Sustainable Horticultural Production in Argentina

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Introduction.

The agriculture and horticulture industries provide Argentina with over half their foreign exchange and 7% of the country's employment. A country known agriculturally for its fertile, humus rich soils has recently moved far ahead of other countries regarding environmental issues. As one of the world leaders in setting voluntary target greenhouse gas emissions and home one of the largest organic farming industries in the world, Argentina has recently surpassed many countries in the race to become environmentally sustainable.

With a total area of 2,766,890 square km, and 2,736,690 square km of land area, Argentina is the second largest country in South America, aside from Brazil. It is located in the Southern Hemisphere, at the geographic coordinates of 34 00 S, 64 00 W, with an elevation that ranges between -105 m and 6,960 m in the most extreme sites. Bordering countries include Bolivia, Brazil, Chile, Paraguay, and Uruguay. A total of 4,989 km of Argentina's land area sits on the coast (U.S. CIA Factbook, 2009).

Argentina can be divided into four distinct topographic regions: the Andes to the west, lowland plains in the north, the central pampas, and the southern region of Patagonia. Climate varies drastically throughout the country, ranging from subtropical in the north to arctic in the South. The pampas in central Argentina is the most fertile and densely populated part of the country. Also shared between Argentina and Chile is the offshore island territory of Tierra del Fuego (Encyclopedia of Nations, 2009).

Northern Argentina features an ecosystem similar to other tropical sites; subtropical plants and animals dominate the landscape. The pampas region is perhaps the most vital section of the country, as it provides the greatest economic wealth and houses 80% of the population of Argentina. The pampas is a tallgrass prairie ecosystem with rich, humus soil. Because of this, much of the native ecosystem in the pampas is being removed for agricultural crop growth. In Patagonia, the soils are hard, rocky, and dry and are therefore unsuitable for large scale commercial crop production. Coniferous forests are prevalent in this geographic region as well as the western Andean mountainous region known as Cuyo (Buenos Aires, Argentina, 2002).

Argentina's environment is being plagued by many of the issues that are more common among developing countries, including deforestation and soil degradation, water pollution, air pollution, and desertification. However, Argentina is trying to control greenhouse gas emissions and is currently a world leader in setting successful voluntary greenhouse gas targets (NationMaster, 2009).

Argentina had an estimated population of 40.482 million in July 2008, with an estimated growth rate of 1.068% per year. A high proportion of the population (63.5%) is aged 15-64 years, with a median age of 29.7 years. There are 97 males per every 100 females in the country. Of the population, 97% is of Italian or Spanish heritage, while a mere 3% are non-white or mixed race (Mestizo). Spanish is the official language, followed by Italian, English, German and French (U.S. CIA World Factbook, 2009).

Argentina has 27,900,000 ha of arable land, which is 10.9% of the total land area. The major horticultural crops produced for export include sunflower seeds, lemons and other citrus fruits, grapes, apples, and tea. A total of 3,192,000 ha of land are used in the production of organic crops (NationMaster, 2009). Several other crops are also produced, though almost

exclusively for domestic use, and include potatoes, onions, and tomatoes. Flower production (cut flowers) has been decreasing since 1988, but still occupies 3,000 ha of land use. The most commonly grown cut flowers include chrysanthemum, carnation, rose, and gladiolus (Umetani *et al*. 1994).

Sustainability.

FARN, Fundación Ambiente y Recursos Naturales (The Environmental and Natural Resources Foundation of Argentina), defines sustainability in several ways. First, they believe that environmental factors must be met with both social and economic factors to create a situation that can be carried out in the future. Sustainability involves "meeting needs, reducing resource use and recycling, re-use and reclamation" (FARN, 2009). Participation at all levels (individual, city, and government) is required to help improve overall air quality and conserve water and energy. The development needs in agricultural and community areas must not "impose unsuitable demands on local or global natural resources and systems" (FARN, 2009). And finally, natural resources that are depended on by members of the community must be made to last as long as they are needed.

