Diagnosis and political and strategic repositioning of Tropical Agriculture[1]

Exploring historical and natural barriers and pathways toward the transformation of tropical agriculture into a global development benchmark

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Abstract

Tropical agriculture faces the challenge of increasing food production and ensuring food security while grappling with natural and structural vulnerabilities, dependence on external inputs, and high susceptibility to climate change. This region possesses advantages such as high solar radiation, vast availability of land and water resources, and a strategic positioning in global food trade. Nevertheless, advancing this sector requires deepened and sustained investments that reconcile productivity and sustainability progress. This can be achieved through the strengthening of technological innovation adapted to local conditions, coupled with public and private initiatives aimed at enhancing access to credit, technology dissemination, investments, and inputs tailored to tropical characteristics. Successful models in Latin America and Asia, particularly in Brazil, have achieved significant productivity increases alongside conservationist practices, offering relevant lessons. However, strategic actions are still required to attain productive autonomy and international integration of tropical regions, particularly in Sub-Saharan Africa, which will be critical in meeting local and global demands—both present and future—amid rapid population growth in the intertropical zone.

1. INTRODUCTION

The tropical region, defined as the area between the Tropics of Cancer and Capricorn, encompasses countries that play a critical role in the global agri-food system while hosting a significant share of the planet's natural resources essential for food production, including approximately 40% of arable land and 52% of accessible water resources (World Bank, 2025; FAO, 2025). Despite this potential, significant disparities exist regarding productivity, largely due to structural, climatic, and institutional factors that have historically hindered the efficient utilization of resources, complicating the implementation of effective, regionally-adapted production models.

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As a consequence, food insecurity remains a critical regional challenge—this is particularly true in Sub-Saharan Africa (SSA), where low agricultural productivity levels are driven by climatic, technological, capital insufficiencies, inadequate farming practices, and historical legacies of colonialism and geographic isolation (Byerlee et al., 2002). These factors exacerbate socio-economic inequalities and intensify environmental impacts, perpetuating cycles of poverty in a region experiencing rapid population growth—the tropical zone is projected to host approximately 56% of the world population by 2050 (UN, 2025).

Despite these challenges, successful cases from tropical agricultural ecosystems offer valuable insights. For example, Brazil has emerged as a significant agricultural player in the tropical belt by incorporating technological innovations, scaling up productivity, and generating food surpluses (Chaddad, 2015; Vieira-Filho; Fishlow, 2017). Asian nations such as India, Vietnam, Indonesia, and Bangladesh have experienced meaningful agricultural productivity advancements following the Green Revolution, characterized by extensive technification of smallholder farms (Hazell, 2009). These models yield critical lessons, highlighting strategic pathways for the broader development of tropical agriculture. However, previous experiences also underscore that replication and scalability of such production models hinge on targeted actions to overcome region-specific barriers—whether historical, institutional, agroecological, or technological.

This study aims to critically assess the current state of tropical agriculture, identifying key challenges and opportunities, while evaluating potential development pathways. By adopting an evidence-based approach, it seeks to discuss matters involving the positioning of tropical regions as protagonists in the provision of sustainable, productive agriculture capable of meeting growing local and global food demands while supporting regional socioeconomic development.

2. METHODOLOGICAL APPROACH

This exploratory, descriptive study is grounded in a narrative review of scientific and technical literature, supported by data and document analysis. The analysis relied on secondary data sourced from academic publications, specialized agency reports, digital sources, and international databases such as UN, FAOSTAT, World Bank, UN Comtrade, and Global Forest Watch.

2.1. Objeto de análise e definição de “Agricultura Tropical”

Despite its widespread use, the term “tropical agriculture” does not possess a singular, universally accepted definition. Its origins trace back to the colonial era, when European powers shaped agricultural practices in Latin America and West Africa to support export-driven economies (Buelens et al., 2016). Over time, the concept has come to embody not only geographical and climatic conditions but also political and socio-economic dynamics. Ecologically speaking, the Food and Agriculture Organization of the United Nations (FAO) defines tropical agriculture based on characteristic agroclimatic conditions — high rainfall, low-fertility soils, humidity, and prevalence of pests and diseases — requiring highly adaptive production systems. The Tropical Agriculture Platform (TAP), an FAO-affiliated G20 initiative, characterizes tropical agriculture as practices predominantly occurring in low- and middle-income countries situated mainly between the latitudes of 23.5° N and 23.5° S (FAO, 2025).

