

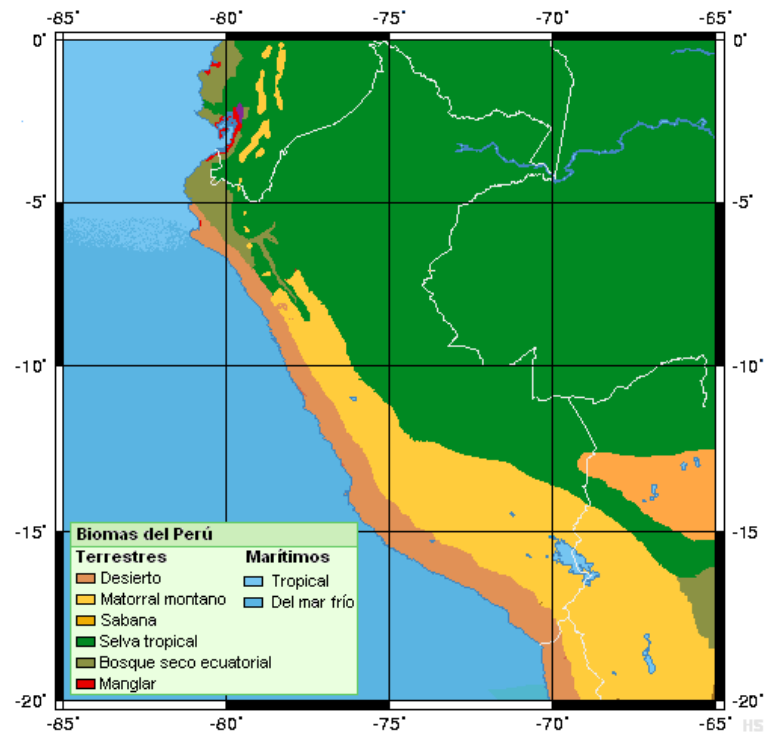
# Sustainable Horticultural Production in Peru

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## I. INTRODUCTION

The country of Peru is found in South America bordering Ecuador and Colombia to the north, Brazil to the east, Bolivia to the southeast, Chile to the south, and the Pacific Ocean to the west (U.S. CIA Factbook 2009). Peru is the subject of my research due to its exotic and highly varied climate; this allows for the production of many crops – some that I am familiar with, but many that I am not.



**Figure 1. *Costa, Sierra, and Selva* regions of Peru (Romero 2005).**

Although located in the southern hemisphere, ten degrees south of the equator, Peru's climate is by no means universally tropical (CIA Factbook 2009). Bounded by the Pacific and divided by the Andes Mountains, Peru ranges from arid in the west, to temperate in the central highlands, to tropical in the east (CIA Factbook 2009). Along the western *costa* there is very little annual rainfall but many rivers flow into the region from the Andes, allowing irrigation for fields and water for many cities, including Lima, the capital (Grolier 1993). Within the central *sierra* region of the Andes, the fertile *quechua* zone ranges from elevations of 2,400 m to 3,500 m, while the grassy pastures of the *altiplano* range between 4,000 m and 4,800 m, and the towering peak of Nevado Huascarán soars up to 6,768 m (Grolier 1993). Beyond the Andes lie 70 million hectares of tropical forest or *selva* in the Amazon Basin (Painter 2008). Although the *selva*

covers nearly 60 percent of Peru's 1,285,220 hectares of territory, it is sparsely populated primarily by indigenous tribes (Grolier 1993).

These indigenous tribes, along with the many other Amerindians living in the *sierra* and *costa* regions make up 45 percent of the 29,180,900 people living in Peru as of July 2008 (CIA Factbook 2009). The official languages of Peru are Spanish and Quechua but many Amerindians speak Aymara or any number of minor Amazonian languages (CIA Factbook 2009).

The bulk of the Peruvian labor force – 75 percent – work in services, 23.8 percent work in industry, while only 0.7 percent work in agriculture (CIA Factbook 2009). This 0.7 percent in agriculture produced 8.5 percent of Peru's GDP in 2008 (CIA Factbook 2009). Peru's main exports of horticultural commodities are *Coffea arabica*, *Solanum tuberosum*, and *Asparagus officinalis* but *Olea europaea*, *Vitis spp.*, as well as the infamous *Erythroxylum coca* are also grown (CIA Factbook 2009).

## **II. Sustainability, Defined**

In this time of economic crisis, climate change, and dwindling fossil fuels it is vital for nations to create regulations to protect their natural resources. This is especially true for Peru with its 70 million ha of delicate rainforest (Painter 2008). In 1997, the Congress of Peru passed a Law on the Conservation and Sustainable Use of Biological Diversity (Peru 1997). The Congress describes sustainability as involving the “[preservation of] the diversity of ecosystems, species and genes as well as maintaining essential ecological processes that depend on the species survival” (Peru 1997). This general statement involves more conservation than sustainability but it does set guidelines, saying that sustainable development does not disrupt or destroy the

balance of nature.