MAOAR, Movimiento Argentino Organico (The Argentine Organic Movement), seeks to produce sustainable products through the use of "ecological methods of production" (MAOAR, 2009). They believe that natural environmental processes should be mimicked and farmers should become better users of the land. They define this process of becoming organic or biodynamic as "an ecological and sustainable system of agricultural production, particularly of food for humans that respects all creation" (MAOAR, 2009). The biodynamic movement, literally meaning 'life force' in Greek, was introduced in Germany in 1924. After "seventy-five

years of practical application and research," the method has been perfected to become the "leading position in alternative agriculture" (MAOAR, 2009). They believe environmentally benign inputs and techniques should be used to create healthy crops that are produced mainly on the balance of soil fertility and beneficial insects, rather than herbicides and petroleum-based fertilizers.

These definitions each have similar goals in mind: to protect natural resources for future generations. Therefore, it could be inferred that, in regards to the horticulture industry, the main focus of these sustainability definitions is to persuade producers to protect the soil, Argentina's most vital asset for creating profitable and sustainable crops.

Historical Production Practices and Current Statistics.

The northeastern portion of Argentina is known mainly for its tea production. Production of black tea (*Camellia sinensis*) and the native yerba mate (*Ilex paraguarensis)* have increased steadily since the early 1990s. Tea crops are harvested from October to May and, in more recent years, production has been increased through the use of large-scale, high-yield clone plantations (Secretaría de Agricultura, Ganadería, Pesca y Alimentos, 2009).

Also an important geographic area, as it provides the land for the important grape production area, is the west-central Andes mountain region. The cool, mild climates provide an ideal environment for grapes and other crops. Grape production in this region was historically of low quality for domestic use. Quality did not increase until rather recently, when the Argentine peso became equivalent to the United States dollar, and exports of Argentine wine became in high demand (Worldwide Wine Tours, 2009).

The humid Pampas region of central Argentina contains some of the most fertile soils in the world, composed almost entirely of humus. Because of this, successful large scale crop production began in the region in the mid 1800s. During both World Wars, exportation of crops to Europe provided Argentina with most of its financing for the mechanization and industrialization that occurred in the late 1940s (Rock, 1987). Most of Argentina's exported and domestic crops were, and still are, field grown in this economically important geographic region of Argentina. Horticultural crops in the other geographical regions of the country have been historically field grown as well.

Only in the last 30 years did the Argentine agriculture and horticulture industries feel the need to become more sustainable. In the 1970s, due to increased stress on agricultural lands and increased food demand, Argentine soils began degrading due to "the application of technology such as fertilizers, biocides and heavy machinery" (Moscatelli and Pazos, 2000.) But not only that, air and water pollution was caused as well. After the 1970s, sustainability definitions were put in place to protect the soil, Argentina's most vital agricultural asset. Currently, sustainability is being practiced by way of "an effective system to prevent erosion and maintain soil structure…widely incorporated in the Pampean Region is the no-tillage or direct planting methods, which presently cover 5,000,000 ha [of agricultural land] in the country" (Moscatelli and Pazos, 2000). Add those efforts to the ever-increasing organic industry and Argentina is becoming a leader for worldwide sustainability.

Because the soil is ideal, rainfall is (typically) adequate, and plant pathogens are low in most areas of Argentina, the prospects are low that controlled environments would soon be needed in these areas. However, many controlled environment structures can be found on university campuses as they provide a way to research plant diseases and hydroponics, a practice

that is rarely used in Argentine horticulture. Greenhouses are also being developed by community action programs in the Patagonia region where soil quality is poor and climate is unfavorable for horticultural crop production. Through the use of these greenhouses, the Argentine Institute of Farming Technology hopes to "improve diets and nutrition by introducing new horticultural crops, providing a reliable food source on a small scale, and foster the growth and education of society" (Morano, 2009). In this southern region, prospects are high for incorporating controlled environments into agricultural activities; however, the cost for these structures is currently too great for many farmers to afford.

Both the cut and potted flower industries have benefited from the use of greenhouse structures. Protected cultivation of ornamental crops in Argentina first began in 1925. As of 1994, the structures remained essentially the same, aside from the addition of polyethylene coverings. Structures rarely contain heat or electricity due to the expense. The first successful *Lilium* crops in the country became possible in 1993 only after growth inside of a controlled environment (Villanova and Morisigue, 2008).

