Tropical agriculture in Latin America and the Caribbean at the United Nations Food Systems Summit[1]

1. Prepared by Dr. Nicolás Mateo. August 2021. Contributors: Federico Villarreal (IICA), Eduardo Trigo (IICA), Muhammad Ibrahim (CATIE), Jorge Faustino (CATIE), Reinhold Muschler (CATIE), Eduardo Somarriba (CATIE), Fernando Conde (IICA), Viviana Palmieri (IICA) and Karen Montiel (IICA).

This publication is also available in electronic (PDF) format from the Institute's web site: http://www.iica.int.

Editorial coordination: Federico Villareal, Eduardo Trigo, Muhammad Ibrahim, Jorge Faustino, Reinhold Muschler, Eduardo Somarriba, Fernando Conde, Viviana Palmieri, Karen Montiel
Mechanical editing: Máximo Araya
Translation: Bertha McLaren, Danielle Kamffer and Laura Moya
Layout: Nadia Cassullo
Cover design: Nadia Cassullo
Printing: IICA Print Shop

Mateo, Nicolás
Tropical Agriculture in Latin America and the Caribbean at the United Nations Food Systems Summit / Nicolás Mateo. – San Jose, C.R.: IICA, 2021.
18 p.; 21x16 cm.

ISBN: 978-92-9248-964-9
Published also in Spanish.

1. Tropical agriculture 2. Production systems in the american tropics 3. Determinants of agricultural evolution by 2030 and 2050 4. Family farming 5. Intensive farming 6. Sustainability 7. Tropical zones 8. Latin America and the Caribbean I. IICA II. Title

AGRIS E16 DEWEY 338

San Jose, Costa Rica
2021

Content

Content

Executive summary

From a geographic perspective, tropical agriculture (TA) is agriculture taking place between the Tropics of Cancer and Capricorn, latitudes 23° 26' north and south of the Equator. However, this is a very restricted definition, therefore different professionals and decision-makers use variables such as population and production system distribution, precipitation, radiation, day length and temperature to delimit or define specific actions in the intertropical belt.

Despite its great importance and potential, there is no consensus on what should be regarded as 'tropical', and therefore, statistics and trends are not grouped under this category, but are organized according to countries, some of which have both tropical and non-tropical regions. Thus, it is difficult to quantify the current volume, level of performance (production, productivity) and impact (environmental services, negative externalities), in order to establish a baseline for future interventions. Consequently, there is no up-to-date characterization of tropical production and food systems, which creates a significant void.

Further complicating the analysis is the fact that anthropocentric modifications have been undertaken in the tropics to produce crops and animals that otherwise would not have been possible through the normal flow of nature. Intensive irrigation, the use of greenhouses and state-of-the-art inputs, advanced genetics, biotechnology and bioinformatics, among other factors, have enabled almost anything to be produced in the intertropical belt, in some cases, at a high environmental cost. Therefore, the boundary between TA and temperate agriculture has become blurred, due to these technological advances and modifications.

The call for the Food Systems Summit was a timely one, because it enabled a link to be established between TA and the five proposed action tracks, providing a strategic framework to streamline and transform agriculture. Harnessing existing scientific and technological strengths in the tropics—which are abundant—should serve as the starting point for this process, although this capacity is often dispersed, not linked to research and innovation networks or has not been adequately characterized. In addition to mapping these strengths, it would be advisable to define long-term priorities, goals and metrics; establish partnerships, policies and incentives at the highest level, as well as to negotiate sustained multistakeholder funding.

The main objective of this document, assuming that the abovementioned conditions are met, is to propose options to drive the transformation and optimization of some tropical production systems by 2030 and 2050, taking into account not only their natural evolution, but also the available capacity in the *region, the advances in science and technology and the new determining factors that are affecting and will affect the intertropical belt.*

As a practical and academic example, the document concludes by prioritizing the transformation of two types of production and agrifood systems that are important to the region, particularly to the intertropical belt: intensive industrial agriculture and family farming (FF). For both production systems, there should be an attempt to compromise and to reconcile strategies to satisfy objectives related to sustainability, as well as to greater productivity. The first one, intensive industrial agriculture, must evolve into a production system grounded in science-based agroecological principles and practices; and the latter, FF, must aim for sustainable intensification and a closer relationship with markets. Policies and incentives to achieve this transformation of both types of agriculture should be consistent with these objectives.

1

Tropical agriculture

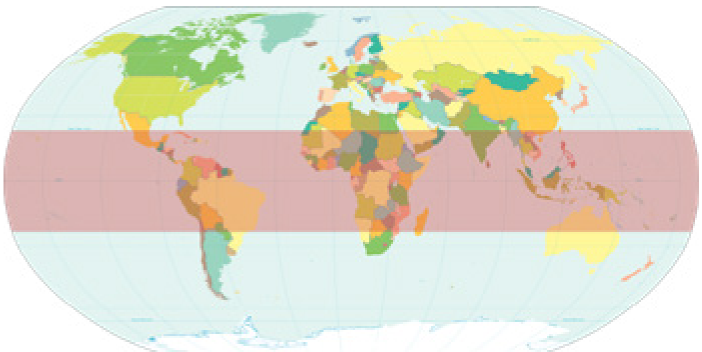
From a geographic perspective, tropical agriculture (TA) is agriculture taking place between the Tropics of Cancer and Capricorn, latitudes 23° 26' north and south of the Equator (Figure 1), a region normally considered as the intertropical belt. Geographers, anthropologists and decision-makers may use elements of biogeography to attempt to define what is “normally” considered to be tropical, and therefore latitude is only one of the factors taken into account in this definition. Other relevant variables that may be considered are population distribution, precipitation, radiation, day length and temperature.

Within this conceptual framework, the tropics could extend beyond the parallels of Cancer and Capricorn. For example, some production systems in the southern part of Florida in the United States—which falls outside of the tropical region, geographically—do not differ extensively from what we know as tropical in the rest of the hemisphere. On the other hand, agriculture in the Andean plateau—which is located within the tropical belt between 2000 and 4000 m.a.s.l., stretching from Colombia to northern Argentina—is hardly similar to the popular view we have of the tropics.

