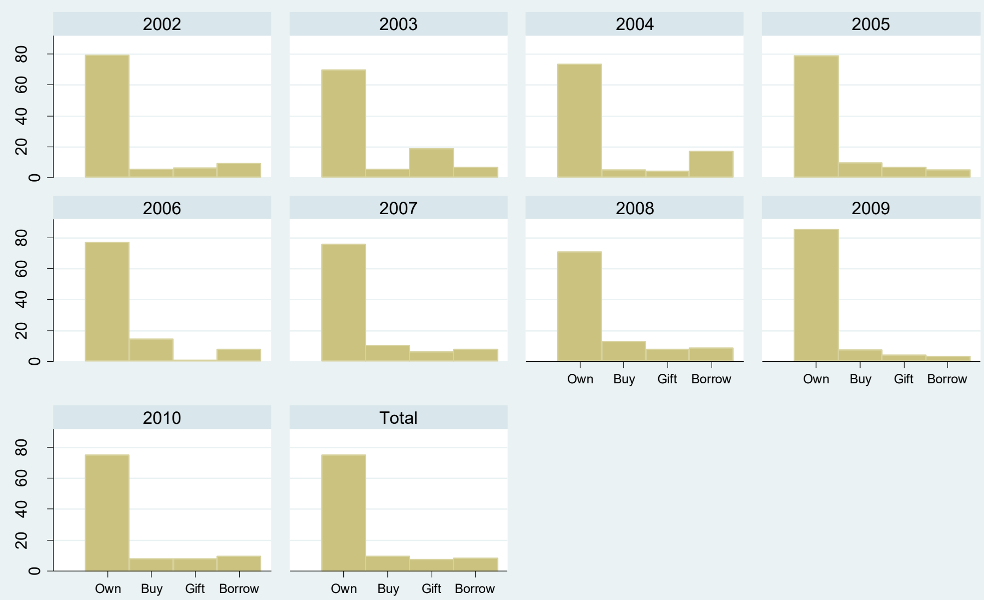
TAPS [2002-2010] & RCT [2008]




Only households that planted rice (N=2,469)

Fig. 6.7c. Sources of maize seeds by survey year:

TAPS [2002-2010] & RCT [2008]




Only households that planted maize (N=1,466)

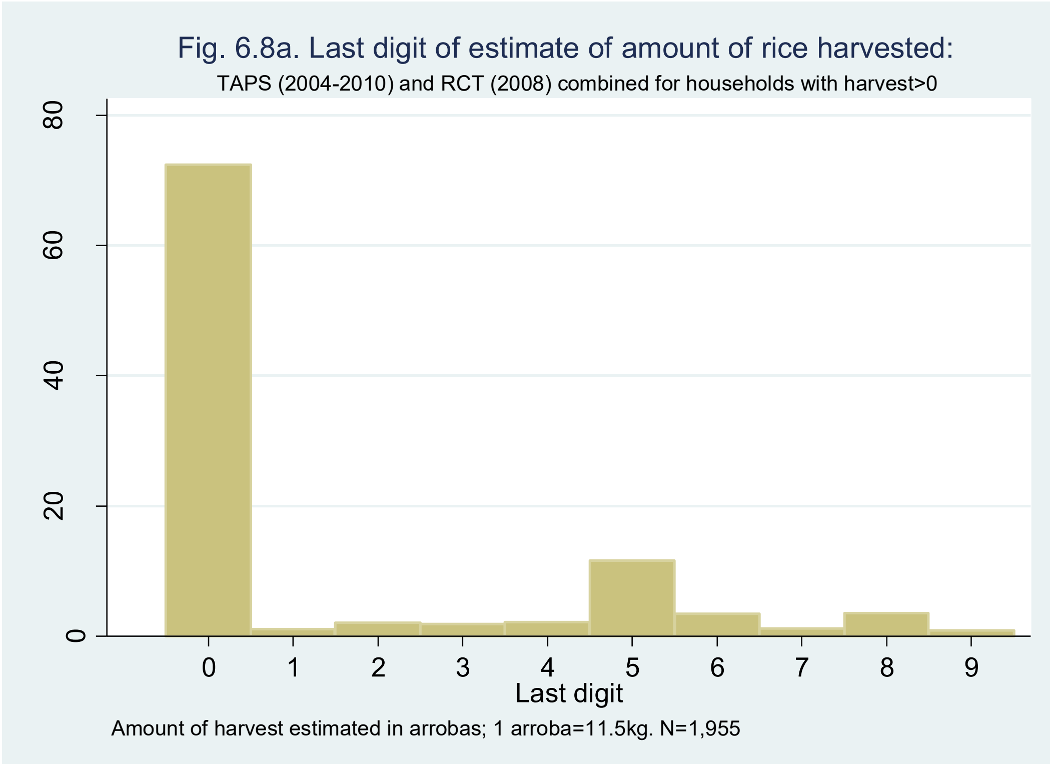



Fig. 6.8a. Last digit of estimate of amount of rice harvested:
TAPS (2004-2010) and RCT (2008) combined for households with harvest>0

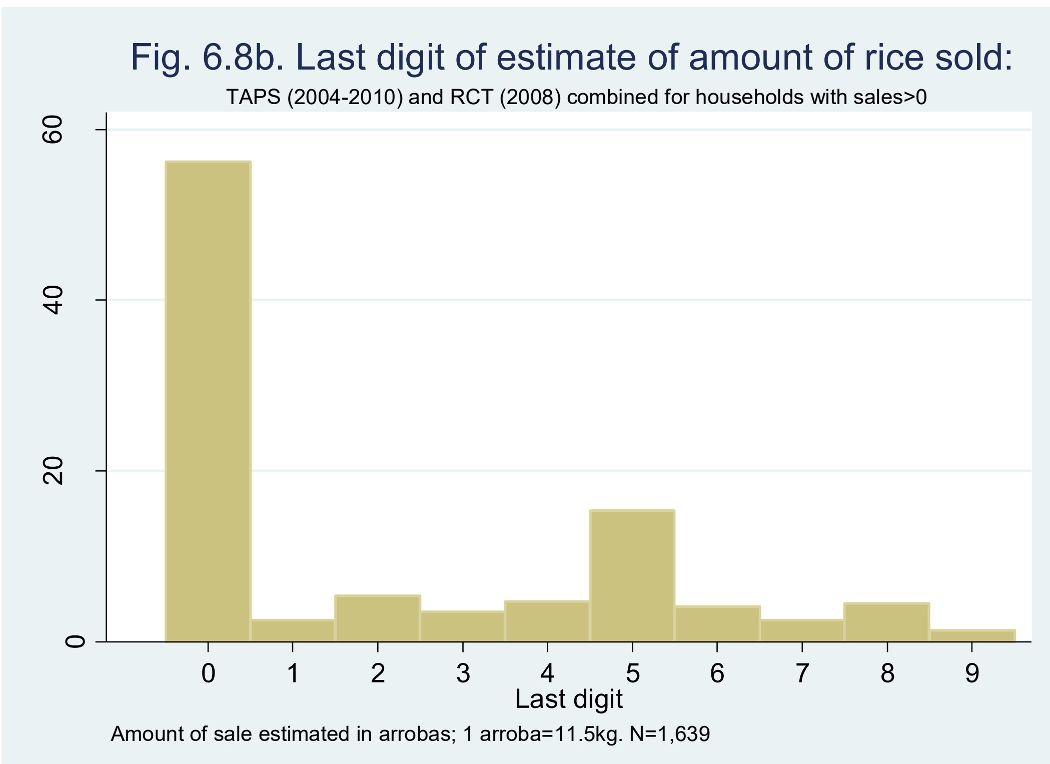



Fig. 6.8b. Last digit of estimate of amount of rice sold:
TAPS (2004-2010) and RCT (2008) combined for households with sales>0

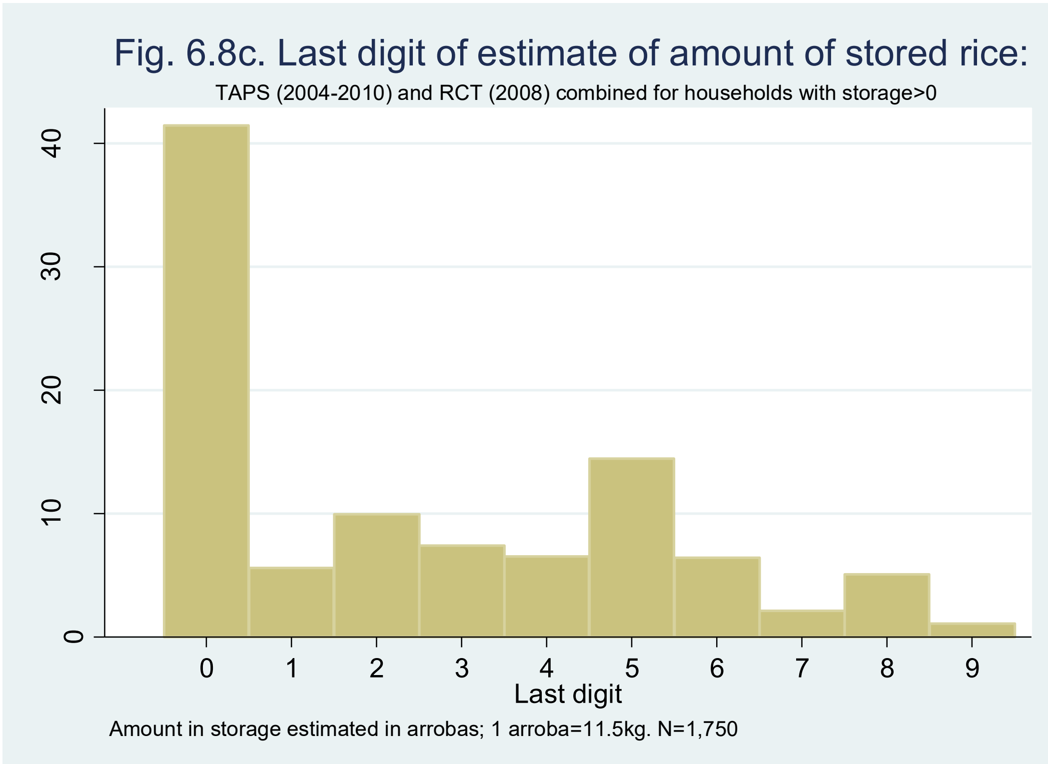
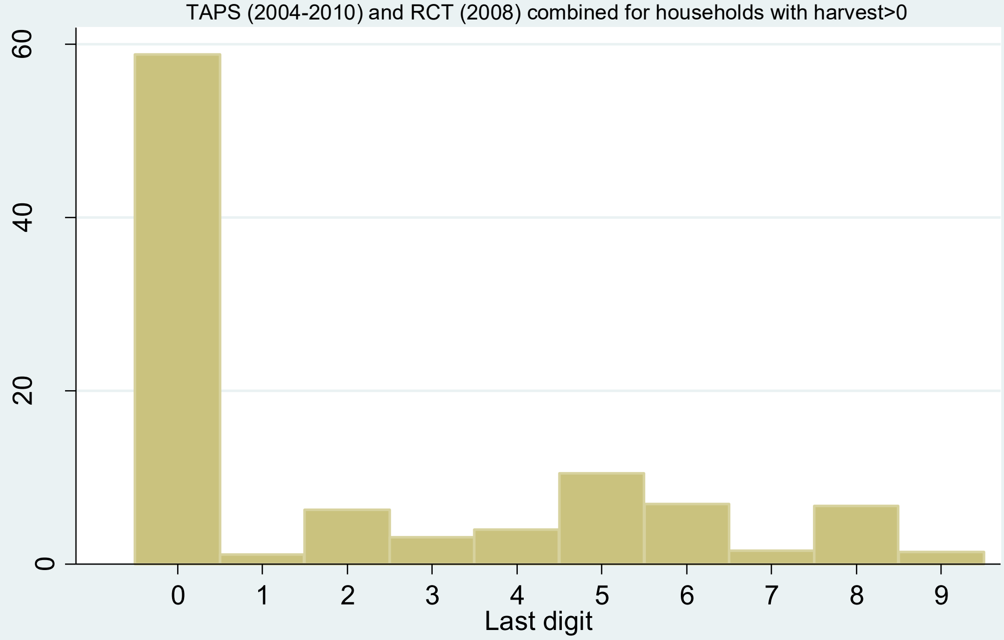


Fig. 6.8c. Last digit of estimate of amount of stored rice:
TAPS (2004-2010) and RCT (2008) combined for households with storage>0
0
10
20
30
40
0 1 2 3 4 5 6 7 8 9
Last digit
Amount in storage estimated in arrobas; 1 arroba=11.5kg. N=1,750

Fig. 6.8d. Last digit of estimate of amount of maize harvested:

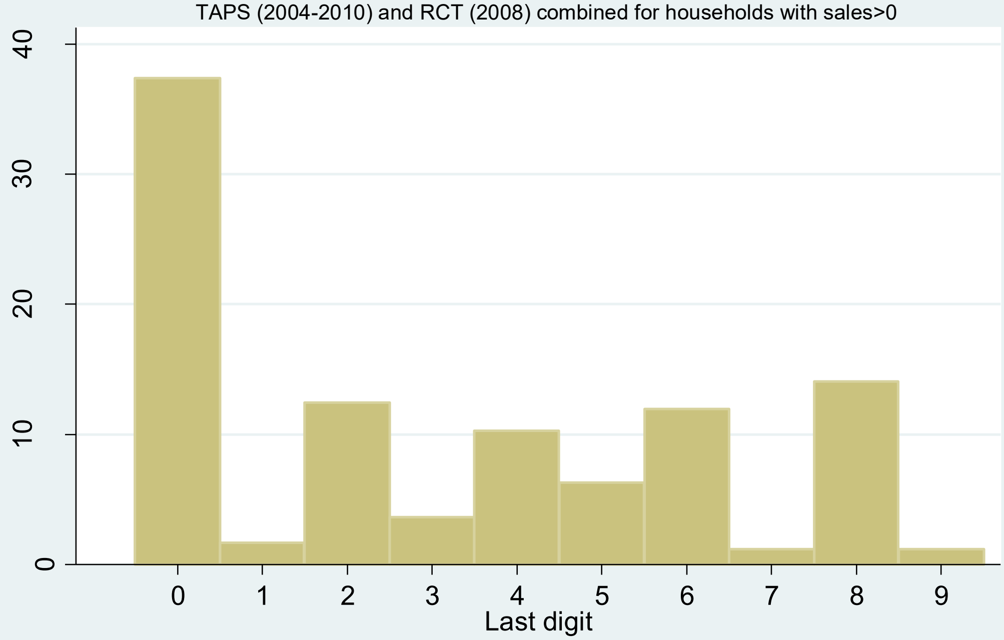
TAPS (2004-2010) and RCT (2008) combined for households with harvest>0




Amount of harvest estimated in mancornas; 1 mancorna≈2 kg. N=1,044

Fig. 6.8e. Last digit of estimate of amount of maize sold:

TAPS (2004-2010) and RCT (2008) combined for households with sales>0




Amount of sale estimated in mancornas; 1 mancorna≈2 kg. N=604

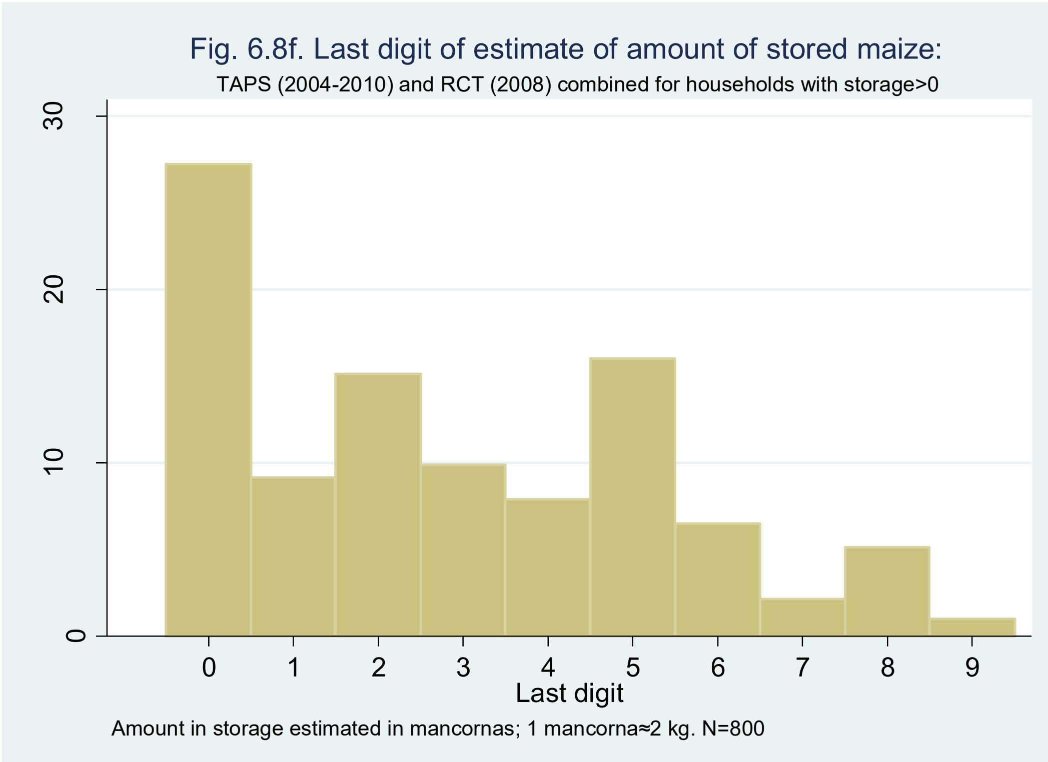


Fig. 6.8f. Last digit of estimate of amount of stored maize:
TAPS (2004-2010) and RCT (2008) combined for households with storage>0
0
10
20
30
0 1 2 3 4 5 6 7 8 9
Last digit
Amount in storage estimated in mancornas; 1 mancorna≈2 kg. N=800

