The Native Exotic: The Reintroduction of Pawpaw Tree Cultivation

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Abstract

This project models the potential profitability of planting the pawpaw tree, *Asimina triloba*, in New England. Due to the consumer-driven local food movement, and desire to expand local food options, the increase in farmers markets in New England, would allow niche crops, like the pawpaw, to succeed in this farmer-to-consumer structure.

The primary research questions are: Under what conditions could pawpaw be profitably grown by farmers in New England; What are the implications of pawpaw's historical distribution and future climate change strategies and policies to encourage pawpaw cultivation? Hypotheses include: Pawpaw can be financially feasible for New England farming, driven by marketing to farmers markets, supporting a high price for this perishable fruit, and low cost of production; Climate warming in New England is expected to make pawpaw more profitable in the future.

In order to get a sense of who, how and why people planted this tree I attended the 19th Annual Ohio Pawpaw Festival, as well as interviewed farmers growing the fruit in Massachusetts and Rhode Island. From these interviews, lectures, first hand experiences, and supporting published information, I created a financial appraisal model to assess whether planting pawpaw in New England would be profitable for farmers.

From my personal interviews, it appears that the marketing aspects of retail is currently fueled by the consumer demand for the fruit. It presently is and will continue to

remain, for the foreseeable future, a niche item. This factor will allow for the price per pound to remain high while gaining traction as a new local food offering.

After witnessing the pawpaw tree thriving in New England during my onsite farm visits and establishing from published materials that the USDA growth hardiness zones are shifting, securing the region into an optimal range for the pawpaw tree, I determined the regional climate can support the reintroduction of this indigenous species. My modeling concluded that pawpaw would be a viable, profitable crop for a small-scale, family operated farm. Pawpaw has the potential to emerge in the New England local food scene as a profitable item.

Acknowledgements

I want to start by thanking Dr. Mark Leighton. From all the brainstorming conversations in Tuscany, to seeing this body of work through every step of the way as my Director, I could not have asked for a more enthusiastic, tremendously helpful mentor. Thank you to Integration Acres, Rocky Point Farm, Whitesfields Farm, Food Forest Farm, Ted Ruegsegger and Clover Food Lab for the wealth of information. Thank you to my mom for the daily inspiration, my dad for continuously believing in my ability and my brother for being a lifelong cheerleader. Thank you to Mike for being my rock and always finding a way to make me smile.

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Definition of Terms

CSA: Community Supported Agriculture

FAO: Food and Agriculture Organization of the United Nations

GIS: Geographic Information Systems

MDAR: Massachusetts Department of Agricultural Resources

NAEB: Native American Ethnobotany Database

NAPGA: North American Pawpaw Growers Association

NCA: National Climate Assessment

NOAA: National Oceanic and Atmospheric Administration

NPV: Net profit value

NRCS: Natural Resources Conservation Service

USDA: United States Department of Agriculture

Chapter I

Introduction

With the establishment of industrial agriculture, which was deemed necessary to meet the demand for the growing population, locally grown produce struggled to compete in the retail market (FAO, 2017). Over the years, many indigenous crops have been phased out in favor of main stream commodities, one being the pawpaw. The pawpaw, *Asimina triloba*, is a deciduous tree native to North America, and the only indigenous tropical tree grown as far north as the Great Lakes region. It is the only member of the Annonaceae to grow in this region of the world.

The pawpaw once flourished throughout the Midwest and East Coast, but its perishability once harvested prevented the fruit from being mass distributed. The pawpaw fruit will not continue to ripen once picked, therefore can only be harvested when ripe. In their ideal condition for consumption, the skin is starting to turn brown and is soft to the touch. This quality does not make it a viable candidate for long distance transport. When options for elongating the shelf life of produce, such as refrigeration, were introduced into the marketplace, products like the pawpaw were neglected, proving to be an inviable crop for retail and subsequently, for mass production. To make the crop a commercial success, local retail seems to be the only effective option.

The consumer-driven local food movement has increased the availability of local items in the United States and the expansion of farmers markets (Shirley, 2013). For produce like the pawpaw, local retail options present an opportunity for the fruit to be commercially viable. An integral component of farmers markets is the reduction of "food miles" traveled. This allows for potentially increased freshness and diversity within the offering since packaging is not as critical an issue. The interaction between farmer and consumer is invaluable when it comes to introduction of new, unfamiliar products (USDA, 2016). The exchange of dialogue and ability to explain the offerings provides a stage for niche items to be showcased. Therefore, the resurgence of the local food movement has created an awareness of and opportunity for perishable agricultural products to have a place in the industry and it behooves farmers to create diversity within their offerings. There is potentially a profit to be made from growing the pawpaw, a tropical tasting fruit, native to non-tropical locations.

Research Significance and Objectives

The rationale for my research is to look at where and why this tree was grown and thrived in the past, why it no longer is a mainstream item, and if it is cost effective for it to be grown in the future. This topic incorporates historical trends, a look at the local food movement, and how working within our available landscape and environment plays a role in defining the future of farming. Therefore, my objectives are to:

- Gauge whether New England farmers could make a profit growing pawpaw for commercial distribution, evaluating what factors and conditions are most important in determining its financial feasibility
- Track where the pawpaw has historically thrived and establish a future growing range, examining how climate change might impact USDA plant hardiness zones

in the future

- Determine how effective of a catalyst farmers markets are at introducing indigenous crops
- Determine necessary steps in establishing policies to incentivize the growing of native food options

Background

The pawpaw tree, whose fruits are actually large berries, is native to 26 states in the United States (Figure 1). It has successfully grown and produced fruit in USDA plant hardiness zones 5-8, which encompasses areas along the eastern seaboard from Maine to northern Florida, up to Canada and the majority of middle America (Peterson Pawpaws, 2017). The tree bears the largest edible fruit native to the United States, with a taste that is described as tropical, somewhere between a banana and a mango. The trees are also pleasant to look at, attributed to their large ornamental leaves (Figure 2).

Aside from their flavorful, fruit and overall plant appeal, the fruits are also nutritionally very healthy (Jones & Layne, 2009) (Table 3, Appendix 1). Research also suggests that there are anti-cancer and pesticidal properties found within the tissues of the leaves, twigs and bark (Oberlies, Croy, Harrison & McLaughlin, 1997). Contributed to the insecticidal properties found within the leaf, twig and bark tissues, the trees are naturally pest and deer resistant, making them great options for all farmers, but especially those who follow organic practices. From the literature, the consensus has been that pawpaw trees have great potential for commercial production, yet very few farmers are currently growing them (Ames, 2017).

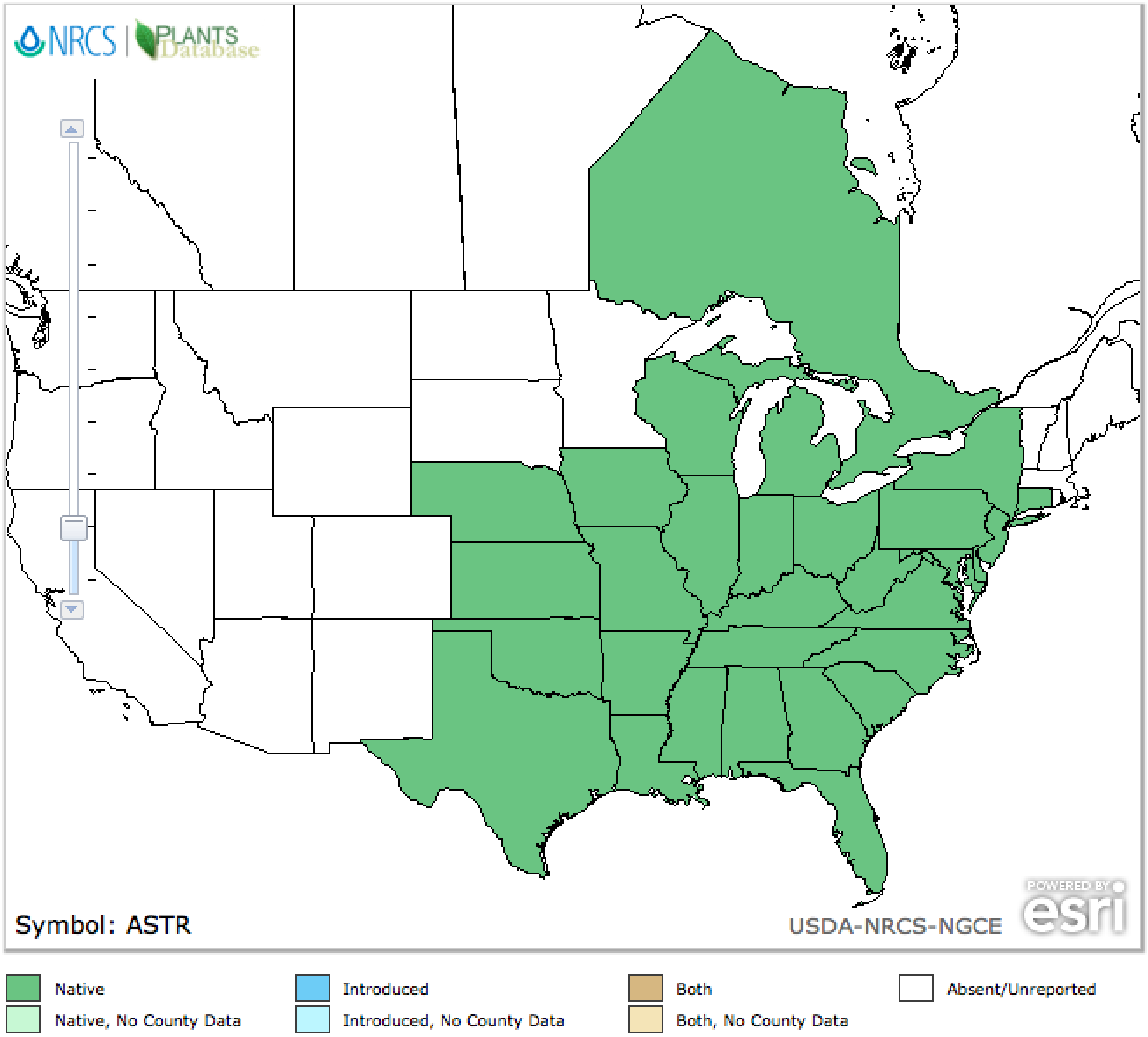

Figure 1. US states and Canadian provinces where the pawpaw is native (NRCS, n.d.).

Demise and Reintroduction

Since pawpaw is not currently grown commercially, most of the pawpaw that are sold for retail have been harvested via wildcrafting or from small scale operations (personal observations and interviews, Ohio Pawpaw Festival, 2017). Pawpaw is harvested in September and October, when the fruits range from 0.4-1 lb in weight. When ripe, the fruits appear borderline rotten, with the skin turning darker, almost bruised, in color and the texture soft to the touch. The fruits are best eaten upon harvesting but will keep for 3-5 days. They can also be stored for a few weeks in cold storage at around 39°F (Archbold, Koslanund & Pomper, 2003). The inability to retain freshness for an extended period of time eventually led to the demise of the fruit. As a result of the short shelf life, the pawpaw was unable to remain a mainstream commodity in competition with less perishable fruit.

Figure 2. Pawpaw tree and fruit near maturity (RareFind Nursery, 2016).

Due in part to the local food movement, niche market items have become more available to consumers. The increase in opportunities to interface directly with the growers at venues such as farmers markets and CSA's and reducing the time it takes from harvest to consumer, bodes well for the reintroduction of the pawpaw. The pawpaw appears to have tremendous potential for farmers to sell retail at not only markets, but also to breweries, bakeries and restaurants. With much of the food industry striving to incorporate more locally sourced ingredients, pawpaw has proven, in certain regional areas, that it can be successfully incorporated into a variety of cuisines and beverages (personal observations and interviews, Ohio Pawpaw Festival, 2017).

Historical Presence

Fossilized evidence, from as early as fifty-six million years ago, suggests that pawpaw predates the peopling of North America (Peterson, 2001). Archaeological sites stretching from New Jersey to Mississippi, suggest evidence that Native Americans enjoyed the seasonal fruit in abundance, leaving behind concentrated amounts of the seeds (Moore, 2015). The first recorded mention of the pawpaw was in 1541 by a member of an expedition led by Spanish explorer Hernando de Soto, while traveling through the southeastern part of the United States. He witnessed indigenous peoples in the Mississippi Valley region eating and growing the fruit (Hormaza, 2014). There are speculations that the Iroquois Nation, who called the fruit *hadi'ot*, were responsible for introducing the tree to the northern and eastern most regions (Keener & Kuhns, 1997). There are a multitude of documented uses for the pawpaw by the Iroquois, as well as Cherokee Nations. The fruit was eaten raw, as well as dried, baked into bread and incorporated with water to make a sauce that was eaten with cornbread. The fibers of the tree were also woven into cordage and rope (NAEB, 2018).

Having once been prolific in Appalachia and the Midwest, pawpaw is also referenced in numerous songs, stories and various folklore, which help to place the fruit in a time and region in United States history. Based on geographic location and time period, the fruit has been referred to by many names: Pawpaw, Paw Paw, Papaw, Poor Man's Banana, Hoosier Banana, Indiana Banana and American Custard Apple. It was documented that Thomas Jefferson grew these trees at Monticello, and that George Washington's favorite dessert was chilled pawpaw. Lewis and Clark also survived off the fruits for a portion of their journey, since they were widely planted by the Native peoples (Moore, 2015). This is an example of a traditional American folk song, from the Appalachia region, referencing the pawpaw (Moore, 2015):

Way Down Yonder in the Pawpaw Patch

Where, oh, where is dear little Susie?
Where, oh, where is dear little Susie?
Where, oh, where is dear little Susie?
'Way down yonder in the pawpaw patch.

Come on boys, let's go find her
Come on boys, let's go find her
Come on boys, let's go find her
'Way down yonder in the pawpaw patch.

Picking up paw-paw, puttin' 'em in your pocket,
Picking up paw-paws, puttin' 'em in your pocket,
Picking up paw-paws, puttin' 'em in your pocket,
'Way down yonder in the pawpaw patch.

Growing the Pawpaw

There are a few different methods for farmers to start growing pawpaw trees, including seed propagation, grafting and purchasing mature trees. The timeline in which the trees would bear fruit also varies. If a farmer were to start the trees from seed, it would require five to eight years before the tree bore fruit, versus as few as three years for grafted cultivars. Trees purchased from a nursery are usually two-year-old seedling trees, or three-year-old grafted cultivars (Jones, Peterson, Turner, Pomper & Layne, 2009). The pawpaw thrives in the understory and is dependent on the protection of the shade as a young tree. Once the tree has matured, fruits will grow in the shade, but the tree will produce more fruit if in full sun.