Argentina's gross domestic product, as of 2008, was US $585 billion or 2035 billion Argentine pesos, with the agriculture/horticulture industry composing 9.2% of the GDP. The fruit and vegetable industries represent the largest part of horticultural production and exports. While number of growers could not be obtained, statistical information on these horticultural crops can be found in Table 1. "Amongst ornamental plants, Argentina shows a privileged position with important commercial genera such as *Alstroemeria*, *Petunia, Calceolaria, Calibrachoa, Glandularia*," and several others due to its unique location and climate (Bulrich, 2008). However, insufficient statistical data could be collected on these crops.

Current Production Practices.

"[Since] the 1980s, the Argentine organic movement has developed strong formal certification practices, good export links, and has received valuable support [from the Argentine government]" (Kristiansen and Merfield, 2006). Both the number of organic farmers and the amount of land dedicated (3,000,000 ha) to organic crops has increased steadily as worldwide demand for organic crops has increased. In fact, Argentina has recently become the world's second largest exporter of organics. "Organic production is gaining ground in recession-hit Argentina as a growing number of producers are willing to spend more to create products that can command premium prices" (Jones, 2001). Organic crops are typically more sustainable than conventional production systems as they rely less on petroleum-based fertilizers and more on natural, renewable materials; however, the sustainability factor is decreased by the fact that the organic industry in Argentina is aimed solely for a global market, as there is there is "not much local interest in organic products," (Jones, 2001).

The introduction of state-of-the-art biotechnology in 1996 has completely changed crop production in Argentina. In 2005, over 17 million hectares of land contained some form of genetically-modified crop. Modern biotechnology has "enabled farmers to adopt sustainable agriculture methods, such as the use of no-till farming" (Monsanto Company, 2006). But not only this, costs have been cut, and the amount of pesticides and herbicides used have been significantly reduced. Many farmers now rely completely on the technology as a method. It is widely believed that many Argentine farmers could no longer continue if biotechnology disappeared: "…we couldn't work in any other way…what we're looking for is a profitable activity … that's sustainable [for] a long time" (Monsanto Company, 2006).

No-tillage methods of harvesting have been utilized in the Argentine horticulture industry as a way to protect and sustain the soils. In 2002 and 2003, Argentina supported a campaign that brought no-tillage methods of production to 55% of the cultivated land. INTA, El Instituto Nacional de Tecnología Agropecuaria (The National Institute of Agricultural Technology) praise no-tillage methods: "…stubble cover, organic matter and soil moisture increase, while better soil conditions generated by SD (no-tillage) create a stable environment, improving animal and plant suitability. At present, research is favorable to SD on soil effects and to emerging weed and pest control" (INTA, 2003). In fact, no-tillage methods have been so successful in Argentine horticulture that many Spanish farmers are adopting the method as well.

Integration of Historical and Current Practices.

Historically, Argentina has supported moderately natural system of field crop production, with minimal use of herbicides, fungicides, and little to no irrigation. As times move on and technology increases, Argentina has expanded its horticulture industry to keep up with world demand, with the addition fertilizers (sometimes manure or plant-based for cost), biotechnology, and irrigation to crop production systems. While the historical models relied less on petroleum products and precious fresh water resources, over-cultivation of the land degraded soils to the point that methods were needed to prevent the continued deterioration of the fertile land. In as little as 30 years, the vast majority of Argentina's horticultural crops have gone from environmentally unsustainable through the continued overuse of the land to a more sustainable method of crop growth based on soil conservation. Table 2 illustrates Argentina's continuing sustainability trends over time; the major events regarding sustainability take place after the 1970s. Included in Table 2 is the effects of the overuse of the land post-World War II and

Argentina's many newer methods of sustainability. Major highlights are organics production in the 1980s, and more recent introductions such as biotechnology and the voluntary lowering of greenhouse gases in the late 1990s. Finally, the introduction of the successful no-tillage campaign in 2002 is presented as the newest method of sustainability.

Strategic Ranking of Sustainable Practices.