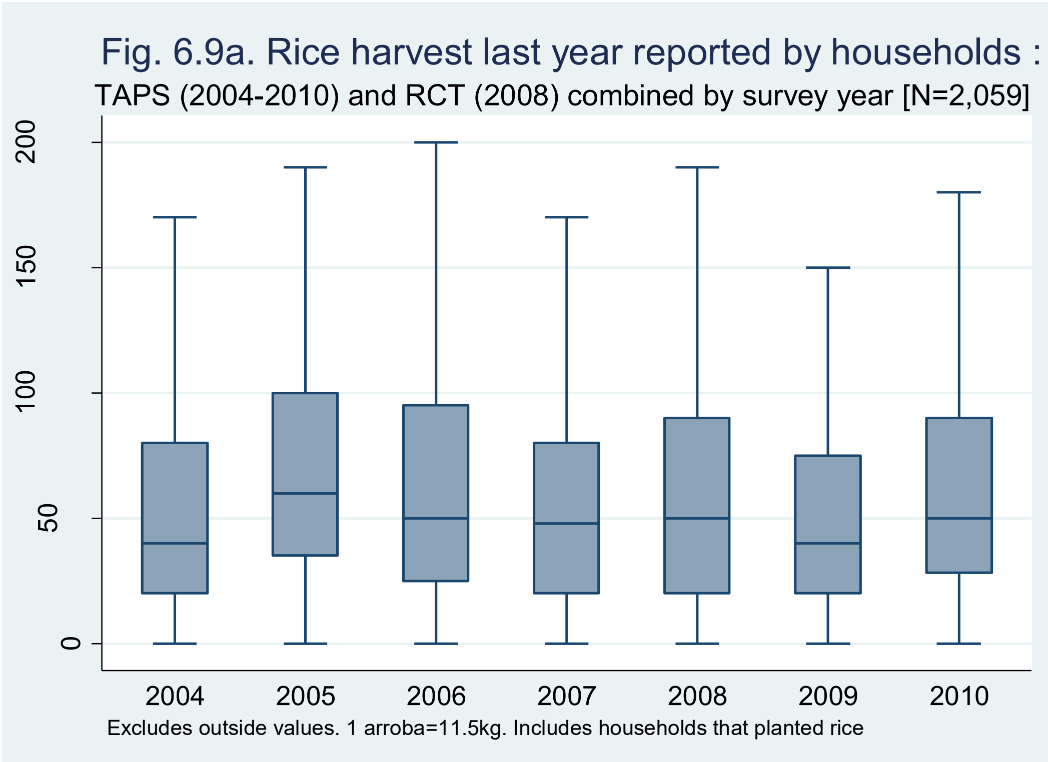


Fig. 6.9a. Rice harvest last year reported by households :
TAPS (2004-2010) and RCT (2008) combined by survey year [N=2,059]
0
50
100
150
200
2004
2005
2006
2007
2008
2009
2010
Excludes outside values. 1 arroba=11.5kg. Includes households that planted rice

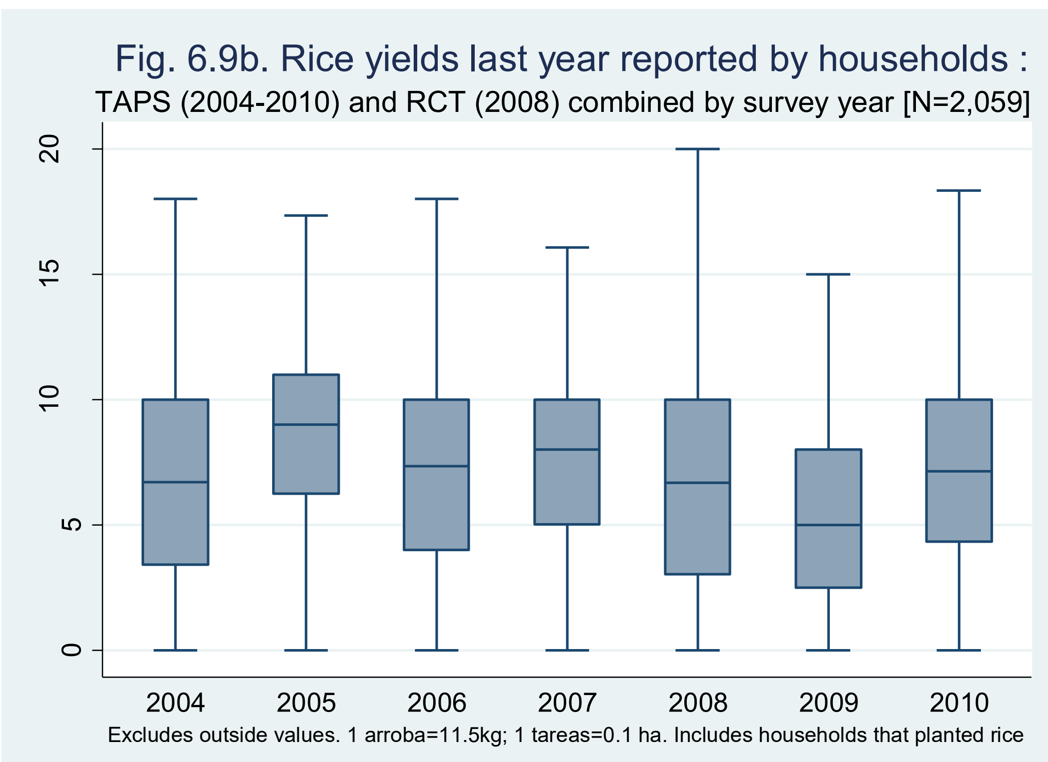
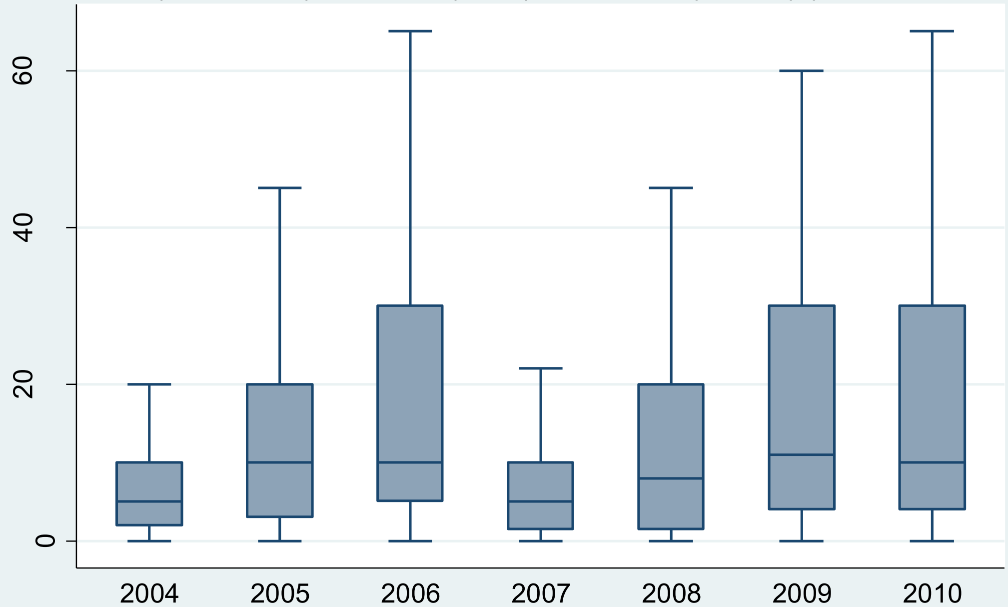


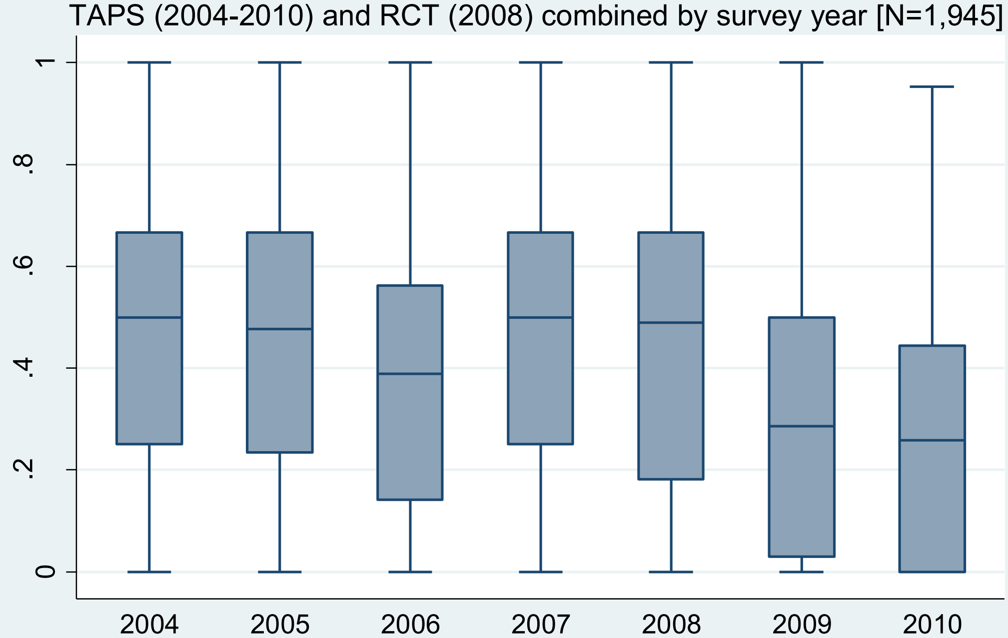
Fig. 6.9b. Rice yields last year reported by households :
TAPS (2004-2010) and RCT (2008) combined by survey year [N=2,059]
0
5
10
15
20
2004
2005
2006
2007
2008
2009
2010
Excludes outside values. 1 arroba=11.5kg; 1 tareas=0.1 ha. Includes households that planted rice

Fig. 6.9c. Stored rice from last year's harvest reported by households:
TAPS (2004-2010) and RCT (2008) combined by survey year [N=2,059]




Excludes outside values. 1 arroba=11.5kg. Includes households that planted rice

Fig. 6.9d. Share of last year's rice harvest sold reported by households:
TAPS (2004-2010) and RCT (2008) combined by survey year [N=1,945]




Excludes outside values. Includes households that planted rice

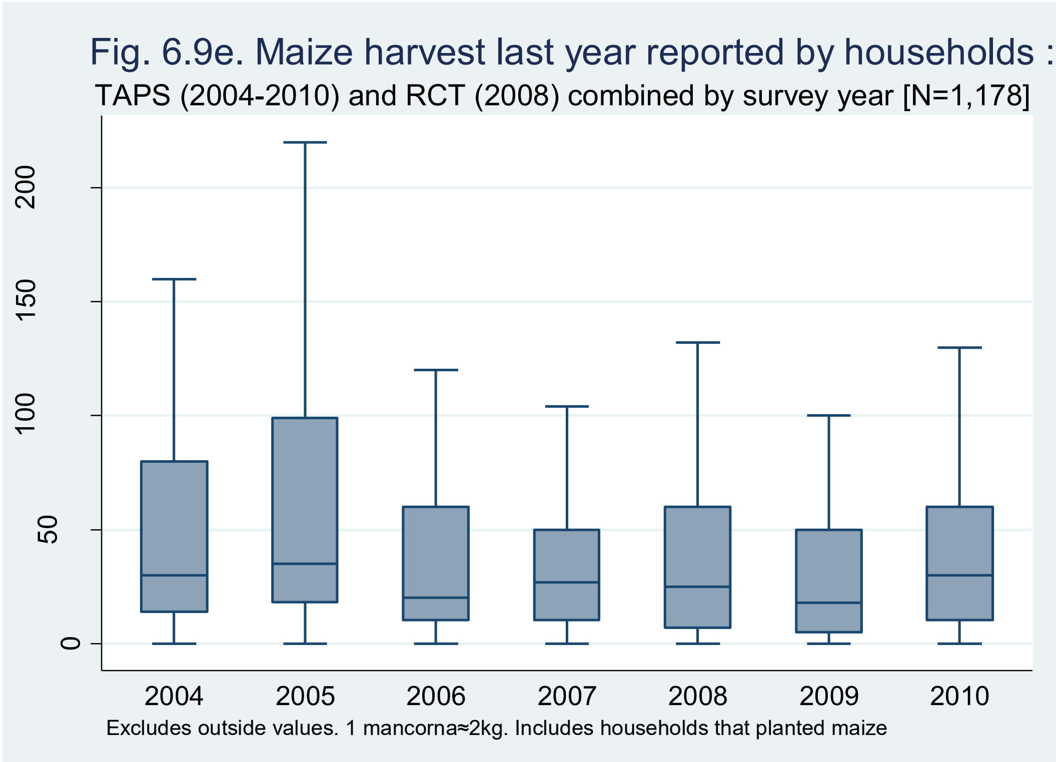


Fig. 6.9e. Maize harvest last year reported by households :
TAPS (2004-2010) and RCT (2008) combined by survey year [N=1,178]
0
50
100
150
200
2004
2005
2006
2007
2008
2009
2010
Excludes outside values. 1 mancorna≈2kg. Includes households that planted maize

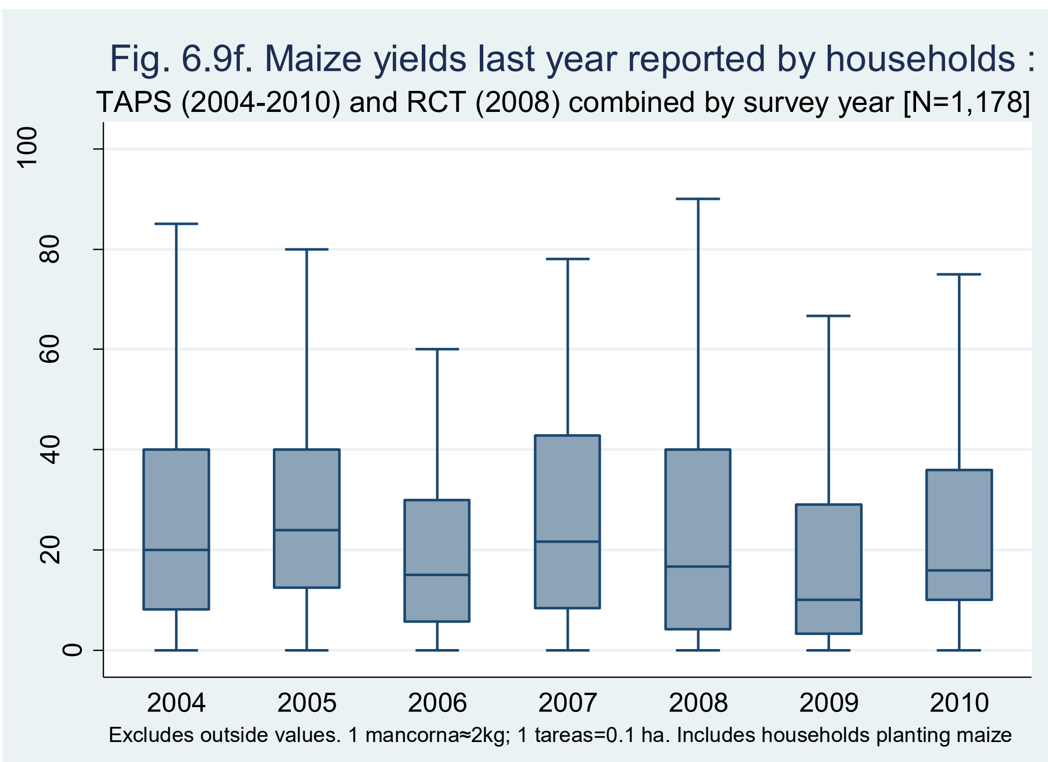
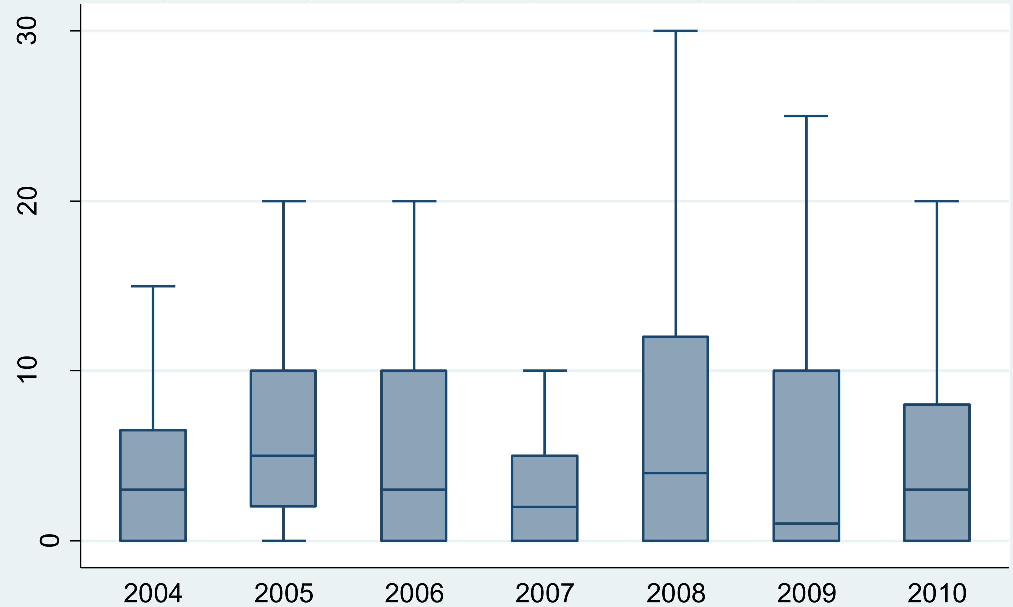