There are a multitude of pawpaw varieties and for proper pollination to occur, two or more genetically different varieties are necessary to ensure cross pollination. As with other Annonaceae species, the primary natural pollinators of pawpaw are beetles and flies, which can be unreliable. To guarantee pollination, it is done by hand with a small brush but would require additional labor from the grower (Jones et al., 2009).

If grown in its native region, the pawpaw isn't greatly impacted by insect pests or deer, which are common throughout the tree's growth range. Young pawpaw leaves are the primary host for the zebra swallowtail butterfly larvae, but most people do not consider this to be a negative pest (Jones et al., 2009). Because of its natural resistance to pests, there would be minimal, if any, additional costs of pesticides. The natural resistance factor would be appealing for those farmers growing organically.

Local Food Initiatives

While the 2012 USDA Census of Agriculture reported a decline in agriculture for the majority of the states since 2007, it also reported an increase in the number of farms for all of New England. With farm growth came a rise in farmers markets in Massachusetts (MDAR, 2015) (Figure 3). The USDA grant funded Farmers Market Promotion Program, as part of the Farm Bill, has also helped to incentivize and promote local farmer-to-consumer initiatives (USDA, 2016). With the resurgence of local food programs, in Massachusetts alone, the majority of towns now have their own summer, and some even a winter, farmers market (Figure 4).

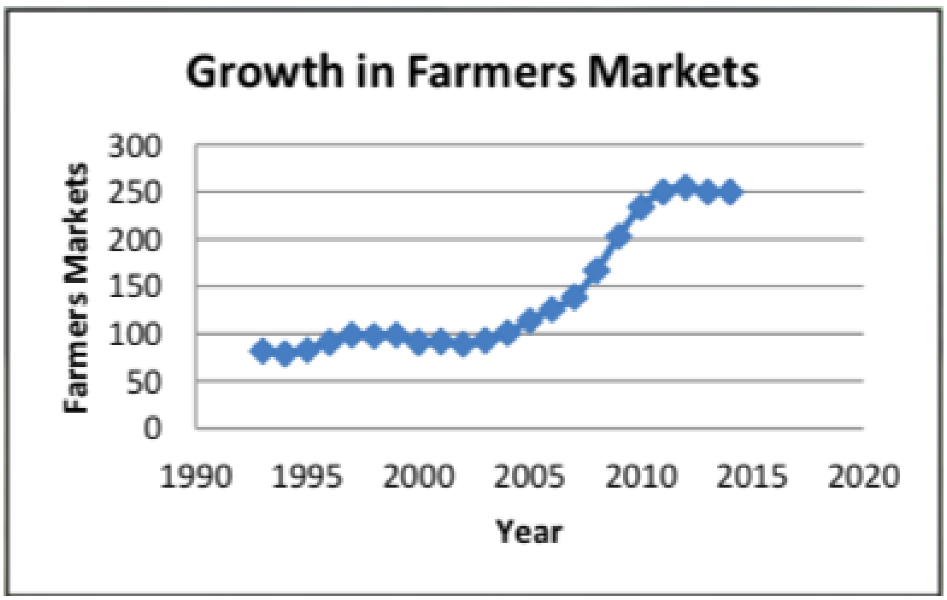

Figure 3. Rise in the number of farmers markets in Massachusetts from 1990’s-2012 (MDAR, 2015).

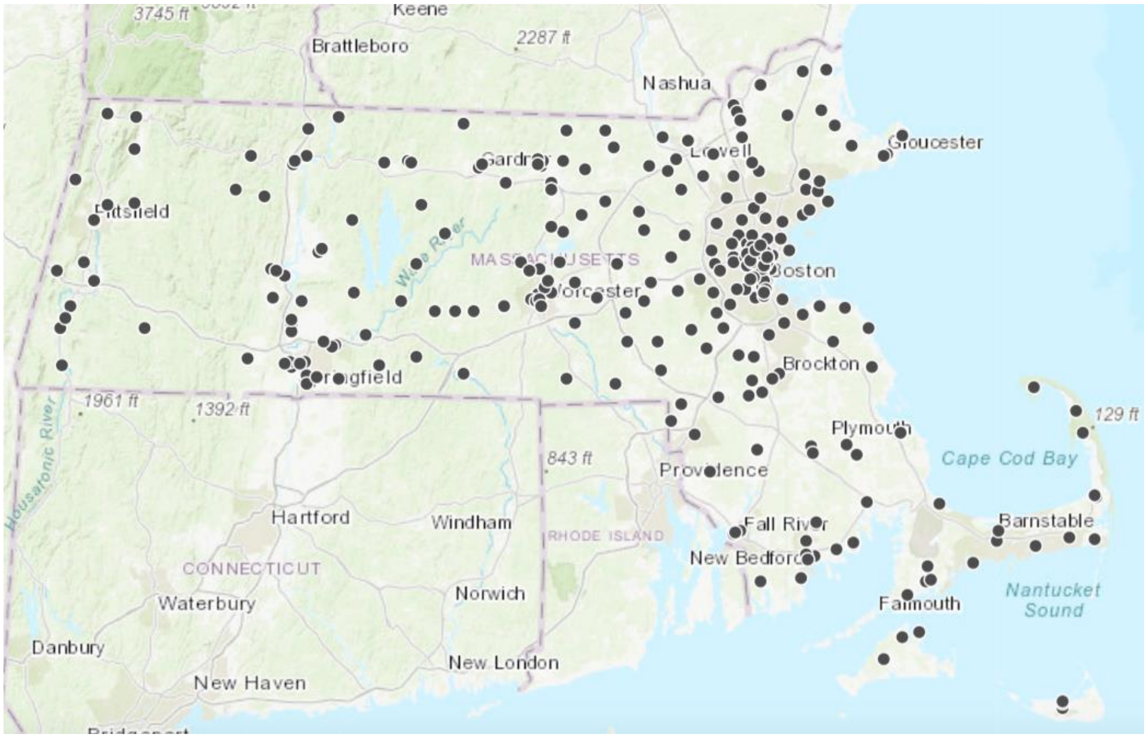

Figure 4. Map of Massachusetts with the points representing the current farmers market locations (MassGIS, 2017).

Impact of Climate Change on USDA Growth Zones

Pawpaw trees are highly frost tolerant, able to withstand temperatures of -20° F, and require a chilling period in order to break deep winter dormancy and flower (Peterson Pawpaws, 2017). The pawpaw currently thrives in USDA hardiness zones 5-8, but in recent years, those zone borders have been shifting due to climate changes and a continual warming. Climate warming has increased the frost-free days in different regions of the United States (Figure 6), resulting in an elongated agricultural growing season (Walsh, 2014). An extended cultivating season presents opportunities for regions where pawpaw historically never flourished because of the average extreme minimum temperatures, like New England.

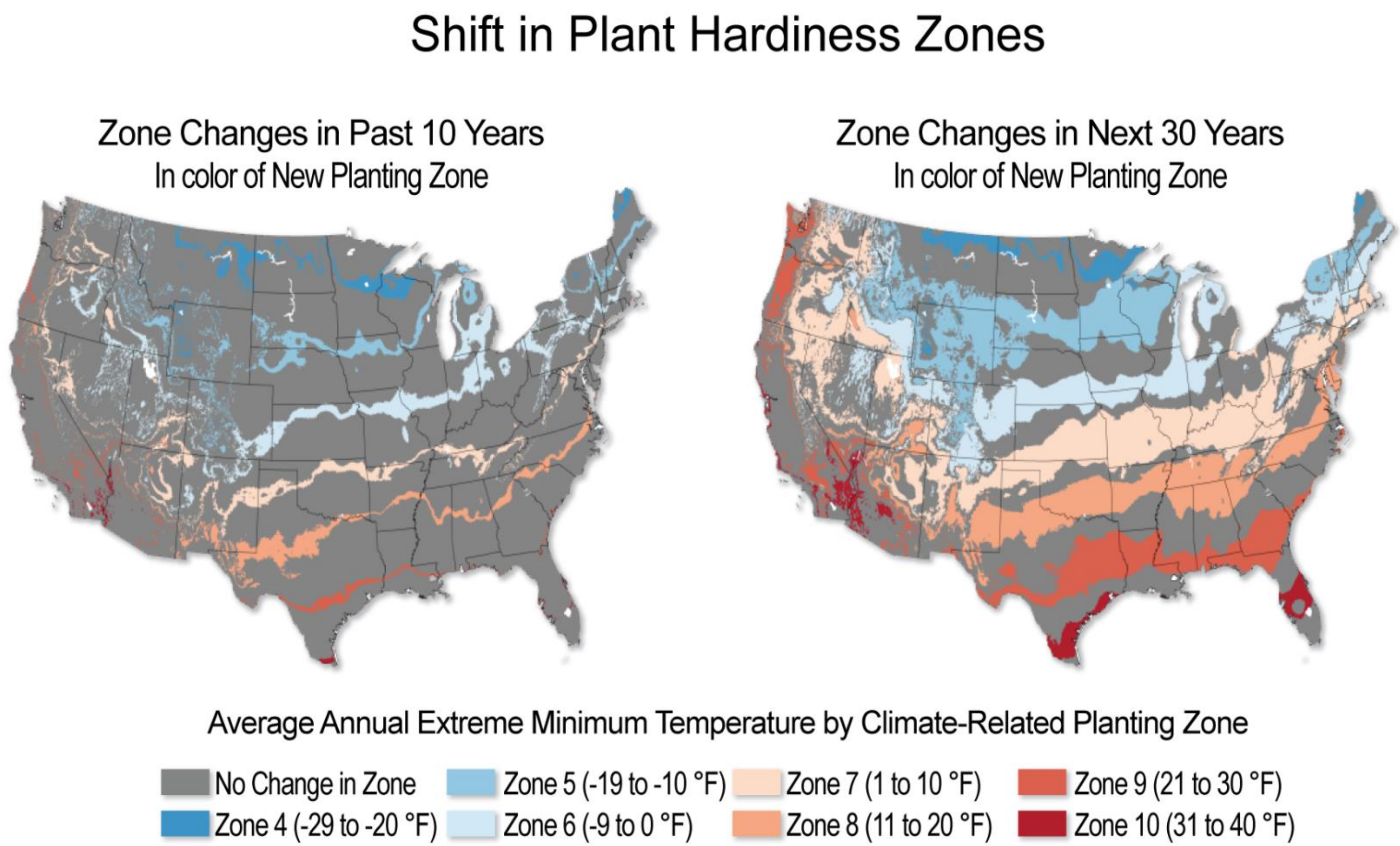

Figure 5. Current changes and 30-year projections for shifting of USDA plant hardiness zones based on annual extreme minimum temperatures (NOAA, 2013).

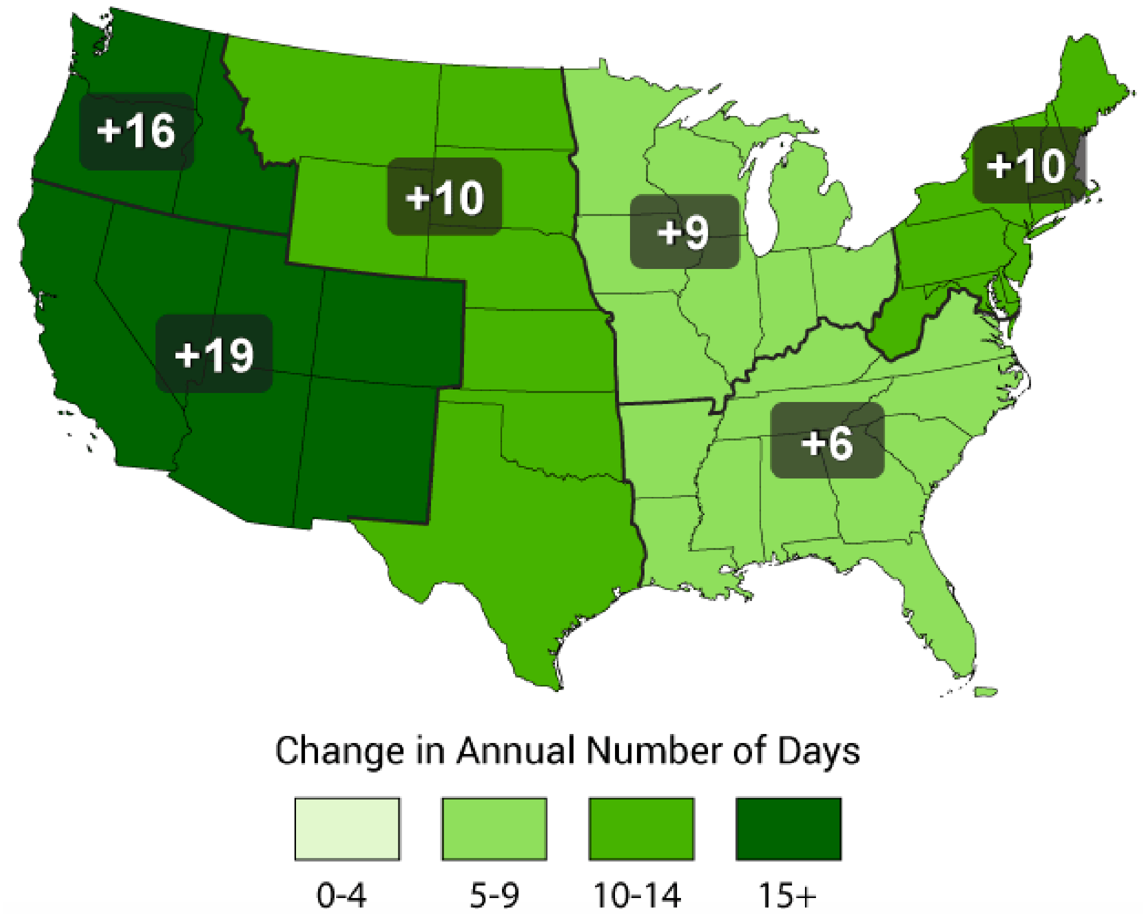

Figure 6. Increase in the number of days per year without frost in the United States during 1991-2012 relative to 1901-1960 (NCA, 2014).

New England currently has a wide range of growth hardiness zones, varying from 3-7 (Figure 7). It is projected that if the temperatures continue on this upwards warming trajectory, almost the entirety of New England will be well within the ideal growth range for pawpaw within the next 30 years (Figure 5). Conversely, a section of the United States where pawpaw has historically thrived will most likely be too warm and no longer within an ideal growing climate for the tree.