The tropics span 40% of the Earth's total land area and are home to approximately 80% of the world's biodiversity and a major share of its linguistic and cultural diversity. Ninety-five percent of the mangrove swamps of the planet and 99% of the mangrove species are found in tropical regions (National Geographic 2021). Specifically, the Latin America and Caribbean (LAC) region (including the intertropical belt), possesses the resources and capacity to more than fulfill its own needs, and thus, it is capable of making a significant contribution to the rest of the world.

A report by the Inter-American Development Bank (IDB) and the Global Harvest Initiative (2014) highlights the fact that LAC has a third of the fresh water reserves of the planet and 28% of the world's farmland with medium to high potential for expansion. Although some problems have been identified in relation to the preservation and fertility of tropical soils, Gardi et al. (2014) maintain that LAC's soil is better preserved than other regions of the world. In short, LAC possesses a wealth of resources that are important for agricultural production: land, water and biodiversity.

FIGURE 1. INTERTROPICAL ZONE, LATITUDE 23° 26' TO THE NORTH - AND SOUTH OF THE EQUATOR



Source: https://es.wikipedia.org/wiki/Trópico

For practical purposes, in the rest of the document, TA will be characterized on the basis of the geographic concept of the intertropical zone, taking place at a maximum altitude of 1800 m.a.s.l. This altitude is the accepted limit for the production of high-quality coffee and a large percentage of production and food systems that are considered as tropical operate at elevations below that level.

Further complicating the analysis is the fact that anthropocentric modifications—not always positive or permanent—have been undertaken in the tropics to produce crops and animals that otherwise would not have been possible through the normal flow of nature. Intensive irrigation in cantaloupe and watermelon cultivation in Central American countries, for example, has enabled the use of a cultivation system that is quite similar to how these crops are grown in Kansas, United States. Similarly, a modern greenhouse in the Dominican Republic is a production system very similar to those in the Netherlands or Spain, including the type and quality of vegetables and fruits that are grown there. Another example of the extreme adaptation of a cultivation system in the tropical region is the super-intensive and successful production in the desert of northern Peru, using water from the snowmelt of the high Andes.

The aforementioned signals that tropical food systems are not “chemically pure”, as modifications, adaptation and additions in recent decades have now enabled the production of almost anything today, with the caveat that what is possible is not necessarily sustainable. Nonetheless, due to these technological advances and anthropocentric modifications, the difference between TA and temperate agriculture is becoming blurred.

TA and temperate agriculture not only have many species and production systems in common, but could be considered to be a continuum, with gray areas in which both the notions of tropical and temperate become imprecise. Despite this, there are important elements that point to significant differences between both zones: the tropical world is more biodiverse, more vulnerable to extreme events and is facing greater biological pressure, due to the presence of pests and other organisms that cause diseases in plants and animals. It also possesses a wide range of beneficial and functional biodiversity (fungi, bacteria) that may act as biocontrol agents and antagonists. Furthermore, weathering processes of soil formation and erosion are 3 to 6 times faster in tropical regions (Ewel 1986). Some important perennial crop systems are exclusive to tropical countries (coffee, cocoa, banana, palm oil). However, other production systems such as citrus, macadamia and annual crops (rice, corn, beans, vegetables), as well as livestock rearing can be found in both tropical and temperate zones.

One challenge, as it becomes apparent from the above, is the lack of consensus about what ‘tropical’ entails, given that statistics and trends are not grouped under this category, *but instead are organized according to countries, some of which have both tropical and non-tropical regions*. Thus, it is difficult to quantify the current volume, level of performance (production, productivity) and impact (environmental services, negative externalities), in order to establish a baseline for future interventions. A recent publication (Pezo et al. 2019) identifies important differences between sub-regions in LAC and reports that there is lower productivity in Central America and Mexico, in comparison to South America. De los Santos and Trigo (2020) indicate that the total productivity factor (TPF) of tropical countries is lower than temperate climate countries: 1.29 and 1.8 respectively. Tropical countries dominate some global markets, such as coffee, pineapple and banana and also play a significant role in other variables, as indicated in Table 1. In this same vein, one pending task is to conduct an up-to-date characterization of those production and food systems that are considered to be tropical, using parameters and tools based on expert consultations. The use and adaptation of agroecological zones (Nin-Pratt 2015) may be one of the options to consider.

TABLE 1. PERCENTAGE SHARE OF VARIABLES OF INTEREST IN TROPICAL COUNTRIES IN THE AMERICAS

VARIABLE	%
The agriculture sector's share of GDP in the tropical countries of the Americas (2019)	5
Average contribution of the agriculture sector to total employment in tropical countries of the Americas (2019)	17
Share of total global agrifood exports attributed to tropical countries in the Americas (2019)	10

Source: IICA (CAESPA), with WB data (WDI 2021), WTO (2021) and Trade Data Monitor (2021).

On the basis of the aforementioned elements, the main objective of this document is to propose options to ensure the transformation and optimization of some tropical production systems by 2030 and 2050, taking into account not only their natural evolution, but also the available capacity in the region, the advances in science and technology and the new determining factors that are affecting and will affect the intertropical belt. In this context, the strengths of tropical countries in science and technology are very significant, although this capacity is often dispersed, not linked to research and innovation networks and has not been adequately mapped and characterized. This must change!

2

Production systems in the american tropics

At the end of the 19th century and the beginning of the 20th century, a visitor to the tropical region of the Americas would encounter medium-sized or large plantations (coffee, sugar cane, tobacco, cotton, etc.), mainly dominated by wealthy families; and small-scale family production systems (corn and common beans in areas with a dry climate, and roots and tubers in areas with greater rainfall). They would also see small gardens (fruits, vegetables, medicinal plants, cattle, pigs or chickens) surrounding local homesites as well as shifting agriculture expanding the agricultural frontier.