In relation to climatic classification, the widely utilized _Köppen Climate Classification_ (Köppen, 1936) identifies tropical climates as regions characterized by humid tropical rainforests (high humidity and year-round evenly distributed rainfall), tropical monsoonal climates (intense seasonal rainfall), and tropical savannah climates (distinct wet and dry seasons). Generally, scientific literature associates tropical agriculture with regions exhibiting tropical climatic conditions.

For the purposes of this study, “tropical agriculture” is defined as agricultural activities undertaken in countries wholly or predominantly situated between the Tropics of Cancer (23.5°N) and Capricorn (23.5°S), as well as those whose territories predominantly feature tropical climates categorized under Köppen’s classification (1936). Physical and productive conditions were prioritized, omitting criteria based on income level or agricultural development status. The list of countries and regional groupings is presented in Box 1.

Box 1. List of countries classified as “Tropical”

América Latina:	**África (SSA):**		**Ásia-pacífico:**
Belize Bolivia Brazil Colombia Costa Rica Ecuador El Salvador Guatemala Guyana Honduras Haiti Nicaragua Panama Paraguay Peru Dominican Republic Suriname Venezuela	Angola Benin Burundi Cameroon Côte d’Ivoire Ethiopia Gabon Ghana Guinea Liberia Madagascar Malawi Mozambique Nigeria Kenya	Democratic Republic of the Congo Central African Republic Republic of the Congo Rwanda Sierra Leone Somalia South Sudan Tanzania Togo Uganda Zambia Zimbabwe	Bangladesh Cambodia India Indonesia Philippines Thailand Laos Malaysia Myanmar Vietnam Timor-Leste Papua New Guinea Fiji Vanuatu Solomon Islands

Source: Author’s.

3. PRODUCTION, PRODUCTIVITY, AND AGRICULTURAL DEVELOPMENT

The “Green Revolution,” initiated in the mid-20th century, marked a turning point in agricultural productivity, particularly in regions such as the Asia-Pacific and Latin America. This movement expanded food supply for domestic consumption and enabled the production of export surpluses, with Brazil becoming a notable example (Hazell, 2009; Ameen; Raza, 2017). The process originated in the 1940s as part of the Marshall Plan initiatives led by the United States and the United Nations to address post-war Europe (Barros, 2022). Subsequently, its dissemination to developing countries was facilitated by partnerships between public and private sectors and was reinforced by the 1967 conference "The World Food Problem: Private Investment and Government Cooperation ," which emphasized governmental cooperation and private investment in combating food insecurity (Edens, 2021; Barros, 2022).

Collaboration between U.S. entities, universities, and local agricultural technology organizations, such as Embrapa in Brazil, played a central role in intensifying land use and expanding agro-livestock productivity (USAID, 2016; Barros, 2022). These advancements countered fears of a "Malthusian" perspective prevalent in the 1950s, which predicted food shortages due to global population growth. Between 1950 and 2000, global cereal production tripled while cultivated land area increased by only 30%, and the global population doubled (Pingali, 2012).

In SSA, however, the effects of the Green Revolution were significantly more limited. Although grain production has grown since the 2000s, levels remain far below those observed in other regions. Tables 1 and 2 illustrate these disparities, presenting the evolution of production volumes for selected cereals (wheat, rice, maize, and soybeans) and animal protein in tropical countries compared to global figures.

Table 1. Evolution of Production of selected grains and cereals* in tonnes

	1974	1980	1990	2000	2010	2024	CAGR (% a.a.)
World (total)	924.9	1195.4	1,526.2	1,749.5	2,215.9	2,988.7	2.2%
Asia-Pacific	124.6	169.1	234.3	308.1	368.9	500.8	2.5%
Latin America (total)	31.0	55.0	62.0	107.9	177.1	357.0	4.6%
Latin America (ex. Brazil)	*7.05*	*8.7*	*12.2*	*18.3*	*29.2*	*39.9*	*3.5%*
Brazil	*24.0*	*46.3*	*50.2*	*89.6*	*147.9*	*317.1*	*4.7%*
Africa	15.0	18.9	28.4	34.5	58.1	92.8	3.7%
ROW	754.3	952.5	1201.6	1,299.0	1,611.9	2,038.1	1.9%

Source: Insper Agro Global based on USDA (2025). *Note: The selected grains and cereals refer to the production of soybeans, maize, wheat, and rice, which accounted for 89.5% of the daily per capita caloric intake from cereals and oilseeds worldwide in 2022, according to FAO data (2025b).

