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Adoption of Mechanical Harvesting for Sweet Orange Trees in Florida: Addressing Grower Concerns on Long-Term Impacts

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Abstract

The purpose of this article is to examine the impact of mechanical harvesting of juice oranges on future productivity of the orange trees. Yield data from several growers were analyzed over a ten-year-period to estimate a statistical relationship between annual fruit yields and harvest method. Results indicated that mechanical harvesting did not create an adverse near-term nor long-term effect on yields.

Keywords: citrus; mechanical harvesting; citrus yields

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The Florida Citrus Industry contributes more than $9 billion annually to the Florida economy (Hodges and Rahmani 2009). More than 67% of the United States citrus supply, including grapefruit, comes from Florida and more than 95% of the Florida orange crop is used for juicing (NASS 2009). In Florida, 30 of the 67 counties grow citrus and more than 80% of the citrus grown is within 10 counties in the southern portion of Florida (Figure 1). In the late 1990s, Florida citrus growers produced fruit from 845,000 acres and produced a record 244 million boxes of oranges in 1997. Citrus acreage was adversely affected by several events, including a mandatory canker eradication program that removed nearly 87,500 acres of commercial groves between 1998 and 2007 (FDACS-DPI 2011); a dramatic run-up on land values between 2004 and 2007 that led to numerous citrus operations being sold to real estate developers; hurricanes in 2004 and 2005 that moved across every citrus production region in Florida; and the onset of citrus greening, or HLB, in 2006 that to-date has no cure other than eradication of infected trees. By 2010, the number of bearing citrus acres had decreased to 569,000 and orange production had fallen, fluctuating between 129 million boxes in 2006 and 170 million boxes in 2007 (Table 1). Even with the significant loss in acreage and number of trees, citrus remains Florida's top horticultural crop (FDACS 2010). Florida is the number one producer of citrus in the United States, and ranks second only to Brazil as the world's leading producer of juice oranges (Roka et al. 2009).

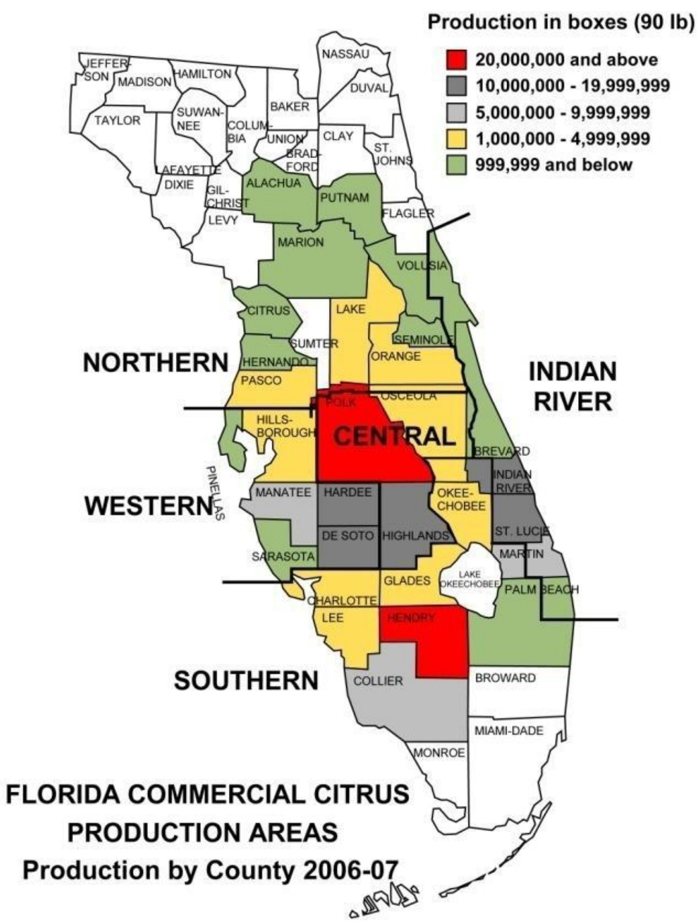

Figure 1. Florida Citrus Producing Regions and Counties, 2006–2007
Source: Roka et al. 2009

Table 1. Orange Production in Florida from 1996 through 2009 Harvest Seasons

Season	Total Orange Production (MM boxes)	Total Orange Processed (MM boxes)	Proportion of Total Orange Production – Processed (%)	Total Orange Value ($MM)
1996	226.2	215.5	96%	$801.3
1997	244.0	233.0	95%	$900.8
1998	186.0	175.1	94%	$900.0
1999	233.0	223.6	96%	$856.1
2000	223.3	213.6	96%	$716.1
2001	230.0	220.6	96%	$797.6
2002	203.0	193.3	95%	$643.8
2003	242.0	232.1	96%	$699.9
2004	149.8	142.4	95%	$522.9
2005	147.7	140.4	95%	$813.3
2006	129.0	122.6	95%	$1,325.7
2007	170.2	164.3	96%	$1,125.3
2008	162.5	155.6	96%	$937.1
2009	133.6	127.8	96%	$856.4

Source. NASS (2009; 2010).

