Sustainable Horticulture Crop Production in Cuba

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Introduction.

Cuba has become a test case for sustainable agriculture. In 1990 the Soviet Union started to fall and a time referred to as the Special Period began for Cuba. Before this point, Fidel Castro had backed the Soviet Union and their supporters in conflicts in Africa and the Middle East. As this put a strain on the Cuban economy, the Soviets purchased all of Cuba's excess sugar at above-market prices and supplied the country with oil at below-market prices (Rosset and Benjamin 1994). After Soviet aid ended, Cuba was left with virtually no oil and lost between $4 and $6 billion dollars in subsidies annually (Morgan et al., 2006).

Though the U.S. had trade embargos in place since 1961, they were tightened in 1992. This further impacted Cuba's floundering economy. With little petroleum or petroleum products being imported, agriculture suffered and the government instituted food rations, though shortages were common. In response, a large sustainable agricultural movement began (Morgan et al., 2006). Before the Special Period began, Cuba had used far more petroleum-based pesticides than the entire United States (Morgan et al., 2006). Land was also almost exclusively in sugar cane production, resulting in extremely low nutrient and organic matter content (Rosset and Benjamin 1994; Funes et al. 2002). Partly as a result of low petroleum availability, animals like oxen and mules became more common in agricultural systems. This helped to bring back the health of the soil (Rosset and Benjamin 1994; Funes et al. 2002; Morgan et al., 2006).

While agriculture was changing, so was small scale food production. Cubans began raising their own food in vacant lots and on rooftop gardens (Morgan et al., 2006). Farmers markets became the main arena for purchasing food (Morgan et al., 2006). They also began eating a more high fiber, high vegetable diet that was lower in meat and other animal products Rosset and Benjamin 1994; Morgan et al., 2006).

Location, Climate and Area.

Cuba is made up of the main island and the small Isla de la Juventud or Isle of Youth (CIA, 2009). The country is located at 21 30 N, 80 00 W in the Northern hemisphere, 150 km south of Key West, FL between the Caribbean Sea and the North Atlantic Ocean(CIA, 2009). Its 1,108,600 hectares is mainly flat to rolling plains with the Sierra Maestra range at the southern end of the island (CIA, 2009). Elevation ranges from 0 m above sea level at the Caribbean Sea to 2,005 m above sea level at the peak of Pico Turquino (CIA, 2009).

The island's dry season is from November to April with temperatures averaging 27°C and precipitation averaging 63 mm (CIA, 2009). The wet season is from May to October with 37°C average temperature and 136 mm average precipitation (CIA, 2009). The climate is tropical and largely controlled by trade winds. Hurricanes are common from August through November, averaging one every other year (CIA, 2009). Droughts are also common (CIA, 2009).

Natural Resources.

Of Cuba's total land area, approximately 27% or 306,300 ha is considered arable with 870,000 ha in irrigation and only 6.5% or 77,200 ha in permanent crops (CIA, 2009). Most of the freshwater withdrawal (69%) goes to agriculture followed by 19% for domestic use and 12% for

industry (CIA, 2009). Other natural resources include minerals like cobalt, nickel and iron, timber and some petroleum (CIA, 2009). Cuba does suffer from deforestation, air, water and soil pollution and biodiversity loss (CIA, 2009).

Population and Demographics .

The 2008 population estimate was 11,423,952 people (CIA, 2009). The GDP was $133.8 billion Cuba convertible pesos, or CUC, [US $144.6 billion (PPP, 2008 est.)] and the per capita GDP is CUC $11,759 [US $12,700 (PPP, 2008 est.)] (CIA, 2009). For comparison's sake, the per capita GDP of the U.S. is $48,000. Of particular interest when looking at a country that is considered poor by U.S. standards is the fact that literacy is 99.8% which is equal to the literacy rate in the U.S (Rosset and Benjamin 1994; CIA, 2009).

Sustainability in Cuba .

There does not seem to be an official, written definition of sustainability for Cuba. However, the practices that the government has developed and encouraged as well as those that the citizens of the country have embraced speak to a definition of sorts. As mentioned above, Cuba transitioned to a petroleum- independent agricultural system in 1990. It is important to note that while the transition was by no means easy, it was helped by the fact that research had already begun on organic and sustainable growing practices before the fall of the Soviet Union (Morgan et al., 2006). So, even though the changes to Cuba's agricultural system were implemented out of necessity, the results have shown that a country and a population can survive using sustainable agricultural practices.