These former 20th century production systems were then joined by other production and food systems that currently co-exist, both in time and location. Some of them could be considered to be "niche" systems, given that, despite their social or environmental value, they have not yet become as prevalent or had as great an impact as others, although they may achieve this in the coming years. Most noteworthy among these are organic agriculture, low impact and low input systems (ILEIA 2017), agroforestry and agrosilvopastoral systems (Montagnini et al. 2015), and more recently, systems in close proximity to urban centers, such as peri-urban and vertical agriculture systems (Hotten 2019). As stated earlier, some of these production systems, although extremely significant, are not exclusive to tropical regions, as they are also found in temperate zones.

Most notable among the systems that have recently had a socioeconomic and environmental impact, whether positive or negative, are intensive industrial agriculture (poultry, swine, aquaculture and crops such as pineapple and palm oil), intensive irrigated agriculture (cultivation of cantaloupe or high value crops in desert areas) and protected environment agriculture that is capable of producing vegetables and fruits, as well as medicinal and ornamental plants, in any location and at any time of year, as long as the required conditions for light intensity, day length and other associated factors are properly regulated.

Finally, more recent developments and technological advances in biotechnology and informatics have given rise to digital agriculture, which has made significant strides in temperate climate environments, but has been slower to take off in the tropics, despite its great potential. Some sources (Kremer and Houngbo 2020) recommend a cautious approach, given that these technologies may produce even greater inequality in the tropics, unless policies and support services to prevent this are implemented. These developments have led to the emergence of various disruptive technologies, Ag Techs, which will also have an impact on tropical areas, particularly gene editing with the CRISPR-Cas9 tool that allows parts of the genome to be edited and new desired DNA sequences for specific crops to be inserted. Furthermore, disciplines such as bioeconomy and biotechnology open up new opportunities to add value to agricultural products and by-products, to reduce post-harvest losses and to generate employment and income sources for producers.

The reasons for the diversification and expansion of the aforementioned production systems are well-known. For example, the trade intensification afforded by various international treaties; the population increase, the rise of a middle class in many countries and the new role of supermarkets and other dynamic trade systems, such as farmers' markets. Another element that bears mentioning is the urbanization taking place in Latin America and the Caribbean (LAC), with the tropical belt being no exception. A recent report by the United Nations (2019) indicates that 81% of the regional population is urban. On the other hand, healthy food trends and the One Health concept are unfortunately offset by the coexistence of obesity, overweight and nutritional deficiencies in the population (Galicia et al. 2016), due to the consumption of poorly balanced foods, high in calories and saturated fats.

3

Determinants of agricultural evolution by 2030 and 2050

Current production systems will continue to evolve as a result of policies and incentives created by countries, but they will also face obstacles and processes that will determine their relevance or obsolescence, and even their permanence over time. Some determinants, technological tools and trends will accelerate these changes, but it is not possible to predict which ones will have the greatest impact on the American tropics. The determinants that could prove most influential are outlined below.

3.1

Planetary boundaries. Planetary boundaries refer to the safe limits of nine quantitative processes (Stockholm Resilience Centre 2021) that regulate the planet's stability and resilience. Crossing these boundaries increases the risk of generating abrupt and irreversible environmental changes, such as ocean acidification, land-system changes and loss of biosphere integrity, to name a few. There is no doubt that tropical agriculture (TA) will be exposed to the same potential impacts should these boundaries be crossed. The Meadows couple (1972, 1992 and 2004), who pioneered the study of such limits, demonstrated that unlimited growth would have serious consequences on the Earth's finite resources, issuing a warning to academics and the political class of the time. This trend has continued to grow, so there is general – though not universal – consensus on the need to limit and rationalize human action on the planet, as argued by the World Resources Institute (2018) and IICA and CATIE (2019), among others.

3.2

The fourth industrial revolution. In essence, this revolution blurs the boundaries between the physical, digital and biological worlds through artificial intelligence, biotechnology, robotics, 3D printing, genetic engineering and quantum computing, among other technologies. It provides both humans and machines with new capabilities, making it easier for these technological elements to become incorporated into society and even the human body. These technologies can have considerable effects on biodiversity, ecosystems and, of course, on TA; therefore, it is important to consider their use, weighing both advantages and disadvantages.

3.3 **Climate change.** Recent evidence suggests that the Earth, where atmospheric CO2 concentrations now exceed 390 ppm, has already crossed the planetary boundary. We have reached a point where the loss of polar sea ice during the summer is almost certainly irreversible. The weakening or reversal of terrestrial carbon sinks as a result of the continuous destruction of the world's rainforests represents another potential tipping point, given the fact that feedbacks between the carbon cycle and climate accelerate global warming and intensify climate impacts (Stockholm Resilience Centre 2021).

3.4 **New approaches to sustainability.** Although nature-based solutions (NBSs) are not new to agriculture (rotations, composting and integrated pest and disease control, to name a few), they have recently acquired greater relevance. Polastry (2020) defines NBSs as actions that protect, manage and restore natural or modified ecosystems. NBSs with the greatest potential impact include agroforestry systems, soil management, diversification, forest management and integrated water management. Sonneveld et al. (2018) discuss NBSs from the point of view of water management and propose that interventions should be assessed, analyzed and implemented in an integrated fashion and considering the ecosystem as a whole.

3.5 **One health.** The SARS-CoV-2 pandemic has highlighted the importance of the concept of One Health. This is achieved through the application of a collaborative, multisectoral and transdisciplinary approach that works at all levels to achieve optimal health outcomes, recognizing the interconnection between people, animals, plants, and their shared environment (CDC 2021). Two current examples of the results of approaches that are not aligned with the One Health concept are the transmission of diseases between animals and humans, as well as the effects of the use and abuse of antibiotics in animal production and agrochemicals in tropical crops.

3.6 **New requirements for international trade.** These requirements, particularly those established in Europe, will require adjustments in order to comply with increasingly stringent regulations. The Green Deal (European Council 2021) and the Farm to Fork Strategy (European Commission 2021) set very specific goals for the European Union by 2030: reducing greenhouse gas (GHG) emissions by 55%, reducing the use of pesticides by 50%, devoting a minimum of 25% of the total agricultural area to organic production, etc. These goals will certainly have an impact on the conditions that tropical countries will be required to meet in order to export to Europe.

