

INTRODUCTION TO TROPICAL AGRICULTURE AND OUTLOOK FOR TROPICAL CROPS IN A GLOBALIZED ECONOMY

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Summary

The Tropics are the center of origin and domestication of many of the most important food crops of the world, including maize, potato, sweet potato, cassava, cocoa, sorghum, millet, tomato, peppers, many cucurbits, peanut, rubber, tobacco, cotton, common bean, oil palm, coconut, sugarcane, coffee, banana, pineapple, mango, and papaya. However, colonial rule of developing nations by European powers drastically reduced the number of crops to a few export commodities (e.g. sugarcane, tobacco and cotton). Staples, such as maize, common bean, cassava, potato, sweet potato, sorghum, and rice, remained as traditional food crops in tropical countries, without much demand or value in international markets. Some high-value crops, such as coffee, tea, or cocoa, have been exploited in the tropics, but trans-national companies in developed countries control the market, industrialization, and commerce of these commodities. The globalization of the economy is the consequence of rapid progress in communication

and transportation technologies that facilitate global commerce. However, the international trade of agricultural commodities is still affected by different barriers, such as tariffs, export/import quotas, and subsidies. Free Trade Agreements seek to eliminate these protectionist measures, but it has proven a difficult objective to achieve. For developing countries to be able to compete with traditional export crops under free trade conditions, they must invest in agricultural research and development, but the gap between the technological development of tropical nations and industrialized temperate countries is still abysmal. The potential use of many under-exploited tropical crops as sources of biofuel is an interesting prospect. Whether small-scale farmers in developing countries will be able to improve their livelihoods because of the creation of new market opportunities for their traditional crops or not, remains to be seen.

1. Introduction

The Tropics is the geographic region of the Earth centered on the Equator and limited in latitude by the Tropics of Cancer (23.5° N) and Capricorn (23.5° S). This region includes all the areas of the Earth where the sun reaches an altitude of 90° and moves between the two tropics during the average length of the year. Thus, the Tropics does not experience marked changes in temperature (seasons) due to the position of the sun and, due to the constant daily radiation, water evaporation produces abundant rainfall in this 'torrid' region during the 'wet season'. Depending on the position of the sun during the year and the region, a 'dry season' also occurs at different times of the year, lasting from a month to over half a year. These dry and wet seasons may present a unimodal or bimodal distribution during the year. However, tropical ecosystems vary considerably from deserts to rainforests, and temperature can be drastically changed by the concept of 'vertical geography', ranging from hot lowlands to snow-capped mountains within a few hundred kilometers.

Based on the above environmental characteristics of the tropical zone, we can expect a large number of different eco-systems and a rich biodiversity of plant and animal life in this region. Thus, we have the humid tropics (rainforests), the arid tropics (deserts and dry areas), and the wet-and-dry tropics (monsoon and other zones receiving abundant rainfall during the wet season). The extreme and highly variable environmental conditions found in the Tropics, particularly the high temperature, high humidity conditions, cause accelerated degradation of tropical soils, making the highly acidic (pH <5), toxic (high aluminum content), and deficient in critical nutrients, such as phosphorus. In the humid tropics, the relative importance of acid soils is greatest in Latin America (81%), but also significant in Africa (56%) and Asia (38%). The rapid degradation of tropical soils is more noticeable in rainforests and mountain slopes that lose their protective vegetation due to human activity. In some wet-and-dry tropical regions, the dry season may last six months on average, impeding the cultivation of plants, unless irrigation is available. However, dry regions in the tropics are usually affected by the presence of soluble salts due to the low rainfall, and irrigation tends to aggravate the salinity problem. On the contrary, the wet season may be so intense that flooding and crop damage occurs in certain tropical regions.

Besides the above-mentioned abiotic stresses, tropical crops are constantly exposed to a large number of pathogens (fungi, bacteria, viruses, etc.) and other pests, mainly insects,

whose populations in the tropics are not reduced by harsh winter conditions as in temperate regions. Moreover, the continuous availability of plant hosts during the year, maintains the populations of a myriad of pests at a damaging level in tropical regions.

