TOWARD LASTING REFORESTATION: GUIDING PRODUCTION STRATEGIES IN AGROFORESTRY NURSERIES AROUND RANOMAFANA NATIONAL PARK, MADAGASCAR

by

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Abstract

Agroforestry projects in Madagascar can address social and environmental threats from rainforest loss. This study aims to better align seedling production in agroforestry nurseries around Ranomafana N.P. with the planting preferences of local farmers. A social survey assessed current fruit cultivation and the fruit planting preferences of farmers, as well as differences in preferences based on distance to roads. Survey results from 200 households in 21 villages indicate current fruit cultivation does not correspond well with planting preferences. Households near and far from roads share similar cultivation patterns and planting preferences with one exception: farmers living far from roads prefer to plant coffee significantly more than do those living near roads. I attribute this preference for coffee cultivation far from roads to coffee's high sales price and relative ease of transport to buyers. This study produced a rank-ordered list of fruit preferences to guide nursery priorities across the study area, though nursery managers are encouraged to focus on coffee for remote planting projects.

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1. Introduction

The Island of Madagascar

Madagascar is a large island (592,800 sq. km) off the southeast coast of Africa, separated from the continent by the Mozambique Channel. Since the island split from India 88 million years ago (Storey et al 1995), Madagascar's flora and fauna have evolved in relative isolation, showing startling rates of endemism as a result. Approximately 90% of the island's 10,000 – 12,000 vascular plant species are endemic (Schatz 2000; Goodman and Benstead 2005); of the 5,800 macroinvertebrate species and 879 land vertebrate species that have been studied thus far, 86% and 84% are endemic, respectively (Goodman and Benstead 2005). These statistics combined with Madagascar's environmental challenges make the country one of the world's "hottest" biodiversity hotspots (Myers et al. 2000).

A large human population also calls Madagascar home. The Malagasy people number approximately 20 million, of 18 distinct ethnic groups and dialects. Their population is growing at 2.7% per year; at the current rate, this primarily agrarian people will double in numbers by 2040 (State.Gov 2012), and resource consumption is expected to increase proportionally.

Deforestation

Deforestation may be the most pressing threat to biodiversity and human populations in Madagascar. Estimates of deforestation extent vary, based on differing pre-human forest area baselines, but it is probable that 70-90% of the original forests have disappeared (Kull 2000; Harper et al 2007); the current extent of forested land in Madagascar is c. 99,000 –125,530 sq. km (Harper et al 2007) and the current rate of forest cover lost is 0.45% per year (FAO 2010). It is widely agreed that Malagasy forests are in danger. Though the ultimate causes are debated among conservationists, historians and anthropologists, unsustainable subsistence agriculture based on fire remains the clear, immediate driver of deforestation (Kull 2000; Styger et al 2009; Peters 1999; Gezon and Freed 1999; Nambena 2003; Jarosz 1993; Holloway 2004; etc.). In the central highlands and western plains and forests, deforestation is driven by farmers burning

vegetation every year to promote cattle forage, and harvesting trees for charcoal (Kull 2000). In the humid eastern forests, slash-and-burn farming, called *tavy*, is the prominent agricultural technology and leading cause of deforestation (Styger et al 2007). In this system, primary and secondary vegetation is cleared to make way for rice (the Malagasies' staple food), manioc, or sweet potato cultivation.

Instead of an applied fertilizer, *tavy* fire releases resources held in aboveground biomass back into the soil via ash. The land is exposed to the sun and it heats up, speeding decomposition of un-burnt litter and soil organic matter. Thus, immediately after a fire, the soil holds elevated levels of nutrients. In this state of increased nutrient availability and decreased competition, the *tavy* field is primed for agriculture (Palm et al 1996; Nye and Greenland 1960).

Crops deplete most of the available nutrients in the first year, and these are not replenished while the field is under cultivation. After a few seasons of planting, the field is left to fallow. Under long fallow rotations, this system can be sustainable. However, fallow periods in eastern Madagascar have been shortening from 8-20 years in the 1970's to 3-5 years in 2009 (Styger et al 2009; Nambena 2003). This means that neither an overstory canopy nor stabilizing roots have time to develop, and the ground is left exposed to the rainy season's deluge. Under such conditions, the land degrades and productivity declines in a few short years as the ferralitic soils erode and nutrients are leached away. Runoff sediments pollute waterways, and mudslides destroy roads and buildings; entire crop fields disappear. The degradation leads farmers to cut and cultivate more forest, perpetuating the pattern (Randrianarijaona 1983, Kull 2000, Styger et al. 2007).

Agroforestry

Agroforestry systems address the immediate causes of deforestation by supplying sustainable income and nutrition to farmers, as well as protecting soils and replenishing nutrients. Agroforestry is a broad term for land use that combines the interactive benefits of agricultural and forestry practices (Young 1989). In eastern Madagascar near Ranomafana National Park (RNP), agroforestry systems are usually mixed stands of native forest trees and exotic woody

and non-woody fruit plants. The native trees are opportunistically involved in the system to shade crops like coffee and vanilla, but most fruit trees are planted. These fruits are usually exotic (e.g. citrus, banana, avocado, mango, etc.), but they are also naturalized and non-invasive in the area. Moreover, these agroforestry orchards' roots stabilize soils and increase infiltration; their canopies shield the soil from sun, wind, and rain; and their litterfall replenishes the soil organic material (Young 1989).

Produce from these agroforestry orchards can comprise a substantial portion of farmer income when farmers are able to transport their produce to wider markets (Nambena 2003). Around RNP, these markets are most commonly accessible via middlemen in trucks traveling the improved roads; the middlemen buy produce from farmers to sell in the major cities and to juice manufacturers. Thus, distance to roads and transportability of fruits probably impacts species compositions in agroforestry systems across the landscape.

Most exotic fruits grown in agroforestry systems require specialized propagation techniques (e.g. grafting, air-layering) to efficiently produce marketable quantity and quality. Technical propagation training is rare around RNP, and fruit quantity and variety are limited as a result. "Friends of Madagascar" (FOM) is a non-profit organization promoting agroforestry projects around RNP by providing technical fruit propagation training and boosting fruit supply and variety in the area via nurseries. In 2010-2011, FOM established two production nurseries, including one in partnership with another local NGO, Centre ValBio (CVB). Seedlings from these nurseries were given to partnering farmer associations to stimulate their agroforestry systems. After a year of production, FOM sought to evaluate the state of agroforestry production in its sphere of influence and to modify seedling production accordingly. The aim of this study is to better align seedling production in agroforestry nurseries around RNP with the preferences of local farmers.

