As green as it gets™

Long-Term Sustainability of Cooperative-Wide Coffee Yields in San Miguel Escobar, Guatemala

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Table of Contents

Abstract

The overarching goal of this study was to investigate the long-term sustainability of the San Miguel Escobar coffee cooperative associated with the non-governmental organization *As Green As It Gets*. A computer simulation determined that while coffee yields are projected to increase at a positive rate over the next five years, by 2020 the cooperative would see decreases of approximately 5000 lbs per year for the following five years. Yield levels following the first decrease would rebound to near their previous highs before the cooperative will be faced with a major challenge, dealing with an overwhelmingly high proportion of trees reaching the end of their productive life cycles in the years between 2035 and 2045. The result of these natural cycles is a decrease in yield of roughly 16,000 lbs over a period of seven years. The focus of this report will be the investigation of possible strategies aimed at mitigating the unsteady yield projections in order to ensure sustainable economic development of the coffee farmers in the cooperative.

INTRODUCTION

As Green As It Gets (henceforth referred to as "AGAIG") is a non-governmental organization founded in 2004 which is focused on the economic development of the coffee farmers that are members of the San Miguel Escobar coffee cooperative. By providing loans, planning, and invaluable marketing connections, the organization seeks to direct the profits from coffee sales towards the farmers, allowing them to lift themselves out of poverty and improve opportunities for their children and themselves. An integral part of the long-term goal of maintaining the significant progress that has already been made is to ensure that economic development (in regards to coffee production) is steady and sustainable. Agricultural outputs are difficult to predict—but using data collected in a 2012 survey on the land holdings of cooperative farmers, a computer simulation was programmed to incorporate tree cycles and estimates based on past years in order to forecast cooperative-wide yields well into the future.

The coffee farmers in AGAIG have planted four species of coffee trees, all of which have different growth and dormancy cycles[1]. The Borbon species accounts for 55.34% of the total 218.25 cuerdas of land that is part of the cooperative, and Catuai trees account for 41.91%. With 97.25% of all trees being one of the two major species, the other two species—Catura and E14—make up 2.29% and 0.46% of the cooperative's plants, respectively. Any strategic planning that must be made in an attempt to sustain yield growth rather than allowing it to be subject to major fluctuations will have to deal with either Borbon or Catura (or both), as these represent the biggest source of the cooperative's harvests. Individual strategies for dealing with the large fluctuations in yield will be discussed in the section entitled "Strategic Planning for Future Sustainability."

It quickly became evident that in the current state of things, the cooperative's yearly yields will be subject to dramatic changes over relatively short periods of time. With the rapid expansion of AGAIG's size, many farmers were able to plant trees in the past five years. Many of these trees will either need to be replaced or trimmed at approximately the same time, and eventually the period of dormancy that follows will affect the two major species at the same time, resulting in the massive drop-off in yield. A number of solutions are explored: purchasing more land, intercropping towards the end of a tree's life—perhaps switching species—, and early pruning are all discussed.

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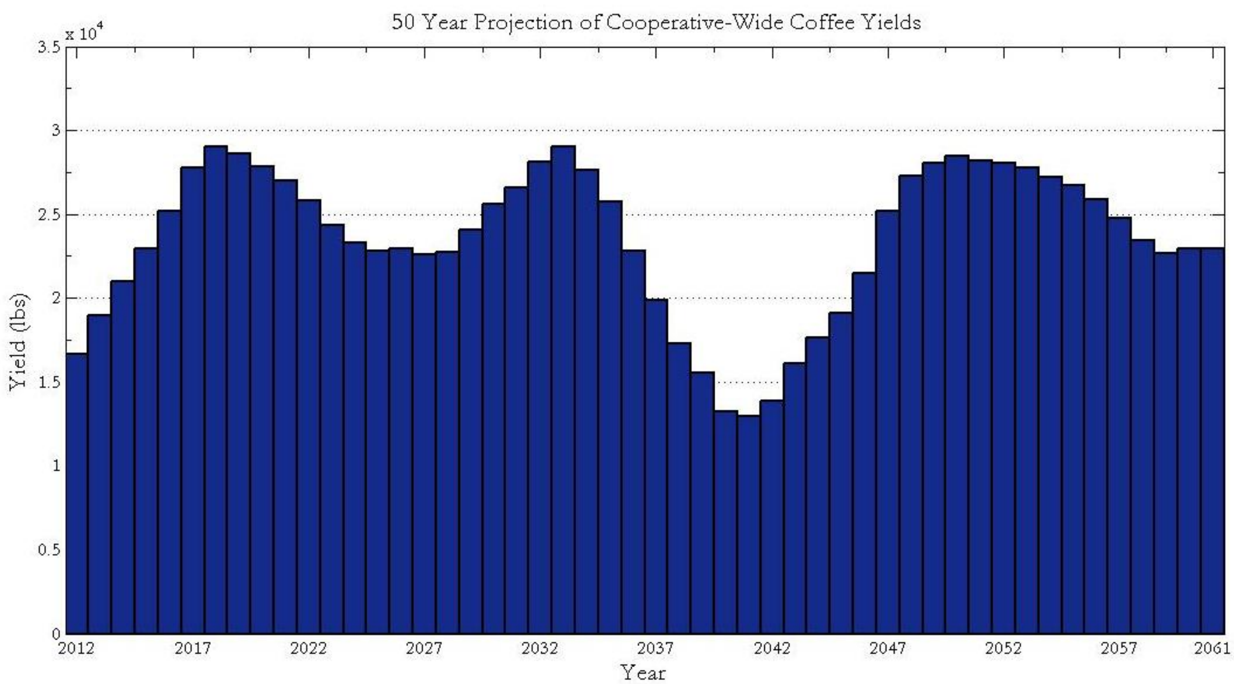
[1] A recommended discussion of tree cycles can be found in Appendix A.

SIMULATION AND RESULTS

A simulation written in the linear programming language MATLAB was used to forecast future cooperative-wide coffee yields of green coffee that has been stripped of its fruit and dried, ready for roasting. Using available data on the number of cuerdas[2] held by each farmer in the cooperative, the type of coffee trees planted, and conservative estimates of likely yield per cuerda for each species, the simulation was able to project yields for each plot of land, sum the result and plot the annual yield for any number of years specified by the user[3]. Originally, the projection was run for only ten years, but upon seeing the decline at the end of the decade, it became evident that a longer-term projection was necessary to visualize the interaction of harvesting cycles. The result of the fifty year simulation should things remain as they are now is shown below. Henceforth, for future comparative graphs in this report, pairs of best-fit line will be used for ease of comparison. The solid curve will represent the bar graph below and a dotted one will represent the hypothetical change being investigated.



One can easily see where the dips occur and their relative severity. The simulation's projections make it inherently clear that something must be done if the health of the cooperative is to be maintained. The costs of such drastic decreases in yield will compound quickly with further capital expenditures on things like purchasing coffee from other cooperatives/farmers in order to fill existing product demand. Large purchases of new trees in a short time frame, as well as the time necessary to plant them will also factor into losses of capital and productivity. If measures can be taken sooner to mitigate the damage, large losses can be avoided and planned for accordingly.

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[2] A cuerda is a local unit of measurement for land, roughly equivalent to a third of an acre.

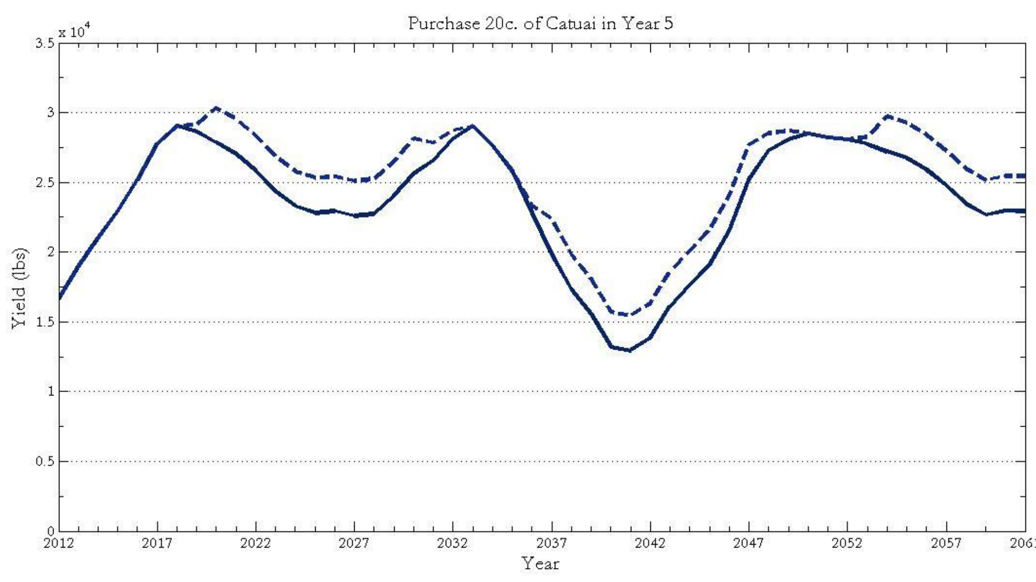
[3] Refer to Appendix A for more details about the simulation and the assumptions used.

STRATEGIC PLANNING FOR FUTURE SUSTAINABILITY

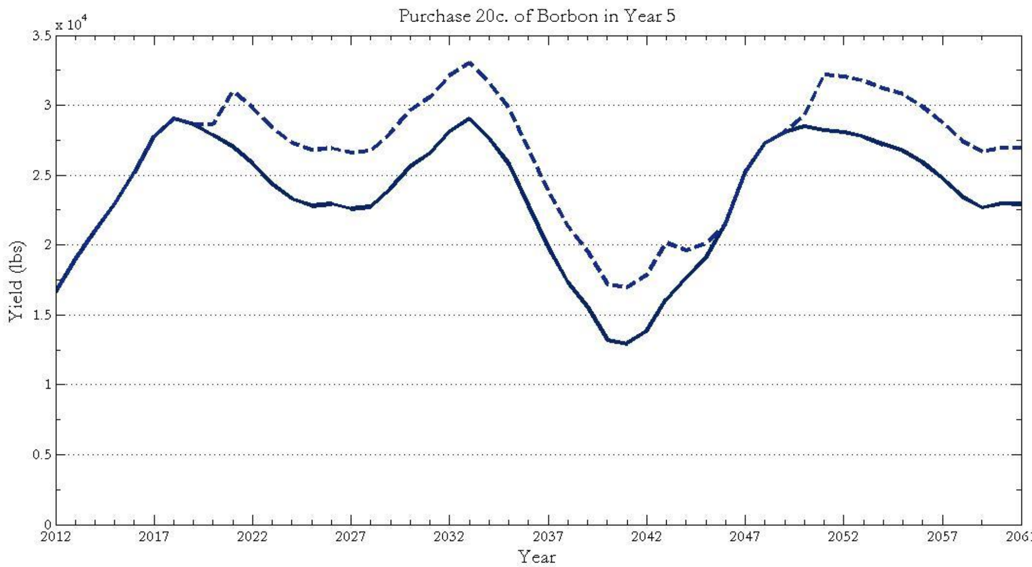
PURCHASING LAND

The most direct and intuitive solution—though certainly the most expensive—would be to purchase more land to even out the inconsistencies. However, the problem with purchasing more land is that doing so will increase peak yields, and might very well result in steeper drops unless the time of purchase coincides perfectly with the decline of other crops. A shortage of over 10,000 lbs would require at least 500 cuerdas of land to be purchased, which is not necessarily realistic given the current land holdings of AGAIG and would triple current levels of production. Thus it is important to investigate when the optimal time would be to buy a more reasonable quantity of land. The purchase of land alone will not solve the problem, but it can certainly be useful in helping ease the strain of crop shortage. Assuming twenty cuerdas of land is a reasonable purchase cooperative-wide; the graphs that follow demonstrate the effect of purchasing and planting one of the two major species at an optimal time[4].