In general, conservation is a constant priority. Agricultural labor is either manual or animal powered, petroleum based products are very rarely used and protecting the health of the soil is paramount (Rosset and Benjamin 1994; Funes et al. 2002; Morgan et al., 2006). Biopesticides and biofertilizers are now produced in Cuba, both for use domestically as well as for export (Morgan et al., 2006). Domestic conservation of fossil fuels also takes the forms of carpooling, using public transportation, biking, walking and hitchhiking (Funes et al. 2002; Morgan et al., 2006). In Havana, where the population is a very crowded 2.1 million, an individual's convenience is less important than conserving resources. Electricity generation from sources such as wind, water, sunlight and ***bagasse***, or the biomass left over after sugarcane processing, are becoming more and more common, especially in rural areas (Rosset and Benjamin 1994; Funes et al. 2002; Morgan et al., 2006).

Historical Production Practices.

When Spain colonized Cuba in the 1500's, the focus was on plantation agriculture (Rosset and Benjamin 1994). Since then, three of the major crops have been sugar cane (***Saccharum*** spp.), coffee (***Coffea canephora*** and ***C. arabica***) and tobacco (***Nicotiana tobacum***) (Rosset and Benjamin 1994; CIA, 2009). Because Cuba has a tropical climate, structures were not generally necessary for growing them (Rosset and Benjamin 1994). Traditionally, coffee was grown in the shade of trees, though it is not necessary. In fact, it was not until modern demands dictated that coffee should be grown in full sun, simply in order to maximize yields. Shade grown coffee is considered to be much more sustainable since clearing a forest is not required and more water is conserved. However, growing monocultures continuously is not sustainable regardless of other cultural methods.

As the documentary “The Power of community: How Cuba Survived Peak Oil” discusses, just before the Special Period began, Cuba was importing 13 to 14 million tons of oil per year (Morgan et al., 2006). They had approximately 90,000 Russian tractors and produced large amounts of petroleum based pesticides and fertilizers in factories that were subsidized by the Soviets. In fact, Cuba was the most industrialized of all the Latin American countries. While other Latin American countries averaged 10% of their land in irrigation, Cuba kept 20% irrigated. Other Latin American countries used about 2.2 tractors per 40.5 hectares in production while Cuba used 5.7 tractors per 40.5 hectares. The most astounding figure, however, is the amount of fertilizer used: other Latin American countries averaged 300 lbs/0.5 hectare, the U.S. 450 lbs/0.5 hectare and Cuba 1000 lbs/0.5 hectare. Though yields were high, according to Roberto Pérez, a permaculturalist with the Sustainable Urban Development Program Cuba was “never able to feed the people”. He went on to say that though much coffee, tobacco sugar cane and later, citrus was exported, large amounts of staple foods were imported (Morgan et al., 2006).

Current Production Statistics and Practices.

Of the US $144.6 million that is the gross domestic product, agriculture constitutes only about 4.4% of it (CIA, 2009). However, it employs about 20% or 1 million people (CIA, 2009). The major agricultural exports are still sugar, tobacco and coffee but citrus has also been added to this list (Morgan et al., 2006; CIA, 2009). Most of Cuba’s agriculture is field production of food crops, however. As will be discussed later in this paper, simply producing enough food for the citizens of the country is generally the focus. Few growing structures are used, as the climate is tropical and hurricanes are common. The main way that a structure may be used is in field

production of tobacco or lettuces (Edelstein, 2009, personal communication). Simple shade structures, sometimes simply shade cloth without a framework to hold it up, are put in place in fields. In the case of lettuces, shade structures are used as a season extender to keep the greens from becoming too bitter in the heat (Rosset and Benjamin 1994).

Much of the farm work is now done by animals or manually by people (Rosset and Benjamin 1994; Morgan et al., 2006). Because of this, the sizes of farms have changed drastically, as well (Morgan et al., 2006). Before the Special Period began, farms were huge, state run affairs because everything was mechanized (Funes et al. 2002; Morgan et al., 2006). After petroleum products became scarce, some of the older farmers who still knew how to train and work with oxen were put to work by the government (Rosset and Benjamin 1994; Funes et al. 2002; The Morgan et al., 2006). Aside from the obvious benefit of saving fuel, oxen also proved to be valuable in that their manure added to the soil and their hooves did not compact the soil the way a tractor would. In fact, the simple action of an ox pulling a plow helped to mix it (Morgan et al., 2006).