Florida's citrus growers face significant economic threats, primarily from diseases, labor costs, and global competition. Since 2005, when citrus greening (HLB) was discovered in Florida, the cost of growing oranges has increased from $800 to more than $1,500 per acre (Muraro 2009). Most of these costs are from increased chemical usage to control the Asian citrus psyllid, which vectors the greening bacteria, and grove labor because harvesting fruit relies mainly on manual labor. The minimum wage in Florida increased from $5.15 in 2005 to $7.31 per hour in 2011. In addition, the new health care law, which will provide new health benefits to farm workers, will likely push labor and harvesting costs higher. While Brazilian citrus growers face similar disease threats and social taxes as do Florida growers, overall costs of citrus production in Brazil are significantly lower than in Florida (Muraro et al. 2003). Lower labor and land costs are important factors behind the Brazilian competitive advantage. If the Florida citrus production and juice processing industry is to remain economically sustainable into the future, new technologies must be developed and adopted to increase fruit production efficiencies and decrease harvesting costs.

One possible technology is mechanical harvesting of juice oranges. Mechanical harvesting systems were being developed in Florida as early as the 1950s. At that time, citrus acreage and production were increasing rapidly and the question over whether there would be a shortage of harvest labor motivated the research into mechanical harvesting systems. Unfortunately, these early systems did not provide a sufficiently strong economic justification for commercial investment. In addition, USDA policies discouraged public funds to research "labor-saving" technologies. Ultimately a series of devastating freezes during the 1980s drastically reduced the volume of Florida's citrus crop. Concern about labor availability waned and mechanical harvesting research came to a halt by 1985. Then came the 1990s when citrus acreage and production were again rapidly expanding across the state, particularly in southwest Florida, which renewed the interest in mechanical harvesting. Concerns over labor availability, however, were augmented by concerns with low fruit prices and competition with the increasing world supply of Brazilian orange juice. The goal of the new mechanical harvesting program was focused on lowering harvesting costs.

Mechanical harvesting has the potential to dramatically reduce a grower's harvesting cost. Field observations documented that trunk and canopy shakers with catch frames could improve harvest labor productivity by ten-fold (Roka and Hyman 2004). If the economies of scale from the existing equipment could be realized, then harvesting costs could feasibly be reduced by as much as 50% and grower returns increased by between \$100 and \$200 per acre (Roka, et al. 2009). Achieving these economies of scale, however, required that growers adopt the new mechanical harvesting equipment and aggressively push the physical capabilities of these systems.

At the beginning of the 1999 harvest season, several commercial harvesting companies invested in mechanical systems and began to sell their services as an option to harvest juice oranges. Over the next seven years, demand for mechanical harvesting systems increased steadily from 6,500 acres in 1999–2000 to more than 35,000 acres by 2008 (Figure 2). More importantly, those growers who were able to effectively and efficiently use harvesting equipment reported a reduction of between 20 and 30 cents per box (\$80 to \$150 per acre) in their net harvesting costs (Personal Communication 2011). Looking at the issue of economies of scale, harvesting equipment is a large initial investment if purchased by the grower, hence mechanical harvesting would only be adopted by growers with acreage large enough to spread the cost of such an investment.