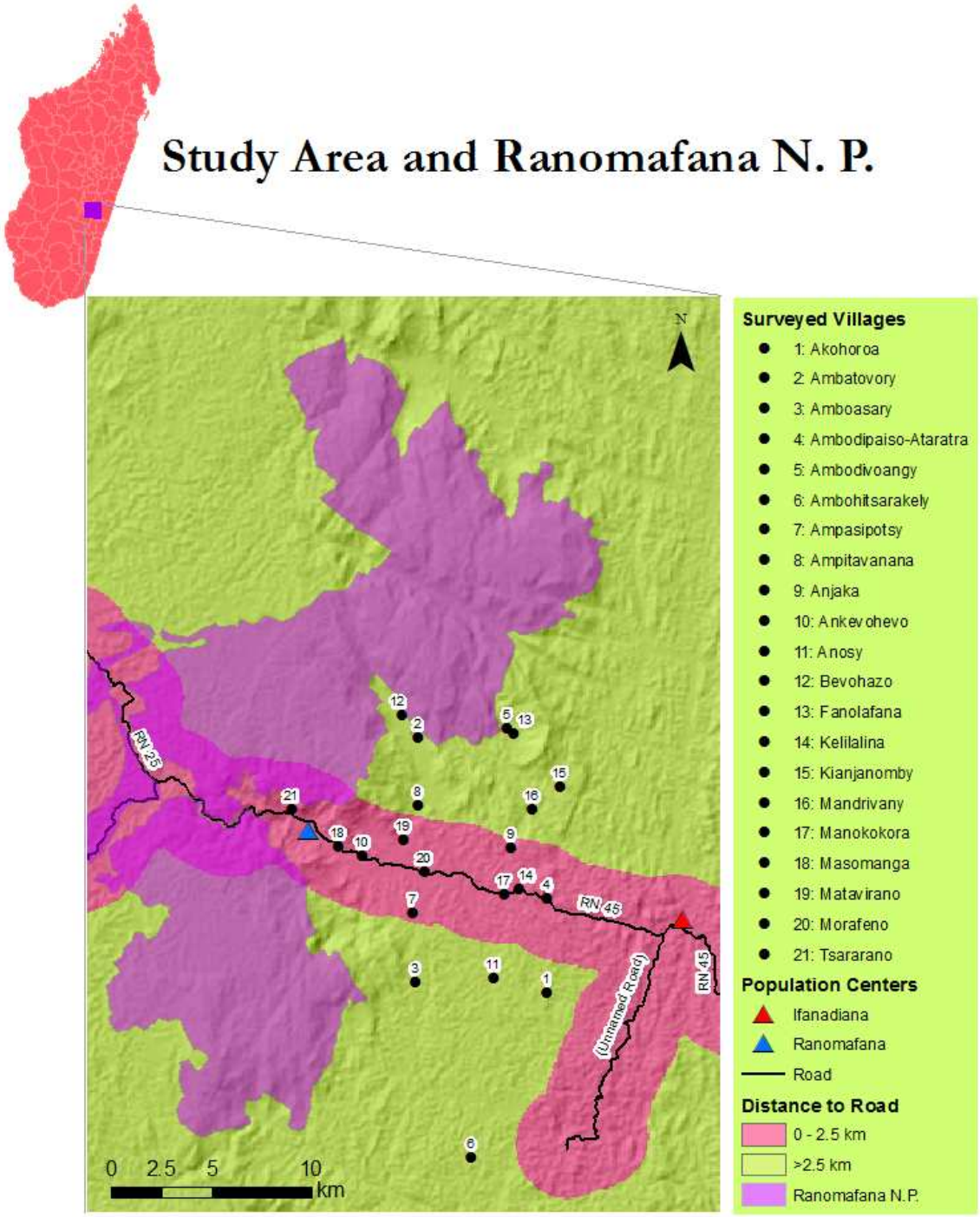
2. Study Area

Ranomafana National Park

Ranomafana National Park (RNP) is a montane rainforest preserve in southeastern Madagascar, in the Fianarantsoa region. It covers 41,600 hectares on the highland plateau's eastern escarpment (ANGAP 2003). The park was established in 1991 after a new species, the golden bamboo lemur, was discovered in the area. As part of the Madagascar National Parks (MNP) system, resource extraction from RNP is restricted (ANGAP 2003). These restrictions strain local populations who used to collect fuel and timber and practice *tavy* in the forest. Resource use has been leaked to and intensified in the areas around the park. Beyond park boundaries, the landscape is almost entirely deforested, either planted with annual crops or fallowing. Approximately 26,000 thousand people live in the two communes studied (Ministere de L'Interieur 2011).

Local Agroforestry Nurseries

Friends of Madagascar established two agroforestry nurseries on the eastern side of RNP. The first was established in 2009 and is located at FOM headquarters in Mahatsinjorano (a.k.a. Madiorano) in the commune of Kelilalina. Eight kilometers west is the second nursery, established in 2010 and overseen by CVB, in the town of Ranomafana, commune of Ranomafana. Both nurseries sit next to Route National (RN) 45. Together these nurseries are capable of growing 4,000 seedlings at a time. Because seedlings are planted in growbags weighing 1-10 kg and are difficult to transport, the nurseries area focused on supplying trees to villages well within 10 km of the road. Furthermore, immediately south of RN 45 is the Namorana River, across which there are no permanent bridges in either commune. Therefore, any village 2.5 km from RN 45 is considered "far" by the NGO nurseries (Map 1).



Map 1. Study area and Ranomafana National Park, highlighting the surveyed villages and their Euclidean distances to roads. The RNP shapefile was provided by Brian Gerber. Projection: Geographic Coordinate System WGS 1984.