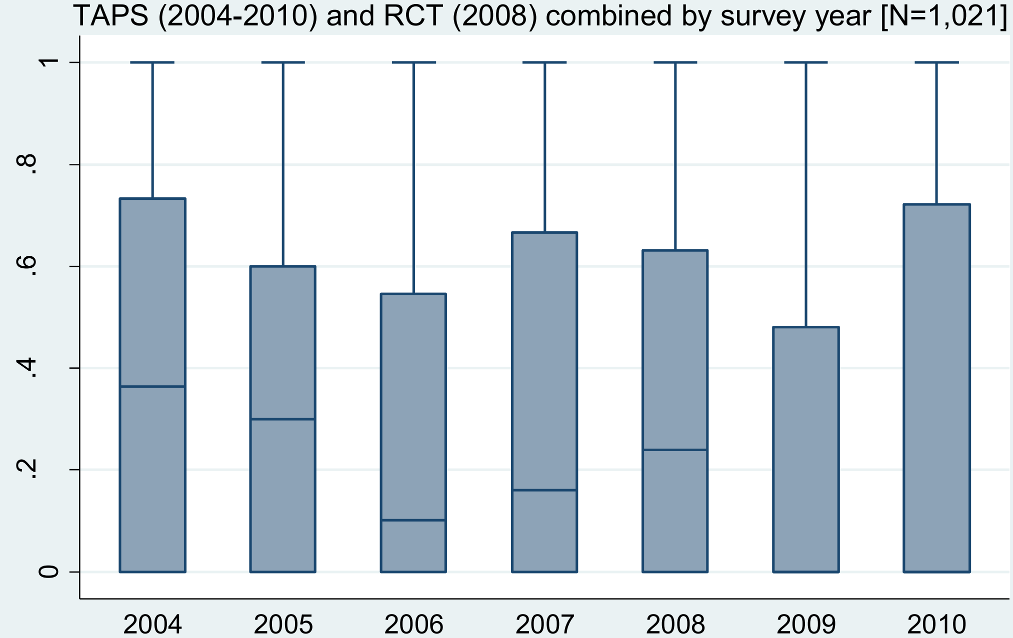
Fig. 6.9f. Maize yields last year reported by households :
TAPS (2004-2010) and RCT (2008) combined by survey year [N=1,178]
0
20
40
60
80
100
2004
2005
2006
2007
2008
2009
2010
Excludes outside values. 1 mancorna≈2kg; 1 tareas=0.1 ha. Includes households planting maize

Fig. 6.9g. Stored maize from last year's harvest reported by households:
TAPS (2004-2010) and RCT (2008) combined by survey year [N=1,177]



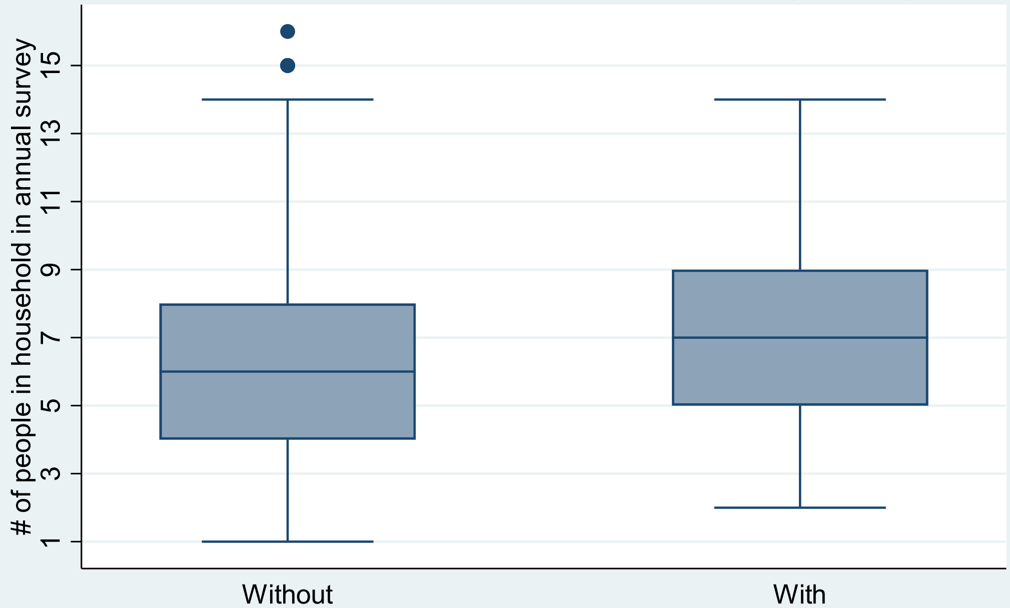

Excludes outside values. 1 mancorna≈2kg. Includes households that planted maize

Fig. 6.9h. Share of last year's maize harvest sold reported by households:
TAPS (2004-2010) and RCT (2008) combined by survey year [N=1,021]



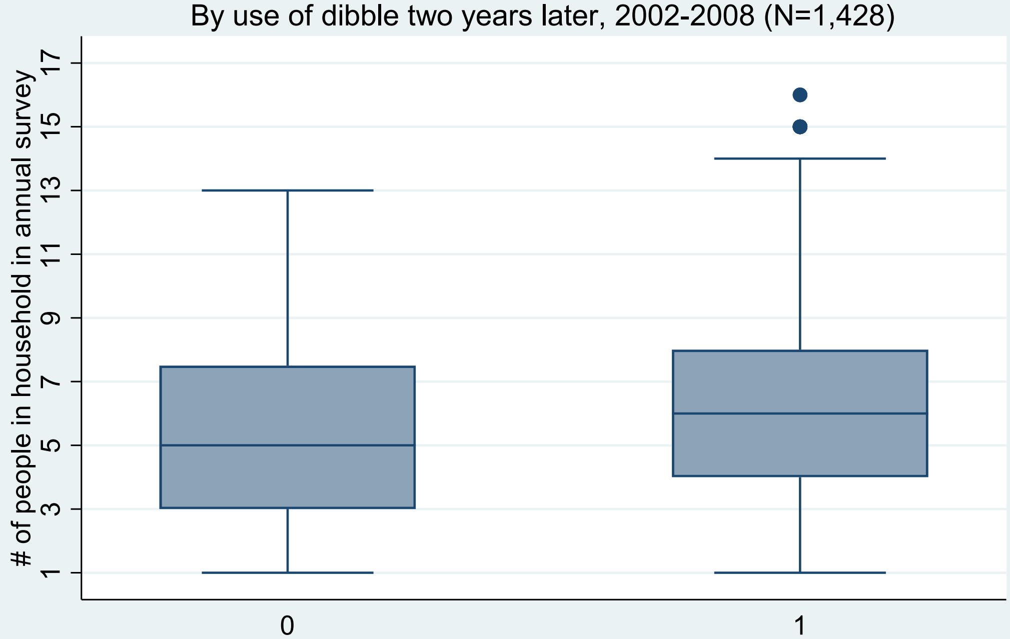

Excludes outside values. Includes households that planted maize

Fig. 6.10a. Comparison of current household size in TAPS:
By use of chainsaw two years later, 2002-2008 (N=1,428)



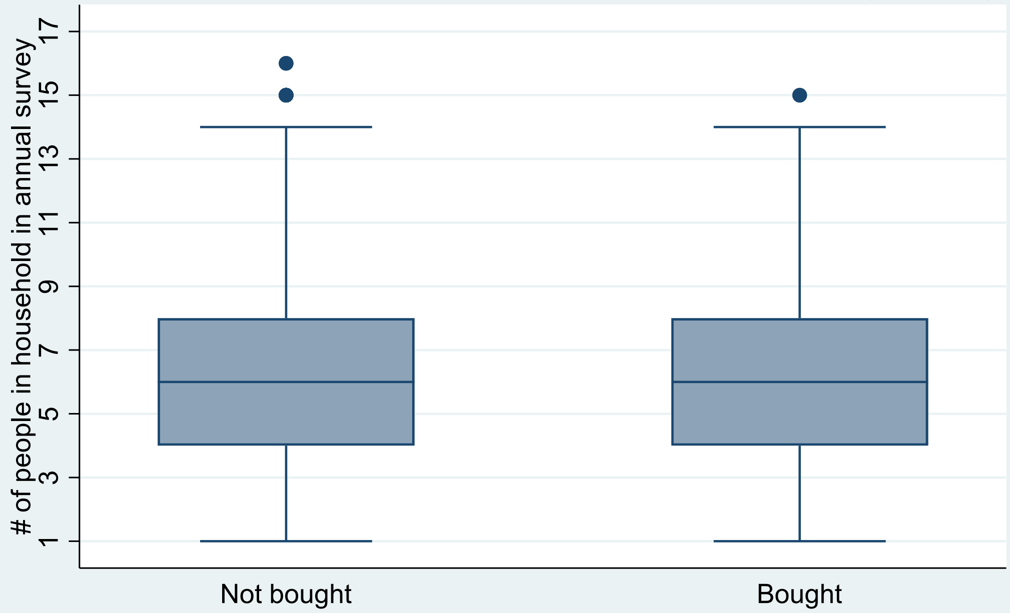

p=0.005 for regression of chainsaw (outcome) against household size (Table 6.8)

Fig. 6.10b. Comparison of current household size in TAPS:
By use of dibble two years later, 2002-2008 (N=1,428)



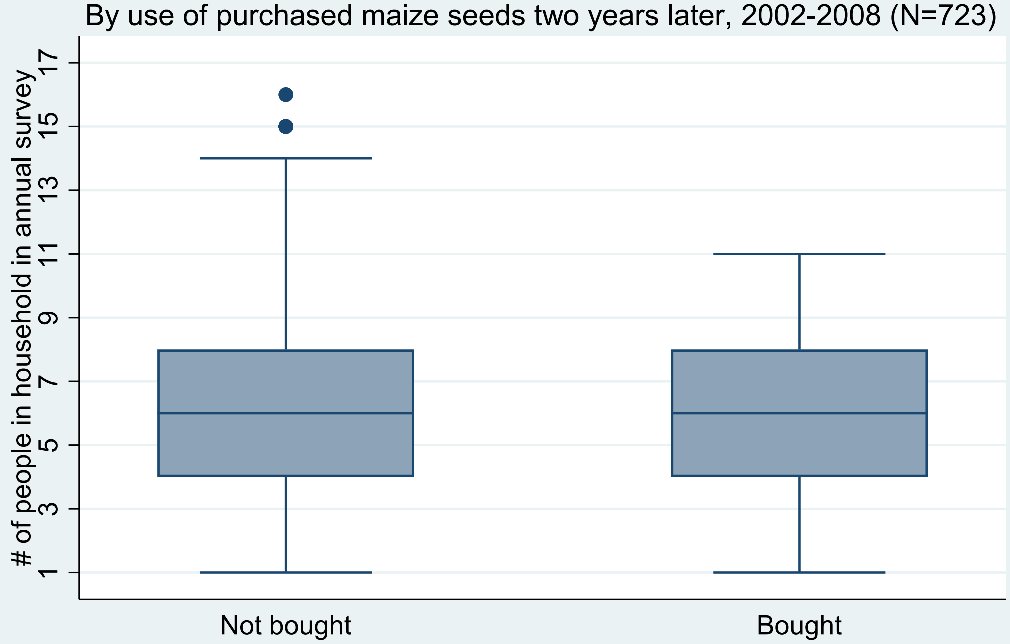

p=0.001 for regression of dibble (outcome) against household size (Table 6.8)

Fig. 6.10c. Comparison of current household size in TAPS:
By use of purchased rice seeds two years later, 2002-2008 (N=1,333)



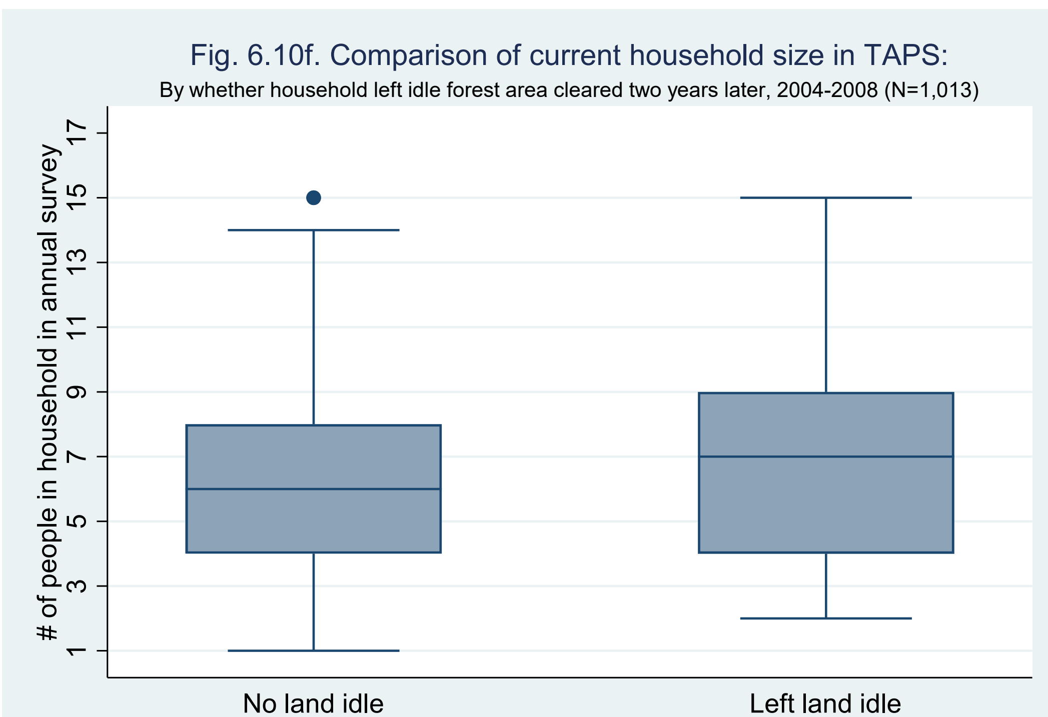

p=0.814 for regression of rice seeds (outcome) against household size (Table 6.8)

Fig. 6.10d. Comparison of current household size in TAPS:
By use of purchased maize seeds two years later, 2002-2008 (N=723)




p=0.141 for regression of maize seeds (outcome) against household size (Table 6.8)


p=0.208 for regression of hired workers (outcome) against household size (Table 6.8)




p=0.087 for regression of idle land (outcome) against household size (Table 6.8)