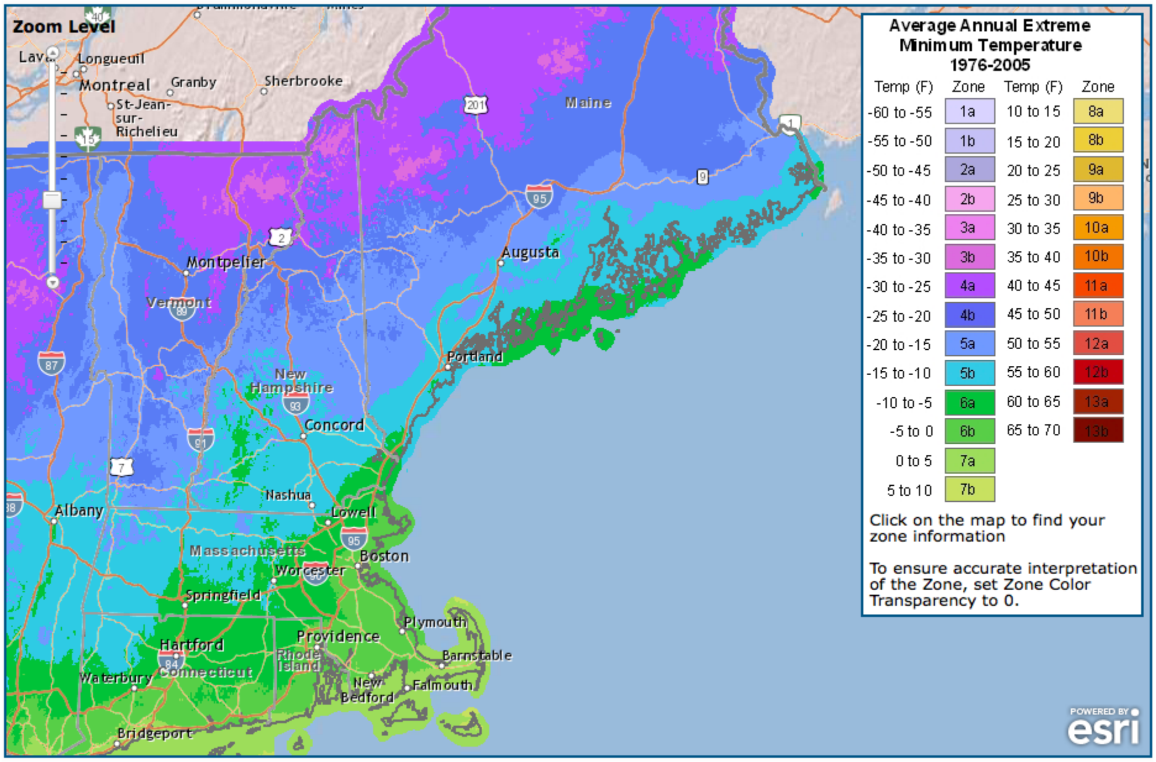

Figure 7. Current USDA hardiness zones for New England (USDA, 2012).

Temperature warming will allow for crops to be introduced into new areas, but also threatens the future of well-established crops. An increase in temperature can impact precipitation patterns, length of winter dormancy and bloom timing (NCA, 2014). These variables greatly influence the success of not only pawpaw, but every agricultural product. Climate change has the ability to affect the stability of food systems, supply and security. With an increasing population size and need for additional resources, agriculture will need to adapt to the climate variations. Introduction and emphasis of species that will thrive within the projected alterations of USDA growth zones, like pawpaw in New England, is the future of agriculture.

Research Questions, Hypotheses and Specific Aims

My research addressed two questions: 1) Under what conditions could pawpaw be profitably grown by farmers in New England? 2) What are the implications of pawpaw's historical distribution and future climate change strategies and policies to encourage pawpaw cultivation?

In answering these questions, I examined the following hypotheses: 1) Pawpaw can be financially feasible for New England farming, driven by marketing to farmers markets, supporting a high price for this perishable fruit, and low cost of production. 2) Climate warming in New England is expected to make pawpaw more profitable in the future.

Specific Aims

To test these hypotheses, and explore related issues, my specific aims were to:

- Create a financial enterprise model to predict economic feasibility for farmers
- Determine how pawpaw can be effectively introduced into mainstream retail settings
- Model potential growth range dependent on USDA zones
- Establish projections of climate change impacts on USDA plant hardiness zones
- Model established farmers markets proximity to farm land in the potential growth range

Chapter II

Methods

In my pursuit to determine whether it is financially advantageous to plant pawpaw in New England, I created a farming and retail analysis of a hypothetical pawpaw enterprise. Through this analysis, I examined a multitude of different variables involved in the cultivation of the pawpaw. In order to best analyze the data, I created both a baseline model financial appraisal showcasing the most realistic scenario of a New England farmer incorporating pawpaw into their currently active farm, as well as a separate production variations spreadsheet. This baseline model sets management options and parameter values for variables at most realistic estimates. To assess how each variable impacts the net profit value, I conducted a sensitivity analysis on the productions variations spreadsheet.

Before determining whether pawpaw could be a financially viable crop in New England, I looked at whether the plant could thrive in the region. The established historic growth zone cut off right at the New England borders, so I sought out farms and individuals who were successfully growing the fruit within the New England region. The scale of crops ranged from individuals growing the tree because of an interest in unique species, to farmers specializing in the crop. The figures used throughout the models are all estimates and approximations based on interviews I conducted with these farmers, information gleaned while attending the 2017 Ohio Pawpaw Festival, as well as from published materials.

Modeling Categorization and Organization

The organization for the methods modeling is based on nursery stock type, and the subsequent addition of pulp processing and retail. Categories of different scenarios are as follows:

- Grafted Trees – No Pulp (Baseline Model)
- Grafted Trees – Pulp Included
- Seedling Trees – No Pulp
- Seedling Trees – Pulp Included
- Trees from Seed – No Pulp
- Trees from Seed – Pulp Included

Labor Costs

One important component in all these scenarios is that labor is accounted for. Whether the individual doing the labor is the farm owner, relatives of the owner, or outside hired help, the cost of labor will be $12/hour for consistency. In his book, *The Organic Farmer's Business Handbook*, Wiswall (2009) states, "when the farmer works on crop production, the hours that he or she contributes are counted as a cost even though no paycheck is written. This way all production hours are accounted for."

Baseline Model Scenario

"80% of farms in Massachusetts are family owned and 95% fit into the category of "small farms" according to the USDA definition of sales below $250,000" (USDA, 2012). So, the baseline model is derived from a hypothetical, but relatively common, small family farm context. A husband and wife farmer team are looking to expand their offerings. They own a ten-acre property, three of which are currently cultivated. They would like to cultivate an additional one acre of their land with a single crop. They would like a versatile product that could both be sold unmodified, as well as create another retail item from. After hearing about the pawpaw through friends and discovering that it can be processed into a pulp that can be sold frozen, they have decided to plant one acre of pawpaw trees.

Working on the farm is the husband and wife who own the farm, as well as their two grown children and their partners, six people in total. The farmers currently follow organic protocols, but have not been, and don't plan to be, certified organic. There is well water available on-site, which they use to water their existing crops, and plan to continue using for the pawpaw. They sell their produce at a local farmers market, located 10 miles from their farm.

For the baseline model, I only evaluated the production and retail of whole fruit both at venues like farmers markets, and wholesale to buyers like restaurants, bakeries and breweries. A pulp processing options was excluded from the baseline model. Once I established the baseline, I looked at how other variables, including pulp and nursery stock type, impact the overall outcome and profitability. The rationale for variables and baseline parameter values used in the baseline model follows in the next sections. These correspond to line items in the baseline financial appraisal.

Baseline Fruit Production

To begin, I modeled overall fruit production in the initial section of my spreadsheet. I established how many acres would be planted and the number of trees per acre. From there, I quantified pawpaw production amount, in pounds per tree. Since each variety of tree produces a different amount of fruit, I use an average of 20 lb per tree for consistency. At least two different varieties need to be planted for pollination to occur, so production from tree to tree will always slightly vary (Jones et al., 2009).

- Annual survivorship: Year 0 has a 100% rate of annual survivorship because this is the initial year of planting and no losses are incurred. Due to the fragility of newly planted pawpaw trees, there is a 90-95% survival rate after the first year, (Peaceful Heritage Nursery and Farm, 2018). To be conservative, I estimated that 10% of the grafted trees planted in 2018 will not survive. After the trees are established, there is evidence of pawpaw having a very low mortality rate, (Pomper, Crabtree, Layne, Peterson, Masabni & Wolfe, 2008). To account for the unpredictability of nature and weather, I estimated a 98% annual survival rate, every year thereafter for this analysis.
- Number of trees per acre: Kentucky State University has performed a multitude of experiments with pawpaw cultivation, leading to a recommended planting density of 295 trees per acre. Tree spacing should be eight to fifteen feet apart for proper pollination, and taking into consideration equipment, such as tractors, that will need to pass through the rows, (Pomper, 2012).
- Pawpaw yield rate (lb of fruit per tree): A grafted cultivar will take approximately three to four years to start producing fruit from the time of planting. A full, mature

crop will not be harvested until five years after planting the grafted tree. Therefore 2021, year 3 in my model, is the first time the farmers will have a partial crop to harvest. I estimated that the yield rate will double yearly over the first three years of fruit production (from five lb to ten to twenty), reaching this year 5 peak production for the duration of this analysis. Since each tree variety differs slightly in production amount, for this analysis I used the average among varieties for a mature, fully producing tree, approximately 20 lb of fruit, (Pomper et al., 2008).

- Total pawpaw yield (unprocessed lb): This is the total weight of fruit that is grown on the farm in a year. This figure includes all fruit, including those fruits not available, or worthy of retail. This is calculated by multiplying the number of trees per acre by the pawpaw yield rate.
- Pack-out-rate (% available to sell retail and wholesale): In hopes of producing the best quality pawpaw, and because farmers want to make a profit, they are willing to spend extra up front and plant only grafted cultivar trees. Typical for fruit tree crops, not every fruit grown will be harvestable or acceptable to sell for various reasons and natural obstacles, so I assume the quality produced from a grafted tree will allow for a 90% pack-out-rate (Pomper et al., 2008).
- Net yield (lb of inventory for retail and wholesale): The total pawpaw yield multiplied by the pack-out-rate percentage, will provide the net yield quantity. This amount is the weight of fruit that is available for the farmers to sell retail.

Baseline Costs

To establish a pawpaw crop, there are a multitude of initial costs associated, mostly due to the price of the nursery stock. Depending on the source of the nursery stock, there are a variety of potential variables considered in the analysis. This singular component determines the projected timeline for initial harvest, as well as a multitude of variables on the farm. But, for the baseline model, I assume the farmers decided to only plant grafted cultivars. Even though the price is much higher per unit, they decided to choose this option in hopes of harvesting a fruit crop sooner than the other stock types would allow, as well as being guaranteed a higher quality fruit, (Jones et al., 2009).

- Type of Nursey Stock:
  - Grafted tree, 3-years-old ($35 per tree): "Although seedlings are much cheaper than grafted trees, there is enough genetic variability in the pawpaw that commercial-scale growers will be taking a significant gamble if they plant ungrafted seedlings, and they will not know the outcome of their bet for around five to seven years because it can take that long for seedlings to begin bearing (grafted trees usually start bearing in three to four years)" (Ames, 2017). Grafted cultivars "retain the clonal identity of the parent and fruit quality is assured" (Jones et al., 2009). Therefore, the entire acre, 295 trees, will be planted with grafted pawpaw trees in 2018. This is only an initial year cost. The figure is calculated by multiplying the cost of the nursery stock by the number of trees per acre (Table 4, Appendix 1).
  - Seedling 2-year-old tree cost ($15 per tree): Not applicable to Baseline Model
  - Trees started from seed cost ($1 per tree): Not applicable to Baseline Model

- Tree planting labor cost: The grafted trees can be purchased through a variety of online retailers. No matter when the trees are purchased, shipping only occurs between March-October. The trees arrive between 18"-2 ft tall in a gallon pot, or with the root system bundled in burlap. Once the trees arrive, they should be planted as soon as possible. Only the initial year requires labor to plant the trees. I assumed it takes the farmers approximately 10 minutes to plant each tree.
- Hand pollination cost: To ensure the best results, it is recommended that trees are hand pollinated, in addition to methods used to attract natural pollinators like flies and beetles. This labor cost is only borne once the trees begin to flower, starting in year 3. To hand pollinate, "use the brush to transfer pollen grains from the anthers of one cultivar to the receptive stigma of another cultivar. Pollen is ripe when the anthers are brown, loose and crumbly, and the pollen comes off on the brush as a yellow dust. Stigmas are ripe when the tips of the pistils are green and glossy, and the anther ball in the same flower is still hard and green" (Bratsch, 2009). It is estimated that five trees can be hand pollinated in one hour, so pollination labor is calculated by dividing the number of trees per acre by five, and then multiply that total by the cost of labor per hour ($12).
- Watering cost: Because the farmers are able to utilize their on-site well water, this is the cost of extending the previously installed drip irrigation system through this newly cultivated acre. There is already an established drip-irrigation system throughout the other three acres of farm land. The farmers have decided to add on and invest in additional components necessary to water the trees during the initial year, an approximate $1000 expense (Simonne et al., 2015). Pawpaw need to be

thoroughly watered the initial year of planting to establish growth. After the first growing season, the trees will receive enough water naturally through rainfall to grow and succeed. Pawpaw need a minimum of 30 inches of rain a year (Peterson Pawpaws, 2018). The average annual rainfall for New England is well over that figure, (U.S. Climate Data, 2018). The irrigation system will be available to use as a supplemental option when natural rainfall isn't satisfactory.