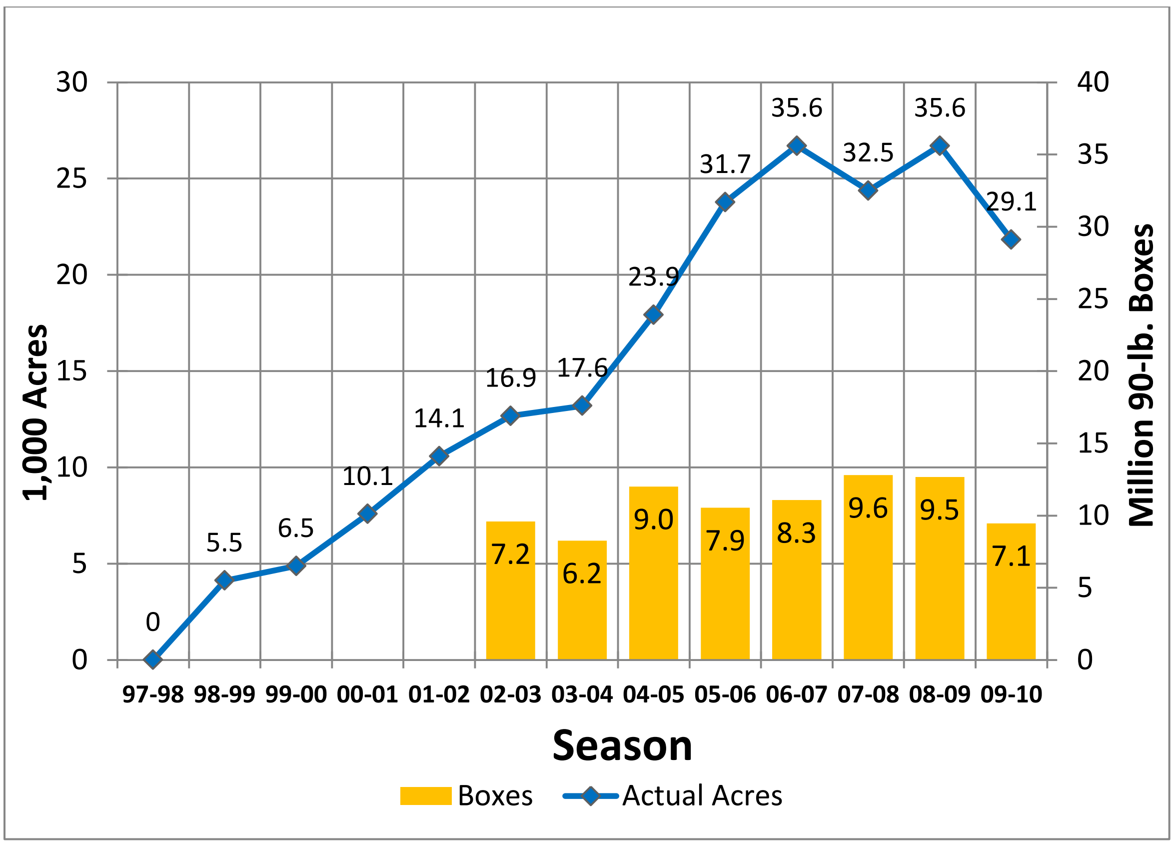

Figure 2. Total Acreage and Boxes Mechanically Harvested in Florida, 1997–2010 (FDOC 2010).

Despite some initial success, mechanically harvested acreage has not expanded since 2008, and in fact, may be on a downward trend. Technical barriers, tree health issues, and grower perceptions about the impact of mechanical harvesting on tree health are some of the major reasons explaining the slow adoption of mechanical harvesting equipment by Florida growers. The registration and use of an abscission compound is one example of a technical barrier without which prevents current mechanical systems from harvesting nearly 40% of the 'Valencia' orange crop.[1] Improvements in catch-frame design are another technological opportunity that would increase overall fruit recovery while at the same time removing all unwanted debris from the fruit load. These technological barriers can be overcome so long as growers commit to mechanical harvesting and thereby provide the financial incentive for equipment manufacturers and commercial harvesting companies to continue their investment into harvesting equipment. Currently, grower commitment to mechanical harvesting systems is in question in large part to their concerns about tree health and their perception that mechanical harvesting equipment has a direct and negative effect on tree health.

Harvesting, even by hand, adds a physiological stress to a tree. Growers have been particularly concerned about mechanical systems because of the visible scars they leave on trees and in the grove. These injuries include the removal of leaves, flowers, and young fruit, broken branches, exposed roots, and bark scuffs (see Figure 3). The question becomes whether the visible damage observed after mechanical harvesting translates to economic losses. Complicating this question is a strong and widespread consensus among Florida citrus growers that overall tree health has declined significantly since 2004. A combination of four hurricanes, a persistent drought, and the spread of citrus greening have imposed considerable physiological stress to trees independent of any harvesting method.

The purpose of this research is to analyze fruit yield data collected from commercial production operations, which have employed both mechanical systems and hand harvesting crews to harvest oranges and determine if there is in fact a negative effect from mechanical harvesting on short or long term production. Results from this study should be useful to commercial growers in helping decide their adoption strategies with respect to mechanical harvesting. In addition, results from this study should provide insights into how Florida citrus growers can achieve the dual goals of maintaining tree health while significantly reducing net harvest costs through mechanical systems.

Previous Research

Several multi-year studies dating back to the 1960s and 1970s were conducted by University of Florida and USDA-ARS horticultural and engineering scientists to investigate whether the visible damage left by mechanical harvesting equipment imparted long-term and adverse impacts on fruit production and tree mortality. These studies consistently found no connection between mechanical harvesting and lower fruit yields nor with higher tree mortality (Whitney 2003; Hedden, Churchill, and Whitney 1988; Whitney and Wheaton 1987; Whitney, Churchill, and Hedden 1986). More recently, experiments have studied the impacts of mechanical harvesting on various aspects of tree physiology. For example, water status and leaf gas exchange within mature trees have not suffered prolonged negative effects following mechanical harvesting (Li and Syvertsen

[1] 'Valencia' orange trees are harvested from March to June. During the entire harvest period, these trees carry two

2005). Further, defoliation caused by trunk or canopy shakers should not significantly reduce canopy light interception in well-developed citrus trees. In fact, healthy trees were shown to sustain up to 25% defoliation without causing any reduction in fruit yield the following season (Li, Burns, and Syvertsen 2006). In general, "well-nourished" citrus trees are very hardy and can withstand the stresses imposed by properly operated harvesting equipment. Trees mechanically harvested should be able to recover from the typical physical injuries to the same health status as hand harvested trees (Roka et al. 2009).