2. The Origin of Tropical Crops

The Tropics are either the center of origin or domestication of many of the most important food crops currently cultivated in the world: maize, rice, potato, sweet potato, cassava, cocoa, sorghum, millet, tomato, peppers, many cucurbits, peanut, rubber, tobacco, cotton, common beans, oil palm, coconut, sugarcane, coffee, and many fruit crops, such as banana, pineapple, mango, and papaya. However, a myriad of other food crops were also domesticated and consumed by the early civilizations that developed in the Tropics. The domestication of these valuable crops took place long before the European conquest of practically all of the nations located in the tropical zone, particularly in Latin America, Africa and Asia. The driving force behind European supremacy was primarily the need to survive in a challenging environment, which demanded constant technological innovation. The early European cultures adopted crops, such as wheat and barley, domesticated around the Middle East some 10,000 years B.P., and eventually developed nations that conquered the ancient civilizations of the world. The driving force behind European expansionism was the relatively limited natural resources of Europe and the discovery of valuable plant products in the tropics. In fact, the discovery of the Americas was motivated by the search of a safe maritime route to acquire the precious spices produced in Asia. The exploitation of the abundant mineral resources of the New World and the trade of human beings in Africa were accidental activities of the European traders in pursue of valuable agricultural products. In a world still dominated by nations outside the tropical zone, where colonial imperialism has been replaced by economic imperialism, the analysis of 'tropical agriculture' cannot be removed from its historical development. From the purely agricultural point of view, we usually describe tropical agriculture in terms of those crops that were either adopted or introduced by European conquerors in the tropical nations that fell under their dominion. But the plant genetic resources and ancestral agriculture of the tropical zone are far richer in terms of number of cultivated species and potential markets for new tropical crops.

The birth of 'tropical agriculture' some 8,000 years ago meant the birth of the main civilizations that developed in the Tropics. Before modern human beings domesticated plants, they were simply hunters and gatherers of the natural biodiversity. When these wandering groups of people domesticated plants, they could finally settle down and develop complex societies and city-states based on the production of surplus agricultural products. In Latin America, maize (*Zea mays*) was the most important and widely adopted crop in pre-Columbian times. Maize was grown by most of the aboriginal societies of the Americas when the Spanish arrived in this region back in the late 15th century. The rapid dissemination of maize from its center of origin, the central highlands of Mexico, throughout Latin America, can be explained by the possibility of transporting viable seed for long distances and relatively long periods of time. This was also the case of the common bean (*Phaseolus vulgaris*), although this species had different centers of origin and domestication ranging north to south from Mexico to Chile. Lima bean (*P. lunatus*) was also an important grain legume in prehispanic times,

having been frequently represented in many ceramics produced by the ancient cultures of Peru. Cucurbits, such as squash (*Cucurbita pepo*), pipian (*Cucurbita argyrosperma*), and ayote (*Cucurbita moschata*), were also highly popular food crops among the pre-Hispanic societies of the American tropics. Peanut (*Arachis hypogaea*), hot and sweet peppers (*Capsicum* spp.), and tomato (*Lycopersicon esculentum/Solanum lycopersicum*) were domesticated in different regions of tropical Latin America. A major crop of the American lowlands was cassava (*Manihot esculenta*), a root crop vegetatively propagated from stem cuttings that also disseminated widely in Latin America from its center of origin in northern Brazil. Another important neo-tropical root crop domesticated in the Americas was sweet potato (*Ipomoea batatas*), with two possible centers of origin or domestication in Mesoamerica and South America. In the highlands, and precisely in the vicinity of Lake Titicaca, potatoes (*Solanum* spp.) were born and domesticated by the pre-Columbian cultures that later gave rise to the Inca civilization and many other Andean societies found by the Spanish conquerors in South America. Among the industrial crops that originated in the neo-tropics, cotton (*Gossypium hirsutum* and *G. barbadense*), tobacco (*Nicotiana tabacum*), rubber (*Hevea* spp.), cocoa (*Theobroma cacao*), were widely used following their domestication in pre-Hispanic Latin America. Important neo-tropical fruit crops include: passion fruit (*Passiflora edulis*), guava (*Psidium guajava*), papaya (*Carica papaya*), sweet pepino (*Solanum muricatum*), and pineapple (*Ananas comosus*).