An undoubtedly controversial aspect that is worth considering is the need and opportunity to transform not only production and food systems, which is the objective of the UN Food Systems Summit, but also organizations and companies within the sector, so that they evolve and respond proactively to an incredibly dynamic reality. This will be necessary in order to develop context-appropriate policies, achieve sustainable production along with higher productivity, and foster the consumption of healthy food.

4

Tropical agriculture as it relates to the action tracks

While temperate climate farmers in Latin American and Caribbean (LAC) countries collaborate with and learn from their peers in North America and Europe, tropical agriculture (TA) in LAC depends more on its own capabilities and resources, given the fact that interaction with tropical Asian and African countries has been limited. This should also change in the future, to encourage closer ties and exchanges between the countries located in the intertropical belt regions of the different continents.

At first sight, analyzing and discussing the strengths and contributions of TA to the Food Systems Summit, based on each action track, seems logical and appropriate. However, further analysis concludes that this would be impractical and perhaps confusing. TA comprises an enormous diversity of species, environments, production systems and practices; as a result, it would be necessary to design a very complex matrix to describe the myriad of ways in which these elements relate to the action tracks, which is not one of the objectives of this document. Therefore, it seems more appropriate to consider, in general terms, how the action tracks are linked and the ways in which they complement the strengths and conditions that exist in the American tropics, which should facilitate the transformation of some priority systems in the future.

- **Access to safe and nutritious food:** Access to nutritious food in the American tropics is certainly possible; however, nutritious food is often more affordable to segments of the population with higher levels of education, information and resources. Certified food, whether organic or environmentally friendly, may also be inaccessible to segments of the population with fewer resources. For those reasons, this action track should be associated with and analyzed together with that of equitable livelihoods.

- **Sustainable consumption:** Consumption must be directly tied to a type of production that is not only biologically productive, but also environmentally friendly. Therefore, the use of agroecological practices, while taking into account both productivity and the rational use of environmental resources, must be part of the equation for the future in order to achieve expected transformations. The current zero-waste and circular economy trends, which are specifically geared towards sustainable consumption by reducing, reusing, rebuilding and recycling (ZWIA 2021) products and by-products, indicate the path that must be followed.

- **Nature-positive production:** In the case of TA, experiences and results in this area have been varied. On the one hand, LAC has developed systems that are compatible with natural processes, such as agroforestry and agrosilvopastoral systems (IICA and CATIE 2019), organic agriculture and low-input agriculture. On the other hand, systems that pollute and have negative impacts on soil, water and biodiversity have also been designed and practiced in the region; some examples include pineapple and palm oil farming, as well as poultry and swine production. Within the framework of this action track, it is necessary to foster policies and incentives to ensure that systems with the greatest environmental impact become better aligned with and more committed to agroecology.

- **Equitable livelihoods:** This action track is directly related to poverty (an area in which LAC has made significant achievements) and to inequality, which has tended to increase and is likely to increase even more as a result of the SARS-CoV-2 pandemic. This has had a major impact on employment, particularly informal employment, due to the closure of thousands of small and medium-sized enterprises.

- **Resilience to vulnerabilities and stress:** The intertropical belt of LAC is subject to a large number of intense natural disasters and extreme conditions (hurricanes, droughts, floods, landslides, etc.) that impact quality of life and livelihoods. This is exacerbated not only by climate change, but also by the lack of policies, incentives and organization to minimize these disasters and conditions. Climate change adaptation and mitigation within the framework of sustainable TA, as well as hazard prevention and preparedness, have become part of the new normal. With respect to adaptation and mitigation, it is necessary, among other things, to resume and intensify the genetic improvement of crops and animals (Pezo et al. 2019), by means of modern technological tools.

5

Strengths, not weaknesses should serve as the starting point

Unique dynamics characterize TA production system, whose transformation can be accelerated through adequate public policies and incentives. Optimizing their performance (by redesigning systems or utilizing regenerative practices) depends, to a great extent, on research and innovation processes that facilitate their adaptation, increase productivity, improve the quality and safety of the final product and secure competitive prices for consumers. As previously mentioned, the capabilities of research and development teams in the public, private and academic sectors of Latin America and the Caribbean (LAC) may be scattered or lack connectivity; however, they do exist and are significant. Two paper illustrate the achievements of consolidated research and innovation teams in the region. First, Henríquez and Li Pun (2013) have documented 15 successful cases in the region that have achieved proven impacts on topics as diverse as farmers' markets, development of agricultural equipment, fine flavor cocoa, and genetic improvement of guinea pigs, among others. Additionally, a more recent study carried out in Peru (INIA 2020) describes 20 successful experiences of various national teams in areas such as wild fungi for export to Europe, removal of sanitary limitations for the exportation of Haas avocado, bioinsecticides for corn farming and microbiological management of lepidoptera, among many others.

What conditions are necessary in order for R&D teams to achieve relevant outputs, outcomes and impacts? What factors must be taken into account to increase the success rate of these and other groups in the intertropical belt? Below are some possible responses to these questions.

5.1 Mapping of strengths in the American tropics

Literature and various forums often mistakenly assert that research and innovation systems in tropical LAC countries are weak, have shortcomings and generate a low impact on target populations. Although shortcomings and weaknesses do exist and have been clearly identified, they coexist with important strengths that have been poorly documented. There are prominent groups in the public and private sectors and civil society of LAC that are leading transformation and innovation processes, which should be identified and harnessed as potential launchpads for the establishment of new partnerships with leading centers both within and outside of the tropics. Efforts to map these capacities, which should ideally be led by the Inter-American Institute for Cooperation on Agriculture (IICA) and the Tropical Agricultural Research and Higher Education Center (CATIE) and based on objective criteria (academic preparation of the teams, publications, products and current or potential results, among other aspects) is a priority in order to advance the transformation processes discussed at the United Nations Food Systems Summit.