There are also several organizations that are making efforts to make Peru's horticultural practices more sustainable. One such organization is Program Exchange, Dialogue and Advice on Sustainable Agriculture and Food Security (PIDAASSA 2009). A sponsorship of Germany's Bread for the World, PIDAASSA defines sustainability as an "economically efficient but respectful and reasonable management of resources [...] with the long term objective to conserve natural resources and ecological balance" (PIDAASSA 2009). Working with grassroots organizations, PIDAASSA implements what they call "the methodology of Campesino a Campesino." To PIDAASSA *Campesino a Campesino* – or Farmer to Farmer – means that the farmers, villages, and cooperatives who work with and care for the land can meet and discuss problems as well as solutions to collectively develop methods for sustainability. This focus on changing practices locally, and on encouraging discussion and innovation, may well allow PIDAASSA to meet their goal for developing long-term sustainability; however, it will likely be slow in doing so. PIDAASSA's definition also attempts to balance their ecological goals with the recognition of economic hardships for the, oftentimes peasant, farmers.

### **III. Evolution of Production Practices**

Many of these farmers use a mixture of modern and ancient growing practices, some of which date back thousands of years. It is thought that cultivation in Peru began roughly around 7000 BC, mostly with small gardens (James 1992). However, there is little information about ancient Peruvian agriculture until the rise of the Inca Empire around 1200 AD. The Inca grew a great variety of crops including *Zea mays*, *Cucurbita spp.*, and *Solanum spp.* (Inca Agriculture 2009). They utilized a number of advanced production practices such as fertilizing fields with guano to

increase nutrients, developing complex irrigation systems to allow cultivation along the dry coast, and constructing terraces to maximize farmland on slopes with minimal soil erosion (Ortiz 2006). The Inca reduced diseases and pests by rotating their crops and allowing fields to lie fallow for up to seven years (Ortiz 2006). Other disease reducing practices included selecting resistant species, harvesting early to avoid pests, and using raised crop beds, called *waru waru*, which had the added advantage of allowing for warmer soils (Ortiz 2006). All of these practices were accomplished without significant assistance from livestock or even with inventions like the wheel (James 1992).

With the arrival of Europeans in 1532, came Old World farming methods and crops like *Triticum* spp., *Hordeum vulgare*, and *Daucus carota* (Popenoe 1992). Peruvians were brought together into concentrated settlements, creating a tenant farming system of *haciendas* (Ortiz 2006), which remained vital centers of production until the Agricultural Reform of 1968 (Ortiz 2006). These *haciendas* utilized more traditional European methods of production involving draft animals, wheels, plows, and essentially ending the practice of crop rotation (Ortiz 2006). Peruvian production had few advances in methods until the mid 1800s, when the growing demand from Europe for horticultural products spurred interest in implementing new technologies, including steam tractors for *Saccharum* spp. (Ortiz 2006).

Western influence also encouraged the use of pesticides in Peru in the late 1900s (Ortiz 2006). Unfortunately, while Peru's governmental programs helped to subsidize pesticides in the 1980s, the necessary information on the appropriate use of these pesticides was not provided. This led to the "...indiscriminate use of agrochemicals particularly on the potato crop" (Ortiz 2006).

Through the efforts of non-governmental organizations – or NGOs – and the Peruvian

government to teach Integrated Pest Management – IPM – methods as well as the resurgence in interest in indigenous management practices, the use of pesticides is decreasing (Ortiz 2006).

#### **IV. Current Production Practices**

Crop production in Peru, like that of many developing countries, has a lot of room for improvement in the use of technology. The main reason for the limited use of technology is a long history of insufficient government funding for research and development (Villachica and Toledo 2003). This underfunding may explain why Peru is ranked 121<sup>st</sup> out of 134 Latin American and Caribbean countries for “...quality of scientific research institutions” (Global Competitiveness Report). Peruvian research institutions do not currently have the “staff, libraries, nurseries, germplasm banks, laboratories and pilot processing plants to carry out investigation” of new technological innovations (Villachica and Toledo 2003). Unfortunately, Peru’s market is not large enough to allow private research and development to take the place of government institutions, causing Peru to be rapidly left behind (Villachica and Toledo 2003).