From an analysis of different periods of time, the simulation demonstrated that a short-term strategy of buying land was most effective when made in five years (2017). A purchase in ten or twenty years had a similar effect on the larger yield shortage. In addition to the data justifying a purchase sooner rather than later, the fact that land prices are rising also provides an added benefit. For the purposes of analysis, the simulation ran with a hypothetical purchase of twenty cuerdas made at the same time. The relative benefit of which species to plant is easily demonstrated by comparison:

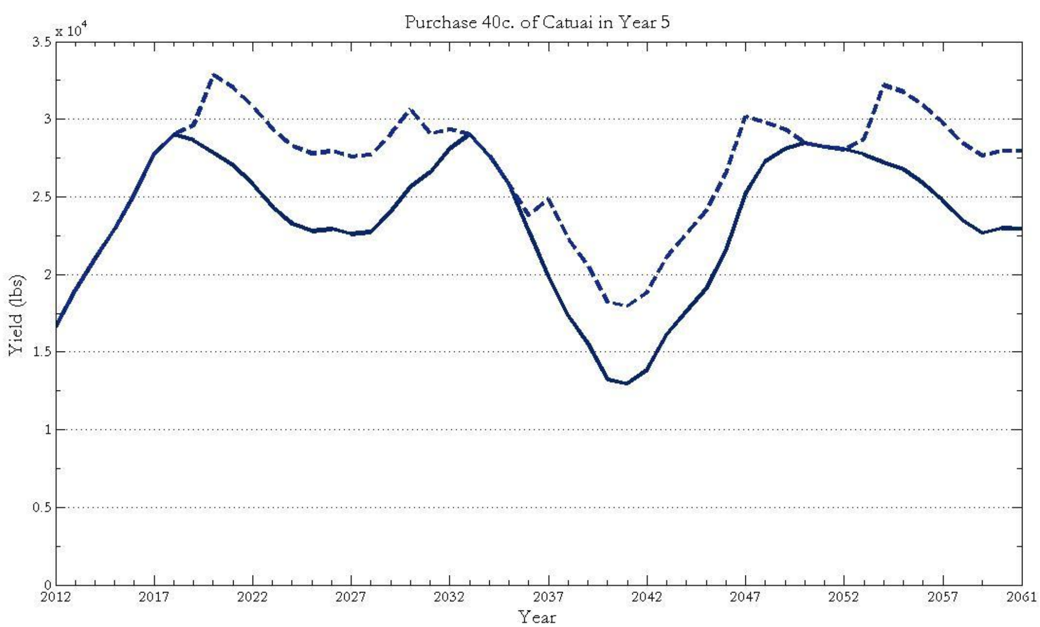


[4] For a discussion of relative benefits of purchasing at different times, consult Appendix B. One's instinct might suggest that purchasing land shortly prior to the large dip would work, but that is not the case.



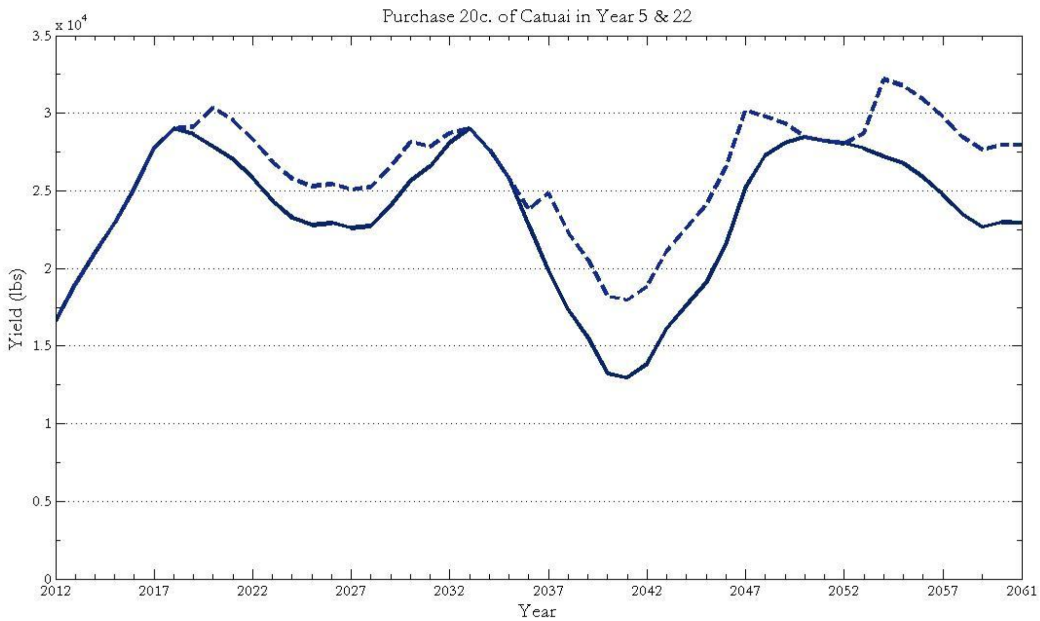
As evident from the graphs above, a purchase of Borbon is much more effective at lessening the minimal yield of both shortages than a purchase of Catuai. However, there is a valid benefit of planting Catuai: it does not exaggerate the second peak but rather acts to fill in the gaps, whereas planting Borbon still creates a similar shortage in relation to new projected peaks and troughs.

It is useful to contemplate the hypothetical scenario of the cooperative being able to raise the necessary capital to purchase forty cuerdas instead of twenty. A purchase of Catuai trees in 2017 would be more effective at filling in gaps than an equivalent purchase of Borbon[5]:



[5] See Appendix B for a graph of a larger purchase of Borbon.

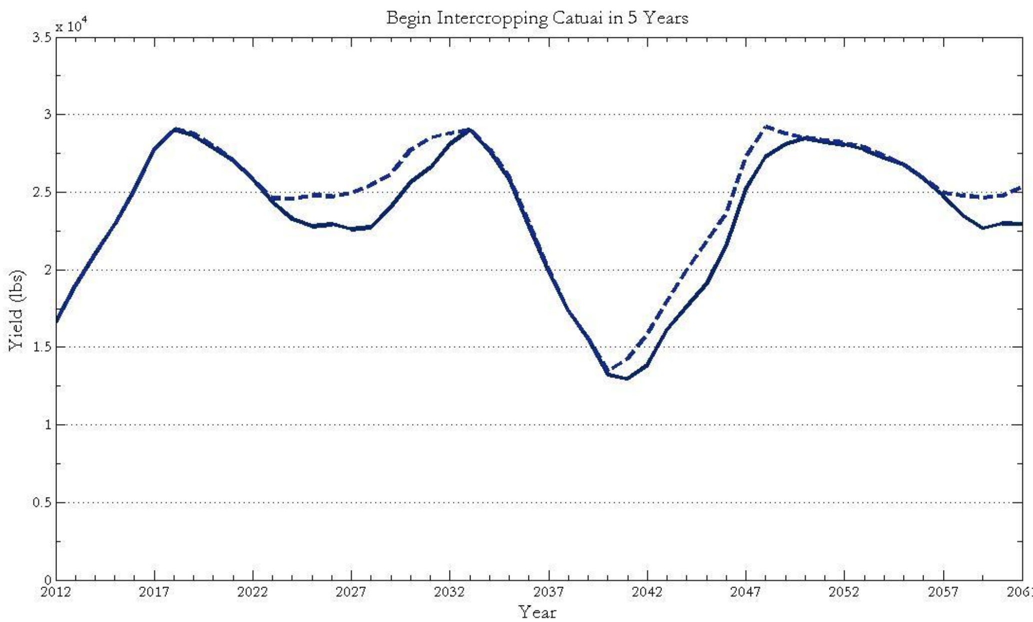
A larger acquisition of land that is distributed into two separate purchases of Catuai trees works best when done in 2017 and 2034[6]. Once again, the downside to planning a purchase of land in 2034 is the likely continuation of current rising land prices.



[6] Assuming that the funds are available, purchasing twenty cuerdas of Catuai in five years could also be paired with an equivalent purchase of Borbon in year ten or twenty-two. For a discussion of these options, consult Appendix B.

Intercropping

The process of intercropping—which is already being contemplated by the cooperative—involves planting young saplings between the rows of plants that are reaching the end of their lives. Since Catuai trees cannot produce fruitful yields after being trimmed (Borbon can) and require being replanted, intercropping shortens the amount of time the land produces no coffee. If intercropping takes place once yields begin dropping off, the number of years of low or nonexistent yield shortens from four to two years. This seems like a logical thing to do and the simulation supports it as well:



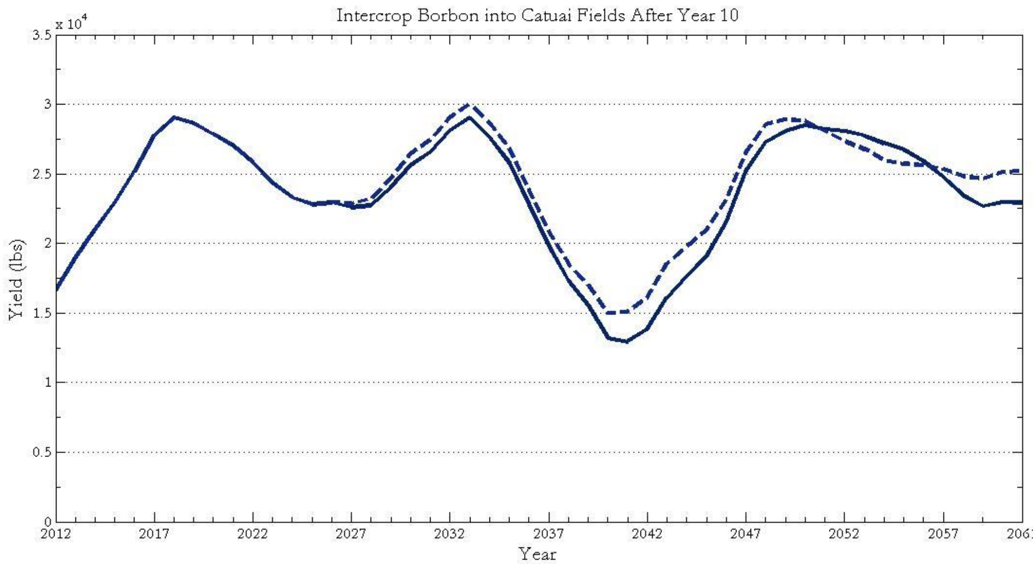
The difference between initiating intercropping in five years and initiating in ten years is minimal, as most Catuai trees won't be reaching their periods of declining harvests until the end of this decade. For farmers who wish to intercrop Catuai saplings into their declining Catuai fields, doing so makes complete sense and starting sooner is better than later[7]. The only relative downside to the strategy of intercropping is the expenditure on crops must be made sooner. Since the expenditure must be made eventually regardless, it is better to do after a year of full harvest instead of spending money after a year in which yields were lower (as they tend to be) at the end of the Catuai production cycle.