5.2 Priorities, goals and metrics for TA by 2030 and 2050

Ministries of Agriculture generally draw up agricultural research and development plans and proposals for the corresponding political cycle. Similarly, national, regional and international organizations do the same for periods of 5 or 10 years. However, current circumstances call for longer-term plans. Nationally Appropriate Mitigation Actions (e.g. NAMA Café de Costa Rica 2021) are a noteworthy exception; through NAMAs, relevant stakeholders explicitly agree on the achievement of national/regional goals for a period of at least 15 to 20 years. Increasing productivity and reducing the GHG emissions of priority products or systems could be good starting points for long-term goals. One such initiative, known as flagship programs, was designed by Dr. Brian Keating[2] and his team in Australia, with the aim of increasing productivity by 50% and reducing GHG emissions by 50% in seven priority crops within 15 years.

In the intertropical belt of LAC, long-term priorities, goals and metrics, with the involvement of relevant stakeholders, as appropriate, could be developed for different products or production systems (e.g. coffee, corn, agroforestry systems, etc.). In strategies of this nature, funding is critical, but if convincing roadmaps are defined, the participation of the private and philanthropic sectors (Mateo 2019) would be more feasible than negotiating new funding based on less ambitious or shorter-term initiatives. An exercise of this nature would require negotiation and leadership and may be another opportunity for collaboration between IICA and CATIE.

5.3 Partnerships, consensus and a strategic policy framework at the highest level

Transforming and optimizing tropical food systems requires advanced negotiations, political decisions, and consensus among producers, the sectors and organizations involved and public opinion. To ensure the success of ambitious initiatives of this nature, support at the highest level is needed, including that of the ministers and presidents of the relevant governments, and the identification of the aforementioned strengths (grouped into research and innovation platforms or networks and structured by teams with proven capabilities).

2 Personal communication within the framework of the meeting *Eco-Efficiency: From Vision to Reality*, held at The International Center for Tropical Agriculture (CIAT) in 2013 in Cali, Colombia.

5.4 Sustained, multistakeholder research and innovation funding

Very few countries in the intertropical areas of LAC currently qualify for the type of external assistance provided to the agriculture sector by the large American and European foundations in the 20th century, which, in some cases, created dependency on research and development funding. Today, the region invests little and very unevenly as shown by data from ASTI (2021). For example, only three countries (Brazil, Argentina, and Mexico) account for about 80% of the region's total annual investment (USD 5.1 billion). Agrifood systems cannot be transformed at current levels of investment, making three elements essential for changing this circumstance: negotiation, policies at the highest level, and multistakeholder funding. In the region and, particularly, in the intertropical belt, science and technology funding comes primarily from the public and private sectors, although with significant variations (Stads et al. 2016). Private sector participation has been lower, but in high-income countries it has increased considerably (Fuglie 2016). The philanthropic sector (including venture capital) is the new frontier to be explored (Mateo 2019), starting with negotiations and long-term visions with concrete goals and metrics.

6

Priorities for transforming tropical agriculture

We are unable to predict what tropical agriculture (TA) will look like in 2030 or 2050, but it would be wise to propose scenarios and define high-priority parameters. Based on the available knowledge and tools of science and technology, we can anticipate that in these time frames we must increase productivity, reduce GHG emissions and achieve higher standards of food quality and safety, for which the sustainability of TA is key. Certain questions may also apply to current systems: will family farming continue to play a leading role as the source of food for the majority of the population of the tropics? Will industrial agriculture continue to pursue its strategy of maximizing productivity with limited consideration for the externalities it causes? Will digital agriculture be the main food source in the future within the intertropical zone?

Setting priorities for transforming and optimizing TA could be approached from several angles: socioeconomic (poverty, employment), sustained growth, adaptation to climate change, specific crops or disciplines (bioeconomy and biotechnology), etc. In this document, as a mere practical and academic exercise, we propose the transformation of two important productive systems in the tropics, as it would not be appropriate or financially feasible to transform them all: a) FF because of its current socioeconomic importance; and b) intensive industrial agriculture, due to the challenges and impacts it has on the environment. A brief analysis of both systems follows, after which some considerations are raised for their future transformation.

6.1 Family Farming[3]

Given the importance of FF, we must consider its current reality and, in particular, the role it will play in Latin America and the Caribbean (LAC) in the future. Family farming takes place both within the intertropical belt and across the rest of the region, making it one of the aforementioned cases in which it is appropriate to establish a baseline, based on a consensus on what constitutes "tropical". While FF is important across the continent, there are no databases that differentiate between FF in tropical regions and FF in temperate zones. However, there are elements that characterize or differentiate each one, such as prevalent species or size of operations (for example, a FF plot in Central America may comprise two hectares, while in Brazil it could be as large as 50 hectares).

According to Salcedo and Guzman (2014), FF represents 81% of all farms in LAC, produces between 27% and 67% of food, occupies between 12% and 67% of the total agricultural area, and creates between 57% and 77% of agricultural employment. In various forums (FONTAGRO 2020), prevails a consensus on the need to increase productivity and improve the quality and safety of FF-produced products to better position them in local, national and international markets. In this framework, research, development and innovation (RD&I) should be the key contributing factors to securing and strengthening the future of FF.

Several authors have defined FF, but without reaching a consensus. A common definition is that it constitutes an activity dependent on family labor. Another includes crop area as a parameter: for example, two hectares maximum. Following this line of thought, Hazell and Rahman (2014) note that there are 450 million productive sites in the world spanning an area of less than two hectares. According to Berdegué and Fuentealba (2014), this concept makes little sense in LAC and go on to propose an alternative classification based on context, resources and capabilities, with which other authors and research and development agencies in the region commonly agree. In essence this classification identifies three categories of FF:

- Producers with significant resources (land, labor and access to capital) located in territories or regions where productivity is high and who are generally integrated into the markets;

3. This section is a summary and adaptation of: Mateo, N. 2018. Presentation at Simposio Internacional de Mercados Inclusivos e Innovación Tecnológica para la Agricultura Familiar (International Symposium on Inclusive Markets and Technological Innovation for Family Farming). La Paz, Bolivia. 24 May 2018.