3. Methodology

Survey methods and questionnaire design

We conducted a social survey to investigate the current state of exotic fruit tree cultivation as well as preferences for future cultivation around RNP. After securing approval for research on human subjects from Duke's Institutional Review Board (IRB Approved Protocol A0463), local interviewers visited 21 villages within 7.5 km of improved roads on the eastern side of RNP (Table 1); given the difficulty of transporting saplings beyond improved roads, this study area represents the likely sphere of influence of the two agroforestry nurseries. Participants in each village were chosen by the *mpanjaka* (village king) from a group of volunteers. Ten participants on average were interviewed in each village, either in their homes or fields, and 200 interviews were conducted in total. Participants were split among male and female, and three age classes, youth, adult, and elderly (Table 2). The survey was conducted from February to April, 2011.

Table 1. List of the surveyed villages and their Euclidean distances to the closest improved road. Villages beyond 2.5 km are considered "far from roads".

Village	Commune	Distance to Road (km)	N Interviews
Ambodipaiso-Ataratra	Kelilalina	0	8
Kelilalina	Kelilalina	0	9
Manokokora	Kelilalina	0	8
Masomanga	Ranomafana	0	12
Morafeno	Ranomafana	0	12
Ankevohevo	Ranomafana	0.1	12
Tsararano	Ranomafana	0.2	12
Matavirano	Ranomafana	1.2	12
Ampasipotsy	Ranomafana	2.0	12
Anjaka	Kelilalina	2.1	1
Ampitavanana	Ranomafana	3.0	12
Mandrivany	Kelilalina	3.9	8
Akohoroa	Kelilalina	4.1	8
Anosy	Kelilalina	4.3	8
Ambohitsarakely	Kelilalina	4.8	8
Amboasary	Ranomafana	5.4	12
Kianjanomby	Kelilalina	5.4	6
Ambatovory	Ranomafana	6.3	12
Bevohazo	Ranomafana	6.9	12
Fanolafana	Kelilalina	7.4	11
Ambodivoangy	Kelilalina	7.5	5

Table 2. Demographic breakdown of survey participants, which included a secondary school (CEG) class as one unit.

Age Class	Male	Female	School
Youth (13-19 yrs.)	20	16	1
Adult (19-55 yrs.)	69	56	0
Elderly (55+ yrs.)	24	14	0
Total	**113**	**86**	**1**

Surveys were conducted in Malagasy through guided interviews following a questionnaire. The questionnaire had twenty multi-part questions, having both open- and closed-ended elements as well as quantitative and qualitative elements to most questions. Interviewers transcribed answers to close-ended questions and took notes on answers to open-ended questions. Participants were asked, among other things, to list the fruits they cultivated, the number of stems growing, and to quantify what is done with the harvested produce. They were also asked to rank their top five preferences for cultivating fruit trees and to explain those rankings. These preference rankings ranged from 5 to 1, descending from 5 as the "most preferred." For these questions, participants were free to list any plant they considered "fruit"; they were not provided with a multiple-choice set of fruit varieties to from which to choose. Reporting on the number of stems grown was given for the house, but preferences represented the participant's personal preference.

Interviewers then read several statements about satisfaction with local fruit cultivation, and participants indicated their level of agreement with those statements on a Likert scale. The Likert scale ranged from 1 to 5, with one representing "strongly agree" to five representing "strongly disagree".

Survey Analysis

The interviewers and I translated the questionnaire responses into English, and I compiled them in Excel (Microsoft Office 2010). For the Likert scale questions, I calculated average scores. For fruits grown, I looked only at the top fifteen fruits grown and the top fifteen preferred to plant, for a total of seventeen fruits. For each fruit grown, I calculated the average number of stems grown per house. For the fruit people preferred to plant, I used the Borda count election method to determine the rank order of all fruits. In this method, for a given fruit, the number of responses per rank is multiplied by the numerical value of the rank, and all added up for a total "Borda

value" (Black 1976). In this study, fruits not ranked were assigned an ordinal value of zero, and total Borda values for all fruits were corrected by dividing by the total number of respondents to estimate "average ranks". I used JMP 9.0 Pro (SAS 2012) to run Spearman's rank-correlation tests on stems planted versus planting preferences.

I also examined differences in stems planted and fruit tree preferences between villages near and far from roads. On GoogleEarth (Google 2012), I digitized all improved roads in the study area, as well as the surveyed villages, and imported these shapefiles into ArcMap 10. I created a Euclidean distance raster, and decided to delineate "near" versus "far" at 2.5 km from the road approximately corresponding to difficult landscape features. Villages "near" the road are those within 2.5 km, and "far" ones lie beyond 2.5 km away. Ninety-eight participants resided "near" the road, and 102 were "far", the farthest being 7.5 km from a road. With Spearman's rank-correlation tests, I compared both stems planted and planting preferences reported near and far from roads.

For the top five fruits grown most overall, in terms of average stems per house, I used ANOVA's to test for differences in distance from roads. I used a Mann-Whitney U test to identify differences between average planting preference ranks for farmers near and far from roads.

Finally, I grouped qualitative responses into meaningful categories, such as "economic", "consumption" or "medicinal" reasons for ranking a fruit; many responses fit into more than one category. I used Excel to create frequency tables for these response categories, in total and delineated by distance from roads.

Results

Likert Scales

Averaged Likert scale scores strongly indicate that respondents 1) are unsatisfied with the varieties of fruit they currently cultivate, 2) want to plant more fruit trees on their lands, and 3) want to plant new fruit varieties (Table 3).

Table 3. Likert scale questions and results, showing the average response score for each statement.

1	2	3	4	5
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

Statement	Average Score	N
"I am satisfied with the varieties of fruit I currently grow."	4.8	197
"If new varieties of fruit were available in the area, I would want to plant them."	1.2	197
"If possible, I would plant more fruit trees on my land."	1.1	198

Current Cultivation vs. Planting Preferences

Spearman's rank-correlation test describes the degree of correlation between two measured variables, and it returns a statistic (ρ) between -1 and 1. A ρ of -1 indicates a perfectly negatively correlated relationship; a ρ of 1 indicates a perfectly positively correlated relationship. The correlation between the average number of stems grown per house and the average ranked preference for each fruit is 0.102, indicating a near perfectly non-existent correlation between farmers' current cultivation patterns and planting preferences (Figure 1; Table 4). Some fruits like banana and pineapple are planted at relatively high numbers, yet are not preferred for additional planting. Coffee, though, is planted at relatively high numbers but it is also highly desired for planting. Other fruits such as lychee and mandarin are not cultivated much but are highly desired for planting. And many fruits, like mango, are neither planted much nor desired highly.