The question remains of the choice of species to intercrop. It is useful to investigate what would happen if farmers switch their fields to Borbon trees. It cannot be assumed that all will do so; many might only consider it if they notice the benefit gained by others[8]. For this reason, the simulation has programmed into it an element of randomness that accounts for the variability in the choice to switch.

[7] For graphs detailing the effects of farmers initiating intercropping later, consult Appendix C.

[8] For most farmers with Catuai fields, there are two or three opportunities to intercrop in the fifty year time frame.

A typical result, if approximately a third to half of farmers will choose to switch is displayed below[9]:



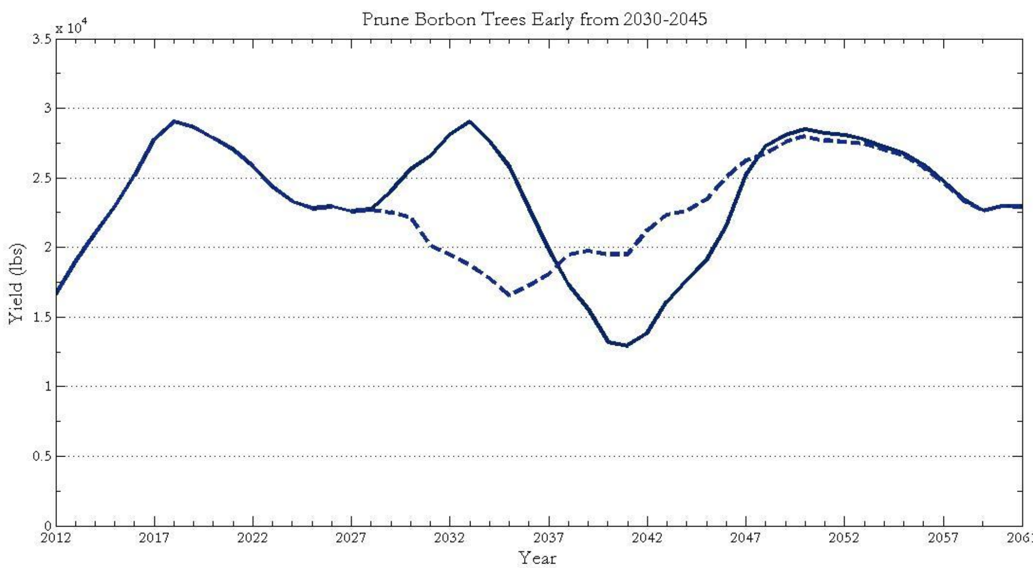
Assuming again that about a third of farmers choose to switch—but running the simulation to initiate switching species after five years instead of after ten gives an almost identical result. This is because the majority of fields begin giving declining yields in about 2020. Waiting longer than five to ten years before beginning to convincing farmers to switch species is not advised[10].

Results are slightly better than those above when the simulation assumes that a little over half of farmers choose to switch, giving an average minimal yield of about 17,000 lbs. However, one should take heed to extrapolate from this increase in the number of farmers that switch. If *all* of the farmers choose to intercrop Borbon into their declining Catuai fields, the result is hardly optimal[11].

[9] Best and worst case scenarios for farmers choosing to switch species can be found in Appendix C.
[10] See Appendix C for graph.
[11] See Appendix C for graph.

EARLY PRUNING

The strategy of early pruning applies only to Borbon trees—they are the only ones that can be trimmed and still yield productive harvests once branches regrow. The idea behind early pruning is to trim trees while they are still in full production rather than waiting for production to decline to a fraction of full capacity towards the end of the tree's productive life cycle. This will indubitably be extremely difficult to propose to farmers[12], but this happens to hold some promise. For example, if the only change that the cooperative makes is pruning Borbon trees after 20 years instead of after 25 for the period of time between 2030 and 2045, the simulation yields the following result:



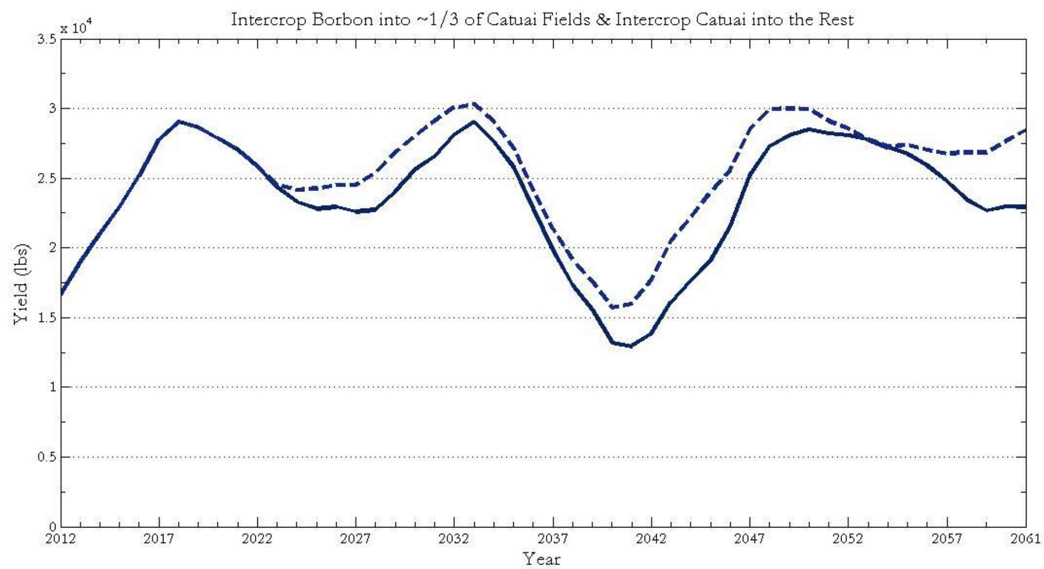
The first dip in the baseline projection is caused by the necessity of Catuai trees to be replanted. The second dip is caused the Borbon trees being pruned at the end of their productive cycle right before many of the Catuai trees need to be replanted again, compounding the decrease in yield. The reason early pruning makes the forecast fluctuate less dramatically is that doing so would shift the Borbon cycle back temporarily, preventing their years without yield from coinciding with those of the Catuai trees.

Even though early pruning results in a steady decline of production from 2017 to 2035, it becomes evident that pruning early has certain advantages when combined with other strategies: one example being that it balances out increases in yield from purchasing land. The inherent disadvantage of pruning early is that farmers are likely to not be receptive to the change as it would require them to sacrifice full yields that they know would continue for a few more years if pruning does not occur. Experimentation with combining the strategy of pruning with other ones yielded some favorable results, to be discussed in the following section.

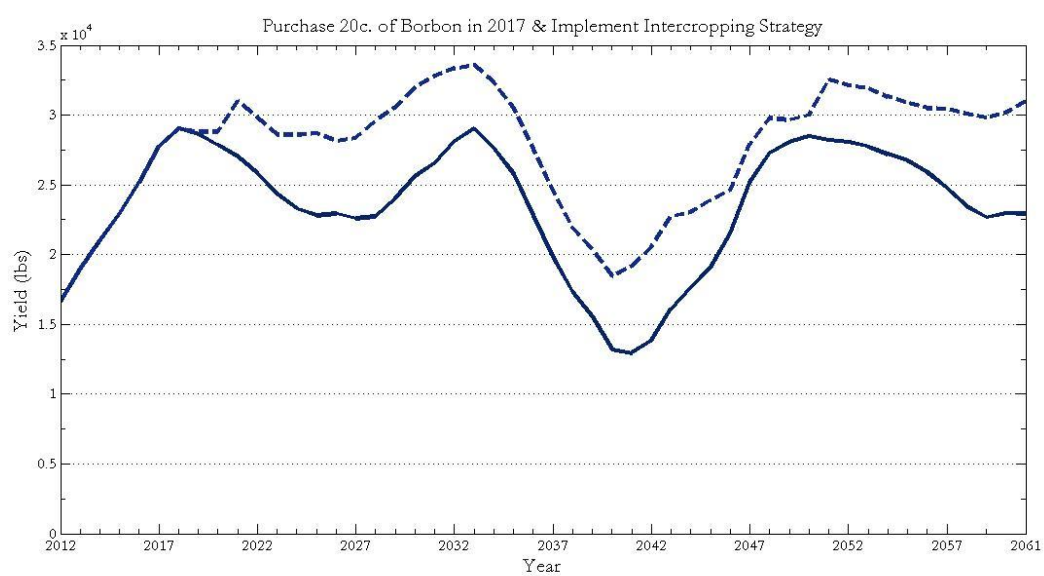
[12] The farmers that own both Catuai and Borbon fields might stand to gain future yield consistency, but for the majority of farmers, early pruning provides little personal benefit and is a sacrifice for the collective good of the cooperative.

MIXED STRATEGIES & DISCUSSION OF OPTIMALITY

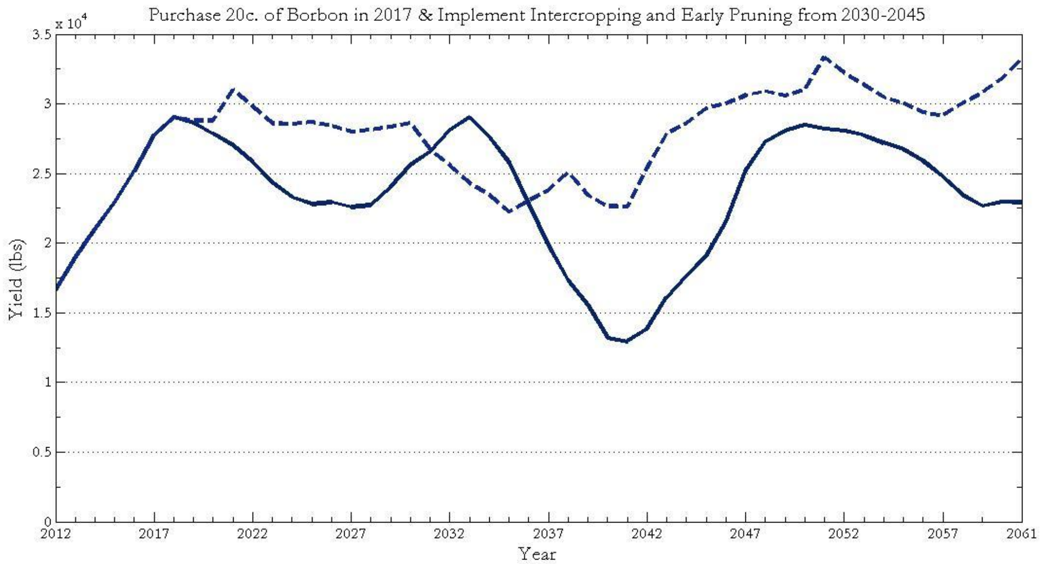
It is clear that none of the aforementioned strategies alone are sufficient enough to solve the problem of sustainable increasing coffee yields. Intercropping was a solution that appears to be an inherently logical thing to implement, as it helps improve yields and will need to happen regardless. If approximately 30-60% of farmers choose to intercrop Borbon in their Catuai fields starting as soon as possible—with most intercropping occurring in the period between 2020 and 2030—and the rest choose to intercrop Catuai, the typical result will help somewhat with future crop yields:



Building on this progress, henceforth referred to simply as the "Intercropping Strategy," running a simulation that also includes a purchase of twenty cuerdas of Borbon in 2017 yields the following:



This result is still not optimal, and in fact still poses the same problem of a steep decline in yield starting around 2030[13]. However, combining the above with the scenario of farmers pruning their Borbon trees early during the period between 2030 and 2045, the simulation yields the following as a typical result, with about 40% of farmers switching species when they intercrop[14]:



To reiterate, the simulation contained a random variable and thus simulates a slightly different variation of the above every time it is run. The reason for this is in order to account for the inevitable possibility of some farmers not wanting to intercrop Borbon into Catuai fields, opting instead to replant the same species. It is assumed however that everyone will decide to intercrop[15] .