- Weed control/mulching cost: Pawpaw are very susceptible to invasion and competition from weeds, especially during the first few years after planting. Using straw or woodchip mulch, around trees will help to suppress weeds, and will also aid in soil moisture retention (Ames, 2017). This cost is only necessary in years 0 and 2, since this method is effective for a couple years. "For larger plantings, unroll round bales of hay in rows and use for mulching (6-8" depth). This method has been very effective in weed control and the hay degrades to add organic matter to the soil" (Pomper, Crabtree, Lowe, 2010). The annual cost for hay is approximately $100 (USDA, 2018). I estimate it will take the farmers approximately four hours of labor every year hay is applied.
- Fertilizer: "In organic production of pawpaw, nitrogen must be applied to trees for excellent growth (16 to 24 inches of shoot extension per year in establishing trees and about 6 inches in mature trees) and optimal fruit production. Organic feather, meat, bone and blood meal (such as 10-2-8 from NatureSafe®) fertilizer can be broadcast under pawpaw trees before bud break in early spring at 1 oz N/tree the first year after planting, 3-4 oz N/tree (about 50 lb/A at 295 trees per acre) in years 2-5, and 5-6 oz N/tree in year 6 and beyond" (Pomper, et al. 2010). One 50 lb bag will need to be

purchased for the first five years. Two 50 lb bags will need to be purchased for every subsequent year thereafter (year 6+). One 50 lb bag costs $100. It will take approximately five hours of labor annually for the application of the fertilizer.

- Shading cost: Not applicable to Baseline Model
- Thinning out/Pruning: An excessive quantity of fruit on the tree will result in an overall smaller sized product. To avoid that, an integral component to producing high quality fruit is the process of thinning out the trees. Remaining fruits will grow larger with less competition on the tree. Throughout the season, but especially around June when the fruits are young and small, thinning of fruit is beneficial to the end product (Moore, 2015). Pruning the tops of trees, to maintain a stature that isn't too tall in height, will also aid in future harvesting. This will take approximately 15 minutes per tree, every year (Pomper, 2012). This cost is calculated by multiplying the number of trees per acre by 0.25 (15 minutes equals ¼ hour). That figure is then multiplied by the cost of labor.
- Total fixed labor: This includes typical land management practices like mowing the area with a tractor, which will take approximately take 20 hours every year (Pomper, 2012). Before crop cultivation can begin, the baseline model assumes the farmers need to clear the previously unutilized land. There are saplings and small brush throughout the acre. The farmers already own the necessary equipment need to clear the land. This will take approximately 40 hours in labor. This additional labor and cost is only incurred in the initial year 0.
- Marketing cost: Because pawpaw is currently a mostly unknown product in the New England retail market, marketing will be critical to the farmers success. The farmers

market is going to be a primary outlet for marketing because it allows for the farmer to have face time with the consumer. Marketing the pawpaw entails preparing information for the farmers market such as a general overview of the fruit, nutrition facts and recipe handouts highlighting what the buyer can do with the fruit. A marketing technique that will aide in the retail of this product is to offer samples of the fruit. Free samples will allow for a consumer who is unfamiliar with the product to taste the fruit and sway any reluctance towards purchasing (Marzolo, 2016). The farmers also prioritize reaching out to wholesale buyers once the trees start producing at full capacity. They recognized that there was a large quantity of fruit to sell, and that it was unrealistic to only sell at farmers markets. In addition, because they are limited to such a short selling season, they can avoid flooding the retail market if they divert to wholesale buyers. With the addition of wholesale clients, the farmers increase their marketing efforts, and therefore costs, in order to sell the product. For wholesale marketing, reaching out to local venders who might be interested, such as bakeries, restaurants and breweries, is advised, especially in the first few years. Having a social media presence is also crucial. The fruits aren't the most physically appealing, but creating a following and a buzz around the pawpaw will be the best sales tactic. Marketing costs will start once there is a product to sell in year 3. During the first two years of retail (2021-2022), I assumed approximately 30 hours a year is spent on marketing, and an additional $200 is spent annually on promotional materials. Once the trees are at peak production, marketing doubles to 60 hours a year to account for the outreach to wholesale buyers and remains at this level.

- Farmers market cost: In order to sell at a farmers market, the labor involved in the process needs to be accounted for. For this analysis, I take into account the time it takes the farmers to load the truck, travel to the market, set up, market vending, pack up, travel back to the farm, unpack and tally sales (Wiswall, 2009). Per each visit to a market, 16 labor hours are involved. Because the pawpaw is only in season for a short window of time, the calculations are based on attending four farmers markets. This base cost of attending a farmers market is consistent throughout this analysis.
- Transportation to farmers market cost: Because the farmers need to transport the pawpaw to market, the mileage traveled must be accounted for. I assumed the farm is 10 miles from the farmers market, a 20-mile round trip. The vehicle cost is 0.40/mile, averaging $8 per trip to the market, totaling $32 for the year (Wiswall, 2009).
- Loan repayment: The upfront cost of establishing a pawpaw farm is high, so the farmers must take out a $10,000 loan to offset some initial expenses. They want to repay the loan in 15 years, starting in year 1 and ending in year 15. Monthly payments are $79.

Baseline Harvesting

The only way to harvest pawpaw is by hand. "Unfortunately, there's little in the way of color change or color break to guide a pawpaw picker. Most pawpaw won't turn from green to yellow while on the tree. Rather, it's all in the touch. Each pawpaw must be given a gentle squeeze between forefinger and thumb, feeling for the slightest bit of give. This means each pawpaw is tested, multiple times, before harvesting" (Moore, 2015). There is a short window of time when the pawpaw is ripe, requiring multiple hours of labor condensed into a small amount of time.

- Labor cost: The University of Kentucky estimates that it takes a minimum of 250 hours to harvest one acre with 295 trees. "When fruit on an individual tree begin to ripen, pawpaw from that tree will need to be hand-harvested a minimum of every other day for a 1- to 2-week period" (Pomper, 2012). For my analysis, I assumed harvesting will take on average one hour per tree.
- Equipment cost: "Equipment consists of four tools: clippers to snip the fruit from the peduncle (or fruit stem), plastic tubs and foam padding for storage, a John Deere cart, and our hands" (Moore, 2015). I assumed the farmers have a stock of pruning shears (5) and foam lined tubs (30), that are devoted for pawpaw's only. The shears need to be replaced yearly, a $100 expense. The tubs will need to be replaced every five years, a $600 expense. The farmers already own a cart that will satisfy the harvesting needs, as well as satisfactory ladders, so there is no additional expense involved. The farmers also purchased three fruit picker/extender tools, and these will need to be replaced every 15 years, a $150 expense. The equipment is purchased and these costs are incurred once there is a product to harvest.
- Ground padding: Unlike other fruits, pawpaw can be harvested from the ground. One indicator of perfect ripeness is when the fruit falls from the tree. Since the fruit skin bruises easily, placing hay, or straw at the base of tree will soften the impact (Ames, 2017). The farmers place straw every other year, after the first few years when hay is already being used as a preventative measure for weeds, in an attempt to pad the earth for fruit fall. This requires approximately four hours of labor every year it is applied.

Baseline Revenues

There are multiple forms and products in which pawpaw can be sold. Retail products can include the whole unaltered fruit, frozen pulp, as well as various items such as baked goods and jams. My baseline analysis concentrates solely on the sale of whole fruit.

- Retail price for whole fruit: The farmers price the whole fruit at $5 per pound. This is the price which the unaltered pawpaw fruit is sold for in venues such as farmers markets (Rocky Point Farm, 2017). I assume the price remains constant for the duration of the study.
- % crop slated for retail (whole fruit): This is the percentage of the net yield that will be brought to the farmers market. This percentage changes according to wholesale purchasing. Eventually the farmers will be allocating 50% to be sold in a retail venue and 50% will be sold wholesale.
- % of crop actually sold retail (whole fruit): A portion of the fruit brought to market are used in sampling as a marketing technique. Also, because these fruits are inherently delicate, there will inevitably be a percentage that is lost in transit. Then there is the chance that not all the fruit will be sold. All of these components need to be accounted for, as a separate percentage from that which is slated for retail. I estimate that 20% of what is slated for retail yearly will not actually be sold.
- Total sales from retail (whole fruit): This is the annual profit made from selling the pawpaw whole in a retail setting. This is calculated by multiplying the percentage of the crop that was actually sold by the net yield. That figure is then multiplied by the retail price.

- Wholesale price for whole fruit: I assume the farmers have received inquiries from restaurants, bakeries and breweries about purchasing whole pawpaw. Because these locations would be buying in much larger quantities than individuals at farmers markets, they are sold at a discounted price of $4 per pound.
- % of crop sold wholesale (whole fruit): I assume a scenario like the following. The farmers don't start receiving wholesale inquiries until year 5. The fruits had been available at farmers markets for a couple seasons and had gained interest on a larger scale after the second year. With an emphasis on using local ingredients, these wholesale buyers loved the idea of incorporating a new, fresh flavor into their products, leading to 30% of the crop is sold wholesale in year 2023. After the positive response from customers the first year of using the ingredients, the order size increased from all buyers; 40% of the crop is sold wholesale in 2024, and 50% is sold wholesale in 2025. The farmers anticipate selling 50% of the overall crop wholesale for the duration of the analysis.
- Total sales from wholesale (whole fruit): This is the annual profit made from selling the pawpaw whole in a wholesale setting. This is calculated by multiplying the percentage of the crop sold wholesale by the net yield. That figure is then multiplied by the wholesale price.
- Retail price for pulp: Not applicable to Baseline Model
- % of crop sold retail (pulp): Not applicable to Baseline Model
- Total sales from retail (pulp): Not applicable to Baseline Model

- Loan: The farmers took out a loan of $10,000 to offset some of the initial costs involved in the first three years. They take out a 15-year fixed loan with a 5% interest rate. They start paying it off in year 1 and ending in year 15.

Alternative Production Scenarios

The values for many of the spreadsheet model variations of production are intrinsically the same as those for the baseline model. The principal differences are the type of nursery stock being examined and the addition of pulp as a retail item. Because grafted trees are the quickest to produce a harvest of all pawpaw nursery stock options, there is a noticeable shift in the timeline of harvesting fruit for the other two stock options. To avoid redundancy, only differences that are not related to timeline shifts will be explained in the following sections.

Seedling Trees

Seedling trees are pawpaw trees that have been started from seed by a nursery. They are usually sold as 2-year-old trees. They sell for around half the price of a grafted tree, but the quality and end results can't be guaranteed to the same degree. Seedling trees are not identical to their parent tree, therefore express more variability than grafted trees (Bratsch, 2009). There isn't a difference in the amount of fruit that is produced, but the quality is impacted.

- Seedling Tree Fruit Production: Like the baseline model, the farmers start by planting the recommended density number of trees, and once again because of the fragility of the trees after planting, there is a 90% survival rate after the initial planting year. The seedlings are a year younger than the grafted trees, and therefore take a year longer to produce fruit. A 2-year old seedling will take four to six years to produce fruit, making 2022 the first year the farmers have a crop to harvest. There is also more variability in the quality of the fruit and they can't guarantee that all the fruits will be deemed worthy to sell. Because of this, the framers are not able to sell as large a percentage of the yearly crop, so the pack-out-rate for a seedling tree was 80% for the entirety of the analysis.

- Seedling Tree Costs: The largest difference between seedling and grafted trees is the price difference. Seedling trees average around $15 per tree, less than half the cost of a grafted cultivar. All of the same planting methods, land management practices and farmers market cost apply to the seedlings.

Trees Started from Seed

This method entails the farmers buying pawpaw seeds and planting them onsite. Much like the seedling trees, the quality of the fruit is unpredictable because the genetic makeup has a much larger degree of variability. In order for pawpaw seeds to sprout, they have to undergo a stratification period of at least 100 days to break dormancy, at a sustained temperature of 32-40°F. This can take place by either refrigerating a moist seed for the required time or sowing the seed directly into the ground in the fall. The winter months will allow for stratification to take place and germination will occur the following summer (Bratsch, 2009).

- Trees from Seed Fruit Production: The farmers sow the seeds directly into the ground in the fall of 2018 (year 0). After the initial planting year, it will take an additional six to eight years to produce a harvest (Jones et al., 2009). There is a lower percentage of survivorship because of the style of planting. I estimated that 80% of the seeds will survive and sprout the first year after planting. In year 2, 90% of the trees started from seeds will survive. Starting in year 3, the survivorship will increase to 98% and remain at that annual rate because the trees become established. Like a seedling tree, there is increased variability within the end product. Because of this, the pack-out-rate was estimated at 80% for the entirety of this analysis.

- Trees from Seed Costs: Depending on where the seeds are purchased from, some have already undergone stratification, but all have been cleaned and kept moist. If a pawpaw seeds dries out, it can destroy the dormant embryo (Jones et al., 2009). Because the farmers want to sow the seed directly into the ground, they are not buying already stratified seeds. Seed prices vary, but for this analysis I approximated that it costs $1 per seed. All the costs are the same as the other nursery stock options, except there is an additional cost for shading trees planted from seed.
- Trees from Seed Shading: Depending on which type of nursey stock is planted, the trees may need to be shaded. Since pawpaw are naturally occurring in the understory, young trees need to be protected from direct sunlight. It is recommended that trees under 1.5 feet, or under two years old, are shaded. Trees taller than that do not require sun protection (Pomper, 2012). Shading is only an associated cost for the first couple years after planting. A technique for shading is to place a tomato cage, covered in window screen/mesh material, over the young trees (Ames, 2017) (Figure 18, Appendix 1). The approximate cost for shading material is $1 per tomato cage and $500 in window screen fabric. Because the seeds are planted in the fall of year 0,

the shading apparatuses is not installed until year 1. Once installed, it will remain over the tree until it has reached the appropriate height, but at least for two years. This variable includes both the materials and the cost of labor and assume the farmers can install the shading protection over 5 trees per hour.

Variations in Cost and Revenue with Different Nursery Stock

The harvesting labor costs for all three nursery stock options, and retail product type, are based on the same equation, number of trees per acre, multiplied by the time it takes to harvest one tree (one hour), multiplied by the cost of labor ($12 per hour). The differences between the costs result from differences in harvesting timeline and number of trees. All the equipment and ground padding remain the same no matter the tree type.

Pricing remain the same as the baseline model with whole fruit sold retail at $5 per pound and whole fruit sold wholesale at $4 per pound. The price at which the whole fruit is sold at remains the same across all three planting methods. To account for the 10% of the net yield that is sold as pulp, a reduced percentage is sold retail and wholesale for the pulp variations. In all scenarios, the first two years of harvesting, no product is sold wholesale. Once wholesale purchasing begins, it starts at a smaller percentage, then expands so that the same amount is sold wholesale that is slated for retail.

Pulp processing costs. The delicate skin must first be removed from the pulp by breaking the fruit in half and scooping out the pulp and seeds. This process is labor intensive and must be done by hand. The pawpaw insides, pulp and seeds together, are then placed into the food processor. Because the pulp has a tendency to stick to the seeds, the pulp needs to be run through the machine twice in order to reduce the percentage of waste. Approximately 10 lb of fruit can be processed and bagged in one hour. To calculate the labor involved in processing, the total pawpaw amount, in pounds, was divided by the pounds able to be processed in an hour (10 lb), and that total was multiplied by the cost of labor per hour ($12 per hour).