Most of Argentina's more important horticultural crops (lemons, yerba mate, grapes, apples, and oranges) are woody perennials and therefore are naturally sustainable according to the definition presented. Since woody plants last decades or longer, constant soil disruption is not required. However, important field crops such as sunflower seeds, potatoes, onions, and tomatoes are more likely to have a significant effect on soil degradation, as they are planted yearly: "…the adoption of sustainable agriculture methods and biotechnology in Argentina has reduced the time required for harvesting and planting crops. Farmers are using this extra time to plant and harvest a second crop… within the same [growing] season" (Monsanto Company, 2006). It is therefore, in Argentina's best interest to focus on soil conservation when dealing with the production of these important horticultural crops.

A ranking of the sustainable strategies implemented by the people of Argentina in recent years would show no-tillage systems as the most efficient strategy, followed by crop rotation, and the use of natural fertilizers. These three methods have the potential to significantly increase the sustainability of Argentina's horticultural crops. These methods have the potential to cut costs for farmers by way of natural methods of pest control and soil fertility. Through utilization of these three methods, the farmer may even have the potential to become organic-certified, a status that commands premium prices in the global market. The effect of these ranked strategies

on sunflower seed production will be discussed in further detail, as it is by far the most highly produced herbaceous horticultural crop in the country. The benefits to each of these systems (Table 3) will also be discussed in further detail with regard to this specific crop.

Finalized Sustainable Development Strategy: Sunflower Seeds.

Sunflower seeds are the most cultivated annual horticultural plant material in Argentina. As many as 3,605 metric tons per year of sunflower crops are produced country-wide, and production occupies over 2,400,000 hectares of land. The current production of sunflower is either accomplished through the rotation of crops with pasture or grazing land, or continuous year-round production. As much of Argentina's arable land has become no-till, much of these sunflower crops have become no-till as well. In a 2002 study performed by Diaz-Zorita, Duarte, and Grove, it has been found that, "…due to the positive effect of soil organic content on crop yields, no-till soil management and pasture-annual row crop rotations are two practices that permit the development of sustainable production systems in the western part of the Argentine Pampas" (2002). Due to the favorable results provided by studies, it is therefore recommended that the remainder of Argentina's sunflower crops become no-tillage systems that utilize crop rotation to further promote sustainability. No-tillage and crop rotation systems have been proven to reduce cost in the long run, as pests are reduced and tillage equipment is no longer required. However, "…without [combining] continuous no-till ***and*** crop rotation the benefits of this technology are diminished significantly" (Solbrig, 2005).

Argentina's cattle, horse, and poultry industries are readily expanding, as is the amount of land dedicated to the growth of leguminous agricultural crops, such as soybeans. Since there is a recent abundance of waste materials such as manure and harvested soybean crops and the high

nutrient contents both of these materials deliver to the soil, it is recommended that these natural fertilizers be composted and used on a large scale in place of petroleum-based chemical fertilizers. “The development of cheap ways of producing nitrates during WWII led to the commercial availability of chemical fertilizers now in widespread use” (Solbrig, 2005). By using waste materials that are readily available, costs could be reduced even further.

Implementing the no-tillage campaign into 55% of Argentina’s horticultural industry proved to be an easy step, as the rewards to farmers seem to outweigh the risks. Positive environmental impacts including continued soil health and moisture content, decreased greenhouse gas emissions and cost through the reduced use of tillage equipment, and a reduced workload seem like a favorable reason for sunflower producers to switch. While 55% of cultivated land is no-till, it could still be higher. To further implement this strategy, uneducated farmers need to be told how this method will help them, their productivity, and their land. More importantly, these farmers need to be shown how to practice no-till methods and still be successful.

Since no-till methods have only been practiced in Argentina since the early 2000s there is still the potential for gaps in research and understanding. While current research suggests no-till is favorable for weed and pest-control, it has not been around for long enough to properly research. Plant pathologists praise tilling as an effective way to rid the soil environment of pathogens and weeds; when soil is tilled under, pathogens and weed seeds are forced to compete with soil microorganisms, generally having a negative effect on their survival. Research needs to be conducted that tests the effectiveness of no-till methods on weed growth and disease development and spread. If this question is answered and proves favorable, it could be the element that causes the remaining 45% of Argentina’s cultivated land to become no-till as well.

