PRODUCTION, PESTICIDE USAGE, AND LABOR COSTS OF APPLE FARMS IN THE NORTHEASTERN US AND NORTH CHINA - A COMPARATIVE CASE STUDY

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Abstract: Pest management practices of three apple farms in the US and China are evaluated for their economic and environmental sustainability. Although these three locations share similar environmental conditions and a reputation for apple production, the management strategies are driven by different factors. The conventional US apple grower manages his farm for maximum production and minimum labor cost. As a result, the farm achieves a high yield of 24.68 kg/dollar, but low health value of $2.43 for pesticide per 100 kg of apples. The organic apple farm aims at minimizing environmental impact and protecting consumers. Its yield is 14.22 kg/dollar with 15% – 30% greater labor cost and health value is $1.66 for pesticide per 100 kg of apples. Although far from being organic, the traditional apple farm in North China does pay considerable attention to consumer protection in their pest management practice. Whereas they use the same pesticides and their spray schedule is similar to a conventional farm, every fruit is manually bagged after petal fall to ensure pesticide free apples. They spend 1,365 hours/ha on bagging comparing to only 252 hours/ha of total labor spent in the conventional apple farm. Annual production of the Chinese farm is 22,727 kg/ha, which is only 50% of the conventional apple production and 71% of the organic apple production. We see a great potential for a much higher production on the Chinese apple farm if they redirect labor from bagging to an effort for production while still providing consumer protection. A new approach would increase economic effectiveness significantly as is evident on the organic farm. The benefit would be even more obvious in a Chinese apple farm given their low labor cost.

Keywords: *organic farm, organic apple farm, Integrated pesticide management (IPM), apple production, Surround, Kaolin clay.*

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INTRODUCTION

Sustainability is an easy word to say but harder to put into operation for a specific situation. For example, what do we mean by 'sustainability'? Sustainability of what?: a farmer's livelihood, crop yields, labor employment and costs, soil and water resources, environmental quality, economic profitability, and/or specific cultural resources. Sometimes sustainability of one factor may conflict with sustaining another factor. We examine the different aspects of sustainability using a case-study of different approaches to apple production in the United States and China.

Apples are a popular and important part of the human diet worldwide because they are full of vitamins and antioxidants. In addition to being eaten fresh apples are also processed into other products such as drinks, dried fruit, baked goods, etc. The health value of apples, however, can be seriously compromised by pesticide applications during a growing season. According to the Environmental Working Group Report (1999), a total of 36 chemical pesticides were detected on over 90% of the apples they tested from conventional apple farms in the US. These chemicals are harmful to human health, especially to children (Wiles et al. 1999). Organophosphate, one of the most effective and therefore popular pesticides of apple trees, is a designated nerve agent that can alter brain function (Leong 2009). Recognizing these problems, government agencies, many environmental groups, NGOs, such as National Sustainable Agriculture Information Services (NSAIS) and the Organic Materials Review Institute (OMRI), have committed huge efforts to promote and facilitate organic apple farming. Even consumers' demand for organic fruit has increased significantly since 2000 (Grubinger 2006, Hipps 2011). However, we have to admit that apples are among the most difficult crops to grow organically, especially in areas of the US with a moist climate. These areas are generally located east of the "tree line" (approximately the 97th meridian) (NSAIS 2011). Apple growers in the Northeast consider organic farming impractical for commercial production due to the astronomical labor cost. That is why only 5% of US organic apples are from the east (Sayre 2004).

Although facing higher production costs, some apple growers in the Northeastern US are committed to organic farming, due to a sense of responsibility for their own health, the health of consumers, and the environment. They profit by marketing their unappealing product for use in cider and other processed food and directly marketing their best apples to consumers because the retail price is much higher than the wholesale price. Although it can be a long road ahead, the future of organic farming will be made easier with development of new technologies and the advance of producer and consumer education. An economically and ecologically successful apple business is always built on self-learning and ad hoc practice in respond to site-specific conditions (NSAIS 2011).