The biggest factor in developing the sort of favorable yield trend lines demonstrated in the graph above is the assumption that every farmer with a Borbon field—all but a few have at least one—will agree to prune their trees once they reach twenty years of full production. This will indubitably be a difficult thing to implement but cooperative-wise, the results would be quite favorable.

The reason that no randomness was programmed to account for farmers refusing to prune early and give up multiple years of full yields is the belief that such a decision would likely cause others to follow in suit. Unless all of the farmers affected are making the sacrifice, it is unlikely that the strategy will work in practice, leaving no use in guessing what fraction of farmers would elect to prune early. Unfortunately, this is one of those strenuous situations where the good of the cooperative would have to outweigh individual imperative for successful implementation.

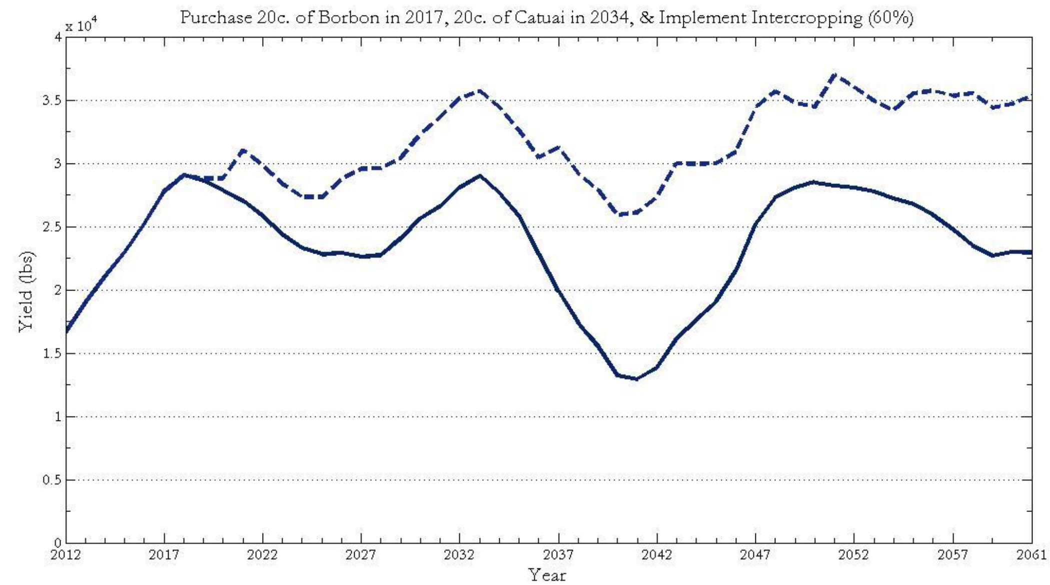
[13] Running the same simulation with a purchase of Catuai instead of Borbon led to a less favorable result. Consult Appendix D for a graph of the result and other less favorable variations of strategies.

[14] Refer to Appendix D for comparisons of different percentages of farmers choosing to switch to Borbon when intercropping. Some variation definitely occurs, but the general trend is still favorable compared to the baseline.

[15] If some farmers choose not to intercrop at all for whatever reason, the variation in the results of the simulation were quite negligible, and thus they were not chosen for inclusion in this report nor the appendices.

Fortunately, if the decision to implement early pruning is made, the cooperative has many years to begin facilitating open discussion with farmers to make the compromise and has thus, the ability to plan accordingly.

Should the capital funds become available, a second purchase of twenty cuerdas in 2034 would help tremendously. Doing so in tandem with the Intercropping Strategy (assuming approximately 60% would switch to Borbon) would work to sustain yields quite well. Though still subject to some fluctuations, the result is not nearly as bad as the baseline forecast. Please note that the y-axis in the graph below has a maximum of 40,000 instead of 35,000 lbs.



This strategy does not require the same kind of personal sacrifice from the farmers that early pruning might, but it would require purchasing large amounts of land twice. Thus, if chosen as a strategy, the cooperative will have to plan accordingly to save capital or host fundraisers. The price of land is also bound to rise significantly by 2034, so the implementation of this optimal strategy relies on the assumption that the cooperative will be in a position to make such purchases. Certainly, with the right coordination and determination, it would become feasible to purchase large quantities of land in the designated years. Doing so would greatly improve the productivity of the cooperative and would not require difficult negotiations with farmers who are unlikely to agree to prune their crops early.

Conclusion

It is important to note that the aforementioned strategic responses to problems forecasted in the next five decades do not sustain the cooperative indefinitely. They are merely solutions to a problem within a fifty-year time frame. The simulation is completely capable of forecasting for any number of years, but the farther away one attempts to look, the less realistic the results will be. More farmers are likely to join the cooperative, and few of the current ones are likely to be farming by the middle of the century, though the next generation very well may be.

It is the suggestion of this report that the cooperative should enact changes if it wishes to maintain steady sustainable growth and continue providing developmental aid to rural coffee farmers in and around San Miguel Escobar, Guatemala. The simulation demonstrated that "Intercropping Strategy," which involves everyone intercropping—and approximately half of farmers switching species when they do so—is highly beneficial, and implementing it should be relatively simple in practice. Doing so would shorten the time a plot of land would not be producing coffee by at least two years, increasing cooperative-wide yields in the periods of decline without any additional capital investment, only a change in tactic.

In addition, a purchase of twenty cuerdas of land in 2017 will likely be necessary, as it would cushion both dips in yield. A second purchase of twenty cuerdas in 2034 would go a long way in maintaining the cooperative's growth in the fifty-year time frame if combined with the aforementioned purchase and Intercropping Strategy[16]. The alternative to a second purchase of land would be pruning Borbon trees five years earlier than they would normally be pruned. This strategy combined with a purchase in 2017 and the Intercropping Strategy is also sufficient to sustain the cooperative's growth. The disadvantage of early pruning is the inevitable difficulty of implementation, as many farmers are bound to be unreceptive to sacrificing years of productive yields for the benefit of the cooperative.

The simulation and resulting graphs demonstrated that while it may not be simple in practice, long-term sustainability and maintainable economic development is absolutely feasible for the San Miguel Escobar cooperative if the strategies discussed in the final section of the report are taken into consideration and implemented.

[16] Again assuming that approximately 30-60% farmers will choose to intercrop Borbon into their fields instead of replanting Catuai.

APPENDIX A: SIMULATION DETAILS & ASSUMPTIONS

Each of the four species has a different harvest cycle. Catuai, Catura, and E14 all have relatively similar cycles and estimated yields per cuerda. They begin giving full yields in the fourth or fifth year, produce at full capacity for about a decade, entering a period of steep decline before needing to be replanted, starting the cycle over again. Borbon begins giving a full yield in the fifth year, produces for about twenty-five years, and has larger harvest on average. Its production capacity then declines as sharply as the others species before the trees need to be pruned, after which the cycle begins again. The table of specific figures pertaining to each of the four species is shown below, and can be considered an accurate representation of major assumptions made by the simulation used in the investigation[17].

Species	Full Yield In Year	Total Years of Production	Declining Harvest Starts	Full Harvest
Borbon	5	25	23	200
Catuai	4	13	11	125
E14	5	10	8	125
Catura	4	12	10	125

Year Before Full Harvest: 20 % of Full Harvest

An iteration of the simulation represents one year; it goes through each plot of land individually and determines firstly whether or not a tree will be in full or partial production, if it is nearing the end of its cycle, or if it is entering a decline in production. Once a state has been determined, the simulation assigns a yield for that specific plot by multiplying the full harvest value by the number of cuerdas on that plot of land. Taking a sum of all these values at the end of the iteration determines the cooperative-wide yield for that particular year.

If a plot of land will enter full production in one year, the simulation assumes that the land will produce 20% of its full harvest capacity. The following year and for the number of years in the "Declining Harvest Starts" column, the plot of land produces at full capacity. Yields enter a steep decline over the difference between the values in the aforementioned column and the "Total Years of Production" column. Once a tree has been producing for the number of total years, the simulation takes it out of production (representing either a replanting or pruning), during which the tree produces zero pounds for one year less than the value in the "Full Yield in Year" column, with the penultimate year before the beginning of full production being a partial harvest year.

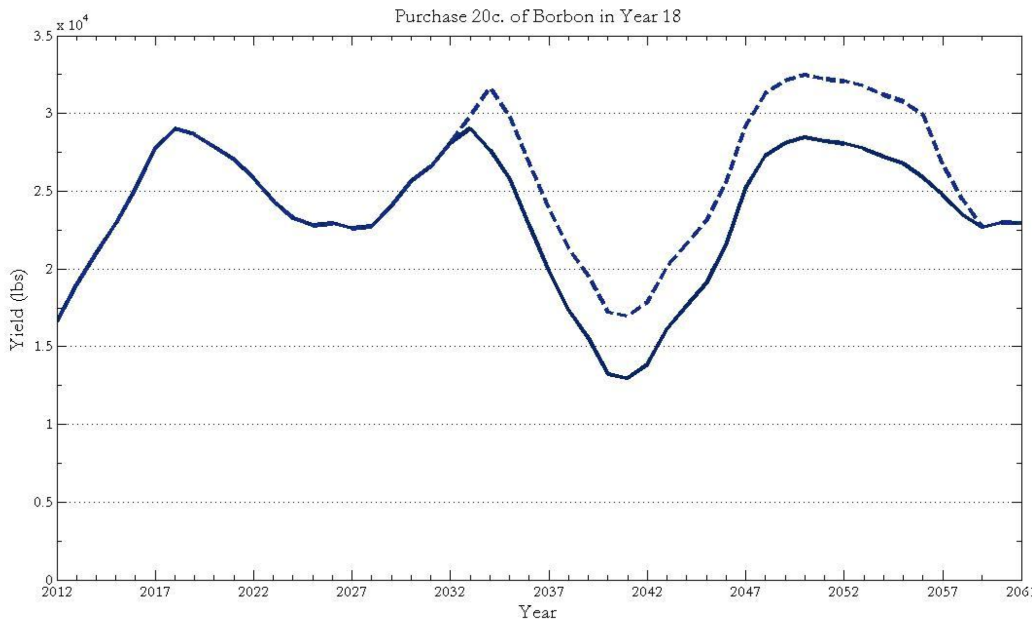
A major assumption made by the simulation is that the full yield for a year is an average based on prior experiences of the cooperative; thus for the purposes of this investigation, it is assumed that the annual full yield is static, changing only if the plot of land is in a partial harvest year or in decline.