Table 4. A table comparing the average number of stems grown per house, the average ranked preference, and the relative rank order for each fruit for all respondents, and also subdivided for respondents near and far from roads.

Fruit	Total			Near			Far		
	Avg. Stems per House	Avg. Pref.	Pref. Rank Order	Avg. Stems per House	Avg. Pref.	Pref. Rank Order	Avg. Stems per House	Avg. Pref.	Pref. Rank Order
Banana	295.44	0.45	6.5	386.44	0.62	6	208.00	0.28	10
Pineapple	59.43	0.15	13	87.91	0.06	15	32.06	0.24	11
Coffee	58.34	2.77	2	35.32	1.95	3	80.46	3.56	2
Avocado	4.23	0.14	14	4.97	0.14	13	3.52	0.14	12
Lychee	3.10	4.03	1	4.78	4.10	1	1.48	3.96	1
Guava	2.74	0.00	17	3.59	0.00	17	1.91	0.00	17
Orange	1.20	2.28	3	1.36	2.50	2	1.05	2.07	3
Mandarin	1.01	1.71	4	1.29	1.90	4	0.74	1.53	4
Jackfruit	1.00	0.02	16	1.15	0.01	16	0.84	0.03	16
Peach	0.64	0.17	11	0.47	0.22	10	0.79	0.12	14
Mango	0.25	0.32	8	0.24	0.20	11	0.25	0.44	7
Annona	0.21	0.11	15	0.31	0.12	14	0.12	0.09	15
Lemon	0.15	0.94	5	0.28	1.28	5	0.02	0.62	5
Papaya	0.07	0.28	10	0.08	0.24	9	0.06	0.31	9
Persimmon	0.06	0.16	12	0.12	0.19	12	0.00	0.13	13
Breadfruit	0.01	0.45	6.5	0.02	0.38	7	0.00	0.52	6
Apple	0.00	0.31	9	0.00	0.27	8	0.00	0.35	8

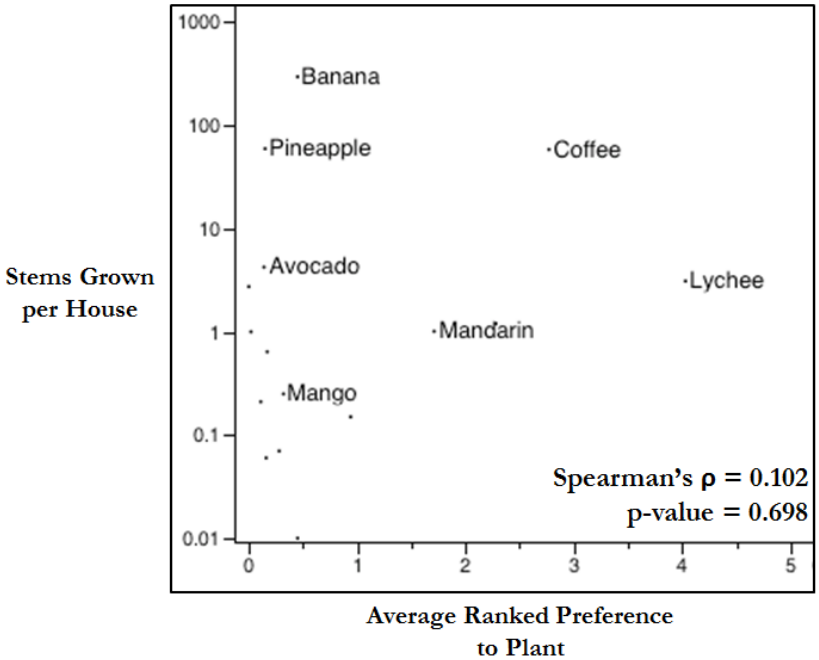


Figure 1. Spearman's rank-correlation test between the average number of stems of each fruit grown per house and the average ranked preference to plant each of those fruits, showing no significant correlation.

Distance to Roads

In communities both near and far from roads, the average numbers of stems grown per house are strongly positively correlated (ρ = 0.966, p-value = <0.000) (Figure 2). Moreover, the correlation places each fruit very close to a 1-1 line, indicating that the relationship is not only monotonic but also nearly equivalent. However, most points lie above the 1-1 line, suggesting most fruits are cultivated more on farms near roads. Banana is grown significantly more in villages near the road (p-value = 0.015), and the same is true for lychee (p-value = 0.000). In addition to those two, pineapple, coffee, and avocado comprise the top five most cultivated fruits in both distance classes. Though they may visually appear independent for each distance class, there are no significant differences in cultivation numbers for the latter three fruits (Appendix 1).