In tropical Africa, specifically in the southern border of the Saharan region, three important grain crops, African rice (*Oryza glaberrima*) sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*), were domesticated some 3,000 years ago. Cowpea (*Vigna unguiculata*) is native of Africa, where about eight million hectares are currently cultivated. This is a drought-tolerant crop adapted to poor soils of the Tropics. Rice (*Oryza sativa*), the food crop that provides approximately 20% of the calories consumed by over 1.7 billion people in the world, was probably brought into cultivation along the temperate region of the Yangtze River in southern China, over 8,000 years ago. However, its domestication and expansion may have taken place across a broad region that stretched from India to Southeast Asia, in the Tropics. Soybean (*Glycine max*) was domesticated in China and Southeast Asia about 4,000 years ago, where it is considered an important source of protein. Bananas (*Musa* spp.) originated in South East Asia, probably in Malaysia, and are currently staple food crops for millions of people in developing tropical nations.

3. Dissemination of Tropical Crops outside Their Centers of Origin

The dissemination of tropical crops beyond their centers of origin is not only associated with population growth, but with the drastic environmental changes that took place in the tropical ecosystems where these crops originated. For instance, the southern part of the actual Saharan region that gave rise to the African cereals was a humid grassland and not a desert 7,000 years ago; and the Amazon basin was not as densely forested at that time. The early human societies developed in areas along the main rivers of the world or water reservoirs, such as Lake Titicaca in the South American highlands; and knew very well that agriculture was highly dependent on the availability of water. Rice, for instance, moved from the subtropical environments where it originated in China, to the humid regions of Southeast Asia, where the crop could thrive due to the abundant

rainfall that characterizes this torrid region. Some tropical crops may have spread with the peopling of the world. The Americas was apparently inhabited by Asian people that crossed the Bering Strait from Siberia into Alaska, until they reached the southern most region of South America over 10,000 years ago. However, the domestication of plants took longer, and, thus, it is not surprising to observe that some of the main crops in the Americas, moved from their centers of origin as much south as northwards, after the population of the entire region in Palaeolithic and Neolithic times. For instance, maize disseminated southwards from its center of origin in central Mexico, some 6,000 years ago, whereas tomato, potato, chili, peanut, cocoa, disseminated northwards from their centers of origin in South America.

When the European powers conquered the Tropics of Latin America, Asia, and Africa, they initiated the intercontinental exchange of plant genetic resources that was to define the agricultural systems of both the developed and developing nations of today. Maize is probably the most valuable gift of the Americas to the entire world, whereas rice is consumed mainly in Asia (90% of the total world production). Another major contribution of the Americas to the world's food supply, was potato, although its adaptation is relatively more limited than that of maize. In fact, the first potato cultigens (subsp. *andigena*) introduced in Europe from Peru, did not adapt well to the long-day, temperate conditions of Europe. Cassava was eventually introduced into Africa from the Americas, where it became a major staple in the diet of millions of resource-poor people in sub-Saharan Africa. Cassava was also introduced in India and Southeast Asia, where it is also extensively produced for local consumption and as a cash crop. Sweet potato, another root crop of the Americas, was introduced into Asia, Africa and the Pacific regions, where it is now an important staple. Asia provided the world with banana and plantains, particularly Africa, the major producer of these crops for domestic consumption. Latin America is the world major producer of bananas for export. Sorghum is the fifth major cereal crop in the world after wheat, rice, maize, and barley, with a global area of about 47 million hectares. Sorghum is an important staple in Africa, the Middle East and Asia. Sorghum was introduced in the Americas through the slave trade, where it is used mainly as animal feed. Millet is still largely consumed in its region of origin, Africa, but Asia produces the majority of the world's millets. Cowpea is a drought-tolerant crop that also fixes nitrogen in poor soils. Cowpea is consumed in Africa and Asia, and to a lesser extent in Latin America, particularly in north-eastern Brazil, a region frequently affected by drought. Brazil is the world's largest producer of common bean, and Latin America grows over half of the global production of this food legume. Common beans are also primary staples in East Africa, and China has shown the capacity to plant large areas of common bean for export. Peanut or groundnut is mainly produced in China, India and sub-Saharan African countries despite its South American origin.