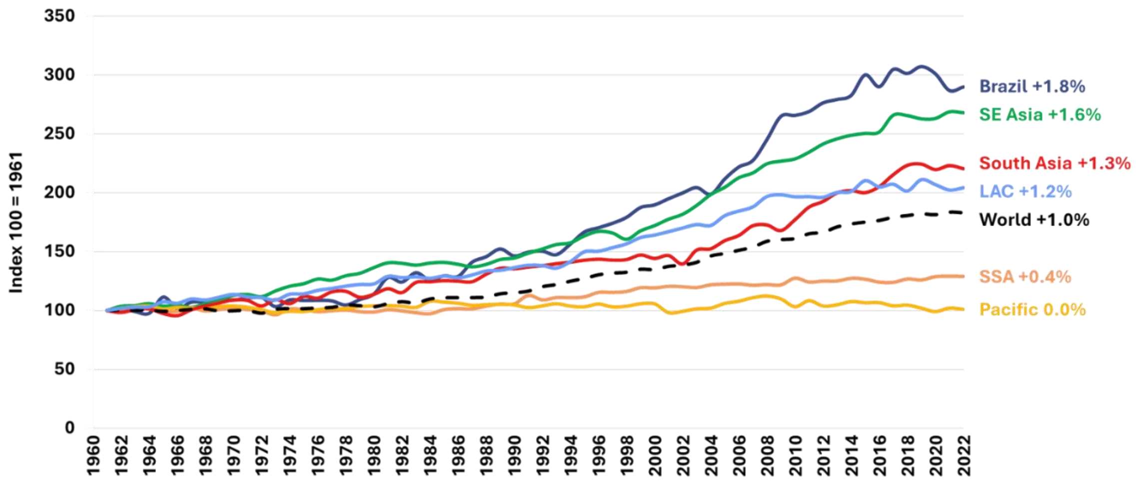
Table 2. Evolution of Meat* production in tonnes

	1974	1980	1990	2000	2010	2024	CAGR (% a.a.)
World (total)	87.2	115.2	151.0	192.2	239.0	281.8	2.4%
Latin America (total)	4.9	8.4	10.9	17.9	29.2	37.9	4.2%
Latin America (ex. Brazil)	*1.5*	*2.9*	*2.5*	*3.4*	*4.4*	*6.5*	*3.0%*
Brazil	*3.4*	*5.5*	*8.4*	*14.5*	*24.8*	*31.4*	*4.6%*
Asia-Pacific	1.4	1.9	4.6	8.4	14.4	17.8	5.2%
Africa	0.0	0.0	0.0	0.1	0.1	0.3	4.4%
ROW	77.8	98.0	128.3	165.7	195.3	225.8	2.2%

Source: Insper Agro Global based on USDA (2025). *Note: Meat refers to total production of beef, chicken, and pork.

The limited reach of the Green Revolution in SSA is highlighted by the relative stagnation of total factor productivity (TFP) in agriculture—used in this study as a reference for broader relative productivity trends—since the 1960s. Meanwhile, Latin America and Asia have shown productivity indices well above the global average, with Brazil leading this progress (Figure 1). This phenomenon is critical to the low per capita food availability in SSA, contributing to the perpetuation of poverty and malnutrition scenarios.