Another contributing factor for the limited use of technology is the “fragmentation of farmland” (Roe 2002). A large number of small farms limit the integration of new technology into production practices because there are, consequently, a large number of farm managers to be trained. Because manual labor is relatively inexpensive in Peru and the average farm size is so small, many farmers prefer to rely on the labor that they, their families, and a few hired *peones*, can provide rather than go through the trouble and expense to update their production (Villachica and Toledo 2003). These factors create a certain amount of resistance to the abandonment of production methods that the farmers have used for years. Consequently, it is usually easier to apply new technology to new crops that are unfamiliar to the farmers (Villachica and Toledo

2003). The effects of this reticence to modernize can be seen in a comparison of worker productivity in Table 1 (Segura et al 2007). One agricultural laborer in Peru adds S5,566 (US \$1,770) to the national GDP compared to the S72,587 (US \$23,081) that a single employee of a developed country contributes – clearly; technologically savvy nations are better equipped to make efficient use of personnel (Segura et al 2007).

However low-tech their methods, Peruvian farmers still managed to contribute 8.5% of the national GDP in 2008 (CIA Factbook 2009). The following subsections are devoted to an exploration of these methods for two important Peruvian export crops: *Asparagus officinalis* and *Coffea arabica*.

#### A. *Asparagus officinalis*

One of Peru's most important vegetable exports is *Asparagus officinalis*, ninety-eight percent of which is grown for exportation to Europe and the US (Toledo 1990). Exports of processed *A. officinalis* were valued at S252 million (US \$80 million) and the value of fresh *A. officinalis* exports was S173 million (US \$55 million) in 2000 (Villachica and Toledo 2003).

*A. officinalis* is grown in several regions along the *costa* (see Figure 2), covering a total of 7,819 ha (Toledo 1990). In the hot northern regions of La Libertad, Ancash, and Piura, growers produce white *A. officinalis* to be canned and sent to markets in Europe (Toledo 1990). White *A. officinalis* for canning is also produced in the cooler central coastal region of Lima while the more southerly region of Ica concentrates primarily on fresh and frozen green *A. officinalis* (Toledo 1990).

With irrigation, the dry climate of the *costa* provides conditions similar to a greenhouse – stable

temperatures and a moderate climate – allowing crops to be grown year-round (Villachica and Toledo 2003). In all the regions but Ica, it is common for growers to produce two crop cycles of *A. officinalis* a year (Toledo 1990). As shown in Figure 3 (Toledo 1990), *A. officinalis* is irrigated during its initial growth but later the irrigation is withheld in order to kill the tops and encourage energy storage in the roots (Toledo 1990). After a month of suspended irrigation the *A. officinalis* are watered, stimulating new growth, and the resulting spears are then harvested by hand (Toledo 1990). The *A. officinalis* are allowed to grow for another four months before they are forced into a second dormancy when their water is once again withheld (Toledo 1990). Irrigation is continued after a month, allowing new spears to grow for harvest (Toledo 1990).

Under these conditions, a field can average yields of 8 ton/ha after the third harvest, although some growers manage to produce more (Toledo 1990). Competition, however, is forcing growers who cannot produce yields greater than 10 ton/ha out of business, increasing the need for adoption of innovations (Villachica and Toledo 2003). Unfortunately, with these conditions of intensive production, *A. officinalis* can only be grown in a field for 10 years (Toledo 1990). A growing method that can only be used for a decade cannot be considered sustainable. It is unclear whether the fields for *A. officinalis* production can later be used for other crops. Since *A. officinalis* is unusually tolerant of adverse soil conditions, namely salinity, these fields may not have been suitable for other crops in the first place (Ester and van Rozen 2003).

## **B. *Coffea arabica***

Grown in nine different regions down the length of Peru, *Coffea arabica* is cultivated on more than 215,000 ha by roughly 100,000 growers (Wilson 2009). Ninety-five percent of *C. arabica* is grown for export, with sales totaling \$1.3 billion (US \$415 million) in 2007 (Hinostroza



2008). The bulk of *C. arabica* is produced on small 3-5 ha farms called *cafetales*, beneath the canopy of the tropical *selva* (Ransom 1995 and Wilson 2009). These *cafetales* are positioned between 200 and 800 meters above sea level on the eastern slopes of the Andes for the optimal balance of temperature and humidity (Ransom 1995 and Wilson 2009).

All of the work in the *cafetales* to grow and produce *C. arabica* is done by hand (Ransom 1995). *C. arabica* plants need three years of careful tending before their first flowering (Ransom 1995). Their ripe, red fruits are harvested and placed in basins of water, where they are allowed to ferment (Ransom 1995). Fermented fruits are spread out to dry before they are passed through a crude machine to separate the valuable beans from the pulp, which is later reused as fertilizer (Ransom 1995). The beans are then repeatedly rinsed and scrubbed to remove their mucus coating, producing washed *C. arabica*, called *café lavado* (Ransom 1995). Several days in the sun are required to dry the beans before they can be called *café pergamino*, named for the husk or parchment that covers them (Ransom 1995). *Café pergamino* can be stored for long periods of time without a reduction in quality or freshness of the beans, allowing even the most isolated farms enough time to transport their crops to market (Ransom 1995).