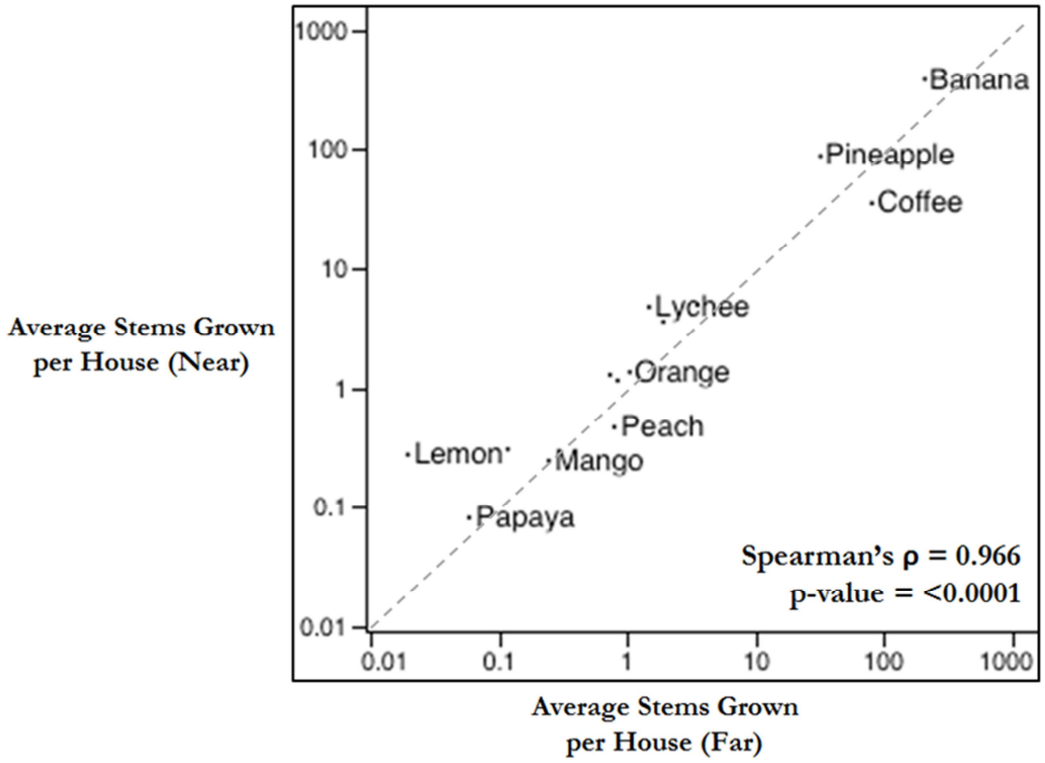


Figure 2. Spearman's rank-correlation test between cultivation patterns near and far from roads. There is a significant positive correlation between the average number of stems of each fruit grown near and far from roads, and this correlation lies very close to the dashed 1-1 line.

The average preferences to plant each fruit are also strongly positively correlated for farmers near and far from roads (Figure 3). The high ρ (0.914) indicates that farmers near and far from roads prefer fruits at similar levels. The top five fruits preferred to plant are the same for each distance class. Again, this relationship sits very close to the 1-1 line. The glaring exception is for coffee, which is preferred at similar levels as lychee by farmers far from roads. The Mann-Whitney U test for independence indicates that farmers far from roads report significantly higher preferences for planting coffee than do farmers near roads (p = 0.000).

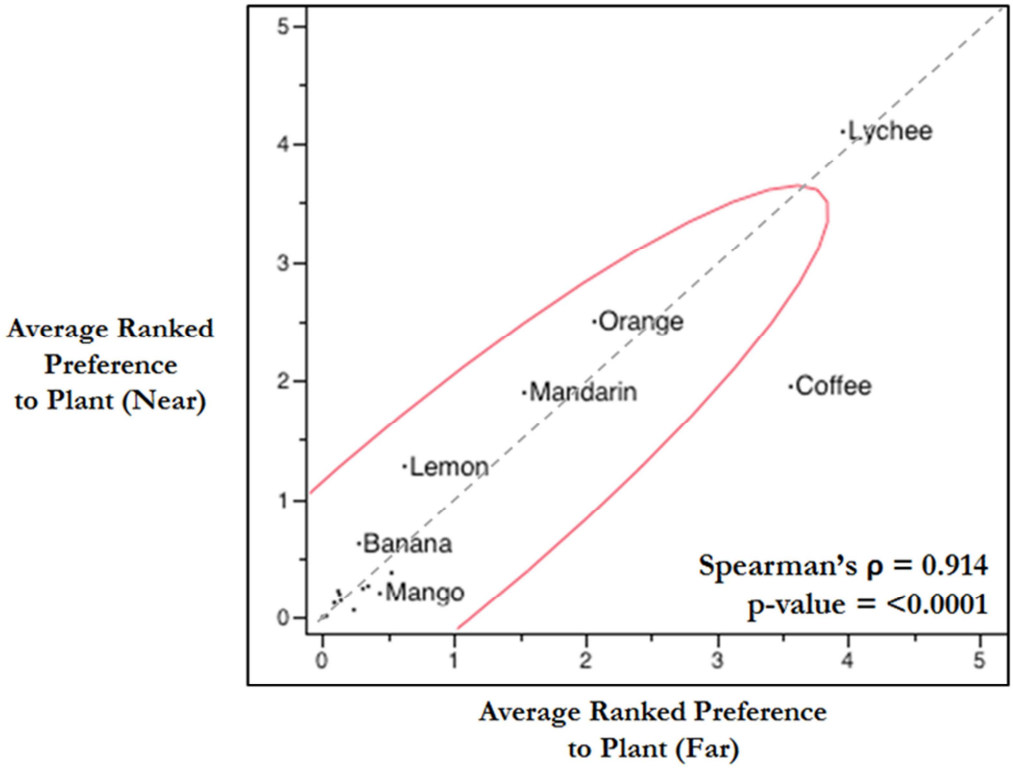


Figure 3. Spearman's rank-correlation test between planting preferences near and far from roads. There is a significant positive correlation between the average ranked preferences to plant each fruit near and far from roads. The dashed line represents the 1-1 relationship.

Qualitative Analysis

Analysis of the qualitative data associated with planting preferences may illuminate the correlations in current cultivation and planting preferences near and far from roads (Table 6). For all of the top six fruits, farmers far from roads mentioned "consumption" reasons for preferring to grow a fruit more than farmers near roads, and farmers near roads mentioned "economic" reasons for preferring to grow a fruit more than farmers far from roads.

"Transportation" reasons for preferring to plant these fruits warranted further exploration. When the qualitative responses associated with the survey question, "List the top five fruits you would prefer to SELL, in order of preference…", were examined, transportation reasons were more prevalent, especially for coffee (Table 5).

Both distance classes mentioned "economic security" reasons at identical rates for preferring bananas. They also had similar rates of citing medicinal reasons for preferring to grow lemons (Table 6).

Table 5. Frequency of mentioning "transportation" reasons for preferring to sell the top six fruits preferred to plant. All mentions of transportation come from farmers far from roads.

Fruit	Transportation Reasons	N
Lychee	4.60%	87
Coffee	18.18%	88
Orange	12.16%	74
Mandarin	6.12%	49
Lemon	5.00%	20
Banana	15.58%	77

Table 6. Table listing the response rates for different categorical reasons for preferring to plant the top six preferred fruits.