Currently, China is the world's largest exporter of apple juice. Apple juice concentrate imported from China increased from 1.1 billion liters in 1998 to 2.3 billion litters in 2008 in the US (USDA 2011). China also dominates the world market for fresh apples, especially in Australia (Department of Agriculture, Fisheries and Forestry 2011) and Asia. Rigorous inspection for food safety requires the Chinese government to tighten its regulations. The focus is on labor-intensive products including vegetables, fruits, and meat (Bingsheng 2001). Only the most appealing and pesticide free apples are qualified for export, which becomes the driving force behind "organic" management of apple farms in China. Government subsidy and cheap labor keep apple growers profitable (Gleason and McGuire 2003).

In this study, we compare differences in apple farm pest management practices and evaluate their economic and environmental effectiveness. This can serve as a basis for future experimental design to improve pest management practices. The comparison is based on data collected from a conventional apple farm in western New York (Williamson, NY, 43°13'26"N, 77°11'09"W), an organic apple farm in eastern Pennsylvania (Kutztown, PA, 40 °31'03'N, 75 °46'36"W), and a traditional apple farm in Shaanxi province of North China (Luochuan, 35 °59'00"N, 109 °30'06"E). All findings reported here are preliminary results.

GEOGRAPHICAL AND CLIMATIC CONDITIONS

Apple farm management and production is closely related to its geographical location and climatic conditions. The state of New York ranks second in the US in apple production because of the suitable climate and fertile soils (Hoying et al. 2008). Western New York is the largest single area with about 1,349 ha of apple farms. The climate is classified as a moist continental type with prevailing wind direction from the west. Its' close proximity to the large body of water to the northwest, Lake Ontario, provides moisture for frontal systems controlling precipitation of the region. The average annual mean temperature is about 8.67 °C according to data from National Climate Data Center (NCDC), with the coldest month in January (-4.5 °C) and warmest month in July (21.5 °C). The growing season runs between 150 to 180 days. Average annual precipitation is 332.7 cm with relatively uniform distribution year round (Figure 1). It is worth noticing that seasonal snowfall of 101 – 127 cm provides a protective cover for apple trees against occasional cold blasts in the region (Peck and Merwin 2009).

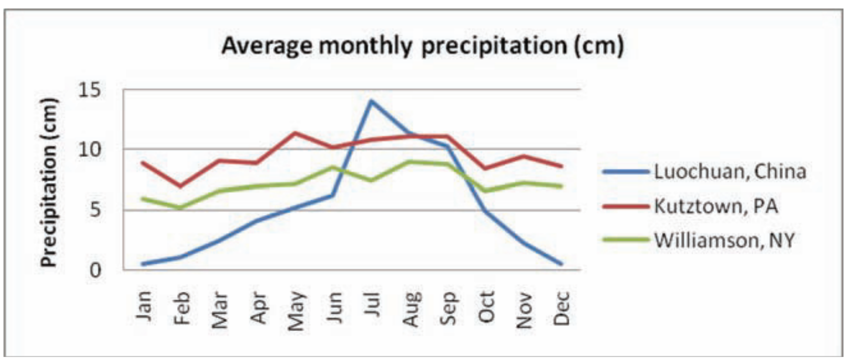

Figure 1. Thirty year (1971 - 2000) average monthly precipitation (cm) in the three locations.

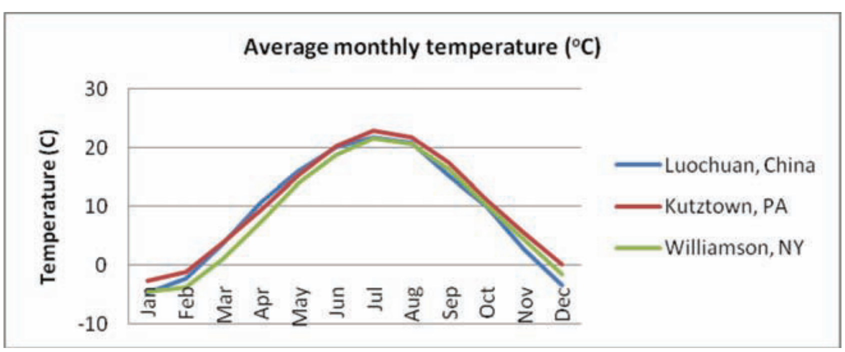

Figure 2. Thirty year (1971 – 2000) average monthly temperature (°C) in the three locations.