With an increase in animal labor as well as the many small animals already grown for food, manure is a valuable, sustainable soil amendment. The soil was quite depleted at the beginning of the Special Period due to heavy tractor, fertilizer and pesticide use as well as very infrequent crop rotation (Rosset and Benjamin 1994; Morgan et al., 2006). In addition to manure, compost derived from kitchen scraps, rice hulls and animal waste is commonly used as well as vermicompost, or compost made from the breakdown of organic waste by earthworms (Morgan et al., 2006). Green manuring, which is a method of improving soil fertility by planting a crop, usually a grass or nitrogen fixing legume, then plowing it into the soil while still growing, is also

frequently done (Morgan et al., 2006). This practice adds carbon, nitrogen and other nutrients to the soil and improves the soil structure by supplying organic matter to it.

Pest problems, such as insect infestations, are generally prevented rather than dealt with after the fact. This is done by nurturing the soil as mentioned above, since healthy soil supports a healthy ecosystem and in turn, few potential pest insect populations will be allowed to flourish (Funes et al. 2002). Not planting monocultures and rotating crops regularly also helps to avoid potential issues by not giving pest populations a large, frequently available or competition-free habitat (Morgan et al., 2006). Biopesticides, usually bacteria or fungi, are also commonly used in lieu of petroleum-based pesticides (Morgan et al., 2006).

Irrigation, as stated earlier, used to be fairly common in Cuban agriculture. It is much less so today, with only about 8% of the country irrigated (CIA, 2009). This is due in part to the use of *permaculture*. According to the Permaculture Institute, this is a way of designing buildings or gardens that mimics natural structures and associations (Permaculture Institute, 2007). *Forest garden* or *food forest* are two interchangeable terms that describe the permaculture practice of planting specifically selected trees, shrubs and low growing plants in a sort of artificial group, or *guild* (Morgan et al., 2006; Permaculture Institute, 2007). The idea is that, as an established forest survives without irrigation by humans, so too can established food forests (Morgan et al., 2006). This practice can work especially well for shade tolerant crops such as coffee when planted as an understory to citrus trees (Morgan et al., 2006; Permaculture Institute, 2007).

Permaculture was brought to Cuba in 1992 by Australian permaculture specialists (Morgan et al., 2006; Permaculture Institute, 2007). They helped Cubans secure US $26,000 to start a permaculture training course. It was put into effect in both rural and urban areas in the forms of everything from rooftop gardens to the food forests discussed above (Morgan et al., 2006).

Urban agriculture is immensely important in Cuba. Because of the fall of the Soviet Union and U.S. embargos, food was scarce and a rationing system was begun and still exists today. As a result, people began to grow their own food on any available piece of land or in pots on patios, rooftops and balconies (Rosset and Benjamin 1994; Funes et al. 2002; Morgan et al., 2006). Much of Havana's food is now produced right in the city and sold at the approximately 1000 farmer's stands located throughout the metro area (Morgan et al., 2006). In smaller cities, local farmers generally grow about 80% of their community's food (Morgan et al., 2006). Locally grown food means fresh, healthy food and income for communities as well as the amount of fuel needed to transport food through the country.

Integration of Historical and Current Production Practices

Currently, there is virtually no integration of historical and current production practices (Morgan et al., 2006). Out of necessity, Cuba had to completely change its agricultural methods and since the situation has not changed in the 19 years since the crisis began, it does not look as though production practices will go back to the way they were in any way, shape or form. From the information available, it seems as though Cubans now successfully produce the food they need while also maintaining the health of their soil, water and air. In addition, since much research and development has gone into sustainable production, education and government-sponsored programs, it looks as though Cuba will continue to lead the way in sustainably feeding their people.

Some methods are, however, more sustainable than others, even in Cuba. The fact that relatively large amounts of food are still grown outside major cities is one that the country would benefit

from changing. If more food could be grown inside major cities like Havana, then the amount of fuel used for transportation could be reduced even further.

It is also important to consider economic sustainability, especially when looking at a country with a financial history like Cuba's. While farmers use crop rotations and mixed or interplanted crops as well as maintain soil health as a means of combating disease and insect pests, Cuban farmers may benefit from other means of preventing disease, pests and general crop damage. In doing so, there is a strong possibility of increasing yields and perhaps securing a larger share of the market or a higher price point. Table 1 ranks the sustainability of these and other practices, both those used in the past and currently. It should be noted that in some ways, this ranking as somewhat akin to comparing apples and oranges. This is because before 1990, there was little vegetable production for domestic purposes, while post-1990 the opposite is true. So, to clarify, in the following table, production practices pre-1990 were those applied to crops such as tobacco, sugar cane and coffee. Production practices post-1990 are applied to staple food crops, primarily.

Table 1: Ranking of the sustainability of past and present growing practices in Cuba.