- Producers who do not possess all the necessary resources or have limitations and who, moreover, are located in territories or regions where biophysical or socioeconomic conditions are not optimal; and
- Producers with a high level of poverty located in areas that are unfavorable not only to agricultural activities, but also to other economic activities. Most of these producers derive only a small fraction of their income from agriculture and depend on poorly paid off-farm jobs.

The above categories are closely related to the definition used by other authors, such as Schejtman (2008), who also assigns estimated percentages to each, based on a total of 14 million farms across LAC. These categories are the following:

- Consolidated, representing 12% of the total;
- Transitional, representing 28% of the total; and
- Subsistence, representing 60% of the total.

From the point of view of research and innovation (R&I), dividing FF into categories makes sense, as it is illogical to design and implement actions or to execute the same policies and incentives for each one. Berdegué and Fuentealba (2014) insist on the need for differentiated approaches to development and policy strategies for each category, as they believe that most FF-oriented interventions in our countries have not assimilated the existing heterogeneity.

6.2 Industrial agriculture

Conceptually, establishing intensive monocultures does not seem logical amidst natural tropical ecosystems, which are much more diverse than temperate regions; however, this is a reality that must be taken into consideration, even though such systems may affect the resilience of TA. Socioeconomic, environmental and ideological prisms encourage the classification of industrial agriculture in a number of different ways. As it is often defined, industrial agriculture is the mass production of a single product; it requires a high degree of technification and a high investment of capital, energy and other resources, often requiring external work and the participation of specialists (Boletín Agrario 2021). Industrial agriculture is characterized by increased productivity, reduced production and processing costs, and efficient management of diseases and pests. This, of course, implies significant social costs, which is the main idea behind the concerns surrounding it: the negative externalities, not properly accounted for, on the environment and health generated by such intensive systems.

The text below summarizes elements of a United Nations report (2020) synthesizing some risks and concerns surrounding practices associated with industrial agriculture. By analyzing these risks, we should be able to identify possible paths for evolution and transformation, as we will see in the next section.

"Industrial agriculture seemed to be a miraculous solution for a rapidly growing world. Synthetic fertilizers, chemical pesticides, and high-yield hybrids promised to reduce hunger, satisfy an increasing population, and stimulate economic prosperity. Between 1960 and 2015, agricultural production tripled, resulting in reduced tariffs and avoiding global food shortages, but not everything went as expected. Decades of industrial agriculture have impacted the environment and raised serious concerns about the future of food production. According to some estimates, industrialized agriculture emits greenhouse gases, contaminates air and water, affects wildlife, and generates environmental costs equal to USD 3 billion annually.

The industry fails to take into account externalized costs, such as the funds needed to purify contaminated drinking water or to treat malnutrition-related diseases, meaning that communities and taxpayers may be footing the bill without realizing. Intensive agriculture discharges large quantities of manure, chemicals, antibiotics and growth hormones into water bodies. This poses risks to both aquatic ecosystems and human health. It generally produces basic crops that are used in a wide variety of cheap, calorie-dense, widely available foods. Sixty percent of all food energy comes from only three grains: rice, maize and wheat.

While increased productivity and low costs have helped to effectively reduce the proportion of people suffering from hunger, this calorie-based approach does not meet nutritional recommendations, such as those related to fruit, vegetable, and legume consumption. Moreover, while there may be fewer undernourished people in the world, there are now many more people suffering from malnutrition. Another element of analysis is the contrast between small and large agricultural holdings. While the former account for 72% of the whole but occupy only 8% of agricultural land, the latter account for 1% of the whole, but occupy 65% of agricultural land".

Like FF, industrial agriculture has a strong presence in both the tropical and temperate regions, but the strengths and weaknesses attributed to it in the tropical zone are not necessarily the same as in temperate regions. The crops, of course, differ (with the exception of animal production, which is generally uniform in terms of the species involved), and the environmental impact may also be vastly different. In temperate regions, public-private partnerships and emphasis on knowledge technologies for achieving greater productivity and a lower environmental impact seem to be more frequent than in the tropics, leading to more resilient intensive systems.

6.3 Can FF and industrial agriculture converge and reach a compromise?

At first glance, considering the enormous differences between the two types of agriculture, it would seem strange to ask this question; however, it does make sense. Both modalities should prepare for a transformation with the aim to respond to the socioeconomic and environmental needs and expectations of the 21st century, as reflected in the United Nations Food Systems Summit action tracks.

On the one hand, according to Mateo and Ortiz (2013), FF must undergo sustainable intensification processes via R&I to achieve higher productivity goals with a lower environmental impact (eco-efficiency). In addition, this type of farming requires national policies that connect producers to the market; access and registration of the next generation of green agrochemicals; and investments in infrastructure for production to flow efficiently to the markets in shorter value chains. Investments in infrastructure (roads, cold chains, transportation facilities and primary product processing) make a huge difference as demonstrated by hundreds of new products now available in local, national and international markets. Finally, a differentiated approach to R&I must be targeted primarily at the categories of consolidated and transitional FF, given that subsistence FF requires other approaches and social assistance rather than technological innovations.

The same authors indicate the need for transforming industrial agriculture, which should follow—through the application of strict policies, incentives and certifications—agroecological guidelines and practices that lead to a significant decrease in its environmental impact. The door is open for the use of state-of-the-art science and technology. As stated by Trigo[4], current times provide a great opportunity to apply biotechnology and detailed engineering, facilitating the necessary adjustments and changes in the postulates of agroecology (often based on the art of observation).

In conclusion, if the indicated changes and adjustments were to take place, FF would remain relevant as an indispensable source of fresh, quality foods for the majority of the population, while industrial agriculture could retake the path of scientific agroecology, allowing not only for significant contributions in terms of quality products and competitive prices, but also for a reduction in negative externalities.