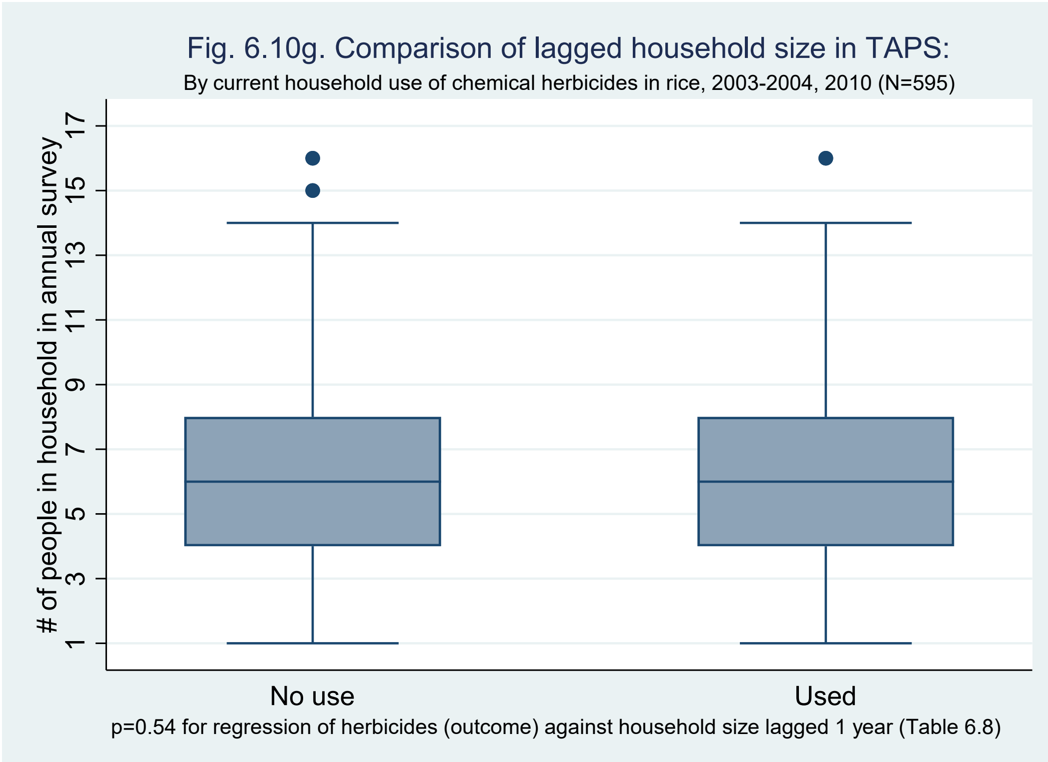


Fig. 6.10g. Comparison of lagged household size in TAPS:
By current household use of chemical herbicides in rice, 2003-2004, 2010 (N=595)
# of people in household in annual survey
1
3
5
7
9
11
13
15
17
No use
Used
p=0.54 for regression of herbicides (outcome) against household size lagged 1 year (Table 6.8)

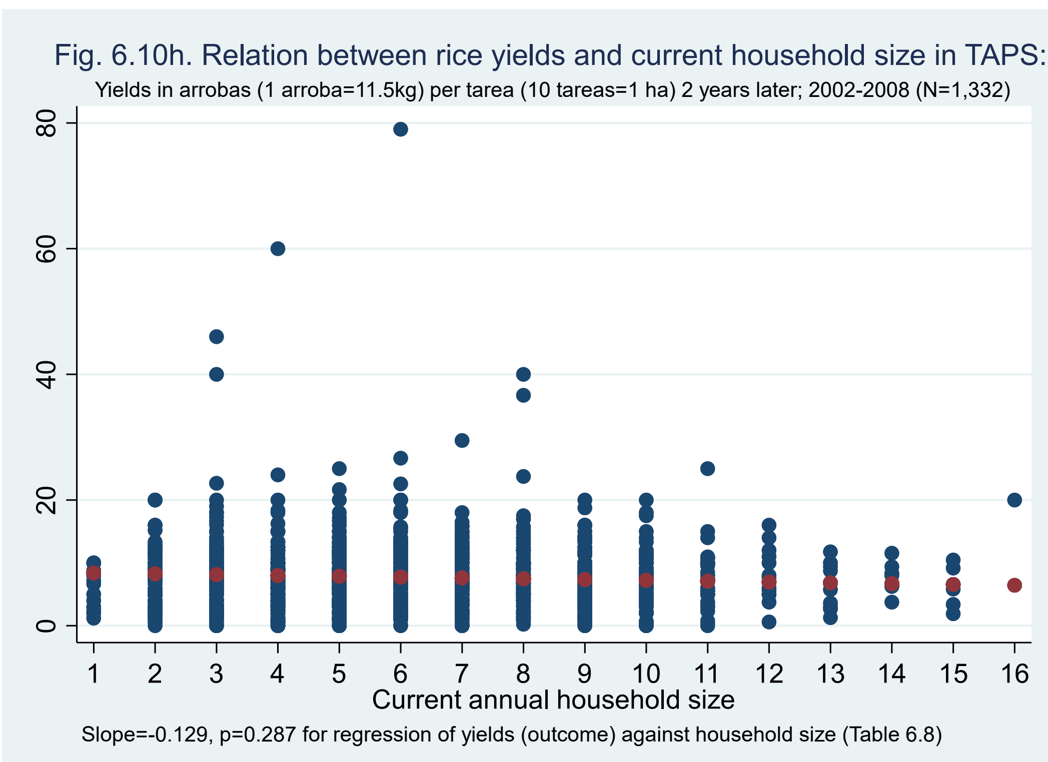
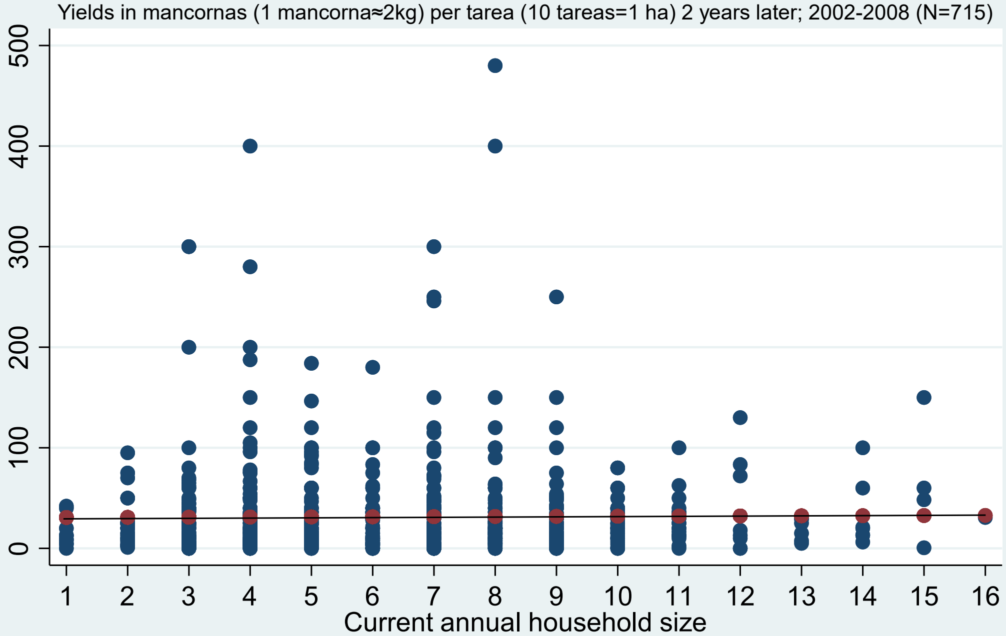


Fig. 6.10h. Relation between rice yields and current household size in TAPS:
Yields in arrobas (1 arroba=11.5kg) per tarea (10 tareas=1 ha) 2 years later; 2002-2008 (N=1,332)
0
20
40
60
80
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Current annual household size
Slope=-0.129, p=0.287 for regression of yields (outcome) against household size (Table 6.8)

Fig. 6.10i. Maize yields and current household size in TAPS:

Yields in mancornas (1 mancorna≈2kg) per tarea (10 tareas=1 ha) 2 years later; 2002-2008 (N=715)




Slope=0.14; p=0.803 for regression of yields (outcome) against household size (Table 6.8)

Table 6.1. Reported number of forest plots cleared by household the year before the survey: TAPS (T, 2002-2010) and baseline survey (2008) of randomized control trial (RCT; R)

| | Survey year and totals: | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2002 | | 2003 | | 2004 | | 2005 | | 2006 | | 2007 | | 2008T[1] | | 2008R[2] | | 2009 | | 2010 | | 2002-10T[3] | | 2002-10R[4] | |
| # plots | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % |
| A. Number of plots | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 15 | 6.5 | 2 | 0.9 | 17 | 7.2 | 8 | 3.1 | 16 | 6.1 | 14 | 5.7 | 16 | 6.3 | 30 | 6.1 | 21 | 8.3 | 19 | 7.0 | 128 | 5.7 | 158 | 6.0 |
| 1 | 105 | 45.6 | 97 | 45.1 | 116 | 49.5 | 137 | 54.3 | 138 | 52.6 | 132 | 54.5 | 160 | 63.2 | 276 | 56.2 | 144 | 56.9 | 160 | 59.7 | 1189 | 53.8 | 1456 | 54.2 |
| 2 | 83 | 36.0 | 66 | 30.7 | 82 | 35.0 | 71 | 28.1 | 76 | 29.0 | 81 | 33.4 | 61 | 24.1 | 145 | 29.5 | 74 | 29.2 | 61 | 22.7 | 655 | 29.6 | 800 | 29.6 |
| 3 | 21 | 9.1 | 32 | 14.8 | 15 | 6.4 | 25 | 9.9 | 24 | 9.1 | 10 | 4.1 | 14 | 5.5 | 32 | 6.5 | 10 | 3.9 | 19 | 7.0 | 170 | 7.70 | 202 | 7.4 |
| 4 | 5 | 2.1 | 10 | 4.6 | 4 | 1.7 | 7 | 2.7 | 6 | 2.2 | 3 | 1.2 | 1 | 0.4 | 6 | 1.2 | 4 | 1.58 | 7 | 2.6 | 47 | 2.1 | 53 | 1.9 |
| 5 | 1 | 0.4 | 4 | 1.8 | | | 3 | 1.1 | 2 | 0.7 | 2 | 0.8 | 1 | 0.4 | 2 | 0.4 | | | 2 | 0.7 | 15 | 0.6 | 17 | 0.6 |
| 6 | | | 3 | 1.4 | | | 1 | 0.4 | | | | | | | | | | | | | 4 | 0.1 | 4 | 0.5 |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | | | 1 | 0.4 | | | | | | | | | | | | | | | | | 1 | 0.05 | 1 | 0.04 |
| Total | 230 | 100 | 215 | 100 | 234 | 100 | 252 | 100 | 262 | 100 | 242 | 100 | 253 | 100 | 491 | 100 | 253 | 100 | 268 | 100 | 2209 | 100 | 2700 | 100 |
| B. Descriptive summary statistics of number of plots cleared from annual samples | | | | | | | | | | | | | | | | | | | | | | | | |
| Mean | 1.5 | | 1.9 | | 1.4 | | 1.5 | | 1.5 | | 1.4 | | 1.3 | | 1.4 | | 1.3 | | 1.4 | | 1.4 | | 1.4 | |
| Median | 1 | | 2 | | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | |
| SD | 0.8 | | 1.2 | | 0.7 | | 0.9 | | 0.8 | | 0.8 | | 0.7 | | 0.7 | | 0.7 | | 0.8 | | 0.8 | | 0.8 | |

Notes: [1]T=TAPS. [2]R=RCT. [3]Only TAPS data. [4]TAPS+RCT (2008).

Table 6.2. Reported annual area of fallow, old-growth, and total forest cleared by household the year before the survey and share of households that left some cleared forest area idle: TAPS (T, 2002-2010) and baseline survey (2008) of randomized control trial (RCT; R). Area in tareas (10 tareas=1 hectare)

| Forest type | Statistic | Survey year and totals: | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008T[1] | 2008R[2] | 2009 | 2010 | 2002-10T[1] | 2002-10R[3] |
| | N | 230 | 215 | 234 | 251 | 262 | 242 | 237 | 491 | 253 | 268 | 2192 | 2683 |
| **Fallow** | % 0 | 30.0 | 25.1 | 26.0 | 28.2 | 30.1 | 25.6 | 24.0 | 44.6 | 43.8 | 35.4 | 30.0 | 32.7 |
| | Mean[5] | 5.0 | 6.3 | 5.4 | 5.2 | 6.3 | 5.4 | 6.2 | 4.6 | 4.5 | 5.2 | 5.5 | 5.4 |
| | Median[5] | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 |
| | SD[5] | 5.4 | 6.3 | 5.6 | 5.0 | 6.5 | 4.8 | 5.6 | 6.9 | 5.17 | 6.1 | 5.7 | 5.9 |
| **Old-growth** | % 0 | 55.2 | 52.0 | 61.5 | 51.0 | 56.8 | 64.8 | 61.6 | 39.9 | 47.0 | 55.6 | 56.1 | 53.1 |
| | Mean[5] | 4.2 | 3.8 | 3.3 | 4.6 | 4.3 | 3.5 | 4.0 | 7.2 | 6.5 | 4.4 | 4.3 | 4.9 |
| | Median[5] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 0 | 0 |
| | SD[5] | 8.2 | 5.2 | 5.1 | 6.0 | 6.1 | 5.6 | 5.9 | 8.7 | 8.2 | 6.2 | 6.4 | 7.0 |
| **Total** | % 0 | 7.3 | 0.9 | 7.2 | 3.1 | 6.1 | 6.2 | 2.5 | 5.5 | 8.3 | 7.0 | 5.2 | 5.2 |
| | Mean[5] | 9.3 | 10.2 | 8.8 | 9.9 | 10.7 | 8.9 | 10.3 | 11.9 | 11.1 | 9.7 | 9.9 | 10.3 |
| | Median[5] | 8.0 | 9.0 | 8.0 | 10.0 | 10.0 | 9.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| | SD[5] | 8.7 | 7.06 | 6.2 | 6.4 | 7.4 | 5.7 | 5.8 | 9.6 | 7.6 | 7.1 | 7.0 | 7.5 |
| **Idle**[4] | N | NA[6] | | | | 262 | 228 | 230 | 491 | 253 | 268 | 1241 | 1732 |
| | % | | | | | 8.7 | 15.3 | 6.5 | 15.6 | 3.5 | 5.2 | 7.7 | 9.9 |

Notes: [1]T=TAPS. [2]R=RCT. [3]TAPS+RCT (2008). [4]Share of households that cleared forest but left some area idle. [5]Statistics include households that reported values of zero for the type of forest. [6]NA = not available.

Table 6.3. Reported annual area planted with rice, maize, manioc, and plantains: TAPS (T, 2002-2010) and baseline survey (2008) of randomized control trial (RCT; R). Area in <u>tareas</u> (10 <u>tareas</u>=1 hectare)

| Crop | Statistic | Survey year and totals: | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008T[1] | 2008R[2] | 2009 | 2010 | 2002-10T[1] | 2002-10R[3] |
| **Rice** | N | | | 234 | 251 | 262 | 242 | 237 | 491 | 253 | 268 | 1747 | 2238 |
| | % 0 | | | 8.9 | 4.7 | 7.2 | 9.5 | 2.9 | 9.9 | 8.7 | 8.5 | 7.2 | 7.8 |
| | Mean[4] | | | 7.7 | 8.2 | 8.7 | 6.7 | 8.3 | 9.3 | 9.8 | 7.9 | 8.2 | 8.4 |
| | Median[4] | | | 6.0 | 7.0 | 8.0 | 5.0 | 8.0 | 8.0 | 9.0 | 8.0 | 8.0 | 8.0 |
| | SD[4] | NA[5] | | 5.7 | 5.6 | 6.5 | 4.7 | 5.2 | 8.2 | 7.2 | 5.8 | 5.9 | 6.5 |
| | | | | | | | | | | | | | |
| **Maize** | N | | | 234 | 251 | 262 | 242 | 237 | 491 | 252 | 268 | 1746 | 2237 |
| | % 0 | | | 50.4 | 46.2 | 47.3 | 50.8 | 40.0 | 36.8 | 51.1 | 60.8 | 49.7 | 46.8 |
| | Mean[4] | | | 1.3 | 1.2 | 1.3 | 0.9 | 1.5 | 1.6 | 1.0 | 0.9 | 1.2 | 1.3 |
| | Median[4] | | | 0 | 0.5 | 0.4 | 0 | 1.0 | 0.6 | 0 | 0 | 0.1 | 0.4 |
| | SD[4] | | | 2.2 | 1.9 | 2.0 | 1.7 | 2.2 | 3.0 | 1.4 | 1.9 | 1.9 | 2.2 |
| | | | | | | | | | | | | | |
| **Manioc** | N | 227 | 212 | 228 | 251 | 262 | 242 | 238 | 491 | 252 | 268 | 2180 | 2671 |
| | % 0 | 43.6 | 32.5 | 60.0 | 42.2 | 50.3 | 55.3 | 54.6 | 39.5 | 56.7 | 63.0 | 51.3 | 49.1 |
| | Mean[4] | 1.02 | 1.3 | 0.7 | 1.1 | 0.9 | 0.8 | 1.1 | 1.2 | 1.1 | 0.7 | 1.0 | 1.0 |
| | Median[4] | 0.5 | 1.0 | 0 | 0.5 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 0.1 |
| | SD[4] | 2.0 | 1.8 | 1.3 | 1.5 | 1.3 | 1.3 | 1.7 | 1.8 | 3.4 | 1.4 | 1.9 | 1.8 |
| | | | | | | | | | | | | | |
| **Plantains** | N | 228 | 212 | 228 | 251 | 262 | 242 | 238 | 491 | 252 | 268 | 2181 | 2672 |
| | % 0 | 3.9 | 3.3 | 15.3 | 7.5 | 23.6 | 27.6 | 16.3 | 16.9 | 26.5 | 15.3 | 15.9 | 16.0 |
| | Mean[4] | 5.8 | 6.5 | 3.6 | 4.5 | 2.5 | 2.0 | 2.5 | 2.9 | 2.4 | 2.9 | 3.6 | 3.5 |
| | Median[4] | 4 | 4.8 | 2.0 | 3.0 | 2.0 | 1.0 | 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 |
| | SD[4] | 6.1 | 6.5 | 7.0 | 4.3 | 2.7 | 2.3 | 2.7 | 3.3 | 3.1 | 2.9 | 4.7 | 4.4 |

Notes: [1]T=TAPS. [2]R=RCT. [3]TAPS+RCT (2008). [4]Mean, median, and standard deviation are computed from the sample that includes households who did not plant the crop. [5]NA = Not available.