Compared to the climatic conditions of western New York, average monthly temperatures of Kutztown, PA, and Luochuan, China, are very similar with an identical seasonal pattern (Figure 2). However, monthly precipitation of the three locations shows obvious differences (Figure 1). While Kutztown's precipitation is about 2 cm higher than that of Williamson in each month, there is no significant difference in seasonality. In contrast, monthly precipitation of Luochuan shows a clear pattern of wetter summers and much dryer winters. Summer rainfall (July to September) amounts for 56.7% of the total annual rainfall. Luochuan is in the transitional zone from semihumid to semiarid climate and is dominated by a monsoon climate characterized by a 180 degree change of wind direction between winter and summer. Winter's off-shore wind from the Asian interior keeps it dry while summer's on-shore wind from the Pacific Ocean provides much needed moisture for frontal systems producing a significant amount of precipitation between July and September.

Soils of western New York developed from glacial deposits. Alfisols are dominant in low land areas with 3% – 8% organic matter, while Inceptisols are found in upland areas with 3% - 6% organic matter content. Both are fine textured and moderately well drained soils with a bulk density of 1.1 – 1.4 and relatively high soil pH. The soils of Kutztown, PA, are developed from the regolith of limestone at the foothills of the Blue Mountains. They are silty loams and moderately well drained soils as well. Alfisols are dominant in the valleys with 1% - 4% of organic matter while Ultisols on the slopes with about 1% - 3% of organic matter content. Soil pH is also relatively high because of the parent material. Luochuan is located in the heart land of the Loess Plateau in China. The Loess Plateau is made of wind-transported silt deposited over many thousands of years and is more than 100 meters in thickness. Because of its weak calcium carbonate bonding and vertical structure, loess is susceptible to water erosion. However, its homogeneous nature and high porosity make it very easy to work with. In the apple farms of Luochuan County, soil organic matter at the top 40 cm is between 0.8% - 0.99%, on average (Free Papers Download Center, 2010). It is also moderately well drained. Although the fertility levels differ to a certain degree, soil texture and pH levels of the three locations are very similar and most suitable for apple production.

MANAGEMENT STRATEGIES AND PRACTICES

Following the strategy of high-density apple trees for high yield, a new generation of rootstocks was introduced in the 1960s. Average apple growers in western New York planted smaller trees with greater potential per unit area production (Image 1). During the 1980s, the average number of trees per ha increased to 597. Currently, a typical grower plants 1600 trees per ha in their new orchards and the recommended ideal planting density for maximum production is 2471 tree per ha in the form of the Vertical Axis and the Tall Spindle Systems (Hoying et al 2008).

Image 1. A traditional apple orchard in Western New York, USA. Note the pruned branches on the ground.

Vertical Axis and Tall Spindle Systems are becoming popular in the apple country because these planting systems maximize profitability through early yield, reduced costs for pruning, thinning, and spraying, and the high turn-over rate for better varieties (Hoying et al. 2011). Such systems require a dedicated water and nutrient management system for a perfect balance between vegetative growth and cropping (Robinson 2011). The trees are supported by vertical trellises with wires, and planted in rows spaced just wide enough for a self-propelled orchard platform (Image 2). Workers on the platform can easily conduct various tasks including pruning, hand thinning, trellis building, and harvesting from both sides of the platform as it moves along each row. This method saves time, reduces labor intensity, and allows for a more diverse labor pool since no climbing ladders are needed. All this, increases labor efficiency and reduces costs significantly (Sazo et al. 2010).

Image 2. Vertical Axis System in Western New York, USA.

In a manner similar to his counterparts, a conventional apple grower in Williamson, New York, manages his farm for maximum production and minimum labor cost. He has a 40 ha apple farm with 25 year old trees on average, which indicates that the new planting system is not in effect yet on this farm. His annual apple production is 45,731 kg/ha while annual hired labor costs are $1,853/ha including $680/ha for harvesting. Compared to the average labor costs ($2,436/ha) of 25 apple farms in the same area (White et al. 2008), he managed to spend 24% less. To keep production high and labor cost low, he has no plans for transitioning to organic production but does strictly follow the Pest Management Guidelines issued by Cornell University (2011). He spends about $1,112/ha per year on pesticide, which is slightly lower than the average expenditure of $1,255/ha on pesticides of the 25 apple farms (White et al. 2008). He also spends $248/ha on chemical fertilizer.