Peruvian *C. arabica* is often marketed as “organic” because it is hand-processed and grown without chemical fertilizers or pesticides, making it highly desirable for environmentally conscious consumers (Hinostroza 2008, Ransom 1995, and Wilson 2009). Although the *selva* must be thinned to allow some light to reach the *C. arabica*, and some areas are cleared for the farmers’ homes and gardens, these small *cafetales* have a fairly low-impact on their surroundings (Ransom 1995). This is a case in which primitive growing methods are preferable to technological ones, being more suited to the delicate environment of the *selva* and more

marketable to developed nations. In this way, *C. arabica* production in the Andes meets the requirements of both aforementioned definitions of sustainability by respecting the surrounding ecosystems while remaining moderately profitable.

## **V. Sustainability for the Future**

Having explored the current and historical production practices of Peru (see Table 2), it is important now to discuss the possible synthesis of methods that best meet the requirements of sustainability for the future. One strategy that modern growers might consider comes from the Incas: diversification. Before their conquest by Europeans, the Incas alone "...cultivated almost as many species of plants as the farmers of all Asia or Europe" (Popenoe 1992). Revitalizing some of these native crops (see Table 3 for descriptions) would not only help to preserve Peruvian species, it would also allow Peru to market itself to the world as a source of unique plant products. The modern world has already accepted *Zea mays*, *Cucurbita spp.*, *Solanum spp.*, and other native Peruvian crops as staple foods. Peru now has a unique opportunity to provide the world with exotic and nutritious alternatives to everyday-food.

There are, however, challenges in marketing commodities in Peru as can be seen in *Annona cherimola* production. *A. cherimola* is a common enough crop in local Peruvian markets but the 'Cumbe' fruits are preferred over all others (Vanhove and Van Damme 2009). 'Cumbe' is a registered trademark used by a select group of *A. cherimola* growers in the Cumbe Valley of the Lima District (Vanhove and Van Damme 2009). Since its registration in 1997, 'Cumbe' fruits have gained a reputation for superior taste, texture, and sanitation (Vanhove and Van Damme 2009). 'Cumbe' producers are intensely selective in the quality of harvested fruits; they also take the added precaution of packing their crop in wooden crates for protection during transport (Vanhove and Van Damme 2009). As a result of this reputation, private and commercial

consumers are willing to pay a greater price for ‘Cumbe’ fruits (Vanhove and Van Damme 2009).

However, this trusted reputation has also attracted trademark-piracy from other growers in the Cumbe Valley (Vanhove and Van Damme 2009). Although these growers are in the correct location, they are not members of the select ‘Cumbe’ growers and are not bound to uphold the standards of ‘Cumbe’ quality and are risking the reputation of real ‘Cumbe’ growers (Vanhove and Van Damme 2009). Thus far, the Peruvian government has not stepped in to protect the registered trademark rights of the ‘Cumbe’ producers; this poor enforcement has many calling for more stringent legislation (Vanhove and Van Damme 2009). If the government were willing and able to protect them, geographical trademarks would be powerful marketing strategies. By banding together and agreeing upon standards of quality, growers are able to compete as a sort of corporation, gaining a reputation and more influence faster than if they worked alone. Marketing a specific population of crop-plants also creates value by setting those plants apart from the rest and encouraging the recognition of biodiversity within species (Vanhove and Van Damme 2009). Rejecting a strict monoculture may also help prevent rapid, wholesale spread of disease. As previously discussed, the Incas already used fairly advanced techniques to increase productivity and prevent disease. Some of these methods, such as growing disease-resistant varieties and planning planting or harvest times to avoid pests, are encouraged as part of IPM training for farmers. Other methods such as terraced or raised crop beds, may not be entirely feasible because of the amount of initial labor required. Practices like crop rotation could be promoted to help preserve and replenish the nutrients of the soil, increasing the longevity and productiveness of a field. Although the practice of allowing fields to lie fallow for seven years may have been possible for a united empire, it would likely be an undue burden for small

farmers.