Table 6.4. Share of households reporting having grown a minor annual crop, TAPS 2004-2010.

| Crop | Statistic | Survey year and totals: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Total |
| **[A] Surveyors asked about the following crops every year:** | | | | | | | | | |
| | N | 228 | 251 | 262 | 242 | 237 | 252 | 268 | 1,740 |
| **Yams**[1] | % | 38.6 | 49.8 | 43.5 | 33.4 | 21.9 | 20.6 | 29.4 | 33.9 |
| **Onions** | % | 24.1 | 19.9 | 27.4 | 21.4 | 21.5 | 15.0 | 22.0 | 21.6 |
| **Peanuts** | % | 25.4 | 22.7 | 24.0 | 14,8 | 15.6 | 19.4 | 20.9 | 20.4 |
| **Sweet potatoes** | % | 41.2 | 51.7 | 55,3 | 38.0 | 29.9 | 35.7 | 37.3 | 41.3 |
| **[B] Most frequent minor crops mentioned by households in response to open-ended questions about other crops grown**[2] | | | | | | | | | |
| | N | | 251 | 262 | 242 | 237 | 253 | 268 | 1,513 |
| **Pineapple** | % | | 31.8 | 32.4 | 21.9 | 11.3 | 24.9 | 23.1 | 24.4 |
| **Watermelon** | % | NA[5] | 2.7 | 32.8 | 14.0 | 1.6 | 17.0 | 12.6 | 13.7 |
| | N | | NA[4] | 262 | 242 | 237 | 253 | 268 | 1,262 |
| **Binca**[3] | % | | | 0.3 | 9.9 | 2.1 | 13.8 | 15.3 | 8.4 |
| **Pigeon pea**[4] | % | | | 23.6 | 16.5 | 0.4 | 0 | 0.7 | 8.3 |

Notes: [1]The Tsimane' call the tuber *ahipa*, which I translated as yam. [2]These are the four crops most frequently mentioned in response to open-ended questions about other crops grown besides the four major crops and the four minor crops listed in section A of this table. [3]Binca is a tuber similar to the potato. [4]The Tsimane' call the crop *curishi*, which is a generic term for any bean-like legume, such as pigeon pea or beans proper. I decided to translate *curishi* as pigeon pea because one of the early projects of the TAPS team introduced pigeon pea as a cover crop. [5]NA=Not available.

Table 6.5. Horticultural inputs. TAPS (T, 2002-2010) and baseline survey (2008) of randomized control trial (RCT; R)

| Crop | Statistic | Survey year and totals: | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008T[2] | 2008R[3] | 2009 | 2010 | Total-T[2] | Total-R[4] |
| **[A] Tools and implements. Percent of households that reported using:** | | | | | | | | | | | | | |
| | N | NA[1] | 197 | 216 | 243 | 246 | 227 | 237 | 464 | 232 | 249 | 1,847 | 2,311 |
| **Chainsaw** | % | | 7.1 | 7.4 | 9.8 | 7.3 | 5.2 | 6.3 | 17.0 | 16.3 | 15.6 | 9.5 | 11.0 |
| **Dibble[5]** | % | | 82.2 | 83.3 | 86.4 | 84.5 | 81.9 | 83.9 | 76.5 | 88.7 | 90.7 | 85.3 | 83.6 |
| **Farmhands[6]** | % | | 17.7 | 18.5 | 20.5 | 15.8 | 11.4 | 12.2 | 23.2 | 20.6 | 15.2 | 16.5 | 17.8 |
| | N | | 197 | 216 | NA[1] | | | | | | 249 | 662 | NA[1] |
| **Herbicides[7]** | % | | 17.2 | 20.3 | | | | | | | 36.9 | 25.6 | |
| **[B] Source of rice and maize seeds for households that planted the crop:** | | | | | | | | | | | | | |
| **Rice** | N | 211 | 205 | 213 | 239 | 243 | 214 | 230 | 441 | 230 | 243 | 2,028 | 2,469 |
| **Own** | % | 78.2 | 76.5 | 73.7 | 69.4 | 79.4 | 81.7 | 78.2 | 66.2 | 79.5 | 72.4 | 76.5 | 74.6 |
| **Buy** | % | 10.9 | 8.7 | 12.2 | 15.0 | 10.7 | 8.4 | 10.0 | 19.0 | 10.8 | 12.3 | 11.0 | 12.5 |
| **Gift** | % | 3.7 | 9.2 | 3.2 | 5.8 | 2.8 | 3.2 | 2.1 | 5.4 | 2.1 | 7.8 | 4.4 | 4.6 |
| **Borrowed** | % | 7.1 | 5.3 | 10.8 | 9.6 | 7.0 | 6.5 | 9.5 | 9.3 | 7.3 | 7.4 | 7.8 | 8.1 |
| **Maize** | N | 130 | 167 | 116 | 135 | 138 | 115 | 136 | 303 | 122 | 104 | 1,163 | 1,466 |
| **Own** | % | 79.2 | 69.4 | 73.2 | 78.5 | 76.8 | 75.6 | 77.9 | 67.3 | 85.2 | 75.0 | 76.6 | 74.6 |
| **Buy** | % | 5.3 | 5.3 | 5.1 | 9.6 | 14.4 | 10.4 | 7.3 | 15.1 | 7.3 | 7.6 | 8.0 | 9.5 |
| **Gift** | % | 6.1 | 18.5 | 4.3 | 6.6 | 0.7 | 6.0 | 2.9 | 9.9 | 4.1 | 7.6 | 6.7 | 7.3 |
| **Borrowed** | % | 9.2 | 6.5 | 17.2 | 5.1 | 7.9 | 7.8 | 11.7 | 7.5 | 3.2 | 9.6 | 8.6 | 8.3 |

Notes: [1]NA=Not available or not applicable. [2]TAPS. [3]R=RCT. [4]TAPS+RCT (2008) data. [5]Commercial dibbles used to plant rice. [6]Hired farmhands. [7]Chemical herbicides used for rice.

Table 6.6. Rice and maize harvest, crop yields, storage, and sales. TAPS (T, 2004-2010) and baseline survey (2008) of randomized control trial (RCT; R) for households that planted rice or maize

| Outcome | Units | Statistic | Survey year and totals: 2004 | 2005 | 2006 | 2007 | 2008T[1] | 2008R[2] | 2009 | 2010 | Total-T[1] | Total-R[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **[A] Rice** | | | | | | | | | | | | |
| **Harvest** | | N | 213 | 239 | 243 | 218 | 229 | 442 | 230 | 245 | 1,617 | 2,059 |
| | | % 0 | 1.8 | 2.0 | 2.4 | 1.8 | 0.8 | 16.2 | 3.4 | 1.2 | 1.9 | 5.0 |
| | Arrobas[4] | Mean | 62.2 | 81.7 | 71.0 | 56.2 | 70.4 | 72.8 | 59.9 | 65.1 | 66.9 | 68.1 |
| | | Median | 40.0 | 60.0 | 50.0 | 48.0 | 60.0 | 40.0 | 40.0 | 50.0 | 50.0 | 50.00 |
| | | SD | 62.4 | 72.8 | 68.8 | 46.4 | 56.3 | 113.8 | 67.9 | 56.2 | 62.7 | 76.6 |
| **Yields** | Arrobas/tarea[5] | Mean | 7.3 | 9.2 | 7.6 | 7.7 | 8.2 | 6.9 | 5.8 | 8.0 | 7.7 | 7.5 |
| | | Median | 6.6 | 9.0 | 7.3 | 8.0 | 8.0 | 5.7 | 5.0 | 7.1 | 7.5 | 7.1 |
| | | SD | 5.0 | 5.6 | 4.8 | 4.0 | 4.6 | 10.3 | 4.8 | 6.8 | 5.2 | 6.7 |
| **Storage[7]** | | % 0 | 10.8 | 10.8 | 9.4 | 18.8 | 10.0 | 27.3 | 12.1 | 9.3 | 11.5 | 14.9 |
| | Arrobas[4] | Mean | 9.0 | 15.9 | 23.8 | 8.8 | 10.8 | 21.6 | 22.0 | 21.2 | 16.2 | 17.4 |
| | | Median | 5.0 | 10.0 | 10.0 | 5.0 | 6.0 | 10.0 | 11.0 | 10.0 | 9.0 | 9.0 |
| | | SD | 15.1 | 20.4 | 33.7 | 12.4 | 14.0 | 36.2 | 30.1 | 26.8 | 24.1 | 27.3 |
| **Sale** | | N | 207 | 233 | 237 | 214 | 227 | 363 | 222 | 242 | 1,582 | 1,945 |
| | | % 0 | 11.1 | 9.4 | 15.1 | 13.0 | 9.6 | 18.4 | 23.8 | 28.5 | 15.9 | 16.4 |
| | % of harvest | Mean | 0.4 | 0.4 | 0.3 | 0.4 | 0.4 | 0.4 | 0.3 | 0.2 | 0.3 | 0.3 |
| | | Median | 0.5 | 0.4 | 0.3 | 0.5 | 0.5 | 0.4 | 0.2 | 0.2 | 0.4 | 0.4 |
| | | SD | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 |
| **[B] Maize** | | | | | | | | | | | | |
| **Harvest** | | N | 116 | 135 | 133 | 118 | 141 | 310 | 121 | 104 | 868 | 1,178 |
| | | % 0 | 3.4 | 2.2 | 10.5 | 5.0 | 4.2 | 24.8 | 16.5 | 3.8 | 6.57 | 11.3 |
| | Mancornas[6] | Mean | 83.3 | 67.3 | 45.3 | 55.3 | 68.8 | 59.1 | 36.1 | 60.9 | 59.1 | 59.1 |
| | | Median | 30.0 | 35.0 | 20.0 | 27.0 | 30.0 | 20.0 | 18.0 | 30.0 | 29.0 | 25.0 |
| | | SD | 180.9 | 78.4 | 53.8 | 86.1 | 107.1 | 119.6 | 47.2 | 174.2 | 112.8 | 114.6 |
| **Yields** | Mancornas[6]/tarea[5] | Mean | 32.1 | 35.2 | 22.6 | 49.7 | 31.3 | 45.6 | 19.0 | 31.3 | 31.5 | 35.2 |
| | | Median | 20.0 | 24.0 | 15.0 | 21.7 | 20.0 | 13.1 | 10.0 | 15.9 | 20.0 | 18.0 |
| | | SD | 40.8 | 45.4 | 38.1 | 123.5 | 40.8 | 196.0 | 22.2 | 46.1 | 59.1 | 112.7 |
| **Storage[7]** | | N | 116 | 135 | 133 | 117 | 141 | 310 | 121 | 104 | 867 | 1,177 |
| | | % 0 | 29.3 | 17.0 | 30.0 | 37.6 | 26.2 | 38.7 | 42.1 | 26.9 | 29.6 | 32.0 |
| | Mancornas[6] | Mean | 6.2 | 8.5 | 7.4 | 3.6 | 11.2 | 16.6 | 7.0 | 7.3 | 7.5 | 9.9 |
| | | Median | 3.0 | 5.0 | 3.0 | 2.0 | 4 | 4.0 | 1.0 | 3.0 | 3.0 | 3.0 |
| | | SD | 12.4 | 11.5 | 11.1 | 6.1 | 35.2 | 46.9 | 18.6 | 12.6 | 18.3 | 29.0 |
| **Sale** | | N | 105 | 127 | 118 | 111 | 135 | 224 | 101 | 100 | 797 | 1,021 |
| | | % 0 | 27.6 | 35.4 | 47.4 | 43.2 | 37.0 | 43.3 | 60.4 | 56.0 | 43.2 | 43.2 |
| | % of harvest | Mean | 0.4 | 0.3 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | 0.3 | 0.31 |
| | | Median | 0.3 | 0.3 | 0.1 | 0.1 | 0.4 | 0.1 | 0 | 0 | 0.2 | 0.18 |
| | | SD | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | 0.3 | 0.35 |

Table 6.6. Rice and maize production, yields, sale, and storage. TAPS (T, 2004-2010) and baseline survey (2008) of randomized control trial (RCT; R) -- continued

Notes: [1]TAPS. [2]R=RCT. [3]TAPS+RCT (2008) data. [4]1 arroba=11.50 kilograms. [5]1 tarea=0.10 hectare. [6]1 mancorna ≈ 2 kilograms. [7]Number of arrobas (rice) or mancornas (maize) left from the latest harvest, but only for households planting rice or maize.

Table 6.7. 2002-2010 annual growth rate (%Δ/y) of horticultural inputs and outputs. Regression results using full sample of TAPS (2002-2010, except where noted) and RCT (2008)[1]

| Outcome is: | | In analysis, values of zero in outcome are: | | | | | | Outcome defined in table |
|---|---|---|---|---|---|---|---|---|
| | | I. Included[2] | | | II. Excluded[3] | | | |
| | | N | %Δ/y | SE[4] | N | %Δ/y | SE[4] | |
| **[A] Number of plots cleared** | | | | | | | | |
| Plots cleared | Number | 2700 | -1.7*** | 0.003 | 2542 | -2.2*** | 0.004 | 6.1 |
| **[B] Area of forest cleared by forest type** | | | | | | | | |
| Forest cleared | Type: | | | | | | | |
| | Fallow | 2683 | -2.8** | 0.01 | 1805 | 1.6** | 0.007 | 6.2 |
| | Old-growth | 2683 | 2.2 | 0.02 | 1256 | 4.1*** | 0.007 | |
| | Total | 2683 | 1.0 | 0.007 | 2541 | 1.7*** | 0.006 | |
| | Idle[5, 6] | 1732 | -2.1*** | 0.006 | Not applicable | | | |
| **[C] Probability the crop is <u>not</u> planted** | | | | | | | | |
| Household did not cultivate | Crop: | | | | | | | |
| | Rice | 2238 | 0.1 | 0.003 | Not applicable | | | 6.3 |
| | Maize | 2237 | 1.3** | 0.005 | | | | |
| | Manioc | 2671 | 2.5*** | 0.004 | | | | |
| | Plantains | 2672 | 2.3*** | 0.002 | | | | |
| **[D] Area planted with main crops** | | | | | | | | |
| Area planted | Crop: | | | | | | | |
| | Rice | 2238 | 1.0 | 0.01 | 2062 | 1.6* | 0.008 | 6.3 |
| | Maize | 2237 | -3.6** | 0.01 | 1188 | -0.8 | 0.01 | |
| | Manioc | 2671 | -3.9*** | 0.009 | 1358 | 5.8*** | 0.009 | |
| | Plantains | 2672 | -9.2*** | 0.008 | 2242 | -7.7*** | 0.008 | |
| **[E] Probability of growing minor crops[6, 7]** | | | | | | | | |
| Minor crops | Yams | 1740 | -3.8*** | 0.006 | Not applicable (2004-2010) | | | 6.4 |
| | Onions | 1740 | -0.7 | 0.005 | | | | |
| | Peanuts | 1740 | -0.9* | 0.00 | | | | |
| | Sweet potatoes | 1740 | -2.5*** | 0.006 | | | | |
| | Pineapple | 1513 | -2.1*** | 0.005 | Not applicable (2005-2010) | | | |
| | Watermelons | 1513 | -0.3 | 0.004 | | | | |
| | Binca | 1262 | 3.3*** | 0.004 | Not applicable (2006-2010) | | | |
| | Pigeon pea | 1262 | -4.3*** | 0.005 | | | | |
| | Any[8] | 1513 | -4.9*** | 0.006 | Not applicable (2004-2010) | | | |
| **[F] Probability of using modern inputs and own rice or maize seeds[9]** | | | | | | | | |
| Modern inputs | Chainsaw | 2,311 | 1.2*** | 0.003 | Not applicable (2003-2010) | | | 6.5 |
| | Dibble | 2,311 | 1.0*** | 0.003 | | | | |
| | Farmhands | 2,311 | -0.4 | 0.004 | | | | |
| | Herbicides | 662 | 2.7*** | 0.005 | Not applicable (2003-2004 & 2010) | | | |
| Own seeds | Rice | 2,469 | 0.1 | 0.004 | Not applicable (2002-2010) | | | |
| | Maize | 1,347 | 1.0* | 0.005 | | | | |

Table 6.7. 2002-2010 annual growth rate (%Δ/y) of horticultural inputs and outputs. Regression results using full sample of TAPS (2002-2010, except where noted) and RCT (2008)[1] -- continued

| Outcome is: | | In analysis, values of zero in outcome are: I. Included[2] N | I. Included[2] %Δ/y | I. Included[2] SE[4] | II. Excluded[3] N | II. Excluded[3] %Δ/y | II. Excluded[3] SE[4] | Outcome defined in table |
|---|---|---|---|---|---|---|---|---|
| **[G] Harvest, yields, storage, and sales: Rice and maize** | | | | | | | | |
| Rice | Harvest | 2,059 | -1.3 | 0.01 | 1,955 | -1.6 | 0.01 | 6.6 |
| | Yields | 2,059 | -2.3*** | 0.008 | 1,955 | -3.2*** | 0.009 | |
| | Storage | 2,059 | 6.7*** | 0.01 | 1,751 | 8.0*** | 0.01 | |
| | Sales | 1,945 | -2.3*** | 0.002 | 1,625 | -4.6*** | 0.009 | |
| Maize | Harvest | 1,178 | -7.2*** | 0.02 | 1,044 | -3.7* | 0.02 | |
| | Yields | 1,178 | -5.9** | 0.02 | 1,044 | -3.1 | 0.02 | |
| | Storage | 1,177 | -4.7* | 0.02 | 800 | 0.5 | 0.02 | |
| | Sales | 1,021 | -2.8*** | 0.007 | 579 | 3.7** | 0.01 | |

Notes: All regressions use robust standard errors clustered by households and, except where noted, control for study type. The regressions are run with contemporaneous values and not lag or leads. We tested the use of leads for section F and arrived at the same conclusion, though the sample size decreased and standard errors rose. [1]Study (TAPS=1; RCT=0). [2]Regressions with zeros are lowered-censored Tobits, with +1 added to the outcome before taking logarithms. [3]Regressions without zeros are ordinary least squares (OLS). [4]SE=Standard errors are robust and clustered by household. [5]Area of forest cleared left idle (1=yes; 0=no). [6]Regressions are probit, with coefficients reported as marginal probabilities. Annual growth rate of probit regressions are expressed as the probability of leaving idle some plots of cleared forest. For section E, probit regressions do not control for study since all the information comes from the longitudinal study (TAPS). [7]For definition of yams and binca, see Table 6.4. [8]Outcome variable is 1 if the household grew any minor crop (not just the ones listed in section E), and 0 otherwise. [9]For all but one outcome of section F, probit regressions control for study. The regression with chemical herbicides as an outcome does not control for study because it was only measured in the longitudinal study (TAPS). *, **, and *** significant p<10%, p<5%, and p<1%.