I assumed the farmers aren't interested in investing in any commercial scale equipment for processing, hence keeping the percent poundage to be processed low. Food processors most commonly used in making tomato sauce, such as the Norpro Sauce Master and the Roma Food Strainer & Sauce Master machines, are recommended for pawpaw pulp production (Powell, 2017). These machines require a few modifications in order to best suit the pawpaw, such as specific screens and attachments, but are affordable and appropriate for the scale of processing.

Processing equipment costs are the same for all three tree types. Two processors need to be purchased every other year, and cost around $100 each. A commercial sized freezer is necessary to store the processed pulp, as well as a cooler for the farmers market. Once the fruit has been processed, pulp is placed into freezer bags (two lb per one-gallon bag), a yearly expense of $50. The farmers purchased a commercial chest freezer, a $600 expense, and a Yeti Tundra 125 cooler, a $550 expense. These both only need to be purchased once for the time frame of this analysis.

Pulp processing revenues. 10% of the pawpaw net yield is processed into pulp, but only half of that weight is available to make a profit. During the pulping process, the weight of the fruit slated for retail is not the same as the weight of the end result pulp product.

The skin and seeds are discarded during the processing. There is also a partial loss of pulp because not every part of the fruit can be removed from the skin and seeds. The end result of pulp is half, or 50% of the total weight of the amount of the crop that was processed, (Crabtree, n.d.).

Revenues from pulp are based upon 10% of the net yield being set aside to be processed into pulp. This percentage remained constant throughout the analysis, no matter the tree type. The retail price for pulp, $8 per pound, was the same across all three nursery stock types. This is the price which the pawpaw pulp is sold for in farmers markets (Integration Acres, 2018). Pulp is only an option for purchase at farmers markets and is not sold at a wholesale rate. The remaining 90% of the crop harvest is equally divided to either be sold wholesale or is slated for market retail.

Chapter III

Results

The aim of my analysis was to determine whether or not producing a pawpaw crop could be financially feasible. Once establishing a baseline net present value (NPV), I thoroughly examined each farming variable to test for impact percentage. It became apparent through the sensitivity analysis which variables most influenced the profitability of the farming enterprise.

Baseline Model Spreadsheet

The nuances of each line item are explained in the Methods section. I left blank any line that wasn't pertinent to the baseline model, but for consistency, I included all the line items that will be evaluated at a later stage in the following production variations analysis. The purpose of the baseline was to establish a realistic profit potential that all other scenarios could be compared against.

In order to establish a baseline net present value of a farmer in New England incorporating pawpaw into their already preexisting farm, I created a model that highlighted only the retail of whole, unprocessed fruit and didn't incorporate any additional mechanics, or variables. Using my amassed information, I compiled a financial spreadsheet that represented what the 15-year projections would be for a small-scale farming enterprise (Table 1).

Table 1. Baseline model of pawpaw financial analysis.

	Discount Rate
	0.03

Pawpaw Baseline Spreadsheet

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	Total
Year	***0***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***	
Fruit Production																	
Number of acres planted	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Annual survivorship	100%	90%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	
Number of trees per acre	295	266	260	255	250	245	240	235	230	226	221	217	213	208	204	200	
Pawpaw yield rate (lbs. of fruit per tree)				5	10	20	20	20	20	20	20	20	20	20	20	20	
Total pawpaw yield (unprocessed lbs.)				1275	2499	4898	4800	4704	4610	4518	4427	4339	4252	4167	4084	4002	
Pack-out rate (% available for retail/wholesale)				90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	
Net yield (inventory for retail and wholesale lbs.)				1,147	2,249	4,408	4,320	4,233	4,149	4,066	3,984	3,905	3,827	3,750	3,675	3,602	
Costs																	
Grafted tree cost	$10,325																
Seedling 2 year old tree cost																	
Trees started from seed cost																	
Tree planting labor cost	$591																
Hand pollination cost				$612	$600	$588	$576	$564	$553	$542	$531	$521	$510	$500	$490	$480	
Watering cost	$1,000																
Weed control/mulching cost	$148		$148														
Fertilizer cost	$160	$160	$160	$160	$160	$160	$260	$260	$260	$260	$260	$260	$260	$260	$260	$260	
Shading cost																	
Thinning out/pruning cost				$765	$750	$735	$720	$706	$691	$678	$664	$651	$638	$625	$613	$600	
Total fixed labor	$720	$240	$240	$240	$240	$240	$240	$240	$240	$240	$240	$240	$240	$240	$240	$240	
Marketing cost				$560	$560	$920	$920	$920	$920	$920	$920	$920	$920	$920	$920	$920	
Farmer's market cost				$768	$768	$768	$768	$768	$768	$768	$768	$768	$768	$768	$768	$768	
Transportation to farmer's market cost				$32	$32	$32	$32	$32	$32	$32	$32	$32	$32	$32	$32	$32	
Loan repayment		$948	$948	$948	$948	$948	$948	$948	$948	$948	$948	$948	$948	$948	$948	$948	
Total Costs	$12,944	$1,348	$1,496	$4,085	$4,057	$4,390	$4,464	$4,438	$4,413	$4,388	$4,363	$4,339	$4,316	$4,293	$4,271	$4,248	$71,854
Harvesting																	
Harvesting labor cost				$3,060	$2,999	$2,939	$2,880	$2,822	$2,766	$2,711	$2,656	$2,603	$2,551	$2,500	$2,450	$2,401	
Harvesting equipment cost				$850	$100	$100	$100	$100	$700	$100	$100	$100	$100	$700	$100	$100	
Ground padding (materials + labor cost)					$148		$148		$148		$148		$148		$148		
Total Costs				$3,910	$3,247	$3,039	$3,128	$2,922	$3,614	$2,811	$2,904	$2,703	$2,799	$3,200	$2,698	$2,501	$39,476
Processing																	
Pawpaw pulp production (lbs.)																	
Processing labor cost																	
Processing equipment cost																	
Total Costs																	
Revenues																	
Retail price for whole fruit (per lb.)				$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	
% crop slated for retail - whole fruit				100%	100%	70%	60%	50%	50%	50%	50%	50%	50%	50%	50%	50%	
% crop actually sold retail - whole fruit				80%	80%	56%	48%	40%	40%	40%	40%	40%	40%	40%	40%	40%	
Total sales from retail - whole fruit				$4,590	$8,996	$12,342	$10,368	$8,467	$8,298	$8,132	$7,969	$7,810	$7,653	$7,500	$7,350	$7,203	$106,678
Wholesale price for whole fruit (per lb.)						$4	$4	$4	$4	$4	$4	$4	$4	$4	$4	$4	
% crop sold wholesale - whole fruit						30%	40%	50%	50%	50%	50%	50%	50%	50%	50%	50%	
Total sales from wholesale - whole fruit						$5,290	$6,912	$8,467	$8,298	$8,132	$7,969	$7,810	$7,653	$7,500	$7,350	$7,203	$82,583
Retail price for pulp (per lb.)																	
% crop processed - pulp																	
% crop actually sold retail - pulp																	
Total sales from retail - pulp																	
Loan	$10,000																
Total Revenue	$10,000	$0	$0	$4,590	$8,996	$17,632	$17,279	$16,934	$16,595	$16,263	$15,938	$15,619	$15,307	$15,001	$14,701	$14,407	$199,261
Profitability																	
Revenues - Costs	($2,944)	($1,348)	($1,496)	($3,405)	$1,692	$10,203	$9,688	$9,573	$8,569	$9,065	$8,670	$8,577	$8,192	$7,507	$7,732	$7,657	

Net Present Value	$62,782

The net present value for this baseline model was $62,782. This figure is the overall profit for the farmers after 15-years. This figure also factors in a discount rate of 3% to account for the change in monetary value over time.

Production Variations Spreadsheet

The production variations spreadsheet is arranged and color-coded by nursery stock type, with the same organization established in the Methods section. Building upon the Baseline Model, I delved deeper into what tree types were available, as well as examined the addition of pulp as a retail item. The utmost differing factor between all the scenarios, when it comes to spreadsheet layout, is the timescale at when the tree produces fruit and the subsequent effects of that timing.

The type of stock planted will determine when the first fruits are harvested and therefore the potential to make a profit. The trees planted from seed take the longest before the first harvest, and the result and effect is clearly displayed when compared against the yearly profit breakdown (Table 2). The delay in producing fruit has a direct correlation to overall NPV. The more delayed the fruit production, the lower the overall NPV.

Scenario Profitability

The scenario with the second largest NPV (grafted trees pulp included) is a continuation of the baseline model. It calculates what the potential profit would be if the

Table 2. Production variations spreadsheet yearly profit breakdown.

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Year	***0***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***
Profitability - Grafted Trees NO PULP																
Revenues - Costs	($2,944)	($1,348)	($1,496)	($3,405)	$1,692	$10,203	$9,688	$9,573	$8,569	$9,065	$8,670	$8,577	$8,192	$7,507	$7,732	$7,657
Profitability - Grafted Trees + Pulp																
Revenues - Costs	($2,944)	($1,348)	($1,496)	($4,943)	$1,372	$9,424	$9,119	$8,815	$8,021	$8,327	$8,142	$7,858	$7,682	$6,807	$7,241	$6,975
Profitability - Seedling Trees NO PULP																
Revenues - Costs	$2,956	($1,348)	($1,496)	($1,348)	($4,056)	$767	$7,768	$7,692	$7,325	$6,658	$6,899	$6,841	$6,491	$6,441	$5,499	$6,056
Profitability - Seedling Trees + Pulp																
Revenues - Costs	$2,956	($1,348)	($1,496)	($1,348)	($5,576)	$482	$7,057	$7,190	$6,632	$6,174	$6,224	$6,375	$5,833	$5,991	$4,857	$5,622
Profitability - Trees from Seed NO PULP																
Revenues - Costs	$7,086	($2,650)	($1,496)	($1,348)	($1,496)	($1,348)	($4,080)	($105)	$5,352	$5,325	$5,005	$4,384	$4,671	$4,658	$4,351	$4,344
Profitability - Trees from Seed + Pulp																
Revenues - Costs	$7,086	($2,650)	($1,496)	($1,348)	($1,496)	($1,348)	($5,574)	($339)	$4,741	$4,921	$4,408	$3,994	$4,088	$4,281	$3,781	$3,980

Net Present Value - Grafted Trees NO PULP	$62,782
Net Present Value - Grafted Trees + Pulp	$56,023
Net Present Value - Seedling Trees NO PULP	$44,896
Net Present Value - Seedling Trees + Pulp	$39,238
Net Present Value - Trees from Seed NO PULP	$22,509
Net Present Value - Trees from Seed + Pulp	$18,396

farmers were to expand their retail offerings to include pulp. Even though the initial cost of tree stock was higher than the other two options, the grafted trees guaranteed superior fruit the farmers were able to harvest sooner, and therefore the ability to turn a profit earlier. Differences between this scenario and the baseline is the percentage at which whole fruit is sold, to accommodate for the addition of pulp retail.

The most profitable scenario is the Baseline model of grafted trees, with no addition of pulp retail (NPV= $62,782). The rest of the scenarios, ranked in order of overall net profit value, are as follows: grafted trees pulp included (NPV= $56,023), seedling trees no pulp included (NPV= $44,896), seedling trees pulp included (NP = $39,238), trees from seed no pulp included (NPV= $22,509), trees from seed pulp included (NPV=18,396) (Table 2). The nursery stock without pulp scenarios always resulted in a higher NPV than their corresponding nursery stock with pulp scenarios.

Sensitivity Analysis

Each scenario had unique factors and variables that influenced each line item differently, but across the board for all six scenarios, yield related items had the largest impact, and was the singular most important variable on the overall net profit values (Figure 8). The net yield, and all the subsequent yield variables that are based off this net figure, have the largest impact on the NPV. The impact rate for each scenario varied between 22.3% to 36.8% for all four yield related line items (Figure 8).

While conducting the sensitivity analysis, it became apparent that the percent change for a range of figures were the same. This is a result of those line items being intrinsically linked. For example, increasing the total pawpaw yield rate by 10% will influence the net profit value in the same way that increasing the net yield by 10% will. They are important line items on their own, but one variable can't change without the impacting the other. In theory these values are creating a ripple effect and ultimately changing every forthcoming fruit related variable by the same rate.

The percent change in NPV for both the +10% and -10% sensitivity analyses are completely symmetrical. To obtain the percent change, I used the equation 1-(NPV +/- 10% ÷ unaltered NPV). In order to obtain a graph that represented percent change only in a positive direction, a combination of the positive percentages and the negative percentages were charted accordingly, (Figure 8 - Figure 13). These graphs display the percentage at which each variable impacts the overall net profit value.

Variables that have the most effect on the NPV include the intrinsically linked yield related items which include pawpaw yield rate (lb of fruit per tree), total pawpaw yield (lb of unprocessed fruit), pack-out-rate (percentage available to sell) and the net yield (lb available to sell). The percentages of impact for these four variables on the NPV are 22.3% for the grafted trees no pulp scenario, 24.3% for the grafted tree including pulp scenario, 24.7% for the seedling tree no pulp scenario, 27.4% for the seedling tree pulp included scenario, 31% for the trees from seed no pulp scenario and 36.8% for the trees from seed pulp included scenario. There is a direct correlation between the most profitable scenarios having a lower rate of impact, than the less profitable scenarios. Factors which are relatively unimportant to the overall NPV across all scenarios include tree planting labor cost, weed control/mulching cost, transportation to farmers market cost, harvesting equipment cost and the cost of ground padding.