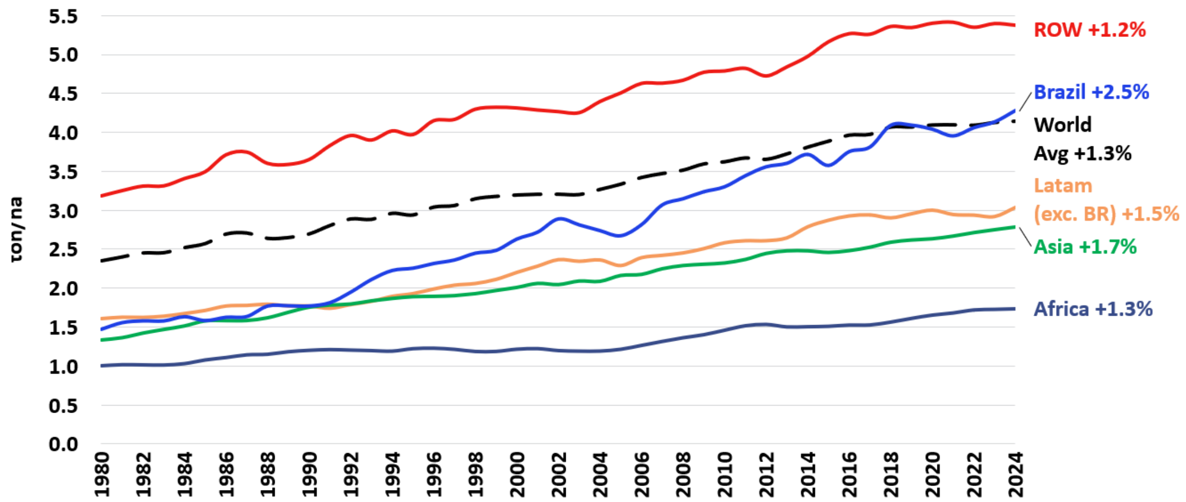
Figure 1. Agricultural Total Factor Productivity (TFP) index across Selected Regions*



Source: Insper Agro Global based on USDA ERS data (2025).*Note: Selected regions approximate tropical regions, adhering to USDA classifications. However, each region may include some countries not considered within the “Tropical Agriculture” classification adopted in this study due to methodological classification differences.

The advancement of agricultural productivity post-Green Revolution was driven by the adoption of modern technologies, such as improved seeds, fertilizers, chemical pesticides, and irrigation systems (Hazell, 2009; Ameen; Raza, 2017). In Latin America and Asia, the success in agricultural growth is attributed to public policies that promoted research, infrastructure development, technical assistance, financing, and even market guarantees (Pingali, 2012). In SSA, however, progress has been delayed and inconsistent, with structural and governance challenges undermining the implementation of continuous and effective agricultural policies (Poulton; Kydd; Dorward, 2006). Figure 2 illustrates this historical evolution, showing that the aggregated productivity of selected grains (maize, rice, wheat, and soybeans) in the region has yet to reach levels comparable to temperate-region countries. Only Brazil has achieved results above the global average (Figure 2).

Figure 2. Aggregated agricultural productivity of selected grains and oilseeds*, by regions and countries.



Source: Insper Agro Global based on USDA data (2025). *Note: Grains include only rice, soybeans, and maize.

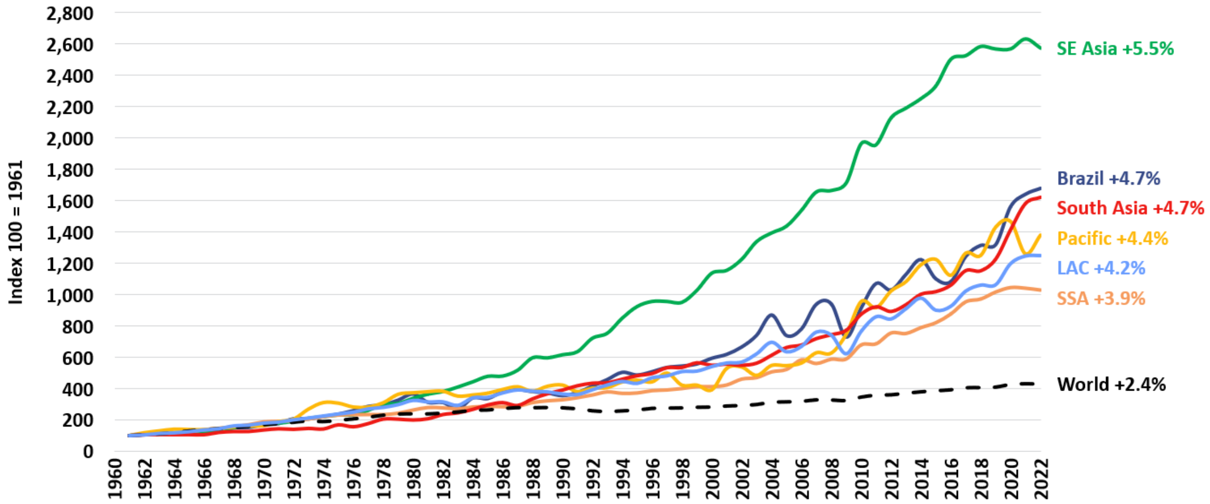
The limited research infrastructure in SSA is one of the primary barriers. For instance, while the U.S. operates approximately 134 research stations per 100,000 farmers, Kenya, Ghana, and Malawi only operate 0.22, 0.28, and 0.34, respectively (Beintema; Stads, 2017). This underfunding, coupled with high professional turnover and weak extension services, hinders agricultural progress. Strategies such as participatory research and decentralization emerge as potential solutions to adapt technologies to local realities (World Bank, 2008).