Fruit	Distance	Categorical Reason										N
		Consumption	Economic	Low Quantity	Flavor	Transportation	Productivity	Land Improvement	Medicinal	Security	Other	
Lychee	Near	33.3%	94.6%	9.7%	10.8%	1.1%	5.4%	1.1%	--	--	1.1%	93
	Far	48.5%	90.9%	10.1%	16.2%	2.0%	2.0%	0.0%	--	--	4.0%	99
	Total	41.2%	92.7%	9.9%	13.5%	1.6%	3.7%	0.5%	--	--	2.6%	192
Coffee	Near	56.5%	78.3%	10.9%	--	0.0%	6.5%	4.4%	--	--	8.7%	46
	Far	66.7%	72.6%	6.0%	--	10.7%	0.0%	2.4%	--	--	4.8%	84
	Total	63.1%	74.6%	7.7%	--	6.9%	2.3%	3.1%	--	--	6.2%	130
Orange	Near	33.3%	85.3%	16.0%	9.3%	0.0%	5.3%	--	1.3%	--	--	75
	Far	56.2%	78.1%	11.0%	8.2%	2.7%	1.4%	--	0.0%	--	--	73
	Total	44.6%	81.8%	13.5%	8.8%	1.4%	3.4%	--	0.7%	--	--	148
Mandarin	Near	38.3%	93.3%	18.3%	6.7%	0.0%	10.0%	--	0.0%	--	--	60
	Far	52.5%	86.4%	8.5%	3.4%	1.7%	6.8%	--	3.4%	--	--	59
	Total	45.4%	89.9%	13.5%	5.0%	0.8%	8.4%	--	1.7%	--	--	119
Lemon	Near	29.3%	97.6%	4.9%	2.4%	--	4.9%	--	29.3%	--	--	41
	Far	30.8%	73.1%	0.0%	0.0%	--	3.9%	--	26.9%	--	--	26
	Total	29.9%	88.1%	3.0%	1.5%	--	4.5%	--	28.4%	--	--	67
Banana	Near	56.7%	93.3%	--	--	0.0%	--	--	--	33.3%	3.3%	30
	Far	81.0%	76.2%	--	--	4.8%	--	--	--	33.3%	4.8%	21
	Total	66.7%	86.3%	--	--	2.0%	--	--	--	33.3%	3.9%	51

5. Discussion

Respondents strongly indicated that they are dissatisfied with both the quantities and varieties of fruit they currently cultivate, and that they are highly interested in planting more fruit (Table 3). These responses highlight local demand for nursery products and therefore justify the existence of agroforestry nurseries around RNP.

However, since there is no correlation between the fruits farmers currently cultivate and those they would prefer to cultivate (Figure 1), the roles of agroforestry nurseries are more complicated than merely filling gaps between cultivation and preferences.

Fortunately for nursery managers, current cultivation patterns and planting preferences are similar throughout their nurseries' spheres of influence (Figure 2; Figure 3). This will facilitate more efficient and focused use of nursery space and resources since one nursery stock can be applied to any project regardless of location.

There are notable exceptions to the geographic similarities. Significantly more bananas and lychees are grown near roads than far from roads (Appendix 1). These differences might be related to roadside farmers' easy access to collection trucks on the roads. Both bananas and lychees are sold at high weight to price ratios (Appendix 2), which means that they may not be as profitable for countryside farmers to transport over the hills to the road. Or, there might be environmental variables limiting cultivation opportunities in the countryside far from the roads, which usually follow river valleys.

For fruit planting preferences as well, there could be several reasons why coffee is significantly more preferred to plant far from roads. However, I am attributing the difference to coffee's recognized transport efficiency. When asked why they ranked their preference to plant coffee as they did, 18% of respondents mentioned transport reasons (Table 5). Coffee beans are small fruits but with disproportionally high market prices. For example, a stalk of bananas weighs about 20 kg but fetches the same price as only 2.5 kg of coffee (Appendix 2). Over muddy mountain footpaths, transporting coffee makes more sense than bananas.

Moreover, roadside respondents were more likely to mention economic reasons for ranking fruit planting preferences, and countryside respondents were more likely to mention consumption reasons (Table 6). These results suggest the intuitive conclusion that easy access to roads broadens economic opportunities, whereas limited access leads people to greater dependency on subsistence cultivation.

However, farmers' distances to roads are not the only factors which influence cultivation. Bananas and lemons, for example, filled specific niches throughout the study area. Bananas, since they have no defined growing season, were commonly mentioned as sources of money in emergency situations, adding to a family's financial stability; that is, they can be harvested and sold year-round unlike most other fruit. Lemons were preferred for their natural medicinal qualities (Table 6).

The mission of the agroforestry nurseries in this study is to produce fruits that will benefit farmers and replenish the land. Currently, nursery production is not well aligned with the planting preferences of local farmers (Table 7). Those preferences ideally reflect the farmers' appreciation of the economic and nutritional values of fruits. Therefore, producing and planting fruit according to farmer preferences will ensure that the trees have the greatest chance of receiving care from the farmer and thus surviving to fulfill the nurseries' mission.

Table 7. Current fruit production in the two agroforestry nurseries established by FOM, in ranked order by number of seedlings produced

Production Rank	Fruit	Total Num. Produced
1	**Orange**	540
2	**Mandarin**	476
3	**Mango**	261
4	**Grumichama**	157
5	**Lemon**	147
6	**Papaya**	108
7	**Lychee**	101
8	**Coffee**	98
9	**Peach**	50
10	**Loquat**	28

Not all fruits that farmers said they preferred to plant are in line with the conservation agendas of the nurseries, though. Bananas, for example, are herbaceous plants, not trees, and do not need to be propagated in nurseries. Furthermore, as an annual crop, banana cultivation is one of the main drivers of post-deforestation degradation since farmers often plant bananas in fallow fields instead of letting natural regeneration take over.

Also worth noting is the fact that all of the top ten most preferred fruits are exotic species. Ideally, conservation NGO's like FOM and CVB would be able to base reforestation projects on endemic or native species. However, around RNP, farmers did not express much interest in growing native fruits, which suggests that focusing on these fruits would waste nursery time and resources. Fortunately, the top ten exotic species famers prefer are all naturalized (already integrated into the natural order) and non-invasive (not direct threats to native species or habitat).

After removing bananas from the list, the top ten most preferred fruits for farmers to plant do not conflict with nursery agendas and therefore comprise our recommendations for production strategies in agroforestry nurseries (Table 8). Since planting preferences were so tightly correlated between farmers near and far from roads, we are presenting a unified recommendation with a caveat for coffee. Coffee should be prioritized in projects far from roads, based on its high preference by remote farmers. Moreover, coffee is an exceptional agroforestry fruit. Coffee production requires an overstory for shade; coffee stumps re-sprout after being cut; and in the study area, coffee's high transport efficiency makes it the most valuable fruit a farmer could produce.