Organic farming requires an integrated approach which means managing a production system "to respond to site-specific conditions by integrating cultural, biological and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity" (USDA National Organic Program, 2011). All organic producers must follow strict federal regulations of the Organic Foods Production Act of 1990, and be certified by the USDA. Instead of using chemical sprays, organic farms turn to mechanical or biological pest controls, such as insect traps, particle-film technology, and farmscaping, in their pest management practice (NSAIS 2011). This practice requires that farmers constantly monitor for pest/disease infestation and apply the right techniques at the right time. As a result, organic apple production requires more frequent organic spray and/or practices that physically reduce pest population. The average labor cost was about $4,017 per ha per year according to a survey of 22 organic apple growers (Higby et al. 2007), which is almost double that of the labor costs of a conventional apple grower.

The organic apple farm in Kutztown, PA, aims at minimizing environmental impact and protecting consumers. It is a 2.43 ha farm with 1100 twenty-year old trees. Similar to a conventional apple grower, the organic grower also works with grafted trees because they are easier to prune, thin, spray, and harvest. However, high density planting doesn't work because crowding prohibits air circulation and promotes disease. A variety of disease-susceptible and disease-resistant apple cultivars are grown here with a combination of early, mid-, and late seasonal products that can spread out the risk of weather and disease. The organic farmers use a new generation of organic pest control materials including insect traps, mating-disruption cards, and a kaolin clay liquefied particle-film called Surround WP. It is a nontoxic particle film that forms a barrier between pests and apple plants. Depending on the frequency of rain events; it may be applied biweekly or weekly between June and August for best protection. As a result, the costs for such pesticide run between $1,204/ha - $2,088/ha. The annual production of the farm is 32,280 kg/ha.

Although it is far from being organic, the traditional apple farm in Luochuan, China, does pay considerable attention to consumer protection in their pest management practice. Like most apple farms in China, this is a family-leased 0.33 ha orchard. Whereas they use the same types of pesticide and their spray schedule is similar as that of a conventional farm, every fruit is manually bagged right after petal fall to ensure pesticide free apples in markets (Image 3). The family spends 1,365 hours/ha on bagging each year compared to only 252 hours/ha of total labor spent in the conventional apple farm. The costs of bags are $723/ha. The annual production is 22,727 kg/ha, which is only 50% of the conventional apple production and 71% of the organic apple production. Given the facts that China's average apple yield is only 12,970 kg/ha (Gao 2008) and the average apple yield of Luochuan County is 16,969 kg/ha, this farm produces much more than the average. The annual pesticide cost is $735/ha, which is 34% less than that of the conventional apple farm. The chemical fertilizer costs are $328/ha per year.

Image 3. Bagged apples in Luochuan County, Shaanxi, China.

EFFECTIVENESS ANALYSIS

Economically, the conventional farm has the highest production and lowest hired labor hours (Figure 3). For every hired labor hour per ha, the conventional farm produces 181.5 kg of apples, the organic farm produces 64 kg, while the Luochuan farm produces only 16.6 kg.

Environmentally, the conventional farm sprays $2.43 worth of toxic pesticides on every 100 kg of apples and the trees that produced them. The Luochuan farm sprays $3.23 worth of pesticides on trees that produce 100 kg of apples, but not on the apples themselves because they are bagged. The organic farm spends the least (Figure 4), which is equivalent to $0.68 for every 100 kg of apples. The Luochuan farm spends the most on chemical fertilizer.