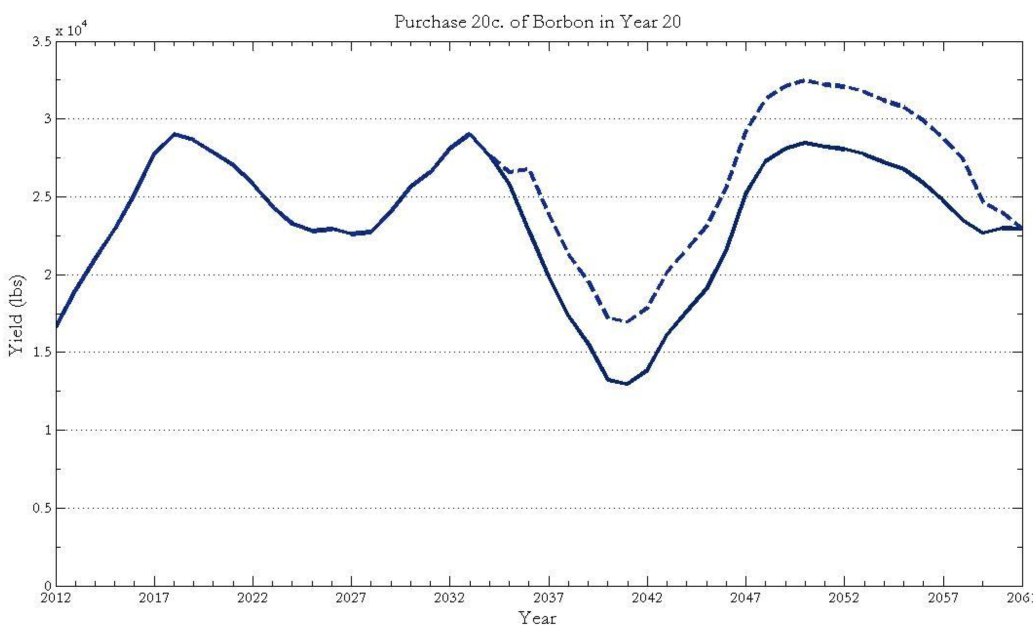
[17] In the interest of transparency, a copy of the simulation can be requested by emailing mpilosov@gmail.com However, information pertaining to the farmers and their land holdings cannot be disclosed.

Appendix B: Notes on Purchasing More Land

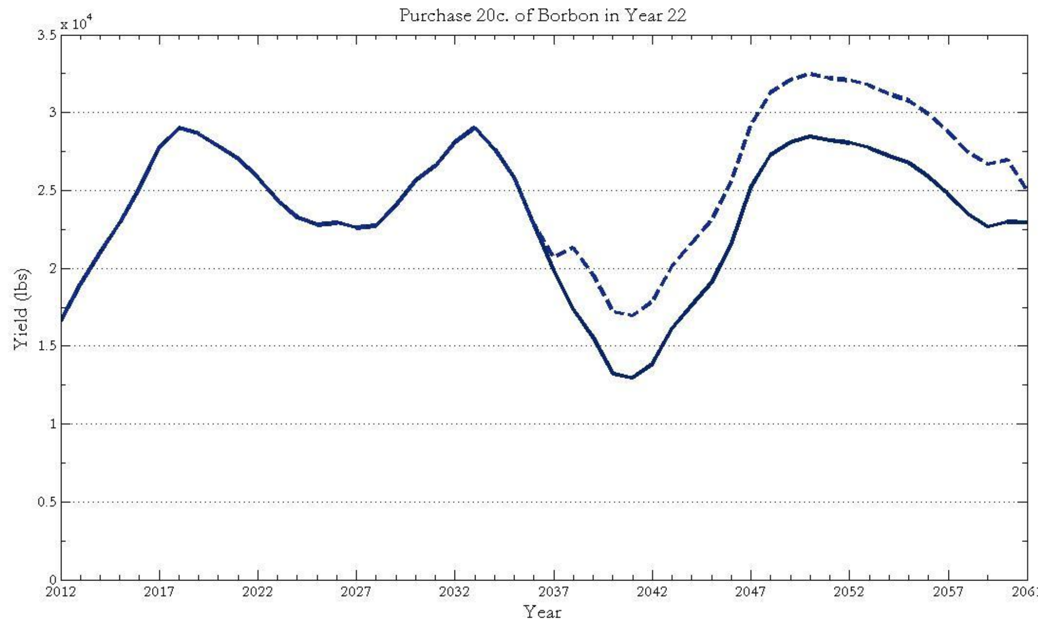
On Purchasing in Different Time Frames:

One would think that purchasing the higher yield per cuerda species Borbon right before the larger dip would be a beneficial strategy, but the simulation quickly demonstrates that this would not work as well as one would hope.

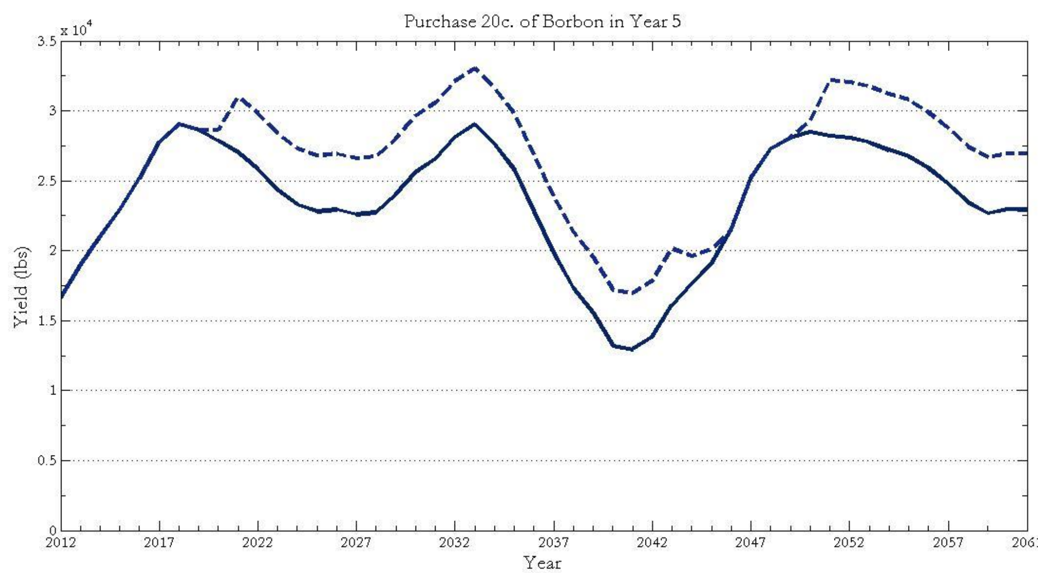




The purchase of land in preparation for the yield shortage results in a bloated peak following the dip. This further exaggerates the inconsistencies in yield from year to year.

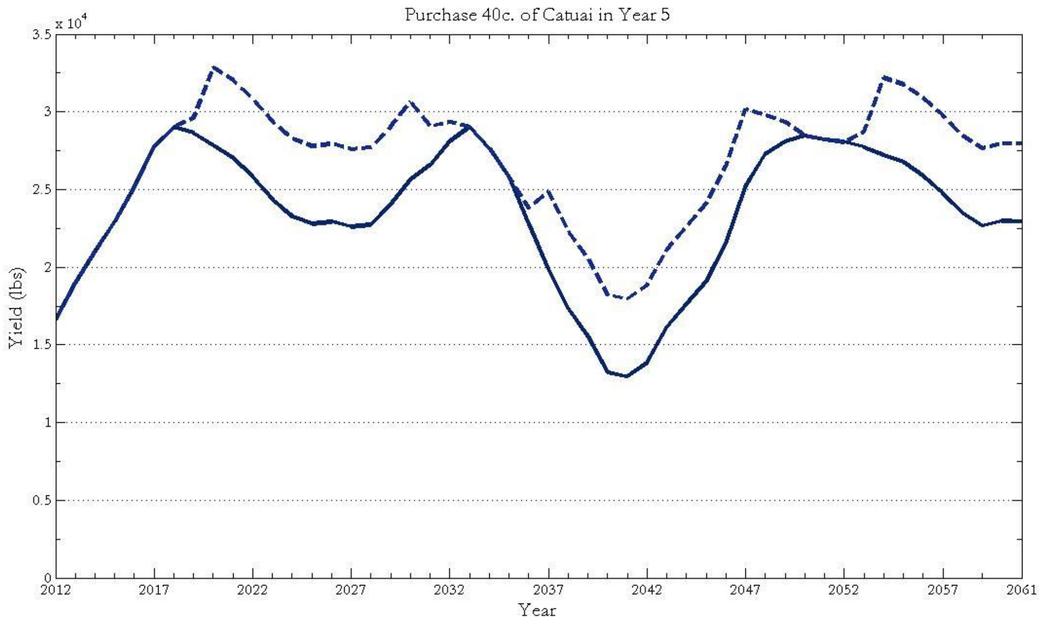


For comparison, here is the graph of the purchase of Borbon in five years. The additional benefit of more predictable land prices also adds to the appeal, as well as increased yields sooner from the new trees producing higher yields than the species that they are replacing.