In order to differentiate between these strategies, they have been ranked for their overall sustainability. As shown in Table 4, the strategies are ranked for sustainability and implementation potential – four being the most and one being the least. These two scores are added together to get the overall sustainability. Diversification of crops has the highest rank for its use of native plants and its practicality – many Amerindian farmers already produce some of these crops on a small scale (Inca Agriculture 2009). IPM ranked second for its reduction of pesticide use, however, the training required for successful IPM practice limits its implementation potential. Raised crop beds ranked after IPM because its disease prevention is less effective than IPM. Raised beds are useful as season-extenders in the chilly *sierra* but they require much labor to set up. Although it helps to preserve soil nutrients, crop rotation received the lowest rank because it decreases the area of land available for cultivation each season. This would be a hardship on smaller farms and encourages increased farm size that may encroach on the tropical *selva*. It must be noted, however, that these strategies can be combined to increase sustainability – using IPM in *Annona cherimola* production on raised beds, for example.

Testing of the diversification strategy must be done to determine the competitive potential of native crops in local and international economies. It may be possible to include this research as part of the Agricultural Research and Extension Program funded by The World Bank. This program is meant to encourage research in technology and innovations for sustainable production by the private sector (The World Bank 2009).

First, the costs and labors of production must be compared. *Amaranthus caudatus* – amaranth – and *Arracacia xanthorrhiza* – arracacha – could serve as test models for other Inca crops.

*Triticum spp.* and *Daucus carota* could serve as test models for non-native crops. As a widely

grown, high-yield grain, *Triticum spp.* will be compared with *A. caudatus*. Another introduced plant, *D. carota* will be chosen for comparison to *A. xanthorrhiza* for its similarities as a root crop but also for its minor crop status, perhaps indicating its unsuitability to Peruvian climate. Once the crops are grown, they must be sold for profit. Studies should be conducted to assess the comparative salability of the crops. Blind taste-tests could be used to compare consumer preferences between each pair of similar products. *A. caudatus* is a high-yield grain, rich in protein and lysine that can be grown in adverse conditions such as cold, drought, or poor drainage at elevations up to 3,000 meters above sea level (Izquierdo and Roca 1998). It has marketing possibilities for infants and nursing mothers due to its proteins' structural similarity to that of milk – these proteins may prove attractive to vegetarians as well (Izquierdo and Roca 1998). Persons' with gluten allergies may use *A. caudatus* as a substitute for *Triticum spp.* The marketability of *Triticum spp.* is undeniable, however, the current quantity of production in Peru cannot keep up with demand. In 2001, 194,000 metric tons of *Triticum spp.* were produced in Peru (Nolte 2002). Grown primarily by small farmers on 154,000 hectares of *sierra* land, *Triticum spp.* yielded 1.26 metric tons per hectare in 2001 (Nolte 2002). As an introduced plant, *Triticum spp.* is not particularly well suited to high elevations and is considered a minor crop (Nolte 2002). Peruvian consumption, however, is far from minor: 855,000 metric tons of flour and 230,000 metric tons of pasta in 2001 alone (see Figure 4), requiring the importation of 1.4 million metric tons that year (Nolte 2002).

*A. xanthorrhiza* is a smooth skinned, carrot-like root (Popenoe 1992). Its varying colors and flavor-blend of cabbage, celery, and roasted chestnuts makes it a potential star in the gourmet world (Popenoe 1992). *D. carota* is produced by a few farmers, measuring 164,000 metric tons of harvested product in 2005 (USDA 2006). By consulting local and international chefs on their

preferences for either root crop, one may determine if there is a unique market opportunity for *A. xanthorrhiza*.

If suitable marketability is found for *A. caudatus* and *A. xanthorrhiza*, then efforts must be made to educate over a million small farmers in production. Many of these farmers may have grown some of these crops on a small scale – in the family garden or for a local market. Their familiarity with these plants will prove useful in the initial stages of production development there are, however, many obstacles. As *A. caudatus* and *A. xanthorrhiza* are not yet extensively grown, there is the question of commercial propagation methods, germplasm quality, harvest methods as well as transportation and storage needs. IPM methods, degree-days, and damage thresholds specific to these crops and their pests will need to be developed. Prime soil, temperature, and moisture needs will need to be determined. If superior production locations are discovered, farmers should consider purchasing a registered trademark for that area. All of these questions will need to be researched and the knowledge passed on to producers before either crop can become commercially competitive.

## **VI. Test Production Sites**

In order to begin answering some of these questions, a test production site should be designed. As the production strategies are meant to be useful to small farmers with limited financial clout, this site will attempt to mirror the conditions of these potential growers. A possible test site could be found in the agricultural land near Shelby in the department of Junín. Shelby is located 10°55'S, 76°16'W, only a few kilometers from Vicco, in which there is a small airport (Keeley and Keeley 1989). Several roads and a railroad line pass through nearby farmland before reaching the city of Cerro de Pasco, less than twenty kilometers away.