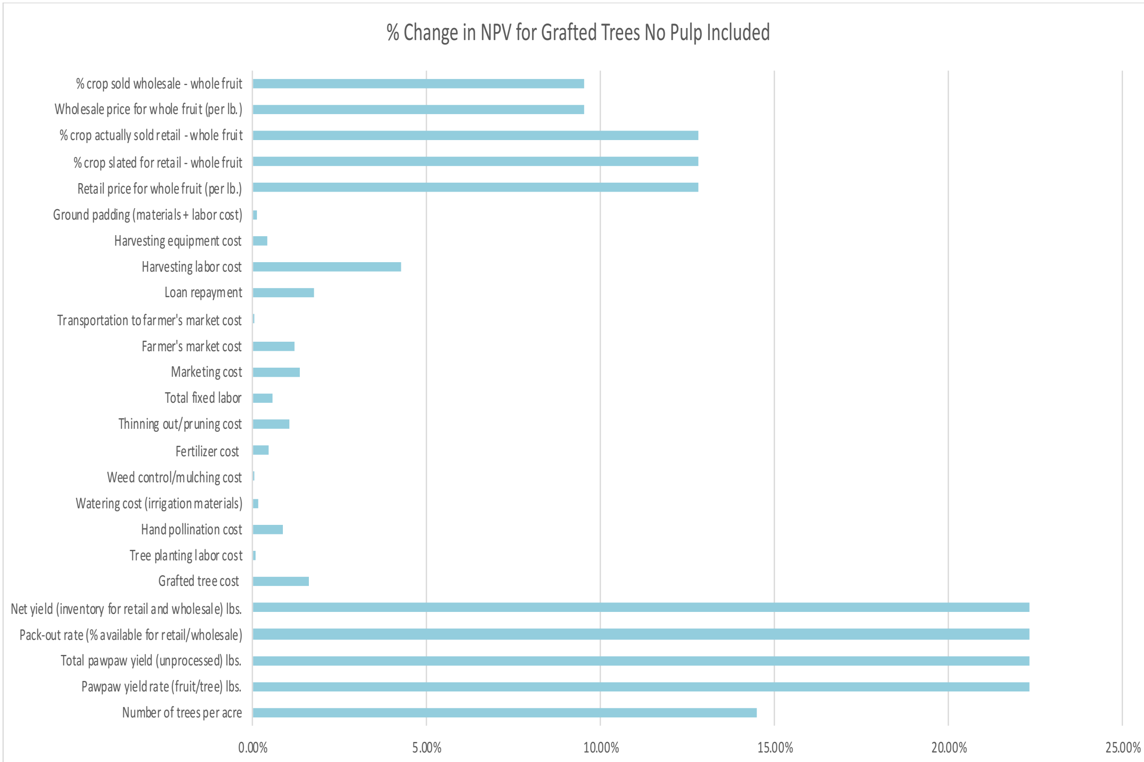

Figure 8. Percentage change in net profit value for grafted trees without pulp included.

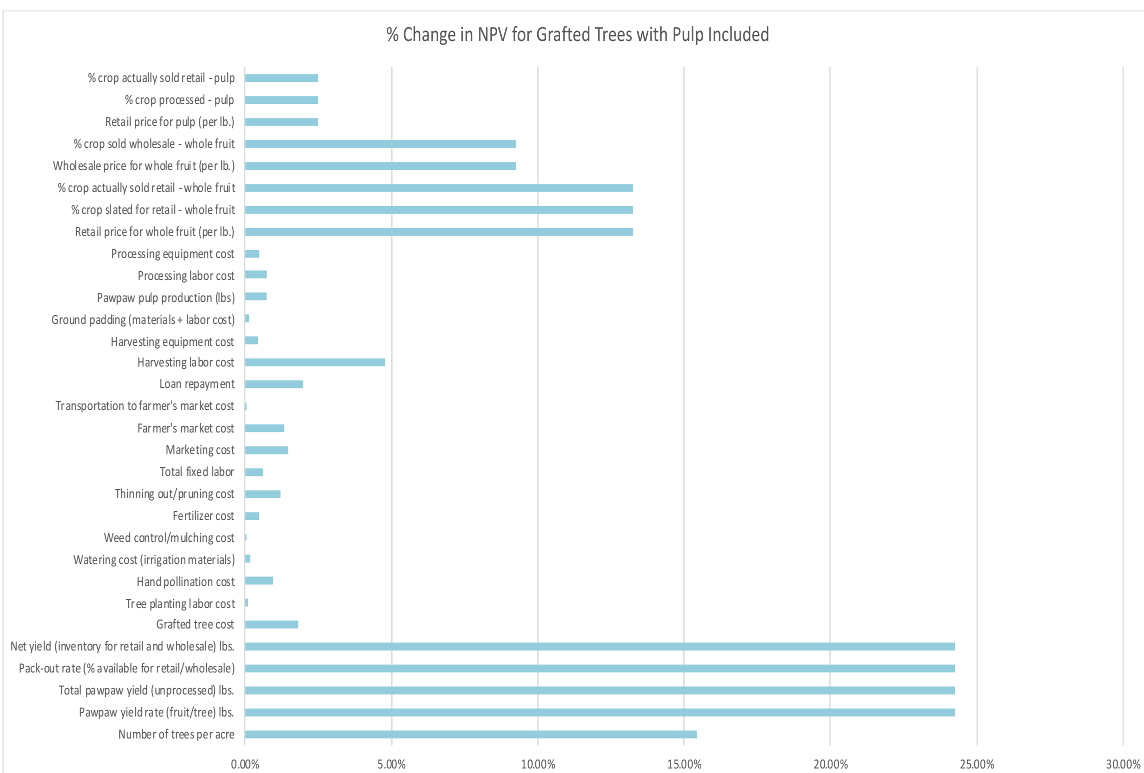

Figure 9. Percentage change in net profit value for grafted trees with pulp included.

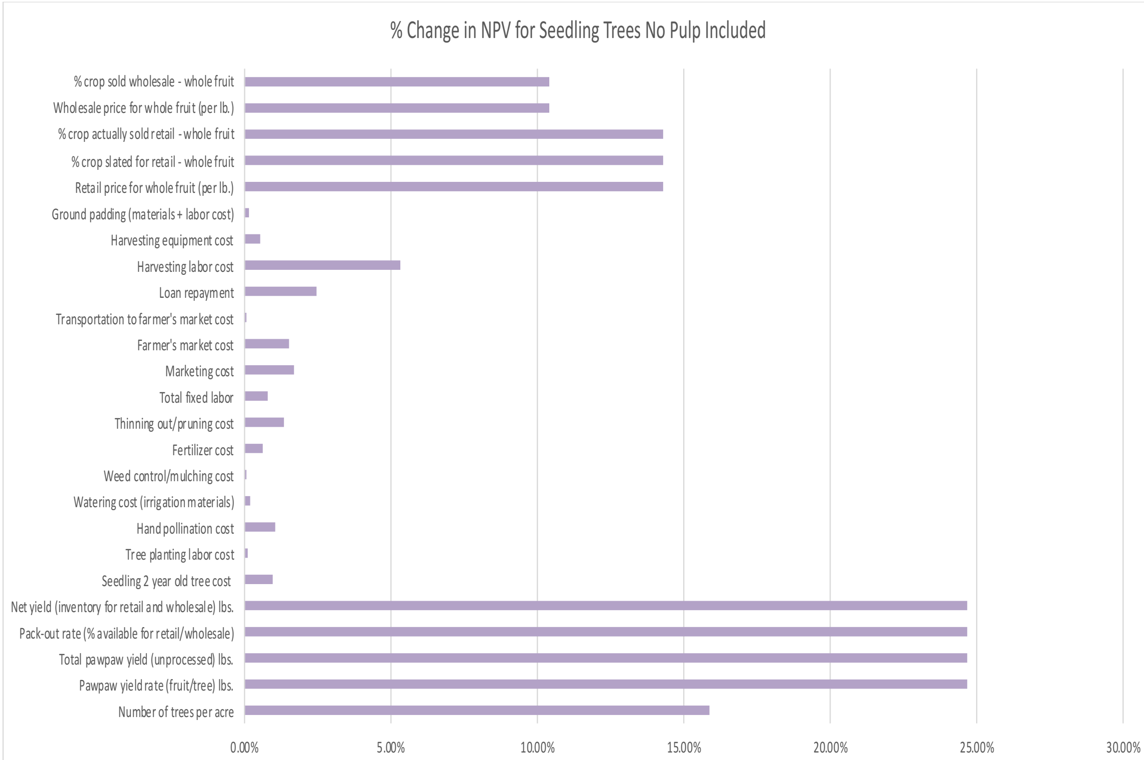

Figure 10. Percentage change in net profit value for seedling trees without pulp included.

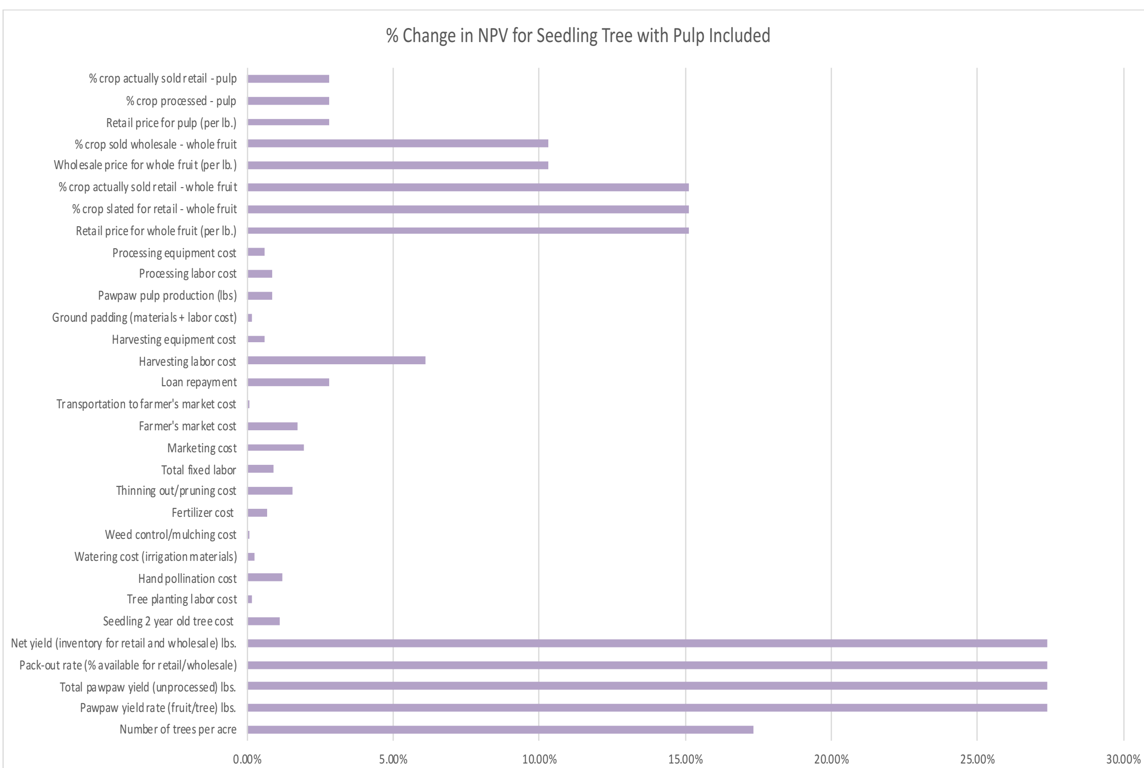

Figure 11. Percentage change in net profit value for seedling trees with pulp included.

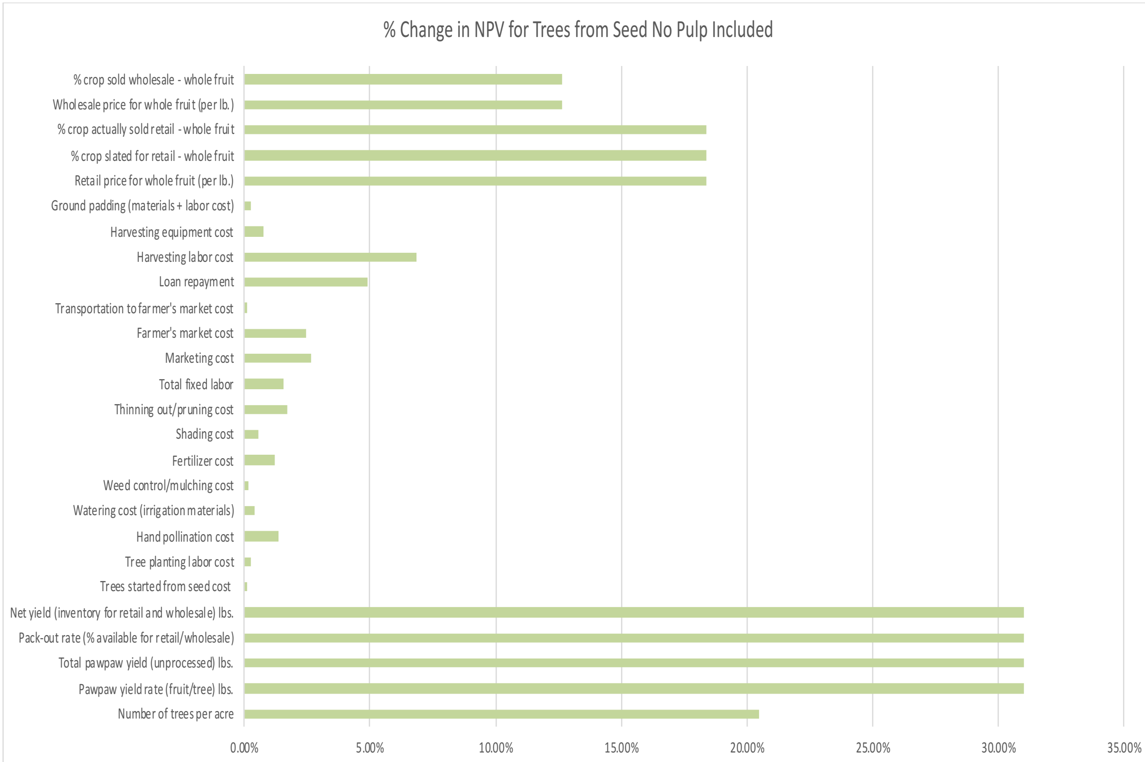

Figure 12. Percentage change in net profit value for trees from seed without pulp included.