Figure 3. Post-mechanical Harvesting Visible Damage

The one issue where mechanical harvesting may have an adverse impact on fruit yield is when 'Valencia' oranges are harvested late in the season. 'Valencia' oranges complicate mechanical harvesting because this variety is a fifteen-month crop, and thus two crops hang on a tree throughout the harvest season, this year's mature fruit and next year's immature fruitlets. When 'Valencia' oranges are mechanically harvested the young fruitlets are small, the reduction in fruit yields the following year is insignificant. However, if mechanical harvesting occurs latter in the harvesting period, there could be more than a 30% reduction in yields the following season (Coppock 1972; Roka, Burns, and Buker 2005). This late period of 'Valencia' harvest occurs typically after May 1 and is defined by the size of the green fruitlets. Early experiments with limb shakers concluded that Valencia oranges could be harvested until the young maturing fruit is approximately 0.85 inches in diameter, without significant reduction in subsequent yields (Coppock 1972; Burns et.al. 2006).

Despite a body of scientific evidence showing no adverse effects from mechanical harvesting, growers remain unconvinced. They see the physical injuries to their trees and conclude that mechanical harvesting equipment seriously jeopardizes next year's fruit production and the long-term health of trees. Informal discussions with growers suggest two reasons for why they have yet to accept the published research on mechanical harvesting and the lack of negative effects on tree yield and health. The reasons given for lack of acceptance of the published research are from two main factors. First, all the previous studies were small-plot field trials conducted under relatively controlled conditions which, from a grower's perspective, may not reflect commercial production conditions. Growers may be reluctant to extend results from six to ten trees per plot to commercial blocks involving hundreds of acres and thousands of trees. Second, the previous field trials lasted at most four seasons. Growers expect their trees to produce for at least twenty years and the production during the latter years of a trees life cycle that are considered to be the most economically valuable. The fact that trees may tolerate four or five years of mechanical harvesting does not allay grower uncertainty over how well trees will respond to mechanical harvesting for ten to fifteen years.

The objective of the research reported in this paper was to address grower concerns about mechanical harvesting and negative impacts on tree health and fruit production from a different angle. Instead of designing a horticultural field experiment, data were collected directly from the production records of commercial groves where both mechanical and hand crews were utilized to harvest oranges. Annual average yields of individual blocks, a grower's management unit, were analyzed as to the extent they were influenced by harvest method, hand versus mechanical. Data were included specifically from growers who had at least five years of mechanical harvesting experience and still harvested some blocks by hand. The study period spanned ten years, from 1999 through 2008. The specific research questions of this study dealt with whether there was an immediate or lagged effect on fruit yields and whether cumulative years of mechanical harvesting adversely affected tree health as measured by declining annual yields.

Data

Data were collected from four citrus operations in Hendry and Collier Counties located in southwest Florida. Each farm used both mechanical and hand harvesting at some point within the past ten years. All operations used mechanical harvesting equipment for at least five years. In three of the four operations there were blocks that were harvested mechanically for the entire time frame. Yield data, harvest method, tree age, tree density, variety, and rootstock data from commercial citrus blocks were collected from 1999 to 2008. A total of 572 observations were recorded, with 25,553 net tree acres represented. From 1999 to 2008, over 11 million boxes were both mechanically and hand harvested from the blocks analyzed in this study. A total of 44% of all blocks harvested between 1999 and 2008 were mechanically harvested. Eight blocks throughout the study were mechanically harvested each of the ten years and fourteen blocks were never mechanically harvested. Tree density ranged from 121 to 141.8 per block. There were four rootstocks and five varieties total (Table 2).

Table 2. Number of Blocks in Data by Variety/Rootstock Combinations

Rootstock Variety	Swingle	Carrizo	Cleo	Cleo-Carrizo	Total by Variety
Hamlin	111	135	10	20	276
Valencia	80	64	0	0	144
Parson Brown	0	10	0	0	10
Pineapple	0	20	10	0	30
Rhode Red Valencia	120	0	0	0	120
Total by Rootstock	311	229	20	20	580

Average yield was measured in boxes[2] per acre, per year (Figure 4). Tree age was calculated by taking the data collection year and subtracting plant date. Citrus trees were generally not harvest-

[2] One box of oranges weighs 90 pounds (41 kilograms).

ed until they were at least three years of age. The majority of the trees in this data set were between the ages of twelve and twenty-one years (Figure 5). Because new trees can be planted at different times within a block, blocks were separated into multiple observations and yields were allocated based on tree age. For the purpose of this research, percentage of production by age was a weighted average adjusted due to the range of tree ages we encountered. Based on research conducted by Albrigo and Burani-Arouca (2010), who investigated tree yields over a 37-year period, any trees ages ten or older were considered to be at 100% production. Production for younger trees was at a lower percentage of full production as they grow to maturity.