Table 6.8. Association between household size and horticultural intensification: Results of panel regressions with household fixed effects and without control variables

| Explanatory variables: | Chainsaw | Dibble | Rice seeds | Maize seeds | Hires | Idle | Herbicide | Rice yields | Maize yields |
|---|---|---|---|---|---|---|---|---|---|
| Household size | 0.005 | 0.012 | -0.013* | -0.010 | -0.011 | 0.017* | 0.009 | -0.130 | 1.923 |
| | (0.006) | (0.008) | (0.008) | (0.008) | (0.009) | (0.010) | (0.015) | (0.122) | (1.208) |
| Constant | 0.057 | 0.745*** | 0.181*** | 0.148*** | 0.225*** | -0.023 | 0.209** | 8.514*** | 19.165** |
| | (0.036) | (0.048) | (0.047) | (0.049) | (0.054) | (0.059) | (0.090) | (0.752) | (7.700) |
| Observations | 1,428 | 1,428 | 1,333 | 723 | 1,428 | 1,013 | 595 | 1,332 | 715 |
| R-squared | 0.001 | 0.002 | 0.003 | 0.002 | 0.002 | 0.005 | 0.001 | 0.001 | 0.003 |
| Number of households | 311 | 311 | 304 | 246 | 311 | 288 | 296 | 304 | 243 |

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. In regression with herbicides as an outcome, I lag by one year the explanatory variables. See Appendix A for details of the approach.

Table 6.9. Association between household size and horticultural intensification: Results of panel regressions with household fixed effects and control variables

| Explanatory variables: | Chainsaw | Dibble | Rice seeds | Maize seeds | Hires | Idle | Herbicides | Rice yields | Maize yields |
|---|---|---|---|---|---|---|---|---|---|
| Household size | 0.001 | 0.012 | -0.012 | -0.012 | -0.011 | 0.017* | 0.032*** | -0.113 | 2.032* |
| | (0.006) | (0.008) | (0.007) | (0.008) | (0.009) | (0.010) | (0.009) | (0.127) | (1.210) |
| Commercial wealth | 0.011** | -0.002 | -0.002 | -0.002 | 0.009 | 0.007 | 0.009 | 0.018 | -0.193 |
| | (0.005) | (0.006) | (0.004) | (0.005) | (0.006) | (0.006) | (0.014) | (0.077) | (0.883) |
| Schooling | 0.008 | 0.011 | 0.002 | 0.020 | 0.016 | -0.008 | 0.000 | 0.078 | 0.820 |
| | (0.009) | (0.009) | (0.007) | (0.015) | (0.013) | (0.009) | (0.000) | (0.158) | (1.567) |
| Change per year | 0.008 | -0.003 | -0.002 | -0.000 | -0.013** | -0.023*** | 0.011 | -0.132 | -1.205 |
| | (0.005) | (0.005) | (0.006) | (0.007) | (0.006) | (0.007) | (0.021) | (0.104) | (1.083) |
| Constant | -16.904 | 7.549 | 5.093 | 0.300 | 26.423** | 45.667*** | -63.559*** | 273.585 | 2,433.347 |
| | (10.655) | (10.531) | (11.195) | (14.095) | (12.387) | (13.992) | (17.715) | (207.582) | (2,168.653) |
| Observations | 1,412 | 1,412 | 1,319 | 715 | 1,412 | 999 | 593 | 1,318 | 707 |
| R-squared | 0.020 | 0.004 | 0.004 | 0.006 | 0.010 | 0.021 | 0.110 | 0.003 | 0.006 |
| Number of households | 308 | 308 | 301 | 244 | 308 | 285 | 295 | 301 | 241 |

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. In regression with herbicides as an outcome, I lag by one year the explanatory variables. Schooling is the median schooling of adults in the household during the survey year. See Appendix A for details of the approach. Commercial wealth is in 1000 of bolivianos (1 US dollar ≈ 7 bolivianos).

Table 6.10. Association between household size and horticultural intensification: Results of panel regressions with household and year fixed effects and control variables

| Explanatory variables: | Chainsaw | Dibble | Rice seeds | Maize seeds | Hires | Idle | Herbicides | Rice yields | Maize yields |
|---|---|---|---|---|---|---|---|---|---|
| Household size | 0.003 | 0.014* | -0.012 | -0.015* | -0.010 | 0.013 | 0.032*** | -0.109 | 2.067* |
| | (0.006) | (0.008) | (0.007) | (0.008) | (0.009) | (0.009) | (0.009) | (0.124) | (1.247) |
| Commercial wealth | 0.014** | -0.004 | -0.001 | -0.003 | 0.012** | 0.009 | 0.009 | -0.120 | -1.543 |
| | (0.005) | (0.007) | (0.005) | (0.006) | (0.006) | (0.007) | (0.014) | (0.092) | (1.201) |
| Schooling | 0.009 | 0.010 | 0.002 | 0.019 | 0.016 | -0.008 | 0.000 | 0.053 | 0.876 |
| | (0.009) | (0.010) | (0.007) | (0.015) | (0.013) | (0.009) | (0.000) | (0.150) | (1.648) |
| Change per year | 0.004 | -0.000 | -0.002 | 0.006 | -0.019*** | -0.018** | 0.011 | 0.259* | 1.153 |
| | (0.006) | (0.006) | (0.007) | (0.009) | (0.007) | (0.008) | (0.021) | (0.145) | (1.691) |
| Constant | -7.943 | 0.992 | 4.675 | -12.071 | 38.878*** | 35.855** | -64.73*** | -511.100* | -2,288.807 |
| | (12.564) | (12.733) | (13.192) | (17.583) | (13.839) | (16.342) | (17.707) | (291.063) | (3,386.954) |
| Observations | 1,412 | 1,412 | 1,319 | 715 | 1,412 | 999 | 593 | 1,318 | 707 |
| R-squared | 0.034 | 0.008 | 0.007 | 0.021 | 0.021 | 0.041 | 0.111 | 0.053 | 0.039 |
| Number of households | 308 | 308 | 301 | 244 | 308 | 285 | 295 | 301 | 241 |

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. In regression with herbicides as an outcome, I lag by one year the explanatory variables. See Appendix A for details of the approach. Commercial wealth is in 1000 of bolivianos (1 US dollar ≈ 7 bolivianos). Schooling is the median schooling of adults in the households during the survey year. Coefficient for individual years are not shown.

Table 6.11. Interaction effects between household size and total household wealth on horticultural intensification: Results of panel regressions with household fixed effects

| Explanatory variables: | Chainsaw | Dibble | Rice seeds | Maize seeds | Hires | Idle | Herbicide | Rice yields | Maize yields |
|---|---|---|---|---|---|---|---|---|---|
| Household size | 0.003 | 0.014 | -0.009 | -0.008 | -0.006 | 0.005 | 0.014 | -0.095 | 2.551 |
| | (0.007) | (0.009) | (0.008) | (0.010) | (0.010) | (0.011) | (0.015) | (0.160) | (1.661) |
| Household size*wealth | 0.000 | -0.000 | -0.001 | 0.000 | -0.001 | 0.001 | -0.001 | 0.001 | -0.074 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.016) | (0.211) |
| Total wealth | -8.079** | -0.259 | 1.564 | -3.899 | -0.320 | 5.206 | -1.693 | -50.292 | -113.972 |
| | (3.826) | (3.177) | (3.226) | (4.395) | (4.999) | (6.339) | (4.526) | (70.480) | (762.033) |
| Change per year | -0.004 | -0.004 | 0.000 | -0.006 | -0.015 | -0.016 | 0.027*** | -0.219 | -2.088 |
| | (0.007) | (0.007) | (0.007) | (0.010) | (0.009) | (0.012) | (0.010) | (0.143) | (1.592) |
| Change per year*wealth | 0.004** | 0.000 | -0.001 | 0.002 | 0.000 | -0.003 | 0.001 | 0.025 | 0.057 |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.003) | (0.002) | (0.035) | (0.380) |
| Constant | 7.832 | 7.923 | 0.074 | 11.553 | 29.353 | 31.927 | -54.9*** | 446.985 | 4,200.067 |
| | (13.270) | (14.789) | (14.784) | (19.370) | (18.262) | (23.438) | (20.268) | (286.199) | (3,187.119) |
| Observations | 1,428 | 1,428 | 1,333 | 723 | 1,428 | 1,013 | 595 | 1,332 | 715 |
| R-squared | 0.030 | 0.003 | 0.006 | 0.004 | 0.009 | 0.026 | 0.112 | 0.004 | 0.008 |
| Number of households | 311 | 311 | 304 | 246 | 311 | 288 | 296 | 304 | 243 |

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. In regression with herbicides as an outcome, I lag by one year the explanatory variables. See Appendix A for details of the approach. Total wealth is the value of annual household wealth in 1000 of bolivianos (1 US dollar ≈ 7 bolivianos) of 22 physical assets that covered assets fashioned from local materials (e.g., canoes), commercial assets bought in the market (e.g., metal tools), and domesticated animals (e.g., ducks). Interaction terms, “Household size*Wealth” and "Change per year*Wealth" refer to interaction of household size with total household wealth and survey year with total wealth.

Table 6.12. Interaction effects between household size and median adult schooling of household on horticultural intensification: Results of panel regressions with household fixed effects

| Explanatory variables: | Chainsaw | Dibble | Rice seeds | Maize seeds | Hires | Idle | Herbicide | Rice yields | Maize yields |
|---|---|---|---|---|---|---|---|---|---|
| Household size | -0.004 | 0.010 | -0.016* | -0.018* | -0.023** | 0.021* | 0.006 | -0.266 | 1.930 |
| | (0.007) | (0.010) | (0.009) | (0.011) | (0.011) | (0.013) | (0.021) | (0.163) | (1.320) |
| Household size*schooling | 0.003 | 0.001 | 0.002 | 0.004 | 0.007* | -0.001 | 0.001 | 0.082 | 0.058 |
| | (0.003) | (0.003) | (0.003) | (0.004) | (0.004) | (0.003) | (0.007) | (0.051) | (0.669) |
| Schooling | -1.412 | -1.216 | 4.866 | 4.557 | 9.915 | 10.330 | -2.115 | 55.069 | 200.288 |
| | (4.837) | (6.111) | (6.795) | (11.306) | (6.701) | (8.157) | (7.511) | (101.728) | (1,205.578) |
| Change per year | 0.012** | -0.005 | 0.000 | 0.002 | -0.001 | -0.009 | 0.032*** | -0.082 | -1.154 |
| | (0.006) | (0.007) | (0.007) | (0.009) | (0.008) | (0.009) | (0.010) | (0.137) | (1.559) |
| Change per year*schooling | 0.001 | 0.001 | -0.002 | -0.002 | -0.005 | -0.005 | 0.001 | -0.028 | -0.100 |
| | (0.002) | (0.003) | (0.003) | (0.006) | (0.003) | (0.004) | (0.004) | (0.051) | (0.602) |
| Constant | -24.27** | 11.649 | -0.730 | -3.347 | 2.295 | 17.478 | -63.5*** | 174.543 | 2,330.080 |
| | (12.035) | (13.809) | (13.485) | (18.052) | (15.143) | (17.910) | (19.766) | (273.999) | (3,124.727) |
| Observations | 1,412 | 1,412 | 1,319 | 715 | 1,412 | 999 | 593 | 1,318 | 707 |
| R-squared | 0.014 | 0.004 | 0.006 | 0.008 | 0.014 | 0.020 | 0.110 | 0.006 | 0.006 |
| Number of households | 308 | 308 | 301 | 244 | 308 | 285 | 295 | 301 | 241 |

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. In regression with herbicides as an outcome, I lag by one year the explanatory variables. See Appendix A for details of the approach. Schooling is the median school grade of adults in the household in a year. Interaction terms, “Household size*Schooling” and "Change per year*schooling" refer to interactions of household size with median level of schooling of adults in the household, and median level of schooling in the household with survey year.

Table 6.13. Association between household size and deforestation: Replication of Tables 6.8-6.10 with total area of forest cleared as an outcome

| Explanatory variables: | Table 6.8 | Table 6.9 | Table 6.10 |
|---|---|---|---|
| Household size | 0.147 | 0.132 | 0.135 |
| | (0.142) | (0.140) | (0.135) |
| Commercial wealth | | -0.085 | 0.011 |
| | | (0.119) | (0.116) |
| Schooling | | -0.132 | -0.114 |
| | | (0.175) | (0.174) |
| Change per year | | 0.191* | 0.145 |
| | | (0.114) | (0.135) |
| Constant | 9.294*** | -373.526 | -281.225 |
| | (0.870) | (228.301) | (270.442) |
| Observations | 1,427 | 1,412 | 1,412 |
| R-squared | 0.001 | 0.005 | 0.022 |
| Number of households | 310 | 307 | 307 |

Notes: These regressions are the same Tables 6.8-6.10, except that the outcome is the area of fallow forest + old-growth forest cleared by the household in tareas in a year (10 tareas=1 hectare). I include all households even if they did not clear forest (n=73; 5.1% of sample did not clear forest).

Table 6.14. Association between demographic composition of household and horticultural intensification: Results of panel regressions with household fixed effects and control variables

| Explanatory variables: | Chainsaw | Dibble | Rice seeds | Maize seeds | Hires | Idle | Herbicides | Rice yields | Maize yields |
|---|---|---|---|---|---|---|---|---|---|
| Demographic composition | | | | | | | | | |
| # women≥16y | 0.015 | -0.022 | -0.002 | 0.016 | 0.029 | 0.019 | 0.059 | 0.407 | 2.710 |
| | (0.026) | (0.021) | (0.021) | (0.027) | (0.027) | (0.025) | (0.061) | (0.394) | (3.561) |
| # men≥16y | -0.018 | 0.025 | -0.039* | -0.008 | -0.023 | 0.027 | -0.011 | -0.114 | 1.043 |
| | (0.023) | (0.020) | (0.021) | (0.018) | (0.022) | (0.025) | (0.047) | (0.340) | (3.321) |
| # girls<16y | 0.019* | 0.015 | 0.011 | -0.013 | 0.011 | -0.012 | -0.013 | 0.031 | 2.571 |
| | (0.011) | (0.017) | (0.015) | (0.017) | (0.019) | (0.016) | (0.033) | (0.287) | (3.165) |
| # boys<16y | -0.010 | 0.017 | -0.021 | -0.029* | -0.047** | 0.038** | 0.019 | -0.525 | 1.794 |
| | (0.014) | (0.018) | (0.016) | (0.015) | (0.020) | (0.016) | (0.032) | (0.449) | (2.433) |
| Commercial wealth | 0.012** | -0.002 | -0.002 | -0.003 | 0.009 | 0.007 | 0.000 | 0.011 | -0.144 |
| | (0.005) | (0.006) | (0.004) | (0.005) | (0.006) | (0.006) | (0.000) | (0.079) | (0.864) |
| Schooling | 0.010 | 0.010 | 0.004 | 0.017 | 0.015 | -0.007 | 0.010 | 0.065 | 0.889 |
| | (0.009) | (0.010) | (0.008) | (0.016) | (0.013) | (0.009) | (0.022) | (0.161) | (1.545) |
| Change per year | 0.007 | -0.003 | -0.004 | -0.000 | -0.014** | -0.021*** | 0.032*** | -0.132 | -1.273 |
| | (0.005) | (0.005) | (0.006) | (0.007) | (0.006) | (0.007) | (0.009) | (0.101) | (1.026) |
| Constant | -14.163 | 6.752 | 8.941 | 0.396 | 27.950** | 42.465*** | -63.12*** | 272.860 | 2,569.546 |
| | (10.612) | (10.963) | (11.450) | (14.829) | (12.544) | (13.884) | (18.512) | (202.692) | (2,054.715) |
| | | | | | | | | | |
| Observations | 1,412 | 1,412 | 1,319 | 715 | 1,412 | 999 | 593 | 1,318 | 707 |
| R-squared | 0.023 | 0.006 | 0.008 | 0.009 | 0.018 | 0.027 | 0.116 | 0.007 | 0.007 |
| Number of households | 308 | 308 | 301 | 244 | 308 | 285 | 295 | 301 | 241 |
| Test of joint significance: | | | | | | | | | |
| Adults=children | | | | | | | | | |
| Chi2 | 0.121 | 0.540 | 0.560 | 1.321 | 0.853 | 0.162 | 0.271 | 1.265 | 0.00720 |
| p-value | 0.728 | 0.463 | 0.455 | 0.251 | 0.356 | 0.687 | 0.603 | 0.262 | 0.932 |
| Females=males | | | | | | | | | |
| Chi2 | 1.571 | 1.352 | 2.397 | 0.882 | 3.906 | 1.855 | 0.122 | 1.152 | 0.173 |
| p-value | 0.211 | 0.246 | 0.123 | 0.349 | 0.0490 | 0.174 | 0.727 | 0.284 | 0.678 |

Table 6.14. Association between demographic composition of household and horticultural intensification: Results of panel regressions with household fixed effects and control variables

Notes: Same regressions as in Table 6.9, but with the variable for household size dropped; instead, the number of girls, boys, adult men, and adult women in the household are included. y=years. Test of joint significance refers to the four demographic groups. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.10$. In regression with herbicides as an outcome, I lag by one year the explanatory variables. See Appendix A for details of the approach. Commercial wealth is in 1000 of bolivianos (1 US dollar ≈ 7 bolivianos).