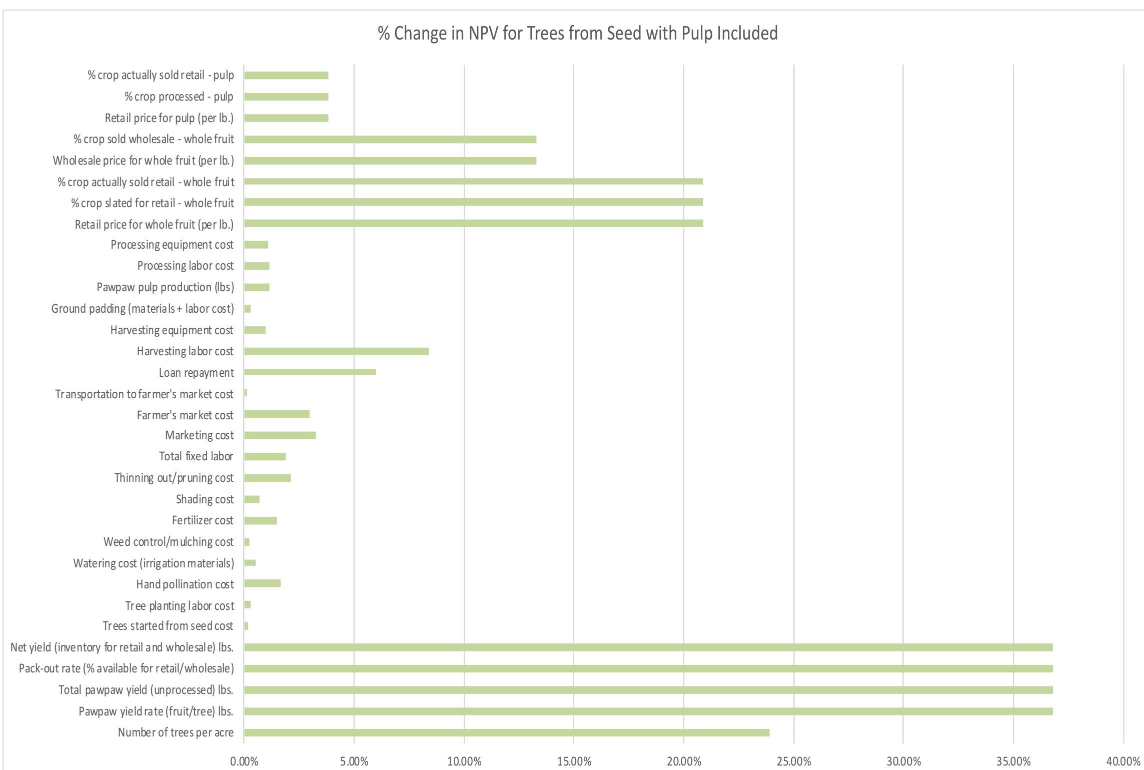

Figure 13. Percentage change in net profit value for trees from seed with pulp included

Chapter IV

Discussion

The results gleaned from the financial appraisal tested the primary hypothesis. Given the assumed cost and revenue streams over 15 years, then yes, pawpaw would be a financial success for a small-scale, family operated farm growing the fruit on one acre. Over a third of all farms in Massachusetts are nine acres or less, and I wanted to keep this scale as my target audience (USDA, 2014). The spreadsheet model allows for the variables to be modified accordingly to fit differing individual parameters of a farm.

Additional Scenarios

Using my spreadsheet, I examined additional scenarios that were outside the scope of my modeled scenarios. These additional results include modeling expanded pulp production, additional acreage, selling only to only farmers markets, selling only to wholesale vendors, as well as looking at the NPV as a function of market price.

Even with a higher price per pound, selling only pulp does not make financial sense for this scale of a farm (Figure 14). The cost of necessary additional equipment, and amount of labor required, are too high to support a profit. The fruits need to be pulped when ripe and that is a short window. It is labor intensive to produce pulp and would require additional personnel to complete the task in the restrictive timeframe. In my scenarios, the scale at which the farmers were processing was small enough to be able to utilize the tomatoes sauce maker/processor method. If a farmer were to increase the

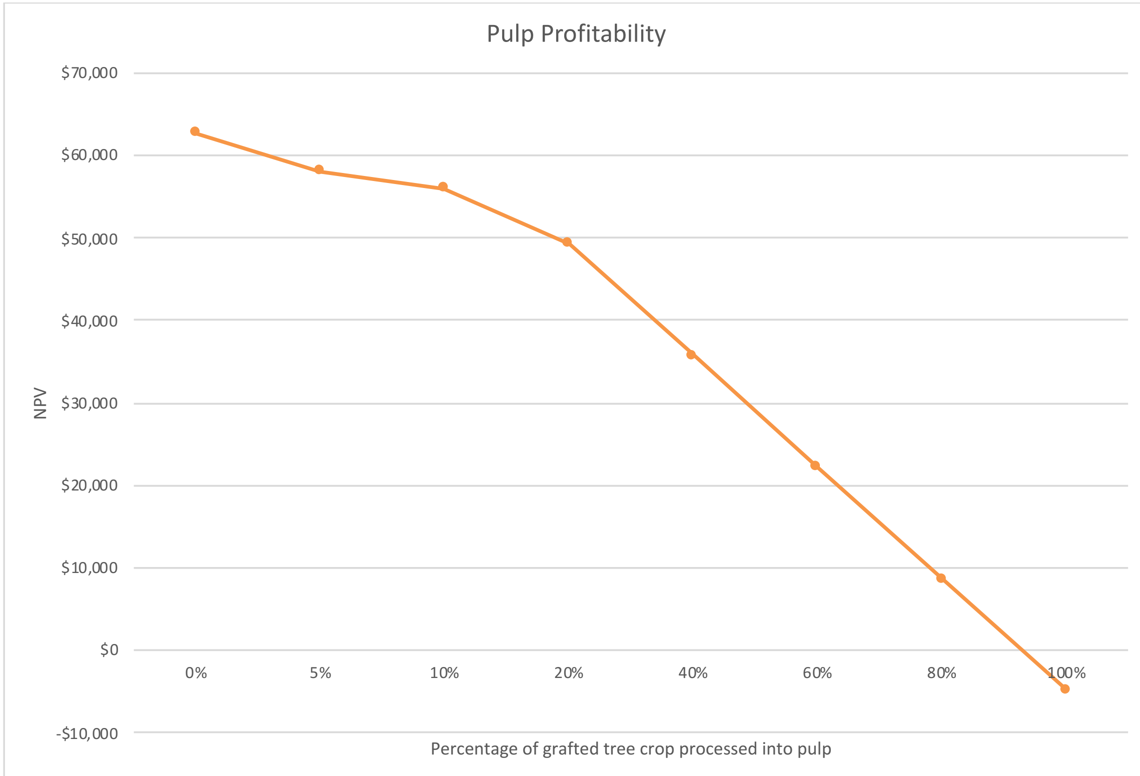

Figure 14. Impact of the percentage of pulp produced from the grafted trees nursery stock against the net profit value.

percentage processed, larger or more machinery would be necessary. Also, the percentage of fruit and weight lost during the process would severely cut into the potential profit.

Although it doesn't make financial sense to have pulp be the only retail item, there are benefits to the product. Pawpaw is a highly perishable fruit, with a short window of availability. Making the fruit into frozen pulp not only allows the pawpaw to be enjoyed past the harvest season, it also allows for the fruit to be more transportable. In pulp form, pawpaw increases its accessibility. Pulp provides an option for farmers looking to expand into online sales and further reaching commercial distribution, or if sales of ripe fruit are capped by local demand.

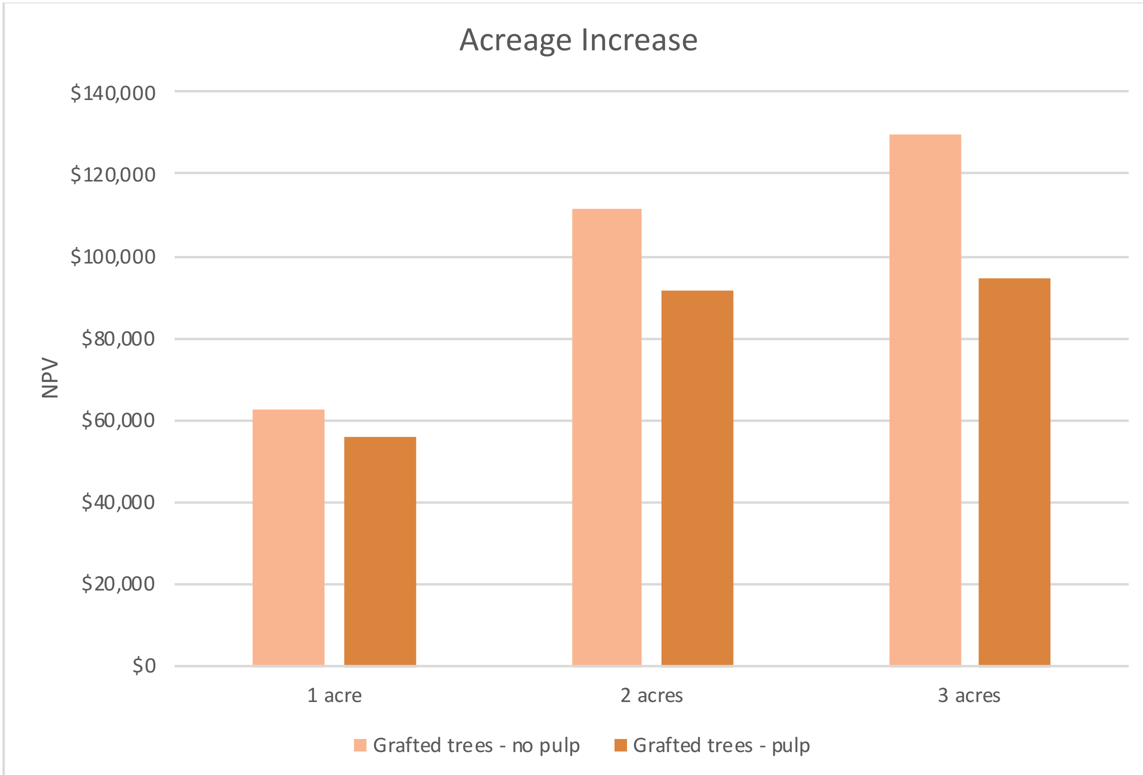

Figure 15. Impact of increasing the acreage planted with grafted tree nursery stock against the net profit value.

Net profit and acreage have a direct positive correlation, but at a per acre decline in profitability (Figure 15). As acreage increases, labor demands increase and pack-out-rate percentage decreases. Pulp labor and equipment would also increase accordingly. The additional labor involved in increasing acreage would likely result in needing to hire additional staff. The same responsibilities of hand pruning, pollinating and harvesting would be required, all within the identical, restrictive time frame and requiring additional equipment and resources. An additional factor arising when acreage is increased is a potential decrease in the pack-out-rate percentage. The larger the cultivated area, the greater the potential for in-field fruit loss and a decrease in quality. Scaling up would require fundamental changes to the farming operations.

With an increase in product available, there is also a chance of flooding the local retail market, which could decrease the percentage actually sold. An influx of fruit means more needs to be sold wholesale to local vendors, more needs to be pulped and more needs to be sold at the farmers market. An important component is making sure the supply doesn't exceed the demand, potentially reducing market price. An increase in acreage planted might be a viable option for a different scale of farm, but at the scale I have modeled, more doesn't necessarily equate to better.

Selling whole fruit to only farmers markets and selling whole fruit only wholesale, resulted in the same NPV as the baseline model (Figure 16). The fact that

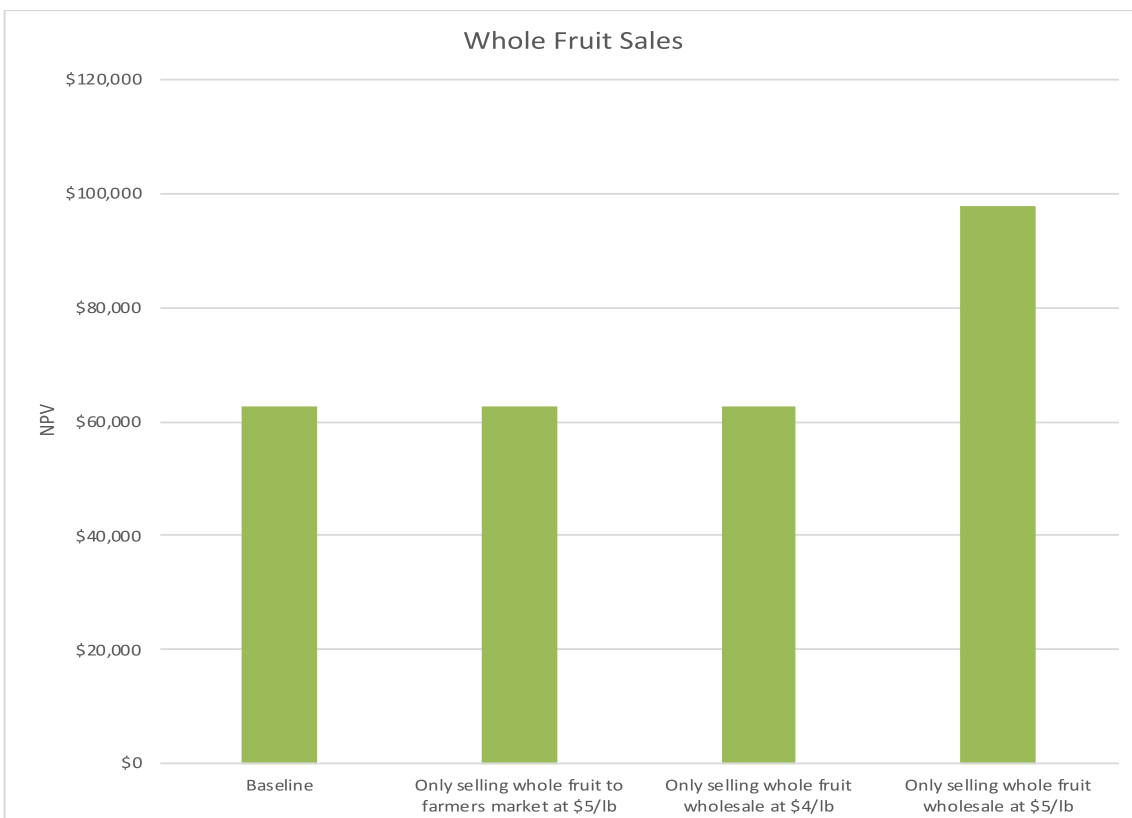

Figure 16. Comparison of selling 100% of product, at modeled price, with baseline model and an increase in wholesale price.

whole fruit incurs a 20% loss when being sold retail at $5, equates to the same differential as whole fruit being sold wholesale for 20% less at $4. Although, this is not taking into account that the percentage of the crop actually sold retail might decline due to a surplus of product. There might also need to be further marketing efforts factored in to account for labor involved in selling to additional wholesale buyers. But, if whole fruit were sold wholesale at the same price as sold retail ($5), with caveats, 100% wholesale would be more profitable.

Only selling to wholesale buyers would potentially make it difficult to create an awareness of what the pawpaw is in an emerging market. Vendor marketing would be essential in order to educate the consumer of pawpaw benefits. While conducting my research I came across a vendor doing exactly that. Clover, a Massachusetts based vegetarian fast food chain restaurant, was selling a limited supply of pawpaw soda. With the release of the soda, they also provided background information about the fruit, and swag in the form of posters and stickers to go along with the product. This allowed for the majority of the customers, who were unaware of what a pawpaw was, to become informed, as well as created hype and an allure around the product.