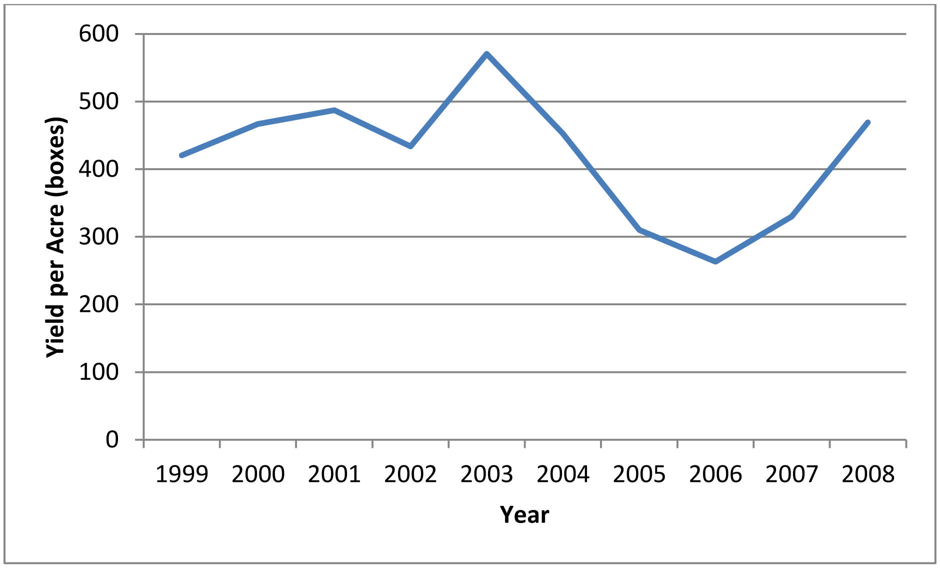

Figure 4. Average Grower Yield in Boxes Per Acre, Per Year

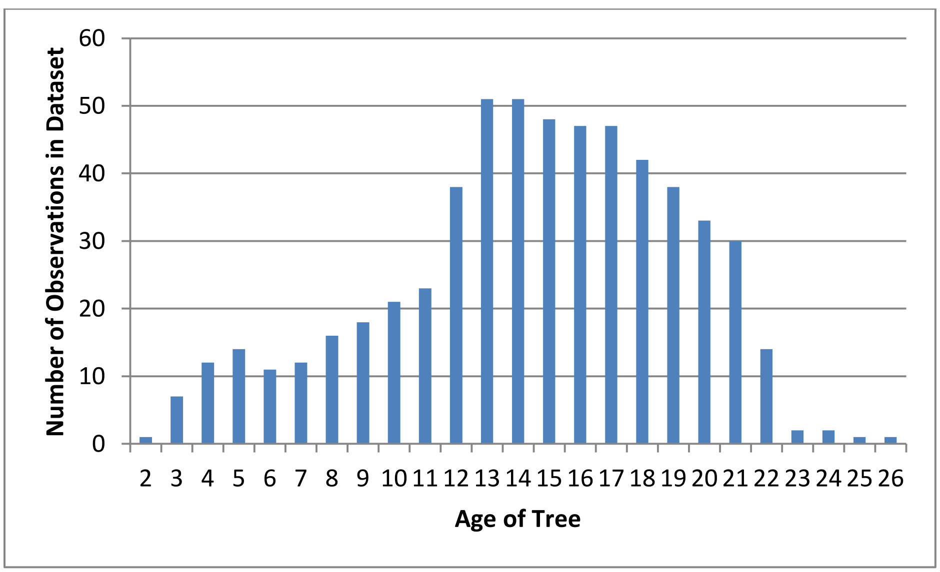

Figure 5. Tree Age Frequency

In addition to data collected from the citrus growers, the annual county average yields were collected from the annual Citrus Summary, published by the NASS Florida Field Office, which provided an estimate of season average yields (boxes per acre), by county, for all orange varieties, and for early, mid, and late season varieties. Valencia oranges were listed in their own category due to being a late-season variety, typically exhibiting lower yields than the early/mid-season varieties. Figure 6 shows both Collier and Hendry County yields in boxes per acre, per year differentiating between early/mid varieties and late varieties. Both counties showed a substantial yield reduction after 2005, which coincides with Hurricane Wilma that hit southwest Florida in October 2005.

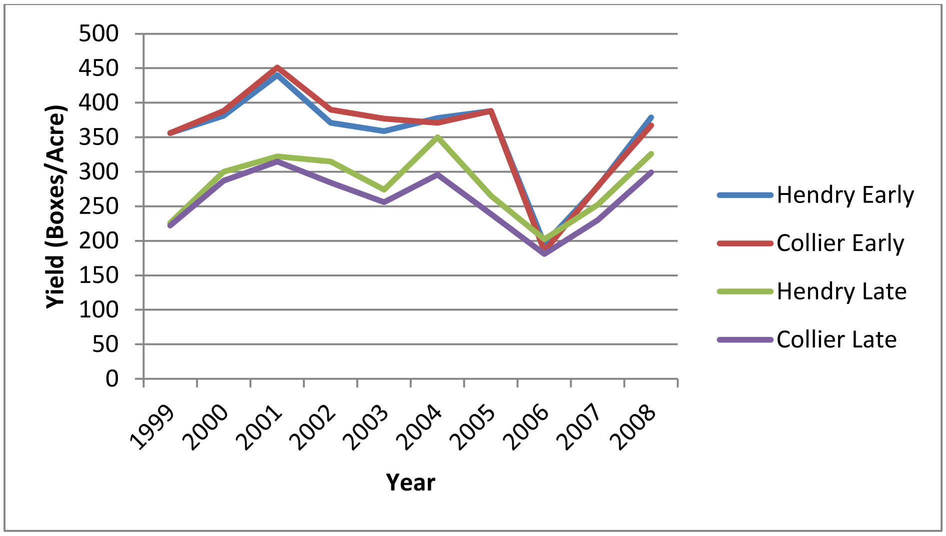

Figure 6. County Yields of Early and Late Season Oranges, Hendry and Collier Counties.