Table 8. Final ranked recommendations for agroforestry production priorities.

Production Order	Fruit	Avg. Rank Overall
1	Lychee	4.03
2	Coffee	2.77
3	Orange	2.28
4	Mandarin	1.71
5	Lemon	0.94
6	Breadfruit	0.45
7	Mango	0.32
8	Apple	0.31
9	Papaya	0.28
10	Peach	0.17

It remains for nurseries to decide how many saplings of each fruit to propagate. The quantity and value of produce will differ for each species of fruit tree, so these recommendations do not necessarily translate to production ratios. Instead they are the first step toward nurseries meeting farmer needs and demands.

Future work will involve increasing the variety of cultivars grown in the nurseries. The cultivars currently grown are not necessarily the best suited to the environment or the human needs in the study area. Since different cultivars often do not bear fruit at the same times, increasing cultivar diversity allows farmers to experience longer growing and harvesting seasons, thereby avoiding low prices in saturated markets.

Moreover, farmer preferences are based on their imperfect knowledge of available fruits and cultivars, and there is room to influence future preferences. For example, neither avocado nor mango is highly desired in the study area, but perhaps this is a reflection on the local cultivars of each, not the species themselves. That is, mangos around RNP are usually struck with anthracnose, causing them to mature slowly and produce poorly, but a hardier and more delicious variety like “Diego” may interest local farmers. The avocados in the study area are small, bland, and rot quickly on trees, but there are cultivars elsewhere in the world that could produce more desirable fruits. The challenge for nurseries is to obtain, maybe by import, budstock of desirable cultivars.

6. Conclusions

This study has documented the current state of fruit cultivation in its study area on the eastern slopes of RNP. We now know what fruits farmers are already planting and what they would prefer to plant. The relationship between these two states is complicated. Farmers throughout the study area are growing similar quantities of the same kinds of fruits, except farmers near roads are growing more bananas and lychees than farmers far from roads. Fruit planting preferences, too, are similar throughout the study area, except that farmers far from roads prefer coffee far more than do farmers near roads. These differences and the qualitative data associated with them indicate that distance to road markets factors into farmer cultivation mentalities.

Nevertheless, a unified list of propagation recommendations is provided for nurseries operating in the study area. The nurseries must now figure out how to address farmer preferences by producing appropriate numbers of saplings and acquiring advantageous cultivars of each fruit.

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Appendix 1. ANOVA Tables for Cultivation Patterns

a. ANOVA results showing the significant independence in the number of banana stems grown near and far from roads.

ANOVA: Banana Stems Grown Near vs. Far from Roads				
Groups	***Count***	***Sum***	***Average***	***Variance***
Near	97	37871	390.42	485542.80
Far	100	21216	210.06	58707.36

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	1609623	1	1609623	6.011	0.015	3.889
Within Groups	52482841	196	267769.6			
Total	54092464	197				

b. ANOVA results showing the significant independence in numbers of lychee stems grown near and far from roads.

ANOVA: Lychee Stems Grown Near vs. Far from Roads				
Groups	***Count***	***Sum***	***Average***	***Variance***
Near	97	468	4.78	74.61
Far	101	151	1.48	6.75

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	542.673	1	542.673	13.569	< 0.000	3.889
Within Groups	7918.522	198	39.993			
Total	8461.195	199				

c. ANOVA results showing no significant independence between numbers of pineapples grown near and far from roads.

ANOVA: Pineapple Stems Grown Near vs. Far from Roads				
Groups	***Count***	***Sum***	***Average***	***Variance***
Near	97	8615	88.814	106975.8
Far	102	3270	32.059	6315.026

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	202451.9	1	202451.9	1.627	0.206	3.962
Within Groups	9831148	79	124444.9			
Total	10033600	80				

d. ANOVA results showing no significant independence between numbers of coffee stems grown near and far from roads.

ANOVA: Coffee Stems Grown Near vs. Far From Roads						
Groups	***Count***		***Sum***	***Average***		***Variance***
Near	59		3461	58.661		3285.09
Far	89		8207	92.213		19593.17
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	39941.94	1	39941.94	3.046	0.083	3.906
Within Groups	1914734	146	13114.62			
Total	1954676	147				

e. ANOVA results showing no significant independence between numbers of avocado stems grown near and far from roads.

ANOVA: Avocado Stems Grown Near vs. Far from Roads						
Groups	***Count***		***Sum***	***Average***		***Variance***
Near	96		487	5.073		69.795
Far	102		359	3.520		13.658
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	119.322	1	119.322	2.920	0.089	3.889
Within Groups	8009.95	196	40.867			
Total	8129.273	197				

Appendix 2. Market Prices of Fruit in 2010-2011

Malagasy	Scientific	English	Price (Malagasy Ariary)
Zanty	*Annona* spp.	*Annona*	500/piece
Poma	*Malus domestica*	Apple	2000/kg
Zavoka	*Persea americana*	Avocado	200/piece
Akondro	*Musa* spp.	Banana	140/kg (unripe) -500-600/kg (ripe)
Frapay	*Artocarpus altilis*	Breadfruit	200-500/piece
Kafe	*Coffea* spp.	Coffee	4000/kg
Voaloboka	*Vitis* spp.	Grape	2000/kg
Pampelimosy	*Citrus* spp.	Grapefruit	200/piece
Goavy	*Psidium spp.*	Guava	(variable)
Zevy	*Spondias* spp.	Hog plum	1000/kg
Apalibe	*Artocarpus heterophyllus*	Jackfruit	(variable)
Voarsary makirana	*Citrus* spp.	Lemon	1000/kg
Pibasy	*Eriobotrya japonica*	Loquat	1500/kg
Lodisy	*Litchi chinensis*	Lychee	200/kg
Makoba	*Syzygium malaccense*	Malay Apple	(variable)
Mandarine	*Citrus reticulata*	Mandarin	5000/kg
Manga	*Magnifera indica*	Mango	2000/kg
Voarsary	*Citrus* spp.	Orange	1000/kg
Papaya	*Carica papaya*	Papaya	500-1500/piece
Garana	*Passiflora edulis*	Passionfruit	2000/kg
Paiso	*Prunus persica*	Peach	1500/kg
Poara	*Pyrus spp.*	Pear	(variable)
Kaky	*Diospyrus* spp.	Persimmon	(variable)
Mananasy	*Ananas comosus*	Pineapple	200-2500/piece
Voamadilo	*Tamarindus indica*	Tamarind	1800/kg
Voarsary gasy	*Citrus* spp.	Wild orange	1000/kg

In 2010-2011, the MGA:USD exchange rate was about 2000:1. Some fruits are priced by weight and others by piece. These prices can vary dramatically with the availability, size, and variety. Most often a fruit's price will correspond with its seasonal availability; prices are high at the beginning and end of the season, due to scarcity, but prices tend to plummet peak season because the market is saturated. There is little variability in fruit harvest schedules since there is a relative dearth of cultivars grown in Madagascar.