No-till methods are generally most effective when combined with crop rotation. Because the two methods go hand-in-hand, this may decrease the overall popularity of the no-till campaign. While crop rotation increases soil organic content and provides natural weed, pest, and pathogen control, the benefits of this system are often not as great as no-till. Crop rotation does not have a higher starting cost, however rotating crops typically causes changes in a farmer's profitability at the end of the growing season. Due to this, Argentine farmers may be more reluctant to introduce these methods into sunflower seed production. Rotating a high-profit crop such as sunflower seeds with a lower-profit crop the following year can have significant impacts on the lives of the producers, especially if profits are low to begin with. Additionally, the farmer's expertise on one crop may not be as great as another, which could affect overall yield.

While research methods have proven crop rotation to be environmentally favorable, it is highly unlikely that poor Argentine farmers will take this, or any further research for that matter, into consideration for the implementation of this strategy. Rather, implementation could be increased by advertising the benefits of the rotation of sunflower crops with highly profitable cattle, horse, or poultry. The manure produced by the livestock highly increases nutrient contents in the soil, and can increase sunflower production when grown again in later years. While this may prove beneficial in regards to soil sustainability, livestock wastes also contribute to increased nitrate production, water pollution, and the production of disease-causing pathogens such as e-coli. The successful composting of soybean waste products could prove to be a safer alternative to manure, but is more time and labor consuming, as composting takes constant turning and high temperatures for long periods of time.

To create a complete sustainable system, these three methods need to be combined and field researched to obtain a complete picture of the finalized sustainable development strategy,

including costs, benefits, and disadvantages to the entire system. The formulation of research questions to be answered can only be obtained once a complete evaluation is provided and all potential problems are addressed. While it may take decades, further research needs to be done to correct these problems so sunflower producers have no excuse for not being entirely sustainable in regards to soil protection.

Future Sustainable Controlled-Environment Production Facility.

The use of controlled environment structures in Argentina, such as high tunnels, could prove to be useful in the field production of sunflower seed crops. The thin polyethylene film has the potential to block some of the intense summer sunlight, crops will be protected should temperatures fall below 10°C (50°F), and insect and bird populations will be reduced inside the enclosure. Not affected is the farmer's access to the crops or the fertile soil that is present in the central region of Argentina.

The central pampas region is the most highly productive region of Argentina with regards to crop growth, and would therefore be the most ideal location to test a proposed high tunnel production facility for sunflower crops. The School of Agronomy at the University of Buenos Aires has been raising field sunflower crops for genetic improvements since the 1930s; therefore, this existing location would be an inexpensive and ideal location to test the effects of typically unused controlled environments on the growth of sunflower crops (López, et al. 1999).

The University of Buenos Aires is centrally located at the approximate coordinates of 34' 00°S, 58'00°W and boasts a temperate climate. The coastal city lies in close proximity to both Uruguay and Rio de la Plata on the Atlantic Ocean (Rand McNally Universal World Atlas, 1987). The current testing facility is located on Av. San Martin 4453 and boasts a large area for

agricultural and veterinary testing, much like the Saint Paul campus at the University of Minnesota, Twin Cities.

The proposed test facility will be two small, freestanding Quonset- style high tunnels, as well as two small field plots. One treatment will test the effects of continuous monoculture, tillage after crop harvest, and chemical fertilizers on the overall growth and harvestable yield of sunflower crops produced both in high tunnels and bare field production. The other will test the overall growth and yield of crops that are sustainably produced in high tunnels and bare field production by no-till, crop rotation, and natural fertilization methods. Also to be tested in each treatment will be the occurrence of weed, pest, and disease issues, organic matter contents in the soils throughout the experiment, water conservation (if drought situations occur), and overall cost and labor time of producing crops in each system.