Method	Ranking (1= not at all sustainable, 5= very sustainable)				Reasoning
	Environmental	Economic	Social	Overall	
Plantation-style agriculture	1	3	3	2.3	Monocultures, little or no crop rotation

Machinery and petroleum dependant agriculture	1	3	2	2.0	Fossil fuel use, constant need for fuel and parts
Urban agriculture	4	4	5	4.3	Little or no transportation needed, mainly human labor, little or no chemical pesticide, fungicide, herbicide or fertilizer use
Small scale rural agriculture, post 1990, with tractors	4	3	4	3.6	Rotations, smaller farms and/or fields provide more jobs, little chemical pesticide, fungicide, herbicide or fertilizer use, some fuel and tractor parts needed
Rural agriculture post 1990, powered by animal and human labor	5	4	5	4.6	Rotations, smaller farms and/or fields provide more jobs, little chemical pesticide, fungicide, herbicide or fertilizer use, little compaction from tractor tires, manure builds soil fertility, livestock determine workday length

Sustainable Development Strategy.

Since Cuba is now quite environmentally sustainable, and at least from an outsider's point of view, seems to be fairly socially sustainable, at least in terms of food production and nutrition, there are few challenges to be overcome in those regards. The issue of economic sustainability is an important one, but without unfettered international trade and an expendable income amongst its citizens, this is something that will be difficult to change.

The Cuban government does offer incentives for both high production and environmental sustainability, however. Producers that are determined to be "excellent" producers in these respects are awarded scarce resources such as fuel and machinery parts, and their operations are used as training and demonstration facilities for other producers (Koont, 2008). Aside from the obvious benefit of resource allocation, this is considered a great honor.

Cuban farmers are generally held in high respect by the public. They are seen as providers and are absolutely necessary to the day to day lives of Cuban citizens. In fact, they more than provide for their countrymen and women: the Food and Agriculture Organization of the United Nations recommends that each person should eat 0.3 kg of vegetables per day (Koont, 2008). As of 2006, Cuban farmers were producing over 1 kg of vegetables per person, per day (Koont, 2008). As such, sustainability from a health and social standpoint is high. In addition, farmers are some of the highest wage earners in the country. The Cuban government regulates some prices for food and others are free market determined, but in general, fresh, quality food is seen as necessary and farmer's earnings reflect this. Thus, sustainable development in Cuba is leaps and bounds ahead of many countries with much larger GDPs. Since nearly all farmers, both rural and urban, are petroleum-independent, use human and animal labor, rotate crops and

nurture the health of the soil, I find it difficult to critique the state of Cuba's sustainable development. Rather, I would suggest that the methods and mentality seen in Cuban agriculture be implemented around the world.

Use of Sustainable, Controlled Environment Production Facilities

Cuban farmers could perhaps take advantage of simple growing structures to combat disease, pests and general crop damage as well as potentially securing a higher price at market. Since Cuba has such a long, warm growing season, greenhouses are not practical options as more energy would be used to cool the structures than would be redeemed in product quality and price. A viable option could perhaps be to use high tunnels in field production, however.

Tomato (*Solanum lycopersicum*), various pepper species (*Capsicum* spp.) and lettuce (*Lactuca* spp.) are three candidates for high tunnel production. Specifically, high tunnels could provide some season extension for these three important crops in Cuba. Since tomatoes and peppers are both susceptible to blights, such as those caused by *Alternaria* sp., and wilts, such as those caused by *Verticillium* sp. (University of Arizona, 2006). Mildews are also common diseases of tomatoes and peppers. All three of these disease examples require optimal temperatures and either free water on the leaves, or in the case of mildews, high humidity. Lettuce are prone to bottom rot caused by *Rhizoctonia solani*, downy mildew caused by *Bremia lactucae*, powdery mildew caused by *Erisiphe cichoracearum* and Fusarium wilt caused by *Fusarium oxysporum* f. sp. *Lactucae* (University of Arizona, 2006). These diseases of lettuces are also fungal, and so also require specific temperatures and moisture on the leaves or high humidity to cause infection. High tunnels could provide season extension for tomatoes and peppers both at the beginning and the end of the rainy season by keeping the plant and soil surfaces drier at a time of year when

temperatures are also dropping. This would not only reduce the incidence of fungal disease development, but could eliminate the cracking in tomatoes that results from plants receiving water after a period of dry weather. In the case of lettuces, high tunnels could provide season extension into the hot, dry growing season by creating shade, thereby reducing bitter compounds from forming in the leaves and slowing bolting.