Model

The goal of this study is to use data collected from commercial orange groves to determine if harvesting method impacts current and future yields. The empirical model used to answer this question is:

Yield = *f* (harvest method, past harvest methods, variety, rootstock, tree age, tree density, county yield, grower, and hurricane)

where the dependent variable is yield, measured in boxes per acre. The independent variables include the current year's harvest method, the previous years' harvest methods, variety of citrus, type of rootstock, age of trees, density of tree plantings, county yield, and a dummy variable for years 2006 and beyond to measure the impact of Hurricane Wilma, which directly impacted southwest Florida in 2005 and had carryover effects on yields in 2006. (Three hurricanes struck the peninsula of Florida in 2004, causing significant damage in the east coastal, central, and northern production regions, with minimal effects in southwest Florida.) Variable definitions are provided in Table 3.

Table 3. Variable Definitions

Variable Name	Definition
Harvest Method	= 1 if block was mechanically harvested, 0 if hand harvested
Lagged harvest	Harvest method of prior year (=1 for mechanical, 0 for hand)
Total Mechanical	Sum of times block was mechanically harvested (minimum 0, maximum 10)
Early	= 1 if block contained Hamlin or Parson Brown varieties (early varieties)
Mid	= 1 if block contained Pineapple variety (mid-season)
Late	= 1 if block contained Rhode Red Valencia and Valencia varieties (late season)
Swingle	= 1 if rootstock was Swingle
Cleo	= 1 if rootstock was Cleo
Cleo-Carrizo	= 1 if rootstock was a mixture of Cleo and Carrizo
Carrizo	= 1 if rootstock was Carrizo
Tree Age	Year of yield data minus year tree was planted
Tree Density	Number of trees per block divided by block size (in acres)
County Yield	County yield for Hendry and Collier Counties, in boxes per acre, by type of orange (early, mid, or late season)
Grower	Dummy variable representing four growers in the study.
Hurricane	Dummy variable = 1 for seasons after Hurricane Wilma (2005)

The harvest method during the current year was included to determine if there was a significant yield difference between hand harvesting and mechanical harvesting for the current year. The null hypothesis was that harvest method should not affect yield in the current year. If harvest method were to have a significant effect on fruit yield, that impact would be evident in the following year. Lag harvest method captures the harvesting method of the year prior to the current year being studied. In addition, a variable was created to capture the total number of years during the study period that a particular block was mechanically harvested. This variable was designed to measure whether mechanical harvesting had a cumulative or long-term impact on fruit yield. This is used to address the industry concern that the impact from mechanical harvesting might not be an immediate problem, but that the long-term stress created by mechanical harvesting is a problem. The null hypotheses for the lag and cumulative variables were that their parameter values would be zero. A rejection of the null hypothesis for either variable would support the growers' contention of adverse impacts from mechanical harvesting.

Variety and rootstock combinations were included to account for general differences in fruit yield that are typical among early and late season varieties and among the common rootstocks (i.e., Swingle, Carrizo, and Cleo). Production increases as a tree ages up to the point where individual tree canopies form a hedgerow. After that point, production per acre levels off. Therefore, we must take into account how the age of the trees possibly affects crop yields. Tree density was included to reflect differences in the number of bearing trees per net tree acre among the study blocks. Average annual county yields were included to help account for general differences in growing and weather conditions among regions and across time. Counties may vary in a number of environmental ways and this variable was used to ensure that the locations of the groves were captured in the regression. The county yield variable used was specific to the county, as well as the type of citrus (early versus late season). Individual growers were included as explanatory variables to capture any significant differences in overall grove management practices. Lastly, a hurricane variable was incorporated into the regression to distinguish between those years of harvest prior to Hurricane Wilma and her effect on subsequent crop yields.

Results and Discussion

This model was estimated using ordinary least squares regression methods in SAS and results are presented in Table 4. The most important finding from this model is that the coefficients for harvest method, lagged harvest method, and total mechanical harvest method were not statistically significant. Additional models were estimated including each harvest method individually, but results did not change. This indicates there are no significant yield differences per acre for mechanical harvesting versus hand harvesting, whether the mechanical harvesting happened in the current or immediately past season. The coefficient for total mechanical, which measured the number of times a block was mechanically harvested before the current year, dating back to 1999, was also insignificant, indicating that there was not cumulative damage from mechanical harvesting that impacted fruit yields.