Adapting technologies and crops such as wheat, maize, rice, and soybeans to local specificities was critical for Asia and Latin America (Hazell, 2009; Pingali, 2012; Vieira-Filho; Fishlow, 2017). However, in SSA, agricultural technologies often disregarded local conditions, following standardized recommendations, such as the generic application of fertilizers without accounting for soil characteristics (Jayne and Rashid, 2013). For instance, in northern Ghana, the commonly adopted maize variety was initially adapted for South African conditions, illustrating the mismatch between technology and local specificity (Van Asselt et al., 2020). This disconnect is further exacerbated by soil variability, humidity, climate change, poor infrastructure, and policy inconsistencies in some countries (Byerlee et al., 2022).

Regarding input usage, the increase mostly occurred through imports since the “pre-gate” segment of the region’s agribusiness has not kept pace with production demands, deepening international dependency. Between 2000 and 2024, average annual growth rates of fertilizer imports in SSA, Asia, and Latin America significantly surpassed the global average (12.4%, 7.2%, and 6.5%, respectively, compared to 4.4% globally) (TDM, 2025). As a result, input costs and their volatility, particularly fertilizers, have become major obstacles: imports account for over 60% of demand in SSA, with prices reaching up to double those in developed countries (IFDC, 2016).

Poor logistical infrastructure intensifies these challenges, raising costs and limiting connectivity between farmers and markets, further reinforcing local development difficulties and the reliance on imported final food products (FAO, 2015; Sheahan; Barrett, 2017). The evolution of input usage by region is illustrated in Figure 3, highlighting SSA's greater lag compared to other tropical regions.

Figure 3. Evolution of Input Index (Fertilizers and Feed) by region, 1961–2022, base 100 = 1961



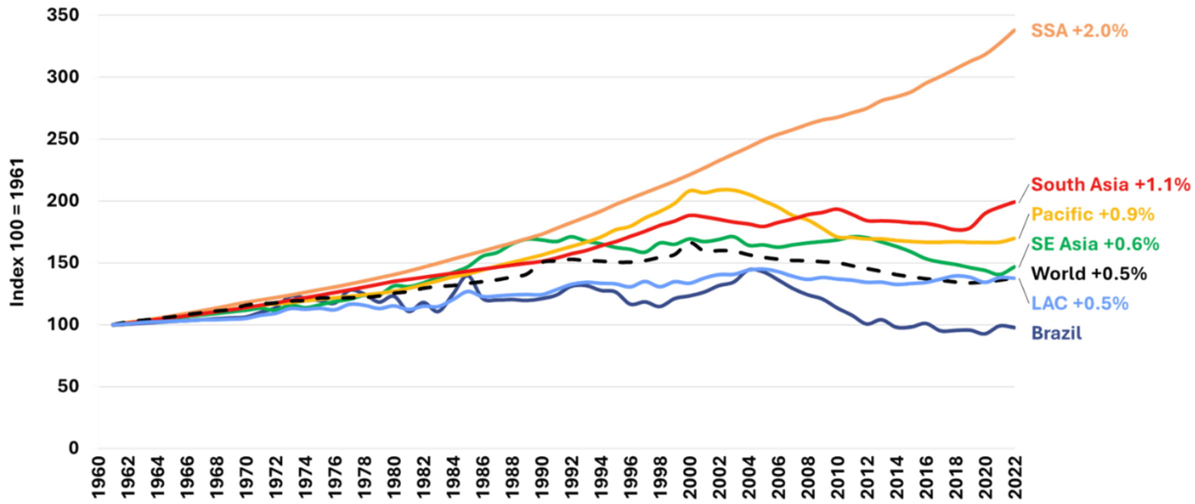
Source: Prepared by Insper Agro Global based on USDA ERS data (2025). *Note: Index based on the use of fertilizers (NPK) and animal feed, with base 100 = 1961

Additionally, access to irrigation remains insufficient, with only 6% of arable land in SSA being irrigated, compared to 37% in Asia (FAO, 2020). Promising technologies, such as drip irrigation and solar-powered systems, have shown potential but still face implementation challenges and financial constraints for investment (You et al., 2011).