4 Eduardo Trigo. Personal communication.

Bibliography

- **Aapresid** (Asociación Argentina de Productores en Siembra Directa). 2019. El desafío de romper el lazo entre la producción y el impacto ambiental (online). Rosario, Argentina. Consulted on 1 Feb. 2021. Available at https://www.aapresid.org.ar/blog/el-desafio-de-romper-el-lazo-entre-la-produccion-y-el-impacto-ambiental/.
- **ASTI** (Agricultural Science and Technology Indicators). 2021. Country benchmarking - Latin America and the Caribbean (online). Washington, D.C., United States of America. Consulted on 1 Feb. 2021. Available at https://www.asti.cgiar.org/benchmarking/lac.
- **Berdegué, J; Fuentealba, R.** 2014. . The State of Smallholders in Agriculture in Latin America. In Hazell, PBR; Rahman, A. (eds.). New Directions for Smallholder Agriculture. London, United Kingdom, Oxford University Press and IFAD. p. 115-152.
- **Boletinagrario.** 2021. Boletín. Agricultura industrial (online). n.p. Consulted on 1 Feb. 2021. Available at https://boletinagrario.com/ap-6,agricultura+industrial,978.html.
- **CDC** (Centers for Disease Control and Prevention, United States of America). 2021. One Health Basics (online). Atlanta, United States of America. Consulted on 1 Feb. 2021. Available at https://www.cdc.gov/onehealth/basics/index.html.
- **Davis, N.** 2016. What is the fourth industrial revolution? (online). Geneva, Switzerland, World Economic Forum. Consulted on 1 Feb. 2021. Available at https://www.weforum.org/agenda/2016/01/what-is-the-fourth-industrial-revolution/.
- **De los Santos, L; Trigo, E.** 2020. Visión para el fortalecimiento de la innovación en América Latina y el Caribe. Soon to be published.
- **European Council.** 2021. European Green Deal (online). Brussels, Belgium. Consulted on 1 Feb. 2021. Available at https://www.consilium.europa.eu/en/policies/green-deal/ .
- **European Commission.** 2021. Farm to Fork strategy for a fair, healthy and environmentally-friendly food system (online). Brussels, Belgium. Consulted on 1 Feb. 2021. Available at https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en .
- **Ewel, JJ.** 1986. Designing Agricultural Ecosystems for the Humid Tropics (online). Annual Review of Ecology and Systematics 17:245-271. Consulted on 1 Feb. 2021. Available at https://people.clas.ufl.edu/jackewel/files/ewel-ann-rev-ecol-syst-1986.pdf.
- **FAO** (Food and Agriculture Organization of the United Nations, Italy). 2021. Climate-Smart Agriculture. Urban and peri-urban agriculture (online). Rome, Italy.

Consulted on 1 Feb. 2021. Available at https://www.fao.org/climate-smart-agriculture/knowledge/practices/periurban/en/ .

- **FONTAGRO** (Fondo Regional de Tecnología Agropecuaria). 2020. El rol de las instituciones públicas en la promoción del abastecimiento de alimentos en la agricultura familiar (online). Washington, D.C., United States of America. Consulted on 1 Feb. 2021. Available at https://www.fontagro.org/es/publicaciones/prensa/comunicados-de-prensa/el-rol-de-las-instituciones-publicas-en-la-promocion-del-abastecimiento-de-alimentos-en-la-agricultura-familiar/.
- **Fuglie, K.** 2016. The growing role of the private sector in agricultural research and development world-wide. Global Food Security 10:29-38.
- **Galicia, L; López de Romaña, D; Harding, KB; De-Regil, LM; Grajeda, R.** 2016. Tackling malnutrition in Latin America and the Caribbean: challenges and opportunities. Pan American Journal of Public Health 40(2):138-146.
- **Gardi, C; Angelini, M; Barceló, S; Comerma, J; Cruz Gaistardo, C; Encina Rojas, A; Jones, A; Krasilnikov, P; Mendonça Santos Brefin, ML; Montanarella, L; Muñiz Ugarte, O; Schad, P; Vara Rodríguez, MI; Vargas, R.** 2014. Soil Atlas of Latin America and the Caribbean. Luxembourg, Publications Office of the European Union. p. 13.
- **Hazell, P; Rahman, A.** 2014. New Directions for Smallholder Agriculture. London, United Kingdom, Oxford University Press, IFAD.
- **Henríquez, P; Li Pun, H.** (eds.). 2013. Innovaciones de Impacto: Lecciones de la agricultura familiar en América Latina y el Caribe. San Jose, Costa Rica, FONTAGRO, IICA, IDB. 224 p.
- **Hotten, R.** 2019. The future of food: why farming is moving indoors (online). London, United Kingdom, BBC. Consulted on 1 Feb. 2021. Available at https://www.bbc.com/news/business-49052317.
- **IDB** (Inter-American Development Bank, United States of America), Global Harvest Initiative. 2014. The Next Global Breadbasket: How Latin America Can Feed the World. Washington, D.C., United States of America. 56 p.
- **IICA** (Inter-American Institute for Cooperation on Agriculture, Costa Rica); CATIE (Tropical Agricultural Research and Higher Education Center, Costa Rica). 2019. Nature-based solutions: Experiences and opportunities in agricultural landscapes in Latin America and the Caribbean (online). San Jose, Costa Rica. 1 Feb. 2021. Available at https://repositorio.iica.int/bitstream/handle/11324/8633/BVE20017765i.pdf?sequence=2&isAllowed=y.
- **ILEIA.** 2017. Building Food Sovereignty. Farming Matters. Formerly known as LEISA Magazine 04-2017-33.1 (online). Consulted on 1 Feb. 2021. Available at https://www.ileia.org/wp-content/uploads/2017/04/FM_01_2017_Web_LR_FINAL.pdf.
- **INIA** (Instituto Nacional de Innovación Agraria, Perú). 2020. CARAL 2020: veinte innovaciones de impacto de la agricultura familiar. Concurso nacional de premiación a la calidad de los proyectos de innovación agraria: premio

nacional INIA – CARAL 2020 (online). Lima, Peru, Ministro de Agricultura y Riego, INIA. Consulted on 1 Feb. 2021. Available at http://repositorio.bibliotecaorton.catie.ac.cr/handle/11554/10105.