Table 4. Regression Results

Variable	Coefficient	Error	Pr > |t|
Intercept	511.65	89.48	< .0001
Harvest Method	-10.45	20.73	0.61
Lagged Harvest	9.67	23.73	0.68
Total Mechanical	-2.04	4.31	0.64
Early	133.52	17.16	< .0001
Mid	86.77	39.50	0.03
Swingle	108.75	18.11	< .0001
Cleo	-84.70	42.52	0.047
Carrizo-Cleo	-120.28	68.68	0.08
Tree Age	11.30	1.65	< .0001
Tree Density	-3.03	0.53	< .0001
County Yield	0.49	0.12	< .0001
Grower 1	-29.73	24.72	0.23
Grower 2	-46.70	56.37	0.41
Grower 3	-99.54	19.98	< .0001
Hurricane	-134.66	18.15	< .0001

Results from our regression are confirmed with prior research and published data. Parameter estimates for orange varieties were significant, as would be expected. Early varieties, which included Hamlin and Parson Brown, yielded 134 more boxes per acre than did the late varieties (Valencia and the Rhode Red Valencia). Mid-season Pineapple oranges produced on average 87 more boxes per acre than the late season varieties. These results match yield differences reported in the annual Citrus Summary (NASS 2010)

Swingle, Cleo, and Carrizo-Cleo (groves that are a mix of Carrizo and Cleo rootstocks), were three rootstocks included as independent variables in the regression. Carrizo was included as part of the model's intercepts term and becomes the reference point around which to compare yield effects from other rootstocks. Parameter estimates for Swingle and Cleo rootstocks were statistically significant and suggested that Swingle rootstock produced on average 109 more boxes per acre than those trees with a Carrizo rootstock, while Cleo rootstock produced 85 fewer boxes per acre as compared to Carrizo. The coefficient for the Cleo-Carrizo mixture was not statistically different when compared with trees on a Carrizo rootstock. Carrizo is generally known as being a vigorous rootstock and growers typically expect trees on Carrizo to yield more than trees on Swingle (Castle 2003). However, as trees age and canopies begin to hedge together, yield of orange trees on Carrizo rootstock tends to decline. This conclusion is supported by a long-term study of yields in southwest Florida, which indicates that Carrizo is a more vigorous rootstock and provides higher production during the first ten years of production. Afterward, however, production from trees with Swingle rootstocks outperforms the same varieties but on Carrizo rootstock (Roka 2009).

The coefficient of tree age was positive and statistically significant, implying that as trees increase in age by one year, production increases by an average of eleven boxes. The coefficient of tree density was negative, indicating that for each additional tree per acre (within the range we studied), yield decreased by three boxes per acre. This estimate closely approximates production data from southwest Florida orange groves (NASS 2010). Of the four growers, grower three had statistically significant lower yields than grower four (yields from growers one and two were not different from grower four yields). One possible explanation for this significant difference could be related to grove management practices.

County yield, which is a variable used to help incorporate countywide trends such as weather, soil, and other environmental factors, had a positive coefficient of 0.49. This indicates there is more variation in yield at the block level than at the county level. County yield captures overall growing conditions and the value of yield in any given year should vary directly with general growing conditions. Finally, a variable was included to capture the impact of Hurricane Wilma (October 2005) on overall tree productivity. The coefficient for the hurricane variable was negative and statistically significant, indicating that after the hurricane, yield decreased by 135 boxes per acre, per year. This is important as it gives evidence that the hurricane did cause long-term damage to grove health in this region.

Conclusions

The data collected for this study were from four commercial grove operations in southwest Florida. More than 90% of citrus mechanical harvesting occurs with the southwest Florida region (Roka and Hyman 2004). Data were collected from a ten-year time period in order to determine if lag effects exist in addition to short-term impacts. These research findings support earlier conclusions that mechanical harvesting does not negatively impact productivity of sweet orange trees. Variables testing harvest method, a one-year lagged harvest method, and total number of times a grove was mechanical harvested were not significant. As found in the study conducted by Whitney and Wheaton (1987), yields were very similar between hand harvesting and mechanical harvesting. Results from this study suggest the same conclusion but for a ten-year period of time and based on commercial production data. Another interesting finding was the apparent long-term impact of Hurricane Wilma on the productivity of citrus trees (yield per acre) in this region of Florida.

Previous research based on replicated small trial plots concluded that mechanical harvesting had no adverse effect on yield or productive life of an orange tree. An important caveat of those results was that trees were "well-nourished" before and after mechanical harvesting. Further research by Li and Syvertsen (2005) indicated that citrus trees are very resilient to leaf loss, drought stress, and root damage. A limitation of our research was the absence of data that quantified the health status of the study blocks and how health status changed over the study period. Consequently, we cannot say definitively that the blocks included in this analysis were representative of tree health status across the study region. If one argues that the sample blocks were biased towards unhealthy trees, the results of this study are magnified by the fact that mechanical harvesting had no adverse effect even on unhealthy trees. If, on the other hand, the study blocks were biased to only harvesting healthy trees, one could argue that purposely selected "healthier" blocks to be mechanical harvested and could mask adverse effects from mechanical harvesting equipment when yields were compared to presumably inferior hand-picked blocks.
Long-term sustainability of the Florida citrus industry rests on the assumption, perhaps requirement, that tree health must be restored and average production across the citrus industry return to at least its historic levels of between 400 and 500 boxes per acre. Once that happens, the contribution of this paper will be to reinforce and reiterate previous research findings that growers can mechanically harvest "healthy" trees without worrying about adversely affecting short- and long-term tree health.