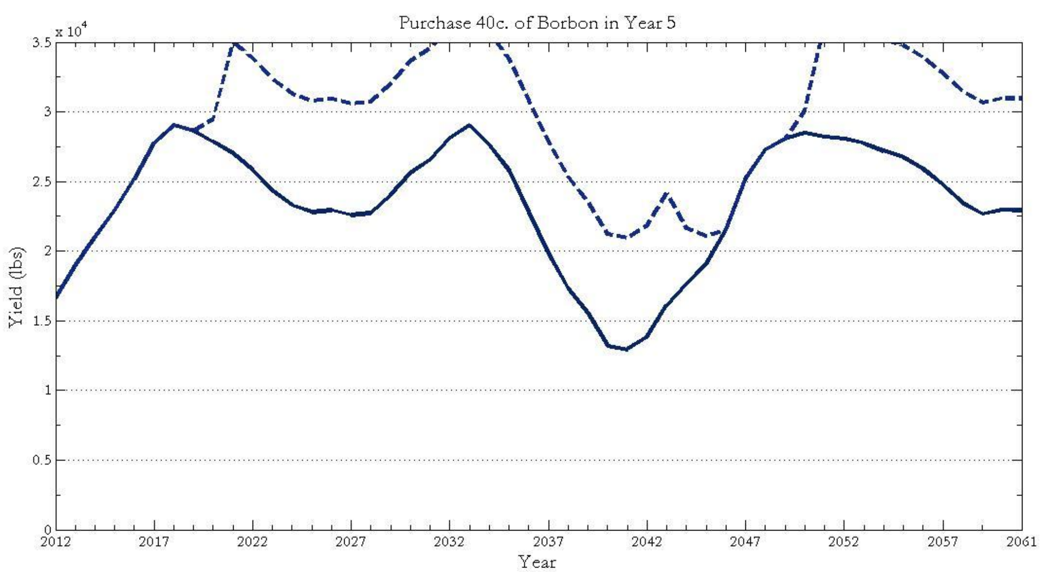


On Purchasing Larger Amounts of Land

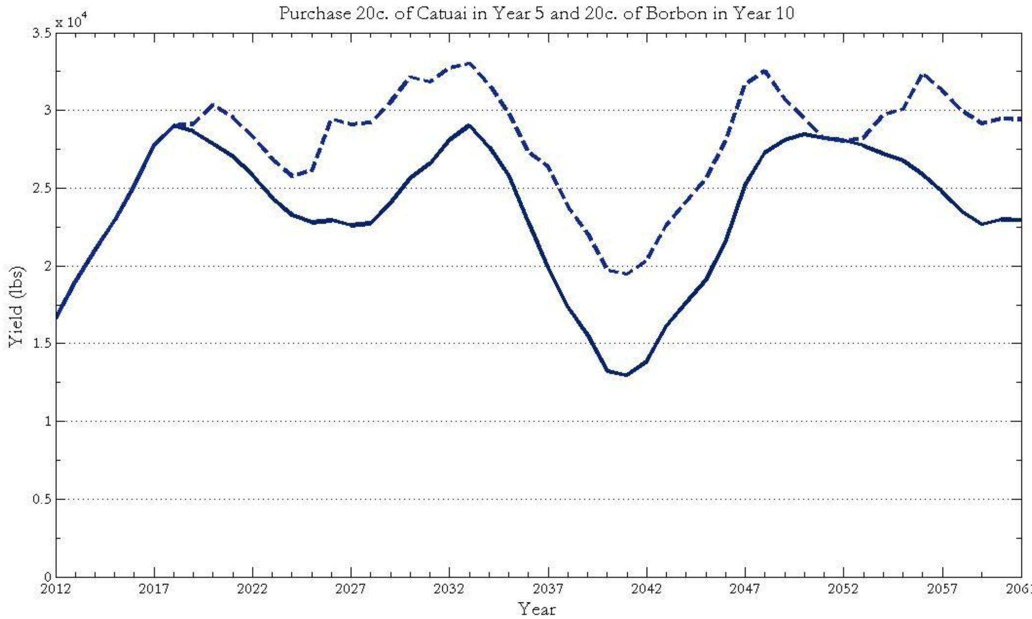
Should the funds become available, it is useful to evaluate what the effect of hypothetically purchasing forty cuerdas of land instead of twenty. The graph for a purchase of forty cuerdas of Catuai was shown earlier but is reproduced below for comparison.



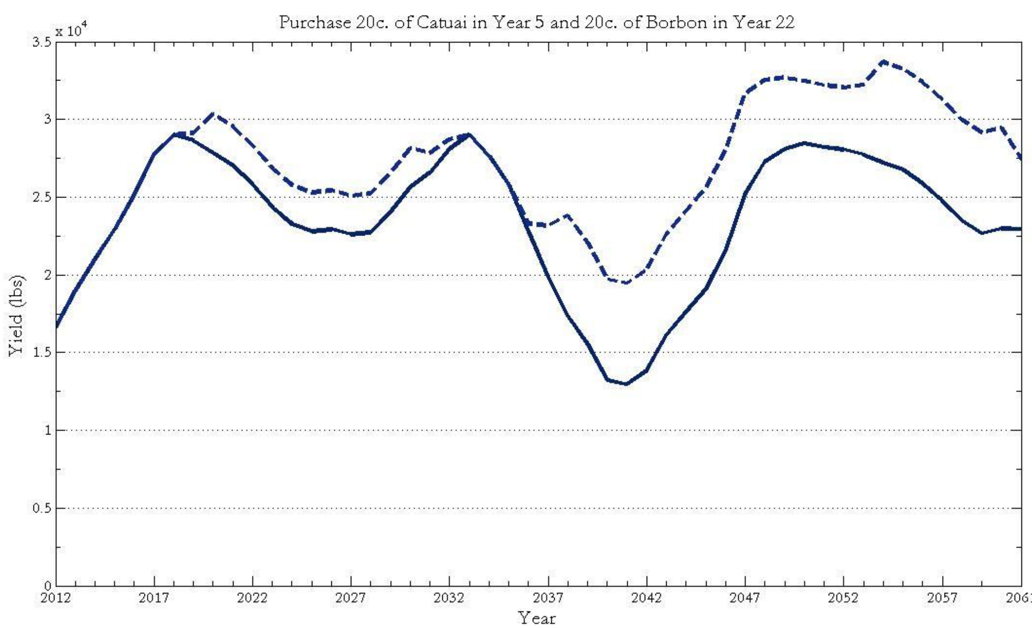
Planting forty cuerdas of Borbon trees in five years will result in a less desirable result than purchasing and planting the equivalent amount of Catuai trees at the same time.



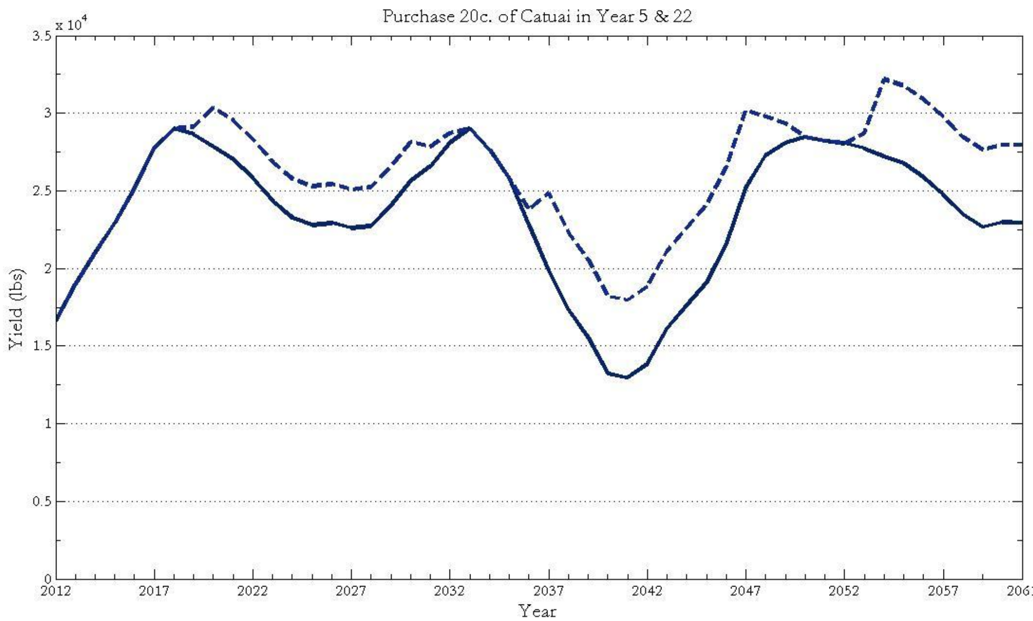
Using the strategy of purchasing Catuai in 2017 and then Borbon at a later time should be taken into consideration, and whilst both of the following graphs help ease the larger shortage by similar quantities, there are disadvantages to sustainability with both, as there is still a lot of fluctuation.



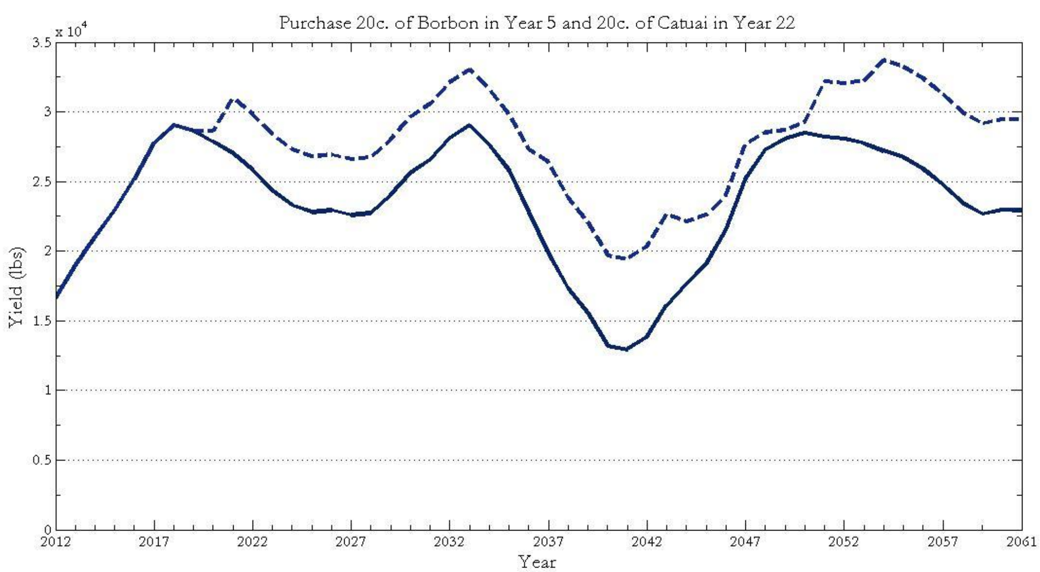
As seen above, a purchase of Borbon in 2022 would lower the minimum yield but also still retain the relative dip by raising the yield in the years around 2030. Although the price of land will be higher in 2034 than in 2022, delaying the purchase would result in a less extreme difference between peaks and troughs overall. The benefit of rapid growth after the second dip is subjective; some might prefer slower but steadier and consistent growth:



The yields from purchasing twenty cuerdas of Catuai in 2015 and again in 2034 are certainly lower than the previous graphs, but it was chosen for inclusion in the report because of its ability to fill in the drops in yield without greatly increasing the average rate of growth.

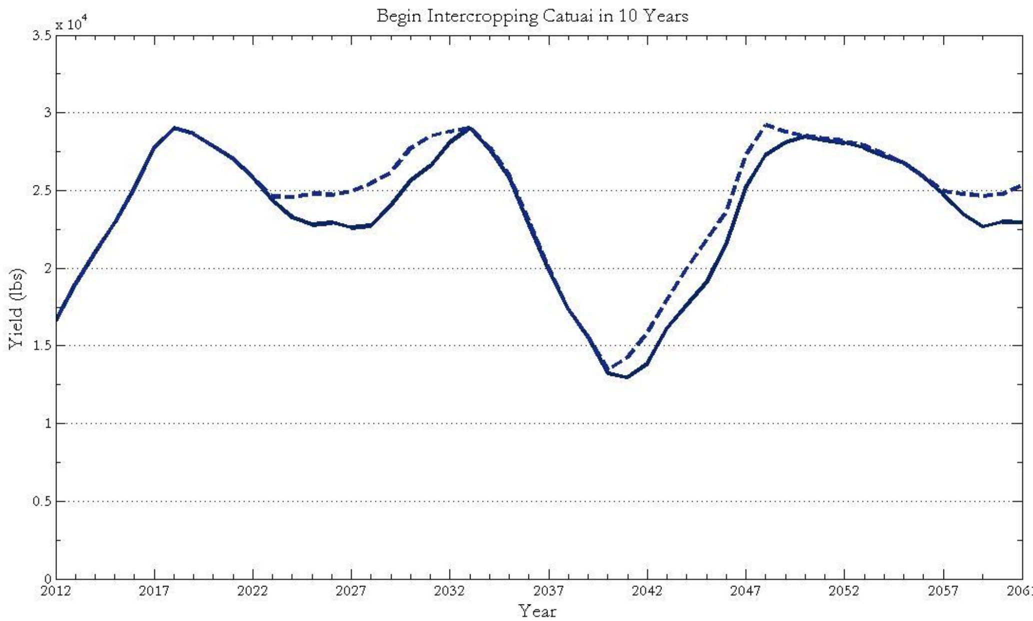


Purchasing twenty cuerdas of Borbon in 2017 and twenty of Catuai in 2034 had the best result from the sole strategy of two purchases:

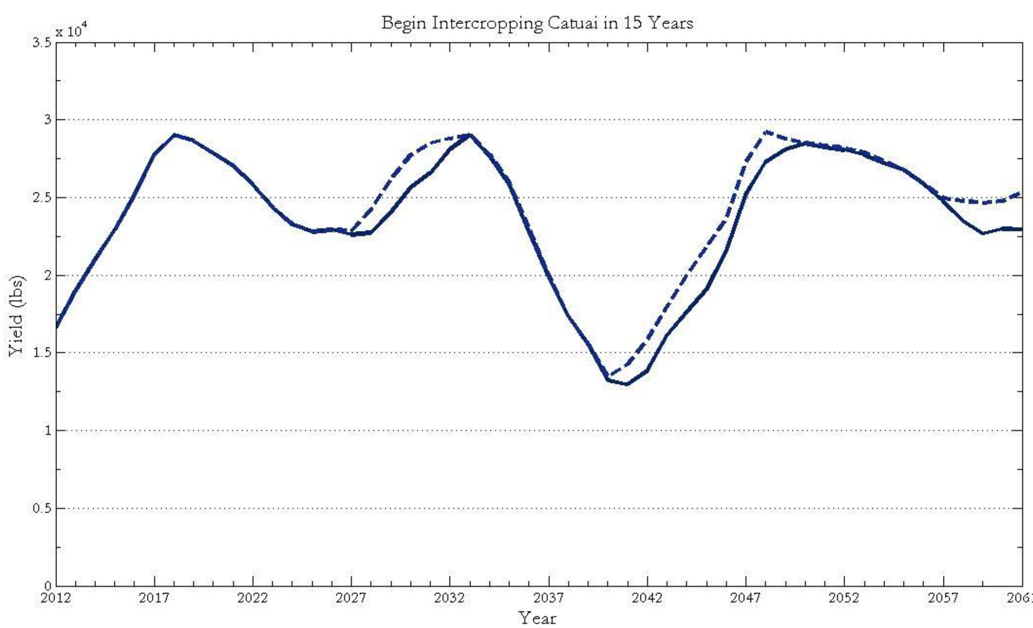


Appendix C: Notes on Intercropping

Intercropping Catuai

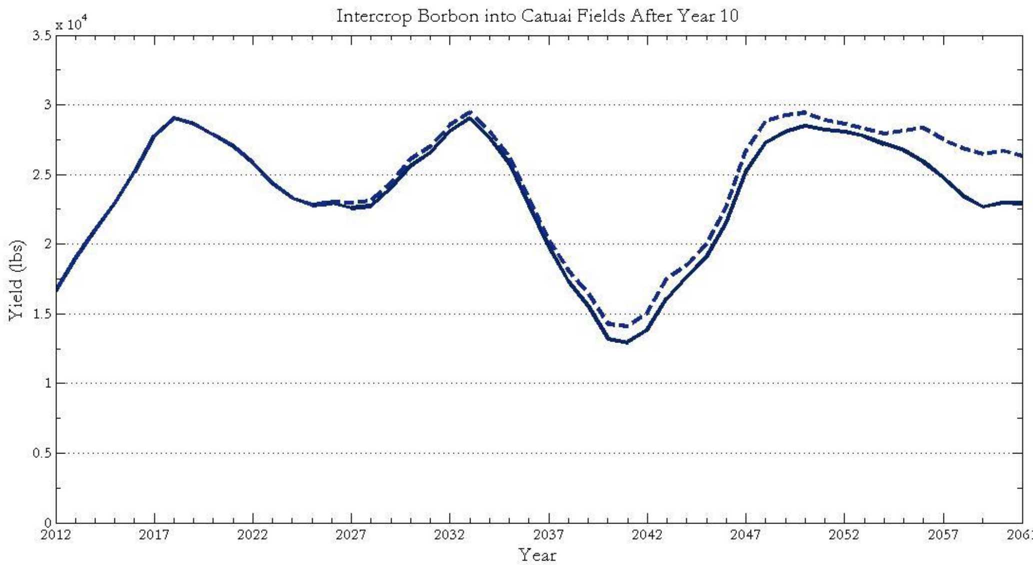


As mentioned in the report, the sooner one starts intercropping Catuai fields, the more beneficial it will be. Beginning to intercrop in 2022 is almost identical to doing so in 2017. Waiting until 2027, however, is not recommended, as it will not help the first decline in yield at all, providing no added benefit compared to beginning to intercrop sooner:

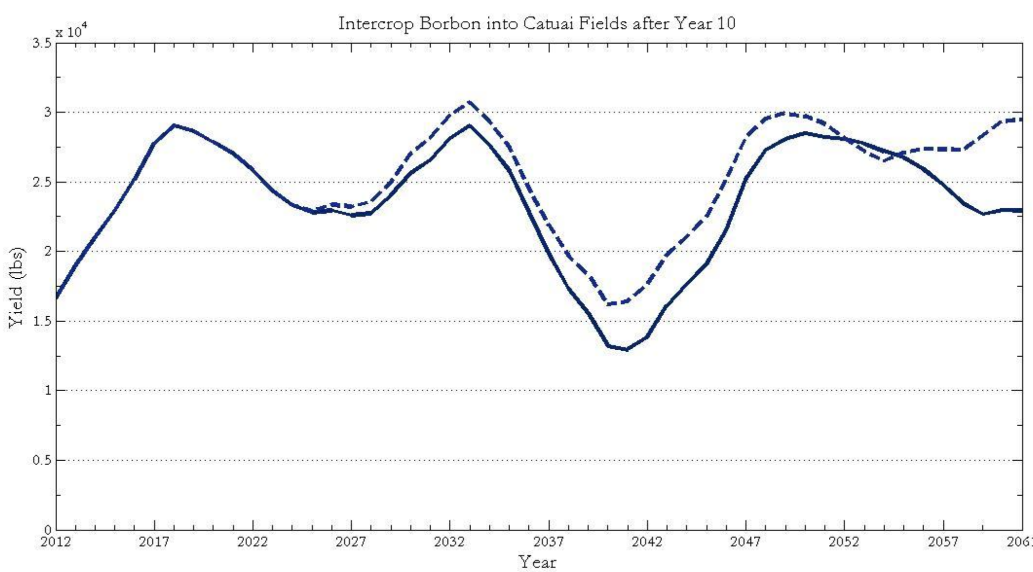


INTERCROPPING BORBON

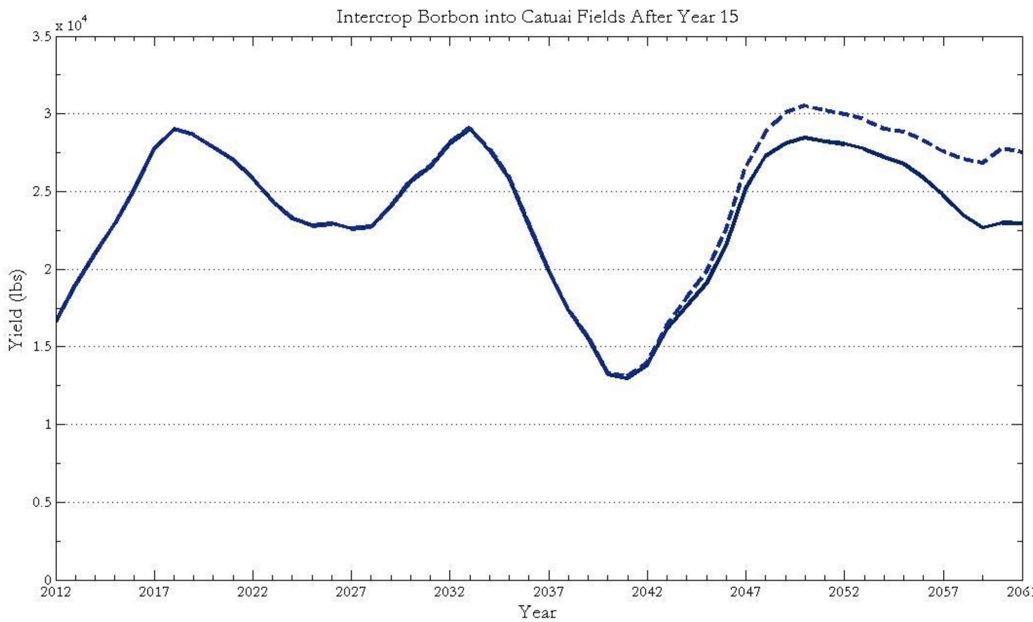
The result displayed earlier in the paper was a fairly typical result of the simulation, assuming between a third and half of farmers would begin to switch to Borbon once their Catuai fields reached the end of their productive cycles. The lower spectrum of results of the simulation looked more like the following:



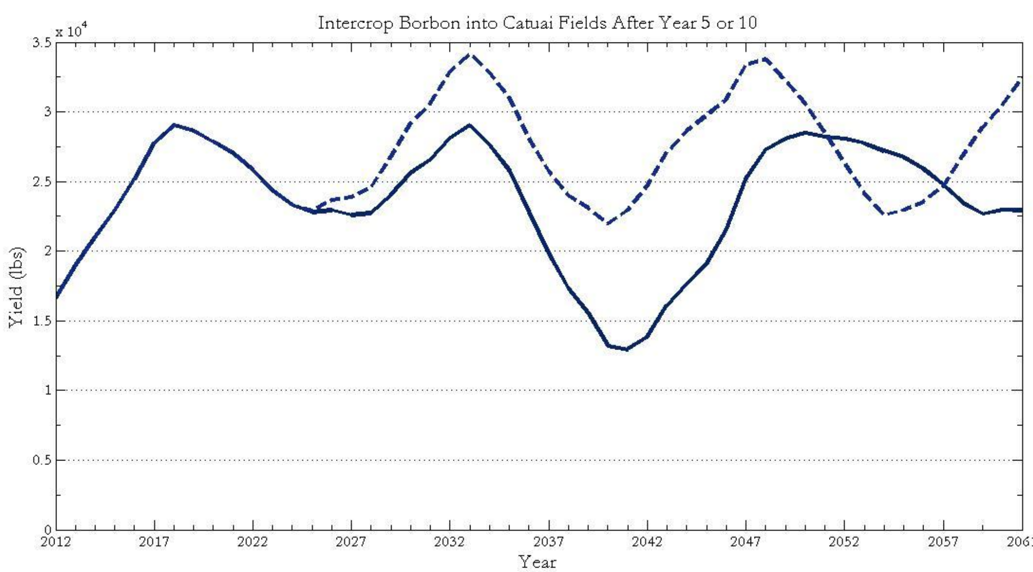
An optimistic result would help fill in the second dip in yield significantly more. The following is not the largest improvement the simulation managed to plot, but is certainly an accurate representation of the better results of the simulation (more farmers switching), with more favorable minimal yields:



As mentioned in the report, waiting fifteen years to begin implementing a switch of specied is ill advised, as the effects are not nearly as significant. Waiting twenty years is even worse. Attempting to begin intercropping Borbon trees into Catuai fields in decline is best started sooner than later. The best case scenario from waiting fifteen years is shown below:



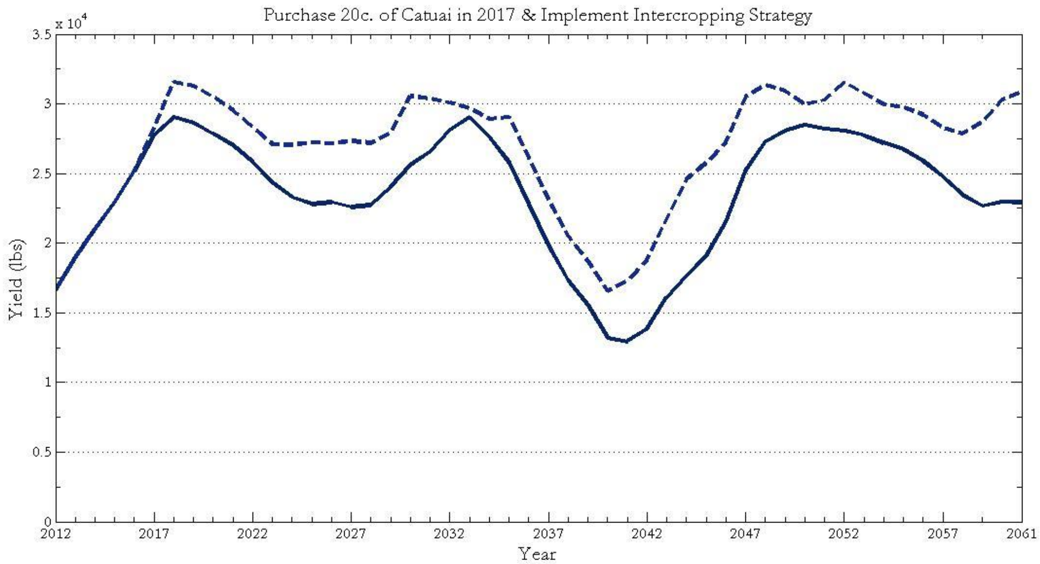
Furthermore, as unlikely as it will be that all of the farmers will choose to intercrop Borbon into their Catuai fields, it is important to reiterate that if they do, the results will not be desirable[18]:



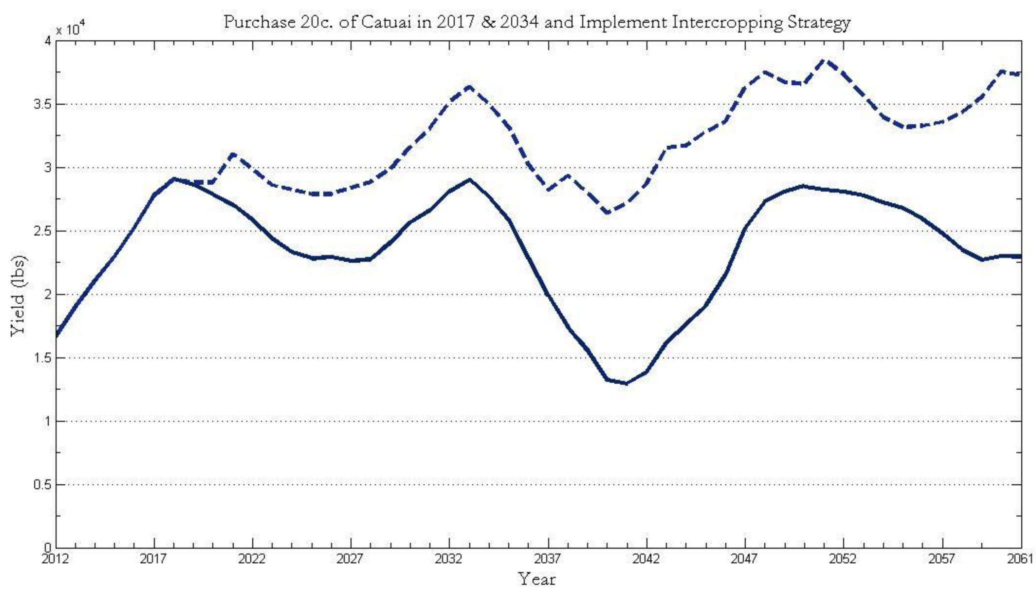
[18] A note on the graph title: results from switching species after five years were nearly identical to doing so after ten, this is due to the first opportunity to intercrop for most farmers occurring around 2020.

Appendix D: Notes on Mixed Strategies

There were many less favorable combinations of strategies, most of which were not selected for inclusion in this report. However, for the curiosity-inclined reader, this section will provide some graphs of other possible scenarios. The first is a graph resulting from the combination of the Intercropping Strategy and a purchase of twenty cuerdas of Catuai instead of Borbon in 2017:

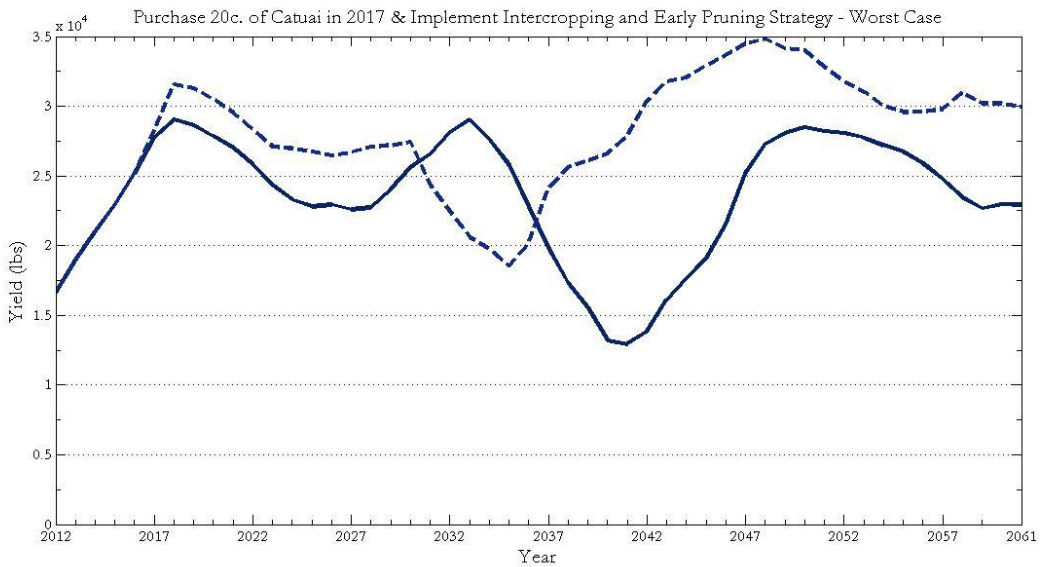


Purchasing twenty cuerdas of Catuai both times results in the following graph. Please note that graph below has a y-axis with a maximum of 40,000 instead of 35,000 lbs.

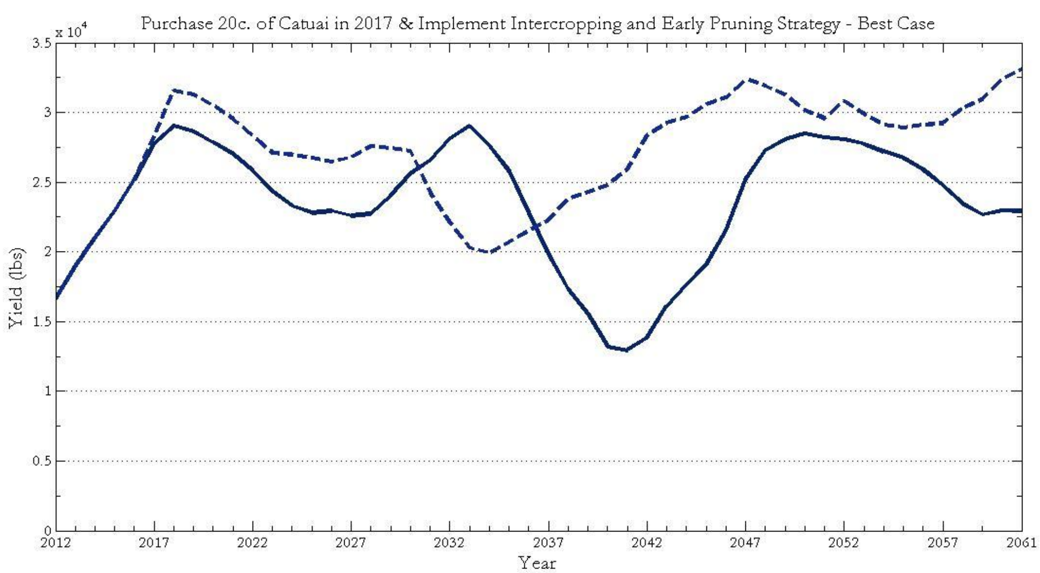


The remaining graphs in this appendix are all less favorable than the strategy of two purchases of land in combination with the Intercropping Strategy that involved about 60% of farmers switching to Borbon during their first chance to intercrop. The reason for their inclusion in this appendix is to account for the possible scenario of land prices climbing so drastically by the period before 2030 that AGAIG decides that it will not be able to raise enough capital to make the necessary purchase of twenty cuerdas, and must turn to the alternative and less favorable strategy of early pruning.

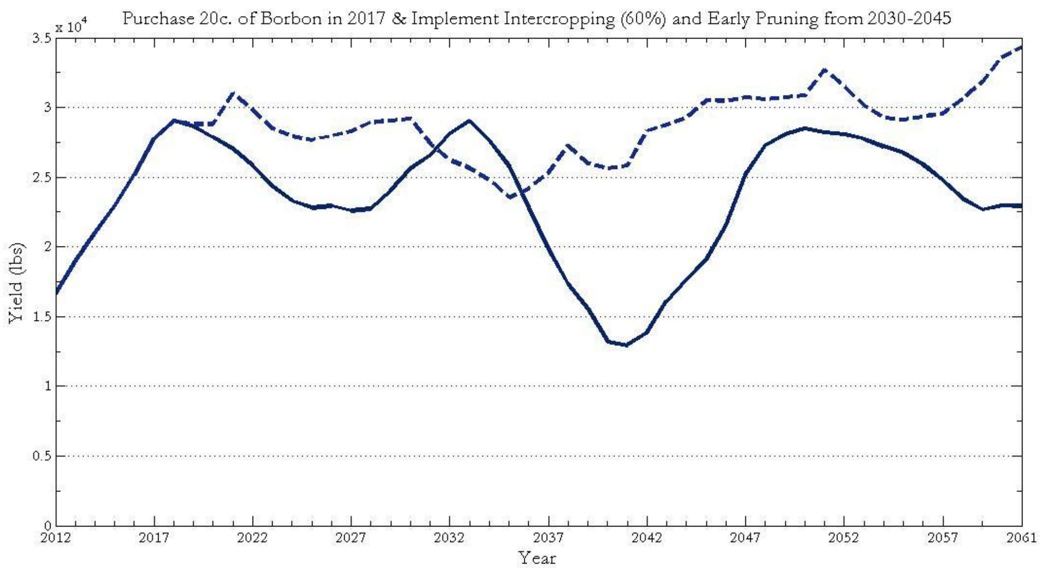
The Intercropping Strategy combined with Early Pruning and one-time land purchase, only this time with a purchase of Catuai instead of Borbon produces the following two graphs:



The above is the result of closer to 40% the farmers choosing to switch to Borbon when they intercrop. The graph below is the result of a simulation where the proportion that switch was 20%:



For comparison, the best case scenario for purchasing Borbon in 2017 was the following, with about 60% of farmers choosing to switch when intercropping. Yields are more stable than in the graphs on the previous page.



The result of approximately 20% of farmers choosing to intercrop Borbon is shown below, which could be considered a worst-case scenario for the mixed strategy, still assuming that all farmers prune early. The results in the report used middle ground for the final graph of this strategy, assuming that 40% of farmers would switch to Borbon when it came time to intercrop.