Thus, while the Green Revolution spurred significant advancements, it also revealed limitations in the replicability of models, particularly in SSA. Achieving sustained agricultural productivity growth depends on adopting long-term strategies tailored to local specificities, which have largely been absent in the region.

Regarding labor intensity, there has been a decline in demand for agricultural workers in countries with more advanced production systems (Figure 4). Despite developmental model differences—such as Brazil's predominance of large-scale, highly mechanized farms with a focus on a few crops, versus Asia's prevalence of family-run smallholder farms—reduced labor intensity in agriculture is a common trend. This reflects a substitution of labor with capital through mechanization and the adoption of advanced technologies (Garcia, 2014). However, this trend is less evident in SSA, underscoring the region's limitations in scaling agricultural technologies.

Figure 4. Agricultural labor – index of economically active adults primarily employed in agriculture*



Source: Insper Agro Global based on USDA data (2025).

The modernization process not only transforms the productive dynamics of the agricultural sector but also reinforces the dominance of capital-intensive agricultural systems. This shift encourages productive specialization in activities that are often less labor-intensive, consequently excluding producers who fail to adopt emerging technological standards (Garcia, 2014; Blanco & Raurich, 2022). This dynamic is also linked to the advancement of urbanization processes in many of these regions, although disparities remain more pronounced in SSA.

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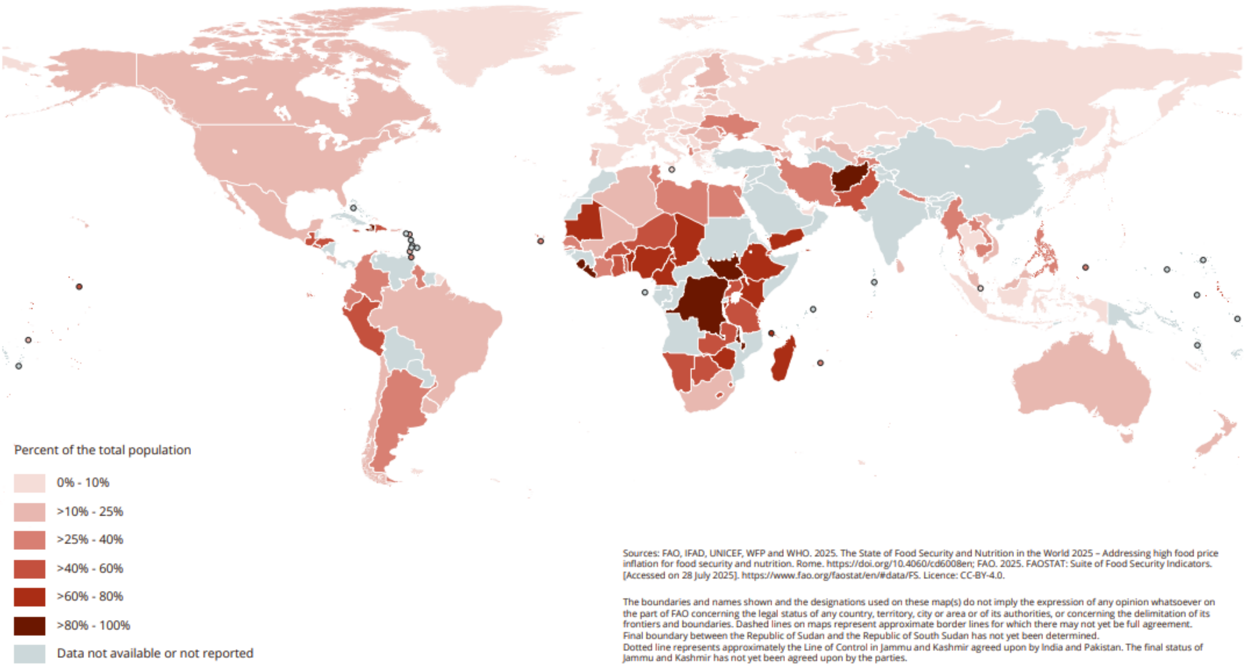
4. FOOD SECURITY AND THE RELATIONSHIP BETWEEN FOOD PRODUCTION, CONSUMPTION, AND GLOBAL TRADE

Food security is commonly discussed in the scientific literature under four essential dimensions: availability, access, utilization, and stability (FAO, 2006; Rodriguez-Sáenz et al., 2021). Figure 5 illustrates the prevalence of food insecurity, based on FAO data (2025b). The map highlights that the tropical belt of the globe concentrates the majority of the population experiencing food insecurity.