The challenges with using high tunnels are that irrigation would need to be used, which would cut down on economic sustainability. Parts for irrigation systems are difficult to obtain, the infrastructure for large scale irrigation systems are not in place in Cuba and there is little money to create them. The cost of high tunnels is also a large obstacle to overcome. Even though it was stated above that Cuban farmers earn some of the highest wages in the country, this is still relative to the fact that the average per capita GDP is less than 25% of the U.S.A. average. The initial cost of purchasing high tunnels and irrigation systems may be too high for any but the largest of farmers in Cuba.

Another factor to consider is the weather. As mentioned, the country is prone to hurricanes, especially on its eastern coast. On average, Cuba is hit by a hurricane every other year (CIA, 2009). This would make putting any structures up a large financial risk. Even if they were taken down throughout the majority of the rainy season, the life of the glazing material would be cut down significantly. Tears are common when removing high tunnel coverings and they must be fully dried before storing or mold and mildew will develop. Replacing the covering every year is neither financially nor environmentally sustainable. Table 2 shows a ranking with the same criteria as in Table 1, but theoretically considering high tunnels included with past and current production methods.

Table 2: Ranking of the sustainability of past and present growing practices with integration of high tunnels in production for Cuba.

Method	Ranking (1= not at all sustainable, 5= very sustainable)				Reasoning
	Environmental	Economic	Social	Overall	
Plantation-style agriculture with high tunnels	1	3	3	2.3	Monocultures, little or no crop rotation, high tunnel coverings are fossil fuel based
Machinery and petroleum dependant agriculture with high tunnels	1	1	2	1.3	Fossil fuel use, constant need for fuel and parts, would need to take frames down in order to use large machinery, high tunnel coverings are fossil fuel based
Urban agriculture	3	3	5	3.6	Little or no transportation needed, mainly human labor, little or no chemical pesticide, fungicide, herbicide or fertilizer use, high tunnel coverings are fossil fuel based

Small scale rural agriculture, post 1990, with tractors	3	2	4	3.0	Rotations, smaller farms and/or fields provide more jobs, little chemical pesticide, fungicide, herbicide or fertilizer use, some fuel and tractor parts needed, would need to take frames down to use large machinery, high tunnel coverings are fossil fuel based
Rural agriculture post 1990, powered by animal and human labor	3	3	5	3.6	Rotations, smaller farms and/or fields provide more jobs, little chemical pesticide, fungicide, herbicide or fertilizer use, little compaction from tractor tires, manure builds soil fertility, would need to take frames down to work fields with livestock, livestock determine workday length

The conclusion to be drawn from this is that any system that uses large machinery is not going to be as conducive to integrating high tunnels because the frames would have to be taken down in order to work the soil. The alternative is the use small tillers or raised beds, but this adds on high

costs in the forms of labor and materials. Frames would also need to be taken down in systems that used livestock, especially since the animals could be injured by metal frames left in the field. Therefore, the best situation for using high tunnels in Cuban food production may be in an urban setting. They could provide season extension into the rainy season as well as the dry. They could additionally provide shade for poultry and people, provided that they were vented well enough. If a neighborhood shared the cost of materials, this might be a viable option. Ranges would ideally be small, perhaps 0.25 to 0.5 ha^2. This would be enough to feed a small neighborhood. Additionally, if they were located in sheltered, vacant lots, the effects of wind damage to the glazing material would be less.

Metal frames would be the strongest and the longest lasting, though with a higher up-front cost. Multiple, gutter connected bays would be ideal as this may make it easier to grow a variety of crops throughout the season as well as house poultry or other small animals. A single layer of polyurethane covering should be sufficient as the structures are not intended for heat retention as much as protection from wind, water and sunlight.

Conclusion.

From an environmental point of view, Cuba is far ahead of the majority of the world's agricultural systems. What's more, the social sustainability of their food production system is impressive, to say the least. Before 1990, few would have imagined that the most industrialized of the Latin American countries would become the most sustainable in a few, short years (Morgan et al., 2006).

Few improvements are possible in their agricultural production systems. They are feeding both their people and soil, use amazingly small amounts of petroleum and are constantly doing

research to find more sustainable methods of growing and generating energy. They have successfully integrated old and new technologies in such a way that farmers are often able to earn a healthy living while providing the citizens with sufficient food.

In a tropical climate, growing structures are not as necessary for season extension, though they could help to reduce the incidence of disease, especially those that are caused by fungal pathogens. The cost is prohibitive, at least for now. With the possibility of trade embargos relaxing, it will be interesting to see where Cuba's economy takes its agricultural system in the future. It will also be fascinating to see what Cuba comes up with next.

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