The most important initial question is whether the native Peruvian crops will be more productive

than the introduced crops. To simulate the growing conditions of a small farm, the test site could have an area of three hectares, divided into 0.75 hectares for four fields. *A. caudatus* could be planted alongside *Triticum spp.* and *A. xanthorrhiza* could be planted next to *D. carota*. All crops should be planted in rows in traditional beds. Planting, production, and harvest should be completed manually to further simulate small farm conditions. Records should be kept of average day and night temperature, soil characteristics, and average annual rainfall for this location. Data collection could include time for germination, time to flower initiation and fruit set (*A. caudatus* and *Triticum spp.*), time to harvest, plant heights over time, losses or damage due to pests or disease, harvest weight, and fresh and dried weights of post-harvest plant material. Comparisons should be made only between the grains – *A. caudatus* and *Triticum spp.* – and the roots – *A. xanthorrhiza* and *D. carota*. If undue disease or pest damage occurs on the native crops, experimenters should consult with Amerindian growers in the area. If the initial crop cycles prove short enough, two cycles should be attempted in the following year. Data should be collected for five years of production.

## **VII. Conclusion**

Peruvians are looking for ways to compete in global markets and the key can be found in their greatest resource: biodiversity. Unique, value-laden crops could be the foundation of future horticultural production in Peru; however, nothing will come of it if proper funding is not available for further research and education. There are many questions to be answered on how to improve horticultural production in Peru, and even more on how to implement these practices sustainably. The Peruvian government and private sector are taking steps towards the goal of economically viable and environmentally beneficial production, however, there is much work yet to be done. Research institutions are in desperate need of funding for developing technological

innovations, farmers require better access to agricultural extensions, producers need active protection of their registered trademarks – all these necessities call for further government involvement.