Appendix 3: English Translation of the Survey

Date: _____
Time: _____
Interviewer: _____
GPS waypoint: _____
Commune: _____
Village: _____
Respondent's name: _____
Number of people in the house: _____
Age: _____
Sex: _____
Occupation: _____

1. **Does fruit grow on your family's land? YES_____ NO_____ (If "NO", skip to Question 10)**

If "YES", which species grow on your family's land, how did they get there, and how old are they?

*****Are you willing to indicate where your fruit trees are located, thereby forfeiting confidentiality? YES_____ NO_____**

*****(If "NO", do not ask for Distance or Compass Bearing)**

Fruit	Variety	Total number	Number already there/ age?	Number self-propagated/ age?	Number purchased and planted/ age?	(Distance)	(Compass bearing)

2. If fruit grows on your family's land, what is done with the fruit? Answer for the entire household.

Fruit	Variety	Kilos eaten	Kilos sold	Kilos for other purposes/ purpose?	Kilos left un-harvested	Why are these left un-harvested?

3. Does your family grow crops other than fruit? YES_____ NO_____ (If "NO", skip to Question 8)

If YES, which ones are grown? Also, indicate if there are any fruit trees that grow near these crops, how many there are, and how close they grow to the crops.

Crop	Fruit planted nearby	Variety	How many fruits planted near other crops?	How close to crops?

4. If fruit is grown on your family's land, do you burn fields close to your fruit trees?

YES_____ NO_____

If yes, how close? _____

How often? _____

5. If fruit is grown on your family's land, does your family ever cut down fruit trees? YES_____NO_____

Why or why not?

6. Do your family raise cows on its land? YES_____ NO_____

How many? _____

7. Does your family eat fruit? YES_____ NO_____ (If "NO", skip to Question 2)

If "YES", in terms of quantity, which 5 fruits on the list do you all EAT the most of? Rank your answers from "1-5", starting with "1" for the fruit you all eat the most of, and estimate the number of kilos eaten per year.

Rank	Fruit	Variety	Kilos eaten	Briefly explain this ranking
1				
2				
3				
4				
5				

8. Does your family sell fruit? YES_____ NO_____ (If "NO", skip to Question 3)

If "YES", in terms of quantity, which 5 fruits on the list do you all SELL the most of? Rank your answers from "1-5", starting with "1" for the fruit you all sell the most of, and estimate the number of kilos sold per year.

Rank	Fruit	Variety	Kilos sold	Briefly explain this ranking
1				
2				
3				
4				
5				

9. Does your family use fruits for purposes other than eating and selling? YES _____NO_____ (If "NO", skip to Question 4).

If "YES", please specify.

Fruit	Variety	What other purpose?	What qualities of the fruit make it desirable for these other purposes?

10.Does your family BUY fruit? YES_____ NO_____ (If "NO", skip to Question 6)

If "YES", which 5 fruits on the list do you all BUY the most of in terms of quantity? Rank your answers from "1-5", starting with "1" for the fruit you all buy the most of, and estimate the number of kilos bought.

Rank	Fruit	Variety	Kilos bought	Briefly explain this ranking
1				
2				
3				
4				
5				

Directions: Read the statement and have the respondent chose their level of agreement.

CIRCLE THE ANSWERS

11. "I am satisfied with the varieties of fruit I currently grow."	Strongly agree	Agree	Nether agree nor disagree	Disagree	Strongly disagree

Why did you answer this way?

12. **"If new varieties of fruit were available in the area, I would want to plant them."**

Strongly agree	Agree	Nether agree nor disagree	Disagree	Strongly disagree

Why did you answer this way?

13. **"If possible, I would plant more fruit trees on my land."**

Strongly agree	Agree	Nether agree nor disagree	Disagree	Strongly disagree

Why did you answer this way?

14. If you had a choice, which 5 fruits on the list would you most PREFER to GROW, and why? Rank your choices 1-5, starting with "1" as most preferred.

Rank	Fruit	Variety	What qualities of the tree make it desirable to plant?
1			
2			
3			
4			
5			

15. If you were to be given fruit trees, rank the 5 types you would most like to RECEIVE, and a realistic quantity you would ask for. Rank your answers "1-5", starting with "1" as the most preferred.

Rank	Fruit	Variety	Quantity
1			
2			
3			
4			
5			

Directions: Read the statement and have the respondent chose their level of agreement.

CIRCLE THE ANSWERS

16. "If new varieties of fruit were available in the area, I would want to eat them."	Strongly agree	Agree	Nether agree nor disagree	Disagree	Strongly disagree

Why did you answer this way?

17. If you had a choice, which 5 fruits on the list would you most PREFER to EAT, and why?Rank your choices 1-5, starting with "1" as most preferred.

Rank	Fruit	Variety	What qualities of the fruit make it desirable to eat?
1			
2			
3			
4			
5			

18. If you had a choice, which 5 fruits on the list would you most PREFER to SELL, and why? Rank your choices 1-5, starting with "1" as most preferred.

Rank	Fruit	Variety	What qualities of the fruit make it desirable to sell?
1			
2			
3			
4			
5			

Directions: Read the statement and have the respondent chose their level of agreement.

CIRCLE THE ANSWERS

19. "I am satisfied with the varieties of fruit available to buy in this area."	Strongly agree	Agree	Nether agree nor disagree	Disagree	Strongly disagree

Why did you answer this way?

20. If you had a choice, which 5 fruits on the list would you most PREFER to BUY, and why? Rank your choices 1-5, starting with "1" as most preferred.

Rank	Fruit	Variety	What qualities of the fruit make it desirable to buy?
1			
2			
3			
4			
5			