CONCLUSION AND DISCUSSION

For obvious reasons, the conventional farm produces the most and pollutes the most as well while the organic farm produces fewer apples with minimal environmental pollution. The data from Luochuan, however, paints a much more complicated picture. The apple farm employed the most labor intensive management practice but produced the least amount of apples and caused about the same amount of environmental pollution as that of the conventional apple farm. The only beneficiary of the practice is

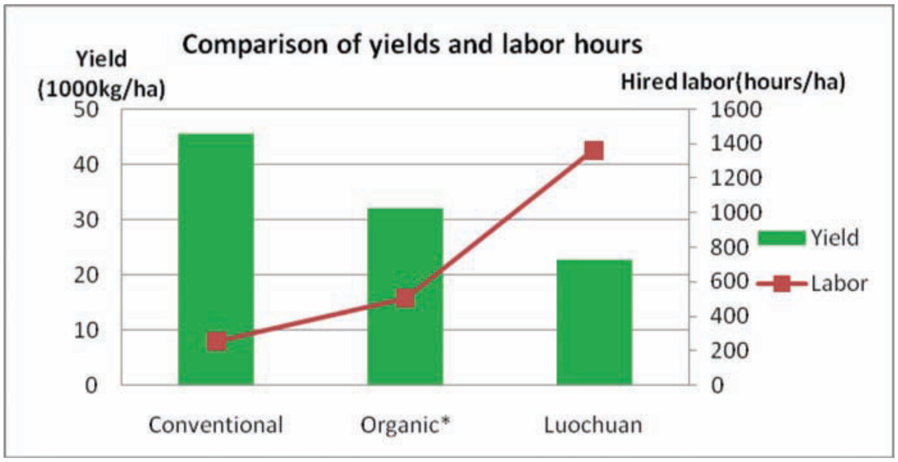

Figure 3. Comparison of yields and hired labor hours in the three farms. The hired labor hours for the organic farm is estimated based on the survey data (Higby et al. 2007).

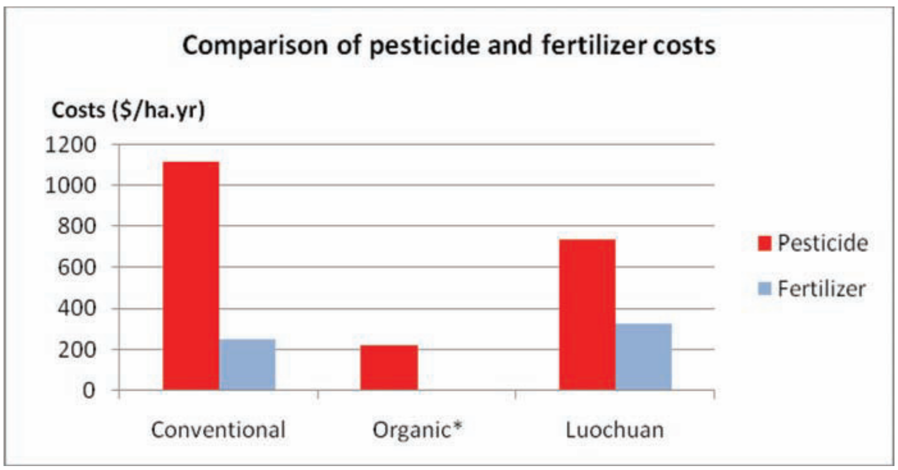

Figure 4. Comparison of yields, pesticide and chemical fertilizer costs of the three farms. Lime sulfur solution is the only chemical pesticide used in the organic farm. Among all chemical pesticides, lime sulfur solution is the least toxic and therefore allowed to be used in organic farms (OMRI 2011).

for consumers getting pesticide free apples. The farm can currently afford the practice as the average wage for farm labor is only $0.96/hr in China, 13% of the minimum wage of New York and Pennsylvania. Although, it may take a few decades to see the impact, the cheap labor advantage of China is already starting to diminish because of a labor shortage, wage disputes, and wage increases for migrant workers in recent years (Fan, 2010). Young farmers will leave their farms for a better paid job if they can find one. For these reasons, the labor intensive practice may not be sustainable in the future.