Table 6.15. Association between household demographic composition and horticultural intensification: Results of panel regressions with household and year fixed effects and control variables

| Explanatory variables: | Chainsaw | Dibble | Rice seeds | Maize seeds | Hires | Idle | Herbicides | Rice yields | Maize yields |
|---|---|---|---|---|---|---|---|---|---|
| Demographic composition | | | | | | | | | |
| # women≥16y | 0.015 | -0.021 | -0.002 | 0.012 | 0.028 | 0.012 | 0.057 | 0.395 | 2.058 |
| | (0.026) | (0.021) | (0.021) | (0.026) | (0.027) | (0.025) | (0.061) | (0.386) | (3.596) |
| # men≥16y | -0.016 | 0.030 | -0.040* | -0.012 | -0.021 | 0.020 | -0.014 | -0.112 | 1.363 |
| | (0.023) | (0.019) | (0.021) | (0.020) | (0.022) | (0.025) | (0.048) | (0.333) | (3.574) |
| # girls<16y | 0.019* | 0.015 | 0.011 | -0.013 | 0.011 | -0.010 | -0.014 | 0.032 | 2.738 |
| | (0.011) | (0.017) | (0.015) | (0.016) | (0.019) | (0.015) | (0.033) | (0.285) | (3.033) |
| # boys<16y | -0.007 | 0.020 | -0.020 | -0.032** | -0.044** | 0.034** | 0.019 | -0.508 | 1.827 |
| | (0.015) | (0.018) | (0.016) | (0.016) | (0.020) | (0.016) | (0.032) | (0.446) | (2.316) |
| Commercial wealth | 0.014*** | -0.004 | -0.000 | -0.004 | 0.012** | 0.009 | 0.000 | -0.128 | -1.480 |
| | (0.005) | (0.007) | (0.004) | (0.007) | (0.006) | (0.007) | (0.000) | (0.094) | (1.176) |
| Schooling | 0.010 | 0.009 | 0.005 | 0.017 | 0.016 | -0.007 | 0.011 | 0.040 | 0.929 |
| | (0.009) | (0.010) | (0.008) | (0.016) | (0.013) | (0.009) | (0.022) | (0.154) | (1.628) |
| Change per year | 0.002 | 0.001 | -0.005 | 0.006 | -0.020*** | -0.017** | 0.032*** | 0.259* | 1.069 |
| | (0.006) | (0.007) | (0.007) | (0.009) | (0.007) | (0.008) | (0.009) | (0.145) | (1.683) |
| Constant | -4.723 | -0.443 | 9.590 | -11.236 | 40.845*** | 33.539** | -63.98*** | -510.312* | -2,120.374 |
| | (12.229) | (13.290) | (13.437) | (18.619) | (14.004) | (16.376) | (18.495) | (290.544) | (3,372.019) |
| | | | | | | | | | |
| Observations | 1,412 | 1,412 | 1,319 | 715 | 1,412 | 999 | 593 | 1,318 | 707 |
| R-squared | 0.036 | 0.010 | 0.011 | 0.024 | 0.028 | 0.045 | 0.117 | 0.057 | 0.039 |
| Number of households | 308 | 308 | 301 | 244 | 308 | 285 | 295 | 301 | 241 |
| Test of joint significance: | | | | | | | | | |
| Adults=children | | | | | | | | | |
| Chi2 | 0.121 | 0.462 | 0.636 | 1.075 | 0.801 | 0.0270 | 0.218 | 1.095 | 0.0259 |
| p-value | 0.728 | 0.497 | 0.426 | 0.301 | 0.371 | 0.870 | 0.641 | 0.296 | 0.872 |
| Females=males | | | | | | | | | |
| Chi2 | 1.286 | 1.812 | 2.338 | 0.960 | 3.570 | 1.636 | 0.121 | 1.208 | 0.0643 |
| p-value | 0.258 | 0.179 | 0.127 | 0.328 | 0.0598 | 0.202 | 0.729 | 0.273 | 0.800 |

Table 6.15. Association between household demographic composition and horticultural intensification: Results of panel regressions with household and year fixed effects and control variables

Notes: This is similar to Table 6.10, but with the variable for household size dropped; instead, the number of girls, boys, adult men, and adult women in the household are included. y=years. Test of joint significance refers to the four demographic groups. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.10$. In regression with herbicides as an outcome, I lag by one year the explanatory variables. See Appendix A for details of the approach. Commercial wealth is in 1000 of bolivianos (1 US dollar ≈ 7 bolivianos). Coefficient for individual years are not shown.

Table 6.16. Association between household dependency ratio (number of children/number of adults) and horticultural intensification: Results of panel regressions household and year fixed effects and control variables. Adults=age≥16y; children=age<16y

| Explanatory variable: | Chainsaw | Dibble | Rice seeds | Maize seeds | Hires | Idle | Herbicides | Rice yields | Maize yields |
|---|---|---|---|---|---|---|---|---|---|
| Dependency ratio | 0.006 | 0.009 | -0.004 | -0.045** | -0.013 | -0.015 | -0.010 | -0.241 | 4.521 |
| | (0.015) | (0.018) | (0.020) | (0.022) | (0.019) | (0.020) | (0.029) | (0.315) | (3.174) |
| Commercial wealth | 0.014** | -0.003 | -0.002 | -0.008 | 0.011* | 0.009 | 0.000 | -0.137 | -1.005 |
| | (0.006) | (0.007) | (0.005) | (0.006) | (0.006) | (0.007) | (0.000) | (0.096) | (1.108) |
| Schooling | 0.010 | 0.012 | 0.001 | 0.012 | 0.014 | -0.008 | 0.013 | 0.025 | 1.718 |
| | (0.009) | (0.010) | (0.007) | (0.014) | (0.013) | (0.010) | (0.022) | (0.151) | (1.716) |
| Change per year | 0.004 | -0.001 | -0.002 | 0.010 | -0.019*** | -0.017** | 0.033*** | 0.273* | 0.738 |
| | (0.006) | (0.007) | (0.006) | (0.009) | (0.007) | (0.008) | (0.009) | (0.154) | (1.663) |
| Constant | -7.198 | 1.967 | 4.553 | -19.426 | 37.225*** | 34.080** | -66.13*** | -539.66* | -1,453.391 |
| | (12.880) | (13.053) | (12.889) | (17.021) | (14.256) | (16.785) | (18.209) | (308.526) | (3,331.216) |
| Observations | 1,412 | 1,412 | 1,319 | 715 | 1,412 | 999 | 593 | 1,318 | 707 |
| R-squared | 0.033 | 0.006 | 0.004 | 0.024 | 0.020 | 0.039 | 0.110 | 0.053 | 0.038 |
| Number of households | 308 | 308 | 301 | 244 | 308 | 285 | 295 | 301 | 241 |

Notes: The regressions are similar to the regressions in tables 6.10 and 6.15, with one difference: here I use the dependency ratio as a demographic variable instead of household size (Table 6.10) or the number of girls, boys, adult men, and adult women in the household (Table 6.15). y=years. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. In regression with herbicides as an outcome, I lag by one year the explanatory variables. See Appendix A for details of the approach. Commercial wealth is in 1000 of bolivianos (1 US dollar ≈ 7 bolivianos). Coefficient for individual years are not shown.

Table 6.17. Association between household dependency ratio (number of children/number of adults) and horticultural intensification: Results of panel regressions with household and year fixed effects and control variables. Adults=age≥13y; children=age<13y

| Explanatory variables: | Chainsaw | Dibble | Rice seeds | Maize seeds | Hires | Idle | Herbicides | Rice yields | Maize yields |
|---|---|---|---|---|---|---|---|---|---|
| Dependency ratio | -0.038** | 0.003 | -0.015 | -0.061** | -0.013 | -0.011 | 0.007 | 0.522 | 6.628 |
| | (0.017) | (0.020) | (0.025) | (0.026) | (0.021) | (0.020) | (0.041) | (0.360) | (4.502) |
| Commercial wealth | 0.013** | -0.003 | -0.002 | -0.006 | 0.011* | 0.010 | 0.000 | -0.113 | -1.175 |
| | (0.006) | (0.007) | (0.005) | (0.006) | (0.006) | (0.007) | (0.000) | (0.091) | (1.148) |
| Schooling | 0.008 | 0.012 | 0.001 | 0.014 | 0.015 | -0.007 | 0.014 | 0.045 | 1.485 |
| | (0.009) | (0.009) | (0.007) | (0.014) | (0.013) | (0.009) | (0.021) | (0.148) | (1.682) |
| Change per year | 0.005 | 0.000 | -0.002 | 0.007 | -0.019*** | -0.018** | 0.032*** | 0.245* | 0.963 |
| | (0.006) | (0.006) | (0.007) | (0.008) | (0.007) | (0.008) | (0.009) | (0.144) | (1.687) |
| Constant | -10.007 | 0.772 | 4.492 | -14.890 | 38.486*** | 35.566** | -63.774*** | -483.578* | -1,904.760 |
| | (12.746) | (12.607) | (13.076) | (16.995) | (14.015) | (16.504) | (17.890) | (288.686) | (3,376.200) |
| Observations | 1,412 | 1,412 | 1,319 | 715 | 1,412 | 999 | 593 | 1,318 | 707 |
| R-squared | 0.039 | 0.006 | 0.005 | 0.026 | 0.020 | 0.038 | 0.110 | 0.055 | 0.040 |
| Number of households | 308 | 308 | 301 | 244 | 308 | 285 | 295 | 301 | 241 |

Notes: The regressions are identical to the regressions in Table 6.16, with one difference: here I define a dependent as a person age<13y and an adult as a person age≥13y. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. In regression with herbicides as an outcome, I lag by one year the explanatory variables. See Appendix A for details of the approach. Commercial wealth is in 1000 of bolivianos (1 US dollar ≈ 7 bolivianos). Coefficient for individual years are not shown.

Table 6.18. Associations between indexes of horticultural diversification in last farming cycle and the natural logarithm of the inflation-adjusted (real) value of current food consumption: Results of panel regressions with household and year fixed effects

| Explanatory variables: | [1] | [2] |
|---|---|---|
| Number of major crops planted | 0.036* | |
| | (0.022) | |
| Dummy variable if household planted: | | |
| Rice | | 0.139* |
| | | (0.082) |
| Maize | | -0.047 |
| | | (0.039) |
| Manioc | | 0.121*** |
| | | (0.039) |
| Plantains | | -0.000 |
| | | (0.053) |
| Total number of minor crops planted | 0.042*** | 0.040*** |
| | (0.013) | (0.013) |
| Number of plots cleared | 0.007 | 0.005 |
| | (0.027) | (0.027) |
| Change per year | 0.110*** | 0.109*** |
| | (0.012) | (0.012) |
| Constant | -216.595*** | -214.318*** |
| | (23.522) | (23.386) |
| Observations | 1,729 | 1,729 |
| R-squared | 0.183 | 0.189 |
| Number of households | 381 | 381 |

Notes: The outcome is the monetary value of the following foods consumed by the household during the seven days before the interview: beef, bread, cow heads, sun-dried meat, eggs, flour, lard, maize, manioc, noodles, oil, rice, sardines, sugar, and fish. Explanatory variables refer to the last farming cycle. Nominal yearly monetary values converted to inflation-adjusted (real) values using the CPI deflator of Bolivia's Instituto Nacional de Estadística (INE, 2017). Base value, 1990=100. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. Coefficient for individual years are not shown.

**Appendix A**
**Statistical approach to test the hypotheses of Boserup and Chayanov**
**(Table 6.8-6.18)**

Dealing with time mismatch. In the survey, the recall period used to gather data for variables about horticulture did not match the recall period used to collect data for the explanatory variables, such as household size, schooling, or wealth. The mismatch required reshaping the longitudinal information before one could analyze it. In Table A.1 I use hypothetical data on household size (explanatory variable) and deforestation (outcome variable) from the 2004-2007 surveys to show how I changed the structure of the data set so that the explanatory variable would take place before the outcome. The information refers to one household.

Table A.1. Numerical and visual hypothetical example of how data was re-shaped

| A. Original data collected in survey | | | | B. Re-shaped data in the statistical analysis | | | |
|---|---|---|---|---|---|---|---|
| Year | Household size at time of survey | *Deforestation (ha)* | | Year | Household size at time of survey | *Deforestation (ha)* | |
| | | *Area* | *Refers to year* | | | *Area* | *Refers to year* |
| 2004 | 6 | *0.8* | *2003* | 2004 | 6 | *0.9* | *2005* |
| 2005 | 5 | *1.0* | *2004* | 2005 | 5 | *0.8* | *2006* |
| 2006 | 6 | *0.9* | *2005* | 2006 | 6 | * | *2007* |
| 2007 | 4 | *0.8* | *2006* | 2007 | 4 | * | *2008* |

Note: * = missing value. ha=hectares

We did the surveys during the dry season, from May until August, when households were clearing forest for the next farming cycle. Because of the survey's timing, questions about horticulture referred to the latest planting cycle. For example, the recall period for question asked during May-August, 2005, about the amount of forest cleared by a household referred to the amount cleared in 2004, not to the amount cleared in 2005, since households were in the midst of forest clearing when we surveyed them. Nevertheless, answers to questions about explanatory variables for the analysis of horticulture referred to the time and day when we did the survey. For instance, during the 2005 survey we computed how many people lived in the household at the time of the survey. With the original data collected in the survey (Table A.1, section A), we could have estimated the correlation between household size today (explanatory variable) and deforestation a year ago (outcome variable), computationally doable, but conceptually odd since the cause should take place before the effect.

To estimate the effect of explanatory variables on horticultural outcomes, with information on explanatory variables referring to a period that came after the outcomes, I had to move horticultural outcomes by two years, such that explanatory variables that referred to the instant when we asked the question (e.g., 2005) were matched with horticultural outcomes that referred to a later period (e.g., 2006). So reformed, the data set had explanatory variables that pertained to a period that came before the outcomes, allowing for sensible analyses. I could have moved horticultural outcomes by one year instead of two years, and assess contemporaneous associations between explanatory variables and outcomes. In the example above, I could have matched household size in 2005 (five people) with information gathered in 2006 about deforestation in 2005 (0.9 hectares), but that approach would have enfeebled our understanding of cause and effect since we would not know whether household size changed deforestation, or deforestation household size. The gain of moving values by two years comes at the cost of having a smaller sample. In Table A.1, we can see that moving horticultural values by two years means that we cannot use information collected during 2004-2005, so the sample size shrinks by 50%.

Because we collected information on chemical herbicides only during three years (2003-2004 and 2010)(Table 6.5), following the approach just described would have meant losing two thirds of the sample (years 2003-2004). To avoid losing data, I left data on chemical herbicides collected during the three yearly surveys, but I lagged by one year explanatory variables. This produced a data set in which herbicide use and explanatory variables occurred during the same planting cycle.

Test of non-linearity for household size. I included a quadratic term for household size to find out if horticultural outcomes and household size bore a non-linear (parabolic) relation, and found that generally they did not. This explains why I only include household size to test Boserup's hypothesis.