Regarding fruit crops, papaya is widely cultivated in Asia and Africa, where it was introduced from the Americas. Cocoa, another American crop, is currently grown mainly in West Africa (Ivory Coast, Ghana, Nigeria, and Cameroon) with 67% of the world's production; followed by Indonesia (13%), Brazil (5%), and Ecuador (4%); the latter country being the most likely center of origin. The origin of coconut (*Cocos nucifera*) is not clearly defined, and this species is now widely distributed in the Tropics, providing a variety of important food products, including oil. Pineapple is an

American fruit crop, but South East Asia currently dominates world production, followed by Brazil. Hawaiian pineapples ('Smooth Cayenne') are famous as canned fruits.

With regard to industrial tropical crops, cotton seems to be native to both the Old and New Worlds. *Gossypium hirsutum* has been the main species grown in Central and North America, whereas *G. barbadense* was the species grown in pre-Columbian South America and currently in Egypt, where some of the finest cotton is produced. Rubber (*Hevea brasiliensis*) was taken in the 19th century, from its center of origin in Latin America to Asia, where it is now abundantly produced. However, over half of the rubber produced nowadays in the world, is synthetic. Coffee (*Coffea arabica*) is indigenous to Ethiopia, and it was eventually disseminated in the 15th century by Muslims. Coffee was introduced in Latin America in the 18th century, where it rapidly adapted, becoming the main agricultural export product of this regions until the mid 20th century.

4. Tropical Agriculture in Colonial Times

The Arabs had the monopoly of the spice trade since biblical times. They acquired spices such as pepper, cinnamon, cloves and ginger in Asian countries (*e.g.* India, China and Indonesia), at a time when most food products were bland and, consequently, spices were in high demand. Egypt became the main spice market for Europe, particularly for Venice and Genoa. Following Marco Polo's accounts of his trips to the land of spices in the late 13th century, European merchants set sail for the ports described, and, soon, the major western powers (*e.g.* Portugal, Holland, England) took control of the spice-producing nations of Asia. Spain dropped out of the spice trade and sold its rights to the Spice Islands to Portugal. Spain then focused its attention on the mineral riches (gold and silver) of the newly discovered American continent. But, land was also a precious commodity, and large areas were seized from native tribes and nations, to be assigned, leased or sold to European settlers, who used slaves and primitive technologies to exploit these extensive landholdings. In Latin America, the 'encomienda' system allowed Spanish settlers to exercise total control over the aboriginal communities reducing them into slavery. The productivity of these extensive 'haciendas' was usually low per unit area, and was characterized by a 'subsistence' agriculture practiced by the enslaved native population. This inefficient agricultural system, referred to as 'latifundismo' in Latin America, was still common in the middle of the 20th century. The more intensive 'plantation' agriculture, also involved rather primitive agricultural practices, even though the use of draft animals to till the land was considered a major improvement in Latin America, where pre-Hispanic societies did not have draft animals. Furthermore, agriculture was heavily taxed in colonial Latin America, to discourage the development of an agricultural industry that could eventually compete with agricultural products imported from Spain. The main plantation crops at this time were: tobacco, sugarcane, cotton, cocoa, and natural dyes (*e.g.* indigo blue., and 'Pau Brasil').

As in the case of Latin America, the colonial system in Africa gave land to settlers, who could make use of the cheap labor provided by the dispossessed local communities. European policy favored white settlers, particularly in countries such as Kenya, South Africa and Zimbabwe. In the Belgian Congo, the land was owned by the state, and

African laborers who did not meet their harvest quotas, could be severely punished and even executed. The main plantation crops in Africa were: coffee, cotton, tea, tobacco, rubber, and sisal. In 1498, the Portuguese reached India, thus beginning European infiltration of Asia. Towards the end of the 18th century, India was under British control. The British extended their dominion to Malaysia. In 1618, the Dutch took over Indonesia, and the French over Vietnam, Cambodia and Laos (French Indo-China). The Philippines were already a Spanish colony since 1565. The colonies became a cheap source of raw materials for the European continent, with most of the land being devoted to export crops: cotton, spices, tea, sugar, coffee, indigo, coconut, pineapple, and tobacco. One of the main agricultural export products of colonial Asia, under European control, was opium (poppy).