- **Keating, B; Carberry, P; Thomas, S; Clark, J.** 2013. Eco-Efficient Agriculture and Climate Change: Conceptual Foundations and Framework. In Hershey, CH (ed.). Eco-Efficiency: From Vision to Reality. Cali, Colombia, CIAT. p. 18-28. (CIAT Publication 381).
- **Kremer, M; Houngbo, GF.** 2020. Grow back better? Here's how digital agriculture could revolutionise rural communities affected by COVID-19 (online). Geneva, Switzerland, World Economic Forum. Consulted on 1 Feb. 2021. Available at https://www.weforum.org/agenda/2020/07/digital-agriculture-technology.
- **Mateo, N.** 2019. El sector filantrópico ¿Nueva frontera para financiar investigación e innovación agrícola, forestal y ambiental? Revista de Ciencias Ambientales UNA 53 (1):171-181.
- **Mateo, N; Ortiz, R.** 2013. Resource Use Efficiency Revisited. In Hershey, CH (ed.). Eco-Efficiency: From Vision to Reality. Cali, Colombia, CIAT. p. 1-17. (CIAT Publication 381).
- **Meadows, DH; Meadows, DL; Randers J.** 1992. Beyond the Limits: Confronting Global Collapse, Envisioning a Sustainable Future. Post Mills, Vermont, United States of America, Chelsea Green Publishing Co. 300 p.
- **Meadows, DH; Meadows, DL; Randers J; Behrens III, WW.** 1972. The Limits to Growth. New York, United States of America, Universe Books. 205 p.
- **Meadows, DH; Randers, J; Meadows, DL.** 2004. Limits to Growth: The 30-Year Update. White River Junction, Vermont, United States of America, Chelsea Green Publishing Co. 322 p.
- **Montagnini, F; Somarriba, E; Murgueitio, E; Fassola, H; Eibl, B.** 2015. Sistemas agroforestales: Funciones productivas, socioeconómicas y ambientales. Turrialba, Costa Rica, CIPAV, CATIE, Yale School of Forestry and Environmental Studies, INTA, Facultad de Ciencias Forestales El Dorado, Universidad Nacional de Misiones. 454 p. (Serie Técnica, Informe Técnico 402, CATIE).
- **NAMA Café de Costa Rica.** 2021. Cambio climático ¿Qué es una NAMA? (online). Barva, Heredia, Costa Rica, ICAFE. Consulted on 1 Feb. 2021 Available at https://www.namacafe.org/es/que-es-una-nama-0.
- **National Geographic en español.** 2021. ¿En qué región del mundo habita la mayor parte de la diversidad biológica? (online). Washington, D.C., United States of America. Consulted on 1 April 2021. Available at https://www.ngenespanol.com/traveler/en-que-region-del-mundo-habita-la-mayor-parte-de-la-diversidad-biologica/.
- **Nin-Pratt, A; Falconi, C; Ludena, CE; Martel, P.** 2015. Productivity and the Performance of Agriculture in Latin America and the Caribbean: from the Lost Decade to the Commodity Boom. Washington, D.C., United States of America, IDB. (IDB Working Paper No. 608).

- **Pezo, D; Muschler, R; Tobar, D; Pulido, A.** 2019. Intervenciones y tecnologías ambientalmente racionales (TAR) para la adaptación al cambio climático del sector agropecuario de América Latina y el Caribe (ALC) (online). Washington, D. C., United States of America, FMAM/FONTAGRO/BID. 272 p. Consulted on 1 Feb. 2021. Available at http://dx.doi.org/10.18235/0002086. (Monografía del BID 687).
- **Polastry, R.** 2020. Building up family farmers' resilience through nature-based solutions in Latin America and the Caribbean (online). Rome, Italy, IFAD. Consulted on 1 April 2021. Available at https://www.ifad.org/en/web/latest/-/blog/building-up-family-farmers-resilience-through-nature-based-solutions-in-latin-america-and-the-caribbean.
- **Salcedo, S; Guzmán, L.** 2014. Agricultura familiar en América Latina y el Caribe: Recomendaciones de políticas. Santiago, Chile, FAO. 497 p.
- **Schejtman, A.** 2008. Alcances sobre la agricultura familiar en América Latina (online). Santiago, Chile, RIMISP. Consulted on 1 Feb. 2021. Available at https://idl-bnc-idrc.dspacedirect.org/handle/10625/39808. (Documento de Trabajo N°21. Programa Dinámicas Territoriales Rurales).
- **Sonneveld, BGJS; Merbis, MD; Alfarra, A; Ünver, O; Arnal, MF.** 2018. Nature-Based Solutions for Agricultural Water Management and Food Security. Rome, Italy, FAO. 66 p. (Land and Water Discussion Paper no. 12).
- **Stads, GJ; Beintema, N; Perez, S; Flaherty, K; Falconi, C.** 2016. Agricultural Research in Latin America and the Caribbean. A Cross-Country Analysis of Institutions, Investment, and Capacities (online). Washington, D.C., United States of America, ASTI-BID. Consulted on 1 Feb. 2021. Available at https://www.asti.cgiar.org/sites/default/files/pdf/LACRegionalReport2016.pdf.
- **Stockholm Resilience Centre**. 2021. Planetary boundaries (online). Consulted on 1 Feb. 2021. Stockholm, Sweden, Stockholm University. Consulted on 1 Feb. 2021. Available at https://www.stockholmresilience.org/research/planetary-boundaries.html.
- **United Nations.** 2019. World Urbanization Prospects: the 2018 Revision (online). New York, United States of America, Department of Economic and Social Affairs Population Division. Consulted on 1 Feb. 2021. Available at https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf.
- **United Nations.** 2020. Ten things you should know about industrial farming (online). Nairobi, Kenia, UNEP. Consulted on 1 Feb. 2021. Available at https://www.unep.org/news-and-stories/story/10-things-you-should-know-about-industrial-farming.
- **WRI** (World Resources Institute, United States of America). 2018. Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050. Washington, D.C., United States of America. 90 p.
- **ZWIA** (Zero Waste International Alliance). 2021. Zero Waste Hierarchy of Highest and Best Use (online). n.p. Consulted on 1 Feb. 2021. Available at https://zwia.org/zwh/.