Impact Variables

My sensitivity analysis made one thing evidently clear, that yield is the component with the largest impact on overall profitability. In my analysis the crop yield was based on the average production per tree. A dominant factor in yield is cultivar type. Farmers could increase their overall yield, without having to increase the number of trees planted, by initially choosing pawpaw varieties that have statistically greater performance yields. Much of the current research on pawpaw is centered around increasing yield rate, fruit quality and size (Ames, 2017):

> A major research effort centered at Kentucky State University and involving a few other universities (including Cornell, Clemson, Purdue, Ohio State, Iowa State, and Oregon State) should contribute significantly to the commercial development of this crop. These universities have established identical plots of pawpaw, which they hope will identify the best cultivars and best management techniques. They are breeding for the following desirable traits: yellow to orange flesh; fruit size 10 ounces or larger; seeds small and few; fruit of uniform shape and free of external blemishes; and mild, sweet flesh with no unpleasant aftertaste.

All of these developments would have positive effects for farmers looking to maximize their profits without having to increase the amount of land that is cultivated.

Weather is another variable that, although not analyzed in my spreadsheet, could impact yearly profitability. Variables such as early frost or drought, which would kill the buds and blossoms, could result in a total crop loss, or a detrimental impact to a portion of the crop. Unlike annual crops, such as tomatoes, that require a significant amount of time, energy and money to establish the crop, pawpaw don't require much after the initial planting, until the fruit start to ripen on the tree. Farmers would be aware of the crop loss before spending any significant time or capital that year.

Conclusions

While attending the 19th Annual Ohio Pawpaw Festival in September 2017, I was exposed to enthusiasm towards a fruit like I had never before witnessed (Figure 17). Like myself, people had come from all over the country to celebrate, discuss, eat and learn about the pawpaw. While there I not only collected invaluable information but was also introduced to a variety of pawpaw food offerings. Not only were the whole fruit and frozen pulp for sale, but a plethora of food and drink stands had incorporated the fruit into a huge array of items. Vendors had pawpaw ice cream, bread, beer, barbeque sauce, salad dressing, waffles, whipped cream, fudge, cotton candy, cookies, salsa, popsicles, jams, mayo, cheesecake and soda, just to name a few. In a mainstream retail setting such as a bakery, restaurant or brewery, the fruit has limitless options.

Throughout my research and the discussion of my thesis topic, I was met with either confusion or elation depending on familiarity with the fruit. Those who knew of the pawpaw were excited to tell me their stories and experiences with the fruit. Those who had never heard of the pawpaw were mystified by the concept that they were unaware that this historically significant fruit existed and wished they could try it immediately. The farmers I met with were enthusiastic to share their knowledge and described the excitement for the fruit, that they have experienced, as that of a cult following. Whether at their local farmers market or onsite farm stand, when the pawpaw was available, people started to que in line hours before opening and everything was sold within minutes.

The types of responses received and the enthusiasm witnessed, assured me that if this product were to be available, it would succeed. With the allure of the tropical flavor, mystic of a niche item and the social responsibility of a locally grown product, the pawpaw has the potential to be a profitable item for farmers in New England.

Figure 17. A display of enthusiasm at the 19th Annual Ohio Pawpaw Festival (Frej, 2017).

Appendix

Ancillary Pawpaw Information

Table 3. Pawpaw fruit nutritional facts and information (Jones and Layne, 2009).

	Units	Pawpaw	Banana	Apple	Orange
Composition					
Food Energy	Calories	80	**92**	59	47
Protein	grams	**1.2**	1.03	0.19	0.94
Total Fat	grams	**1.2**	0.48	0.36	0.12
Carbohydrate	grams	18.8	**23.4**	15.25	11.75
Dietary Fiber	grams	2.6	2.4	**2.7**	2.4
Vitamins					
Vitamin A	RE [b]	8.6	8	5	**21**
Vitamin A	IU [c]	87	81	53	**205**
Vitamin C	milligrams	18.3	9.1	5.7	**53.2**
Thiamin	milligrams	0.01	0.045	0.017	**0.087**
Riboflavin	milligrams	0.09	**0.1**	0.014	0.04
Niacin	milligrams	**1.1**	0.54	0.077	0.282
Minerals					
Potassium	milligrams	345	**396**	115	181
Calcium	milligrams	**63**	6	7	40
Phosphorus	milligrams	**47**	20	7	14
Magnesium	milligrams	**113**	29	5	10
Iron	milligrams	**7**	0.31	0.18	0.1
Zinc	milligrams	**0.9**	0.16	0.04	0.07
Copper	milligrams	**0.5**	0.104	0.041	0.045
Manganese	milligrams	**2.6**	0.152	0.045	0.025
Essential amino acids					
Histidine	milligrams	21	**81**	3	18
Isoleucine	milligrams	**70**	33	8	25
Leucine	milligrams	**81**	71	12	23
Lysine	milligrams	**60**	48	12	47
Methionine	milligrams	15	11	2	**20**
Cystine	milligrams	4	**17**	3	10
Phenylalanine	milligrams	**51**	38	5	31
Tyrosine	milligrams	**25**	24	4	16
Threonine	milligrams	**46**	34	7	15
Tryptophan	milligrams	9	**12**	2	9
Valine	milligrams	**58**	47	9	40

Table 4. Complete list of pawpaw cultivars (Pomper, Crabtree and Lowe, 2009).

Pawpaw Cultivar	Description
Allegheny™	Selected by R. Neal Peterson. Fruit has medium fleshiness; percent seed approximately 8% by weight. Texture medium firm and smooth. Flesh color yellow. Fruit size approximately 125 g/fruit at KSU. Fruit size can benefit from thinning when fruit set is high. Limited availability of nursery stock.
Belle	
Collins	Selected in GA.
Convis	Selected from Corwin Davis orchard. Large fruit., yellow flesh; ripens 1st week of October in MI.
Davis	Selected from the wild in MI by Corwin Davis in 1959. Introduced in 1961 from Bellevue, MI. Medium sized fruit, up to 5 inches long; green skin; yellow flesh; large seed; ripens 1st week of October in Michigan; keeps well in cold storage.
Glaser	Selected by P. Glaser of Evansville, IN. Medium size fruit.
Greenriver Belle	Original tree grown near the Green River in Hart County, Kentucky. Selected by Carol Friedman in 1998.
IXL	Hybrid of Overleese and Davis; large fruit, yellow flesh; ripens 2nd week of October in MI.
Jonathan	
Kirsten	Hybrid seedling of Taytwo x Overleese; selected by Tom Mansell, Aliquippa, PA.
KSU-Atwood™	Seedling from Maryland. Released by the Kentucky State University Horticulture Program in 2009. The release is named for Rufus B. Atwood, who served as president of Kentucky State College (now university) from 1929 to 1962. Fruit: greenish-blue skin, yellow-orange flesh, few seeds. Fruit size and flavor medium; averaging 120 g/fruit and 150 fruit per tree at KSU. (Note: Trees may not yet be available for sale from licensed nurseries)
Lady D	
LA Native	From LA, blooms late in TN, small fruit.
Lynn's Favorite	Selected from Corwin Davis orchard. Yellow fleshed, large fruit; ripens 2nd week of October in MI.
Mango	Selected from the wild in Tifton, GA, by Major C. Collins in 1970. Vigorus growth.
Marla	
Mary Foos Johnson	Selected from the wild in Kansas by Milo Gibson. Seedling donated to North Willamette Expt. Sta., Aurora, OR, by Mary Foos Johnson. Large fruit; yellow skin; butter-color flesh; few seeds; ripens first week of October in MI.
Middletown	Selected from the wild in Middletown, OH, by Ernest J. Downing in 1915. Ripens in mid-September in Kentucky. Fruit size small; averaging 75 g/fruit and 75 fruit per tree at KSU.
Mitchell	Selected from the wild in Jefferson Co., IL, by Joseph W. Hickman in 1979. Fruit: slightly yellow skin, golden flesh, few seeds. Fruit size medium; averaging 115 g/fruit and 60 fruit per tree at KSU.
NC-1	Hybrid seedling of Davis x Overleese; selected by R. Douglas Campbell, Ontario, Canada, in 1976. Fruit has few seeds; yellow skin and flesh; thin skin; early ripening, 15 Sept. in Ontario and early September in Kentucky. Fruit size large; averaging 180 g/fruit and 45 fruit per tree at KSU.
Overleese	Selected from the wild in Rushville, IN, by W.B. Ward in 1950. Ripens early September in Kentucky and 1st week of October in Michigan. Fruit size large; averaging over 170 g/fruit and 55 fruit per tree at KSU.

PA-Golden 1	Selected as seedling from seed originating from George Slate collection by John Gordon, Amherst, NY. Fruit has yellow skin when ripening, golden flesh; matures late August in Kentucky and mid-September in New York. Fruit size medium; averaging 110 g/fruit and 120 fruit per tree at KSU.
PA-Golden 2	Selected as seedling from seed originating from George Slate collection by John Gordon, Amherst, NY. Fruit: yellow skin, golden flesh; matures mid-September in NY.
PA-Golden 3	Selected as seedling from seed originating from George Slate collection by John Gordon, Amherst, NY. Fruit: yellow skin, golden flesh; matures mid-September in NY.
PA-Golden 4	Selected as seedling from seed originating from George Slate collection by John Gordon, Amherst, NY. Fruit: yellow skin, golden flesh; matures mid-September in NY.
Potomac™	Selected by R. Neal Peterson as seedling of a tree in the Blandy Experimental Farm. Extremely fleshy. Percent seed ~ 4% by weight. Texture firm, melting, smooth. Flesh color medium yellow. Fruit size large; averaging 235 g/fruit and 45 fruit per tree at KSU. Problems with fruit cracking some years. Limited availability of nursery stock.
Prolific	Selected by Corwin Davis, Bellevue, MI, in mid-1980s. Large fruit, yellow flesh; ripens first week of October in MI. Fruit size medium at KSU.
Rappahannock™	Selected by R. Neal Peterson as seedling of a tree in the Blandy Experimental Farm. Ripens Mid-September in Kentucky. This fruit typically exhibits a yellowish color break at picking stage. This tree has an unusual leaf habit, where the leaf is held horizontal-to-upright, making the fruit more visible under the canopy of leaves. Fruit size small; averaging 95 g/fruit and 95 fruit per tree at KSU. Patented 2004; propagation restrictions apply. Limited availability of nursery stock.
Rebecca's Gold	Selected from Corwin Davis seed, Bellevue, MI., by J.M. Riley in 1974. Medium sized fruit; kidney-shaped; yellow flesh. Fruit size medium at KSU.
Ruby Keenan	Medium size fruit with excellent flavor.
SAA-Overleese	Selected from Overleese seed by John Gordon, Amherst, NY, in 1982. Large fruit; rounded shape; green skin; yellow flesh; few seeds; matures in mid-October in NY.
SAA-Zimmerman	Selected as seedling from seed originating from G.A. Zimmerman collection by John Gordon, Amherst, NY, in 1982. Large fruit; yellow skin and flesh; few seeds.
Shenandoah™	Selected by R. Neal Peterson as a seedling of Overleese. Fruit with few seeds (approx 7% by weight). Fruit has creamy yellow flesh. Ripens in September in Kentucky. Fruit size medium-large; averaging 150 g/fruit and 80 fruit per tree at KSU. Patented 2004; propagation restrictions apply. Limited availability of nursery stock.
Sibley	
Sue	Selected in southern IN. Medium fruit size, yellow flesh, skin yellow when ripe.
Sunflower	Selected from the wild in Chanute, KS, by Milo Gibson in 1970. Tree reported to be self-fertile. Large fruit; yellow skin; butter-color flesh; few seeds; ripens early to mid-September in Kentucky and first week of October in MI. Fruit size large; averaging 155 g/fruit and 75 fruit per tree at KSU.
Sun-Glo	Yellow skin, yellow flesh,large fruit; ripens 1st week of October in MI.
Susquehanna™	Selected by R. Neal Peterson as a seedling from a tree in the collection of the Blandy Experimental Farm. Fruit has few seeds, very fleshy, medium yellow flesh; thickish skin; this variety is less fragile than most. Few seeds (approx 4% by weight). Ripens late September in Kentucky. Patented 2004; propagation restrictions apply. Fruit size

	large; averaging 185 g/fruit and 40 fruit per tree at KSU. Limited availability of nursery stock.
Sweet Alice	Selected from the wild in West Virginia by Homer Jacobs of the Holden Arboretum, Mentor, OH, in 1934. Fruit size medium at KSU.
Sweet Virginia	
Taylor	Selected from the wild in Eaton Rapids, MI, by Corwin Davis in 1968. Fruit; green skin; yellow flesh; ripens in September in Kentucky and 1st week of October in MI. Fruit size medium; averaging 110 g/fruit and 70 fruit per tree at KSU.
Taytwo	Selected from the wild in Eaton Rapids, MI, by Corwin Davis in 1968. Sometimes spelled **Taytoo**. Fruit: light-green skin; yellow flesh; ripens in September in Kentucky and 1st week of October in MI. Fruit size medium; averaging 120 g/fruit and 75 fruit per tree at KSU.
Tollgate	Yellow fleshed, LArge fruit, ripens 1st week of October in MI.
Wabash™	Selected by R. Neal Peterson as seedling of a tree in the Blandy Experimental Farm. Very fleshy. Percent seed ~ 6% by weight. Texture medium firm, creamy, smooth. Flesh color yellow to orangish. Fruit size large; averaging 185 g/fruit and 65 fruit per tree at KSU. Problems with fruit cracking some years. Limited availability of nursery stock.
Wells	Selected from the wild in Salem, IN, by David Wells in 1990. Fruit; green skin; orange flesh. Ripens mid to late-September in Kentucky. Fruit size medium; averaging 105 g/fruit and 65 fruit per tree at KSU.
Wilson	Selected from the wild on Black Mountain, Harlan Co., KY, by John V. Creech in 1985. Fruit; yellow skin; golden flesh. Ripens in September in Kentucky. Fruit size small; averaging 90 g/fruit and 130 fruit per tree at KSU.
Zimmerman	Selected in NY from G.A. Zimmerman seed by George Slate. Medium sized fruit at KSU.

Figure 18. Shading apparatus constructed of a tomato cage and window screen material, protecting a young pawpaw tree (Ames, 2017).

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