5. Independence and Tropical Agriculture

Most of the nations located in the Tropics were colonies of a European or North American power, and consequently, their agriculture was based on the inefficient use of large landholdings, protectionism, abundant capital from local natural resources (*e.g.* mining), and slave labor. Independent nations in the Tropics had to face a different reality of depleted natural resources, the end of slavery, competition from other independent nations, and the loss of the main market. Moreover, one of the most negative production factors that characterized colonial agriculture, the concentration of land in the hands of few privileged people, has continued to date in most developing nations. Independence also brought extreme social and political unrest to tropical nations that soon found themselves consuming their energy and scarce economic resources in civil wars and endless struggles for power among local chieftains and politicians. Eventually, these impoverished nations had to replace the Spanish rule by the economic neo-colonialism created by their dependence from other European powers that were finally able to access these potentially rich markets and cheap sources of natural resources. The arrival of European merchants and emergence of the United States as another world power, created new markets for Latin American agricultural products, but, as in other tropical continents, the marketing and wealth generated by these agricultural exports ended up in the hands of foreign companies. The end of the 19th century witnesses the entrance of Latin America to the world market as a provider of raw materials, mainly agricultural products, such as sugar, cocoa and cotton.

Undoubtedly, the most important agricultural commodity of the late 19th and most of the 20th century in Latin America, was coffee. This crop adapted well to this region, particularly to marginal mountain slopes occupied by small-scale farmers that found in this crop a sustainable source of income with relatively low production costs. Coffee also became a regular source of employment in the rural sector of many Latin American countries, and soon surpassed all other agricultural exports in terms of its contribution to the economy of the region, becoming the dominant export crop of many countries, including Brazil. Coffee and other crops, such as cocoa, oil palm, rubber, peanut, and cotton, remain important export commodities of Africa, even after this continent regained its independence in the mid 20th century. The 19th century was a period of foreign domination and exploitation of the natural resources of tropical Asian nations. For instance, the ‘cultivation system’ (taxes, custom duties, monopolies) imposed by Holland in its south-eastern Asian colonies, made up to a third of Holland’s national

budget at that time. The main commodities produced were sugar, coffee, tea, and indigo. In India, famine has been a constant threat and ugly reality Since independence (the mid 1900s) induced by the economic exploitation of rural communities by the colonial powers, uneven distribution of land, exclusion of the poor rural sector, and natural disasters. Export crops, such as sugarcane, jute, cotton, and tea, still under-employ millions of poor people. In South East Asia, export crops, such as pineapple, tobacco, rubber, timber and coconut, exploited by Europeans up to the mid 20th century, remain important agricultural commodities in the region.

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Biographical Sketch

Francisco J. Morales received the B.Sc. degree in Agricultural Engineering from the National University of Colombia, Bogota; M.Sc degree in Plant Pathology from Cornell University, Ithaca; and Ph.D. in Plant Pathology from the University of Florida, Gainesville, in 1978. He joined the International Center for Tropical Agriculture (CIAT) in that year as a post-doctoral Fellow in the Bean Program, and became a Senior Scientist in the same program the following year. In 1988, he created the Virology Research Unit of CIAT and became its Head until the present time. He also worked as a Senior Germplasm Health Specialist for the International Plant Genetic Resources Institute (IPGRI/Biodiversity) from 1999 until 2002. In 2002, he became the Coordinator of the Global Tropical Whitefly IPM Project (TWFP). Dr. Morales also has a temporary office at the International Potato Center (CIP) in Lima, Peru, where he coordinates the South American Andean sub-project of the TWFP. His interests include International Agricultural Development, and the contribution of the pre-Columbian societies of the Americas in the domestication and dissemination of tropical crops. Dr. Morales has received various international awards for his contribution to crop improvement and plant virology in the Tropics, and is the authors of over a hundred publications in refereed journals and books.