References

Albrigo, L.G. and M. Burina-Arouca. 2010. Validation in Florida orange yields over a 37-year period: A standardization evaluation. *Proceedings of the Florida State Horticultural Society* 123: 56-58.

Burns, J.K., F.M. Roka, K-T Li, L. Pozo, and R.S. Buker, R.S. 2006. Late season 'Valencia' orange mechanical harvesting with an abscission agent and low frequency harvesting. *HortScience* 41: 660-663.

Castle, W.S. 2003. Choosing the right rootstock. Electronic Data Information Source (EDIS) HS178. University of Florida, Gainesville, FL.

Coppock, G.E. 1972. Properties of young and mature 'Valencia' oranges related to selective harvest by mechanical means. *American Society of Agricultural and Biological Engineering* 15 (2): 235–238.

FDACS. 2010. *AgFacts*. Florida Department of Agriculture and Consumer Services, Division of Marketing and Development. http://www.florida-agriculture.com/agfacts.htm.

FDACS–DPI. 2011. *Citrus Canker in Florida*. Florida Department of Agriculture and Consumer Services. http://www.freshfromflorida/pi/canker/pdf/cankerflorida.pdf (accessed April 2, 2012).

FDOC. 2010. Citrus mechanically harvested acreage and boxes. UF/IFAS Citrus Mechanical Harvesting website: http://citrusmh.ifas.ufl.edu/index.asp?s=2&p=2 (accessed April 2, 2012).

Hedden, S.L., D.B. Churchill, and J.D. Whitney. 1988. Trunk shakers for citrus harvesting – part II: Tree growth, fruit yield and removal. *Applied Engineering in Agriculture* 4: 102-106.

Hodges, A. and M. Rahmani. 2009. Economic Impacts of the Florida Citrus Industry 2007–08. Electronic Data Information Source (EDIS) FE802. University of Florida–Gainesville.

Li, K-T, J.K. Burns, and J.P. Syvertsen. 2008. Recovery from phytotoxicity after foliar application of fruit loosening abscission compounds to citrus. *Journal of American Horticultural Sciences* 133 (5): 535-541.

Li, K-T, and J.P. Syvertsen. 2005. Mechanical harvesting has little effect on water status and leaf gas exchange in citrus trees. *Journal of American Horticultural Sciences* 130 (5): 661-666.

Muraro, R. 2009. Southwest Florida summary budget costs, 2008–09. CREC, University of Florida. http://www.crec.ifas.ufl.edu/extension/economics/pdf/SW_Budget_Summ_2008-2009.pdf (accessed April 2, 2012).

Muraro, R., T. Spreen, and M. Pozzan. 2003. Comparative costs of growing citrus in Florida and Sao Paulo (Brazil) for the 2000–01 Season. Electronic Data Information Source (EDIS) FE364. University of Florida, Gainesville, FL.

NASS. 2009. Florida citrus statistics 2008–2009. National Agricultural Statistics Services. http://www.nass.usda.gov/Statistics_by_State/Florida/Publications/Citrus/index.asp.

NASS. 2010. 2009–2010 citrus summary, production, price, and value. http://www.nass.usda.gov/Statistics_by_State/Florida/Publications/Citrus/index.asp (accessed April 2, 2012).

Roka, F.M. 2009. Long-term southwest Florida yield study of Hamlin and Valencia oranges on Swingle and Carrizo rootstocks. Unpublished data. University of Florida–Gainesville.

Roka, F.M., J.K. Burns, and R.S. Buker. 2005. Mechanical harvesting without abscission agents yield impacts on late season "Valencia" oranges. *Proceedings of the Florida State Horticultural Society* 118L 25-27.

Roka, F.M., J.K. Burns, J.P. Syvertsen, T. Spann, and B.R. Hyman. 2009. Improving the economic viability of Florida citrus by mechanical harvesting with the abscission agent CMNP. http://citrusmh.ifas.ufl.edu/pdf/db/abscission_white_paper_040609.pdf (accessed April 2, 2012).

Roka, F.M., and B.R. Hyman. 2004. *Evaluating Performance of Citrus Mechanical Harvesting Systems – 2003/04*. Report to the Citrus Harvesting Research Advisory Council, Lakeland, FL (August).

USDOL. 2009. Minimum wages. http://www.dol.gov/dol/topic/wages/minimumwage.htm.

Whitney, J. 2003. Trunk shaker and abscission chemical effects on yields, fruit removal, and growth of orange trees. *Proceedings of the Florida State Horticultural Society* 116: 230-235.

Whitney, J., D. Churchill, and S. Hedden. 1986. A five-year study of orange removal with trunk shakers. *Proceedings of the Florida State Horticultural Society* 109: 40–44.

Whitney, J., and T. Wheaton. 1987. Shakers affect Florida orange fruit yields and harvesting efficiency. *Applied Engineering in Agriculture* 3: 20-24.