Fixed features of household. For substantive reasons discussed in the chapter, I want to rein in the effect of unchanging features of households. This wish trumps the technical concern of whether I should use a regression with household fixed effects or with household random effects (Hausman, 1978).

Definition of variables and summary statistics. Table A.2 contains definition of the variables used in the statistical analysis, and the years in which we measured them. Table A.3 contains summary statistics of outcomes and the main explanatory variables.

Table A.2. Definition of variables from longitudinal study used in the regressions of Tables 6.8-6.18, and years measured

| Name | Definition | Years |
|---|---|---|
| **A. Outcomes: Indicators of horticultural intensification during the latest farming cycle** | | |
| Chainsaw | Household used a chainsaw to clear forest. 1=yes; 0=no | 03-10 |
| Dibble | Household used a commercial digging stick (dibble) with a metal tip. 1=yes; 0=no | 03-10 |
| Rice seeds | Household used its own rice seeds from last harvest (rather than buy or borrow seeds). 1=yes; 0=no | 02-10 |
| Maize seeds | Household used its own maize seeds from last harvest (rather than buy or borrow seeds). 1=yes; 0=no | 02-10 |
| Hires | Household hired workers for any farming task. 1=yes; 0=no | 03-10 |
| Idle | Household left idle or unused some of the forest area it had cleared. 1=yes; 0=no | 06-10 |
| Herbicides | Household used commercial chemical herbicides for rice. 1=yes; 0=no | 03-04, 10 |
| Rice yields | Arrobas per tarea harvested. 1 arroba=11.5 kg. 10 tareas=1 hectare | 04-10 |
| Maize yields | Mancornas per tarea harvested. 1 mancorna=2.1 kg. 10 tareas=1 hectare | 04-10 |
| **B. Other outcomes: Total area of forest cleared (Table 6.13) and real value of food consumption (Table 6.18)** | | |
| Area | Total includes area from old-growth and fallow forest, and is measured in tareas (10 tareas=1 hectare) | 02-10 |
| Food | Inflation adjusted (real) monetary value (in bolivianos) of household consumption of the following foods during the 7 days before the interview: beef, bread, cow heads, sun-dried meat, eggs, flour, lard, maize, manioc, noodles, oil, rice, sardines, sugar, and fish. Base value, 1990=100. Deflators from INE (2017). | 02-10 |
| **C. Explanatory variables: Demography** | | |
| Household size | Number of people present in the household at the time of the yearly survey. | 02-10 |
| Women | Number of women age≥16 years living in the household at the time of the yearly survey | 02-10 |
| Men | Number of men age≥16 years living in the household at the time of the yearly survey | 02-10 |
| Girls | Number of girls age<16 years living in the household at the time of the yearly survey | 02-10 |
| Boys | Number of boys age<16 years living in the household at the time of the yearly survey | 02-10 |
| Dependency ratio | The ratio of (Number of children age<16 years)/(Number of adults age≥16 y) living in the household at the time of the yearly survey | |
| **D. Explanatory variables: Controls** | | |
| Commercial wealth | The nominal current yearly monetary value of the following commercial assets owned by all adults in the household: bicycles, shotguns, rifles, large cooking pots, mosquito nets, cutlasses, axes, fishing nets, radios, watches, grinders, knives, and fishing hooks. | 02-10 |
| Total wealth | The nominal current yearly monetary value of commercial wealth (as in previous row), plus the value of domesticated animals (chickens, ducks, cattle, swine) and physical assets made from local materials (canoes, mortars, cotton bags, stone grinders, bows and arrows) | 02-10 |
| Schooling | The median level of completed grades of schooling among adults in a household at the time of the yearly survey | 02-10 |
| **E. Other explanatory variables (Table 6.18)** | | |
| Major | Total number of major crops planted (rice, maize, manioc, plantains) | 04-10 |
| Rice | Did household plant rice? 1=yes; 0=no | 04-10 |
| Maize | Did household plant maize? 1=yes; 0=no | 04-10 |
| Manioc | Did household plant manioc? 1=yes; 0=no | 02-10 |
| Plantains | Did household plant plantains? 1=yes; 0=no | 02-10 |
| Minor | Total number of minor crops planted | 04-10 |
| Plots | Total number of plots cleared from the forest | 02-10 |

Table A.3. Summary statistics of outcomes and main explanatory variables

| | N | Mean | SD/a/ |
|---|---|---|---|
| A. Outcome: Indicators of agricultural intensification | | | |
| Chainsaw | 1954 | 0.09 | 0.29 |
| Dibble | 1954 | 0.81 | 0.39 |
| Rice seeds | 2040 | 0.11 | 0.31 |
| Maize seeds | 1177 | 0.08 | 0.27 |
| Hires | 1954 | 0.16 | 0.36 |
| Idle | 1241 | 0.08 | 0.27 |
| Herbicides | 673 | 0.26 | 0.44 |
| Rice yields | 1618 | 7.75 | 5.29 |
| Maize yields | 868 | 31.52 | 59.13 |
| B. Other outcomes: | | | |
| Area | 2192 | 9.94 | 7.02 |
| Food | 2235 | 57.77 | 58.68 |
| C. Explanatory variables: Demography, commercial wealth and schooling | | | |
| Household size | 2261 | 5.91 | 2.71 |
| Women | 2261 | 1.24 | 0.63 |
| Men | 2261 | 1.24 | 0.66 |
| Girls | 2261 | 1.67 | 1.37 |
| Boys | 2261 | 1.76 | 1.52 |
| Dependency ratio | 2255 | 1.49 | 1.05 |
| Commercial wealth | 2261 | 2590.71 | 2406.55 |
| Total wealth/b/ | 2261 | 3.86 | 3.74 |
| Schooling | 2226 | 2.11 | 2.04 |

Notes: /a/ SD=standard deviation. /b/ In 1000s of bolivianos

# Appendix B
# Guide to tables and figures for Chapter 6

| *Table* | *Figure* | *Discussion in end notes or text* | *1st line: Folder*<br>*2nd line: Name of Stata do file* | *Comment; in most cases search for table or figure # in Stata do file* |
|---|---|---|---|---|
| 6.1-<br>6.2 | | | AreaCleared:<br>DoAgriculture_area_cleared_V1 | Search for table numbers |
| | 6.1a-<br>6.3c | | AreaCleared:<br>DoAgriculture_area_cleared_V1 | Search for figure number |
| 6.3 | | | MainCrops:<br>DoMainCrops_and_Inputs_V3 | Search for table number |
| 6.4 | | | MinorCrops:<br>DoMinorCrops_V1 | Search for table number |
| 6.5 | | | Inputs:<br>DoInputs_V3 | Search for table number |
| | | Who decides on size of forest clearance (p. 5). | Inputs:<br>DoInputs_V3 | Search for "Agreement of wife and husband in TIM data" |
| | 6.4a-<br>6.5d | | MainCrops_And_Inputs<br>DoMainCrops_and_Inputs_V3 | Search for figure number |
| | | Analysis of open-ended questions re minor crops | MinorCrops:<br>DoMinorCrops_V1 | Search for "open-ended questions" |
| | 6.6a-<br>6.6e | | MinorCrops:<br>DoMinorCrops_V1 | Search for figure number |
| | | Relation between use of chainsaws & type of forest cleared | Inputs<br>DoInputs_V3 | Search for the words in the third column |
| | 6.7 | | Inputs<br>DoInputs_V3 | Search for figure number |
| | 6.7a-<br>6.7c | | Inputs<br>DoInputs_V3 | Search for figure number |
| | 6.8a-<br>6.9h | | Yields_harvest_losses_sales_Main_Crops<br>Yields_harvest_losses_sales_Main_Crops_V2 | |
| | 6.10a-<br>6.10i | | Boserup<br>Boserup_V22 | |
| 6.6 | | | Yields_harvest_losses_sales_Main_Crops<br>Yields_harvest_losses_sales_Main_Crops_V2 | |
| 6.7 | | | Yields_harvest_losses_sales_Main_Crops<br>Yields_harvest_losses_sales_Main_Crops_V2 | Rice & maize growth rates |
| | | | AreaCleared<br>DoAgriculture_area_cleared_V2 | Area of forest and idle lands growth rates |
| 6.8 | | | Yields_harvest_losses_sales_Main_Crops<br>Yields_harvest_losses_sales_Main_Crops_V2 | Search for figure number |
| 6.9-<br>6.18 | | | Boserup<br>Boserup_V22 | Search for figure number |
| | | Relation between household size & deforestation | Boserup<br>Boserup_V22 | Variant of Table 6.13 |
| | | Test household size$^2$ | Boserup<br>Boserup_V22 | Search for "Testing quadratic term for household size" |
| A.3 | | | Boserup<br>Boserup_V22 | Table A.3 |

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[i] The day chosen at random to record consumption varied between and within the two villages, but each quarter researchers collected data on households in both villages. On the day researchers observed a household, they jotted down all the goods entering the household, and used village selling prices to impute a monetary value to goods that had a village price. If the village lacked a price for the good, then the team asked the person bringing the good about the time it had taken to fetch the good, and used the current village wage to impute a value to the time it had taken to find the good in the commons, and transport it back home. Researchers used the monetary value of foraging time to value the good. Reyes-García (2001, pp. 39, 76-77) and Byron (2003, pp. 50-51) acknowledge the biases from the method of imputing values, but they also acknowledge the usefulness of the method for assessing the makeup of consumption among people who do not rely heavily on market transactions. The method of imputing value to goods without a market price might introduce measurement error into the value of the good, but the method should not affect the comparison of consumption between the two villages since researchers followed the same steps to gather information in the two villages.

[ii] The weight of horticulture also shows up in the high share of time adults allocate to horticulture and foraging -- both reach 22% (Vadez & Fernández-Llamazare, 2014, p. 151) -- and in the higher share of monetary earnings from the sale of farm crops and domesticated animals (53%) than from the sale of forest goods (47%) (Reyes-García, 2001, p. 83). Richard Piland (1991, p. 64), who did fieldwork in villages near the town of San Borja between September 1988 and August 1989, says that the bulk of calories came from farming, a finding supported by the research of Lisa Ringhofer in 2004 in the village of Campo Bello, also near the town of San Borja. Ringhofer found that more than 80% of nutritional energy came from agriculture (Fischer-Kowalski et al., 2011, p. 153).

[iii] A deep thinker, Ester Boserup thought that the swelling of a population changed agriculture, but acknowledged that causality could run the other way around, from agriculture to population swelling, and that confounders muddled findings about the nexus between farming and population. On causality, she thought her hypothesis that population growth changed agriculture rested on “a more realistic and fruitful” assumption of reality than other explanations (Boserup, 1965, p. 11). She saw “medical invention” as the “autonomous” force behind population growth (Boserup, 1965, pp. 11-12), and perhaps for this reason felt comfortable saying that population growth -- stimulated by medical breakthroughs over which farming households had no say -- changed farming. She admitted that markets shaped food production in tribal settings (Boserup, 1990, p. 70), but she did not spell out her thinking. When discussing population growth and horticulture in “primitive societies”, she acknowledged that war, migration, towns, and stratification provided other means for easing population pressure (Boserup, 1990, pp. 77-90). Translating her insights into current technical jargon, Boserup seems to have been saying that one could use medical innovations as an instrumental variable for population growth while controlling for third variables that could undermine the validity of the instrumental variable.

[iv] I use the terms planting and sowing interchangeably.

[v] Old-growth forest and fallow forest differ along three dimensions: disturbance, gaps, and tree height (Paneque-Gálvez et al., 2013, p. 114). Old-growth forests have few disturbances and gaps,

and their trees reach 10-40 meters in height. Fallow or early-growth forests have been disturbed by humans or by nature, contain more gaps, and have shorter trees (3-10 meters).

[vi] I use the terms major and minor crops as a short-hand to distinguish staple crops one likely finds at almost any meal from other crops, which, though valuable from other points of view, are less likely to be found in a daily meal.

[vii] Since spouses could hear and mimic each other's answers, we also coded for the presence of the other spouse. The figures refer to answers given by household heads when answering alone. If we restrict the analysis to what the wife and the husband said about each other as decision makers in forest clearance, we find little disagreement. In only 2.3% of cases did one spouse consider herself or himself as the major decision maker while the other spouse thought differently. We have not yet released the information from the survey in the Territorio Indígena Multiétnico, but at least one publication has come out of that research (Bauchet et al., 2017).

[viii] Outliers did not affect growth rates. In 2002, one household reported clearing 100 tareas of old-growth forest and in 2008 one household reported clearing 60 tareas of fallow forest. Removing the outliers produced an annual growth rate for clearing from old-growth forest of 4.3% (p=0.001; n=1,255) and a growth rate for clearing from fallow forest of 1.6% (p=0.029; n=1,804).

[ix] For rice, I dropped 15 observations (n=2,051 to 2,036) >30 tareas, for manioc I dropped 16 observations (n=1,141 to 1,125) ≥10 tareas, and for plantains I dropped 23 observations (n=2,036 to 2,013) >20 tareas.

[x] A probit regression with area of fallow forest and old-growth forest cleared as predictors suggests that an additional tarea of fallow forest cleared (above the mean of 5.71 tareas) and an additional tarea of old-growth forest cleared (above the mean of 5.24 tareas) were associated with a 0.2% (p=0.01) and a 1.1% (p=0.001) greater probability of using a chainsaw (n=2311). The regression included robust standard errors, clustering by household, and controlled for survey year and study.

[xi] To test the hypothesis that health mattered, I ran a probit regression with a binary variable as an outcome, which took the value of one if the household had hired a worker, and zero otherwise. As explanatory variables, I included the number of adult women and men in the household at the time of the interview, the total number of bed-ridden days for women and men during the seven days before the interview, the monetary value of household wealth at the time of the survey, and variables for the year of the survey and a binary variable for the study (randomized control trial or longitudinal study). The regression was run with contemporaneous value for all variables, clustering by household, and robust standard errors (n=1,289). The regression produced no significant results for the number of bed-ridden days of women or men. In Tables 6.10 and 6.15 I provide stronger tests of the effects of demography and household wealth on the probability of hiring farmhands.

[xii] The share of households that sold more rice or maize than what they harvested were 0.51% (10 out of 1,956) for rice and 2.01% for maize (21 out of 1,042).

[xiii] If households had not finished harvesting maize or rice, surveyors estimated the potential harvest from the un-harvested plots.

[xiv] To unclutter the box plots, in Figures 6.9a-6.9h I exclude outside values, defined as values lower than the inter-quartile range (IQR) - 1.5 IQR or higher than the upper IQR + 1.5 IQR.

[xv] Indeed, Zeng et al. (2012) found that among the Tsimane', having an older sibling (particularly an older brothers) predicted completing fewer school grades among younger siblings, probably because parents – impatient and hamstrung by time and income – deflected resources away from the younger to the older offspring.

[xvi] During each annual survey in the longitudinal study we asked adults 16 years of age and older (or younger if they headed a household) to tell us how many of the following commercial physical assets they owned at the time of the interview: bicycles, shotguns, rifles, large cooking pots, fishing nets, cutlasses, axes, mosquito nets, radios, watches, grinding mills, knives, and fishing hooks. People cannot make these assets at home and must buy them in the market. Because they are cognitively salient, because they have to be bought in the market, and because they are owned by the individual (as opposed to the household), they provide a reasonable proxy for a person's contact with the market. In some of the tables (e.g., Table 6.9-6.10) I use the total value of these assets, equal to the quantity of the items owned by the person times the village (or town) buying price of the item. Since the measure of commercial wealth came from each adult in the household, I added the annual value of commercial wealth of all adults in a household, and use that value for tables like 6.9-6.10. One problem with the annual measure of the value of commercial wealth owned by the household comes from measurement errors with prices. As described in Chapter 4, sometimes villages lacked a buying price for the asset. When this happened, we imputed prices to the village. To sidestep measurement errors with prices, I tried computing a principal component factor from the quantities of assets owned, but the assets did not correlate well with each other (Chronbach's alpha=0.58).

[xvii] The cleanest way to control for town nearness is to use household fixed effects, a statistical procedure that sweeps away the role of household traits that does not change, such as the distance from the house to the nearest town. Because travel time can vary between years owing to travel conditions in roads or rivers, I also use year fixed-effects in some of the statistical analysis. The approach erases the role of fixed traits in a year, such as a flood or epidemic that harmed one year, but not another.

[xviii] The p values were 2%.

[xix] Pérez-Diez (1983) who studied farming in Misión Fátima, a Catholic mission in the Maniqui River, came to the same conclusion (quoted in Piland, 1991, p. 24). See also Piland (1991, pp. 88-89) for the Tsimane' penchant for monocropping.

[xx] Tables 6.9 and 6.14-6.17 support these conclusions. Table 6.11 shows that wealth did not interact with demography or with survey year, and Table 6.13 shows that commercial wealth did not predict deforestation.

[xxi] Of the three measures of horticultural ardency predicted by commercial wealth -- chainsaws, chemical herbicides, and farmhands -- two were also predicted by some types of people in the household. Girls improved the chances of using chainsaws while boys lowered the chances of hiring workers (Tables 6.14-6.15). In none of the tables do we find evidence that household size or the separate number of women, girls, boys, and men predicted the use of chemical herbicides.