As the test facility is located in Argentina's busy capital city, space is limited and each individual treatment plot will need to be limited in size to approximately 3 meters (10 feet) by 6 meters (20 feet). The frames of the high tunnels will be built out of sustainable recycled 1.5 cm metal pipe (aluminum or steel) bent at an arc of 180 00. A slightly larger pipe to be the frame of the high tunnel will be buried underground and the pipes will be arched and anchored in. After the frame is built, an approximate 10 meter polyethylene covering will be stretched taught and attached to the metal frame (Nelson, 2003). Additional heating units will not be required, however, horizontal air flow (HAF) fans should be installed in the ridge of the Quonset for summer cooling purposes. Water-conserving drip tape will be used to water each individual plot. Sunflower crops will then be planted in the soil in each of the four treatments.

Sunflower crops will be scheduled to grow twice in a single growing season, as has recently become the trend to increase profits among farmers. Sunflowers will be harvested when

ready and a new crop will be planted as soon as all treatments have reached harvest point. To fully determine the long-term effects of sustainability and controlled environments on sunflower crops, the experiment will need to be performed for at least five years, more if possible.

A researcher must always be present in case of disease epidemics, temperature extremes, tears in the poly covering, crop losses, etc. Should any of these issues arise, the problem must be dealt with immediately. In regards to crop loss, if crops are not able to be salvaged, all environmental conditions (temperature, wind, moisture) and important information regarding the methods of the researcher in charge must be recorded and projected into the final report on the high tunnel test facility. A new crop will be planted as soon as all of the other treatments are harvested.

Conclusion.

In recent years, Argentina has become one of the most sustainable countries in the world through the use of no-till practices, voluntary greenhouse gas emission reductions, and organic farming. By performing the experiments proposed in the controlled environment test production facility portion of this paper, Argentina will hopefully prove their crop production methods to be more efficient, productive, and cost-effective in the long run. Argentina could be well on its way to helping the entire world get on board with environmental, financial, and social sustainability that is needed for the preservation of lifestyles in future generations.

Table 1: Statistical Data on Argentina's Horticultural Crops (Ministerio de Economía y Finanzas Públicas, 2001 and Umetani *et al.*, 1994).

Ranking	Horticultural Product	Production Area (ha)	Quantity (metric tons)	# of Growers	Production Locations
1	Sunflower seeds	2,410,000	3605	1000+	Countrywide
2	Grapes	219,000	2779	Unknown	W-Central Andes Mountain Region
3	Potatoes	83,000	2558	Unknown	Central Pampas
4	Lemons	42,000	1504	Unknown	Northern Central
5	Apples	40,000	1220	Unknown	Southwest
6	Oranges	51,000	938	Unknown	Northern
7	Yerba Mate	166,000	783	Unknown	Northeastern
8	Onions	30,000	735	Unknown	Central Southwest
9	Tomatoes	20,000	687	Unknown	Central Pampas
30+	Cut Flowers Potted Plants	3,000		1800 400	Central Pampas

Table 2: Argentina's sustainability trends over time (INTA, 2003; MAOAR, 2009; Moscatelli and Pazos, 2000; Nationmaster, 2009; and Rock, 1987).

Date	Important event affecting sustainability
1776	Need for intensive cultivation practices recognized
1925	Protected cultivation of ornamental crops
1920s-1940s	Boom in crop exports help promote industrialization
Post-WW2	Pest control methods, agricultural machinery introduced
1970s	Soil degradation, air pollution, water pollution widespread
1980s	Sustainability definitions introduced, large scale organic production
Early 1990s	Irrigation systems become popular
1996	Biotechnology introduced
Late 1990s	Voluntary lowering of greenhouse gas emissions proves effective
2002-2003	No-tillage campaign

Table 3: Sustainable rankings of field production of horticultural crops in Argentina .

Ranking	Method	Benefits
1	No-tillage	Cut costs of tillage equipment Increased soil organic content Increased soil moisture Stable environment for plants and animals Increased stubble cover protects soil Reduced air pollution Less time consuming for farmers
2	Crop rotation	Natural weed and pest control Increased soil organic content
3	Use of natural fertilizers	Readily available Increases nutrient content of soil Less environmental impact than chemical fertilizers Inexpensive

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