Low production may be caused by many factors. Being located on the Loess Plateau with a farming history stretching back thousands of years, Luochuan's apple farms suffer from serious soil erosion (Wang and Hou 2010). A study showed that soil organic matter at the top 20 cm decreased from 5.9% to 0.84% within only 10 years of cultivation of previous woodland in the same area (Xiubin et al. 2002). As a result, available soil nutrients (N, P, and K) are only between 0.05% and 0.07% (Free Papers Download Center 2010) in these apple farms. According to the test results by the Soil and Fertilizer Institute of Shaanxi Province, soils in Luochuan are deficient in many mineral elements such as boron, iron, manganese, and zinc, with the only exception being copper. It is necessary to increase farmland productivity by using fertilizer and increasing soil organic matter. Clearly, apple production of this area is limited by a spring water shortage and low level of soil fertility. Currently, motor-pumped wells and small reservoirs are built mainly for the daily use of people and animals, but not for orchard irrigation.

The environmental effect is especially important in China because it has about 1.9 million ha of apple farms, which is the largest apple farm acreage in the world (Gao 2008). It also has the highest population density. Reducing the amount of chemical pesticide and fertilizer would improve environmental quality and the health of billions of people.

For the reasons listed above, we see a great potential for much higher production and environmental benefit on the Chinese apple farm if the labor from bagging is redirected to the effort for production, such as setting up water-conserving irrigation systems, and managing the orchard floor to increase natural fertility. This goal can be achieved without compromising consumer protection with the help of particle-film technology. Such an approach would increase economic effectiveness significantly as is evident in the Pennsylvania organic farm practice. The benefit would be even more obvious in a Chinese apple farm given their current low labor cost. Of course, a practical pest management approach has to be adjusted to fit site-specific conditions and tested out on site to determine the economic effectiveness.

In the context of the larger problem of sustainability, we believe that this study shows some of the difficulty of applying the concept of sustainability to a specific situation. Much thought needs to go into weighting the interacting factors of sustainability, some of which are scientific and quantifiable and others which are cultural and more open to interpretation and subjectivity. As we like to say in some of our classes, **Science + Values = Policy.** The study of sustainability certainly falls within that equation.

BIOGRAPHY

Dr. Weihong Fan is an associate professor of Environmental Science at Richard Stockton College of New Jersey. She earned Ph.D. in ecology from Colorado State University at Fort Collins, Colorado. With more than 20 years of experience in the applications of geographic information system, she has been working in the fields of broad scale nitrogen and carbon cycling, climatic change, ecological modeling, and tree special diversity. She successfully led a China Field Study Tour in the summer of 2010, which resulted in the collaborated study on the apple farms in the Northern China with colleagues of Beijing Normal University.

Dr. Raymond G. Mueller is Professor of Environmental Sciences at Richard Stockton College of New Jersey. He graduated with a BA in Physical Geography (SUNY-Buffalo), MS in Applied Science (Montana State University), and a PhD. with honors in Physical Geography (University of Kansas). For 25 years he has been conducting research on paleoenvironments at archaeological sites in the Mid-Atlantic (USA) states and in Mexico. This research was primarily involved with the effect of agriculture on the environment and subsequent effect on local societies. In particular, the research examined the unsustainability of ancient agricultural practices which led to severe erosion and the decline of a series of ancient cultures. He has also developed courses on agricultural sustainability at Stockton.

Dr. Michael Hozik is Professor of Geology at the Richard Stockton College of New Jersey. He earned a Ph.D. from the University of Massachusetts, an M.S. from the University of Colorado, and a B.S from Dickinson College. For the past 35 years he has taught introductory and upper level geology courses at Stockton, including Environmental Geology. Most recently he co-led a study tour to China focusing on human interaction with the environment. He has served as both member and chairman of the Hammonton Environmental Commission, serves as Vice Chair of the Hammonton Planning Board, helped promote urban redevelopment as a member and officer of the board of the Hammonton Revitalization Corporation, and writes a regular column for the local newspaper.

Dr. Weili Qiu is an associate professor of physical geography in Beijing Normal University, China. He has been teaching physical geography, geomorphology and geology since 1989. His research interests focus on land use and human impacts, geomorphology and quaternary environments, environmental archaeology and human-nature relation in the past. He has published more than forty papers in both national and international academic journals and surveyed the Loess Plateau of north China and the Yellow River areas for many years. Based on his work, he has started cooperative teaching and research with the Gothenburg University of Sweden and the Richard Stockton College of New Jersey, USA. He has guided field study tours for the students from GU and RSC in north China since 2001.

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