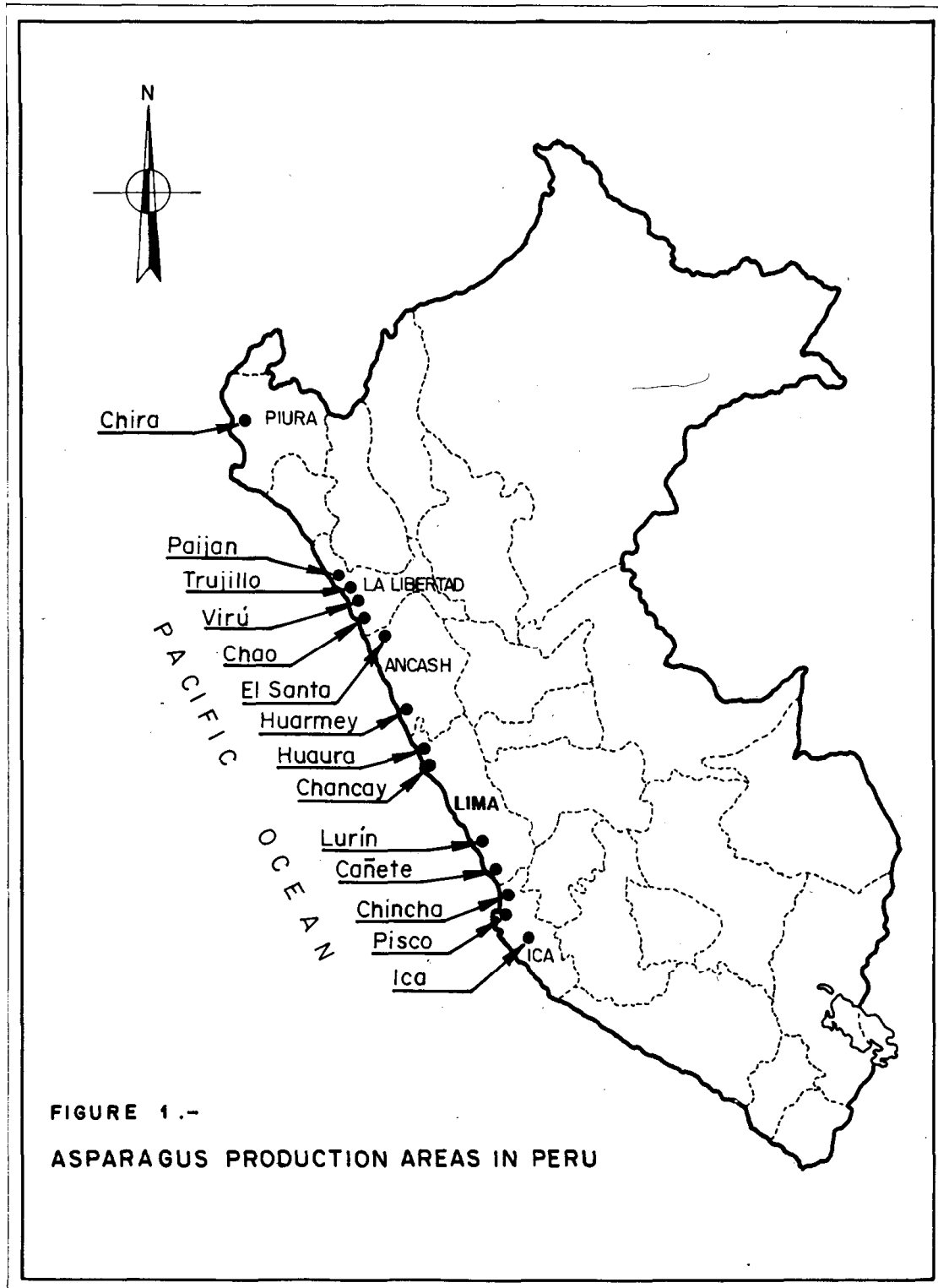


Figure 2. *Asparagus officinalis* Production Areas in Peru (Toledo 1990).



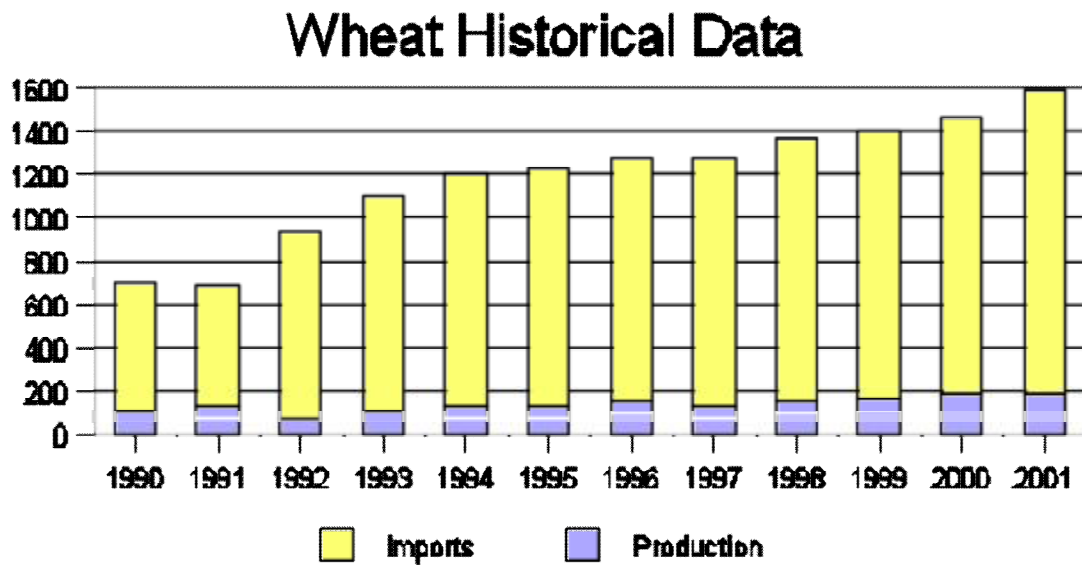


Figure 4. Historic Wheat Production Compared to Importation in Peru (Nolte 2002).

**Table 1. Worldwide value added (% of GDP) crops and value added per employee for in agricultural crops (Segura et al 2007).**

| <b>Country/Group of countries</b>  | <b>Value Added % of GDP<br/>(2004)</b> | <b>Value Added per employee<br/><i>in thousands of U.S. \$</i><br/>[U.S. \$ Constant 2000]<br/>(2003)</b> |
|------------------------------------|--|---|
| Bolivia                            | 15.6%                                  | 0.755   |
| Colombia                           | 11.5%                                  | 2.788   |
| Ecuador                            | 7.1%                                   | 1.491   |
| Peru                               | 10.1%                                  | 1.770   |
| Venezuela                          | 4.5%*                                  | 6.071   |
| Latin America and the<br>Caribbean | 6.1%                                   | 2.966   |
| Developed Countries                | 1.9%                                   | 23.081  |

\*Data from 2003

**Table 2. Historic Peruvian horticulture production and their respective sustainability components.**

| <b>Time Period</b>                           | <b>Sustainable Elements</b>   | <b>Unsustainable Elements</b>   |
|--|---|---|
| Inca Empire:<br>1200s-1532                   | Native and diverse crops, raised beds, crop rotation, disease avoidance, guano, terracing, irrigation.  | Subsistence farming – lower yields, less arable land in production, required much manual labor.   |
| European Invasion:<br>1532- mid 1800s        | Introduction of technologies and resources to increase yield: draft animals, the wheel, plows, and eventually steam tractors. Allowed Peru to move beyond subsistence farming to profitability.   | Intensive cultivation without crop rotation, reduced variety of crops, introduced crops less suited to Peruvian climate.  |
| Increased Demand:<br>Mid 1800s-late 1900s    | Continued growth as a competitor in horticultural economy. Horticulture is the livelihood of many Peruvians.  | Indiscriminate use of pesticides and fertilizers, conversion of <i>selva</i> to fields, continued reliance on a few key crops   |
| Call for Reevaluation:<br>Late 1900s-present | Education on proper use of agrochemicals – <i>reduction</i> in their abuse. Encouragement of IPM practices. Reevaluation of ancient Incan practices and crop choices. Increased demand for “organic” or “eco-friendly” crops encourages more traditional growing methods ( <i>C. arabica</i> ). | Overly intensive methods ( <i>A. officinalis</i> ) – risk declines in soil quality. Continued abuse of agrochemicals by <i>some</i> producers. Continued danger to tropical <i>selva</i> . Resistance to changes in production methods. |

**Table 3. Potential Inca crops for export (Popenoe 1992; Izquierdo and Roca 1998).**

| <b>Crop Species (scientific; common names)</b>   | <b>Description*:</b>   |
|--|--|
| <i>Amaranthus caudatus</i> ;<br>grain amaranth, kiwicha, huautli,                                      | High in protein and lysine, this grain has great potential as a baby food due to its similarity to the milk protein, casein. Is also used in gluten-free diets. Can be grown at high elevations in adverse conditions such as cold, drought, or poor drainage. |
| <i>Annona cherimola</i> ;<br>cherimoya, custard-apple, momona, kelemoio,<br>chirimoyo, anon, cerimolia | A delicious fruit, said to taste like a mixture of pineapples and strawberries.  |
| <i>Arracacia xanthorrhiza</i> ;<br>arracacha, virraca, creole celery, little cassava                   | A smooth skinned, carrot-like root of various colors. Tastes like a blend of cabbage, celery, and roasted chestnuts.   |
| <i>Capsicum baccatum</i> ;<br>ají pepper, Peruvian hot pepper  | This pepper's subtle, unique flavor makes a fine addition to sauces.   |
| <i>Capsicum pubescens</i> ;<br>rocoto, locoto, manzano, caballo, peron                                 | A large, round chili pepper.   |
| <i>Chenopodium quinoa</i> ;<br>quinoa, quinua, kinwa   | A pseudo-cereal, the seeds are an excellent source of protein.   |
| <i>Cyphomandra betacea</i> ;<br>tamarillo, tree tomato, tomate de árbol                                | A tangy, tomato-like fruit grown on a tree. Popular in New Zealand and gaining strength in American markets.   |
| <i>Passiflora spp.</i> ;<br>passionfruit, maracuya, parcha, maracujá                                   | Concentrated flavor and scent enhancer. A Brazilian species is currently the only commercial passionfruit, however, there are many species in the Andes said to be superior to this species.   |
| <i>Phaseolus vulgaris</i> subsp. <i>nunas</i> ;<br>popping beans, nuñas                                | Pops like popcorn when dropped in hot oil. Tasty, with a consistency like roasted peanuts.   |
| <i>Pouteria lucuma</i> ;<br>highland papaya, lucmo, egg fruit  | Dry fruits. A staple, it is rich in starch – suitable as a basic, everyday carbohydrate. It is said a single tree can feed a family year-round and that the dried fruits can last for years  |
| <i>Solanum muricatum</i> ;<br>pepino dulce , sweet pepino, pepino, pepino melon,<br>melon pear         | A shiny, yellow-and-purple fruit, resembling a melon in flavor.  |
| <i>Ullucus tuberosus</i> ;<br>Olluco, Ulluco, papa lisa, melloco, chugua, ruba                         | Rich in vitamin C, this potato-like tuber has a silky texture and nutty taste. Its waxy skin can be bright shades of yellow, pink, red, green, or even striped in color.   |

Table 4. Strategic Ranking for Overall Sustainability of Production Practices

| <b>Production Practice</b>           | <b>Sustainability</b> | <b>Implementation Potential</b> | <b>Total Score</b> |
|--------------------------------------|-----------------------|---------------------------------|--------------------|
| Diversification<br>(Inca Crops)      | 4                     | 4                               | 8                  |
| Integrated Pest Management<br>(IPM)  | 3                     | 2                               | 5                  |
| Raised Beds<br>( <i>waru warus</i> ) | 1                     | 3                               | 4                  |
| Crop Rotation<br>(7 fallow years)    | 2                     | 1                               | 3                  |

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