When analyzing food availability, malnutrition—defined by FAO (2025b) as insufficient energy (caloric) intake, without accounting for dietary quality or diversity—is widely considered a benchmark indicator. These rates vary significantly between and within regions (Figures 5 and 6). SSA exhibits the highest rates, with countries such as Kenya recording over 30% of their population in malnourished conditions.

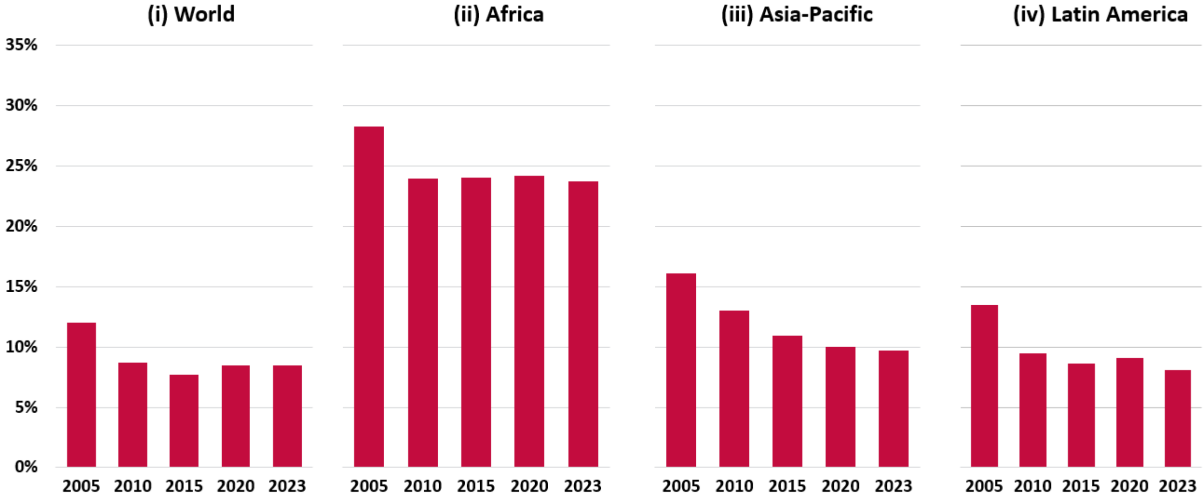
In Asia, although high regional production positively impacts food availability, challenges persist in densely populated countries like India, which still face high malnutrition rates despite substantial production levels. Conversely, Latin America demonstrates a more favorable situation, with malnutrition prevalence averaging below the global rate in 2023. However, significant inequalities still persist across the region.

Figura 5. Prevalence of Moderate or Severe Food Insecurity by Country (3-Year Average, 2022–2024)



Source: FAO (2025b)

Figure 6. Prevalence of Undernourishment (severe) in tropical regions, 2005–2023



Source: Prepared by Insper Agro Global based on FAOSTAT data (2025). Note: The indicator represents the probability of a randomly selected individual from the population consuming an insufficient caloric amount to meet their energy needs for an active and healthy life..

Food insecurity arises from a complex interaction of factors related to population access to food. Since the 1960s, undernourishment in tropical regions has significantly declined, approaching global averages, driven by greater availability of basic foodstuffs at lower prices.

In Asia, countries like India and Bangladesh exemplify this trend, where falling prices of staple foods, such as rice, have allowed resources to be redirected toward more nutritious foods and improved dietary diversity, despite ongoing challenges in these densely populated and inequality (Torlesse et al., 2003; Johnson et al., 2024).

In Brazil, studies such as Alves et al. (2010) show that technological progress and agricultural productivity gains have led to an average annual 3% reduction in real food basket prices since 1970. This price decline, combined with income growth, is directly linked to the lower incidence of malnutrition in Latin America. The increased domestic availability of food has also been accompanied by the production of large surpluses in grains and meats, reducing import dependency, boosting exports, and generating more income in rural areas, particularly in Brazil (Table 3).

The Asia-Pacific region has similarly achieved significant improvements in agricultural production, more effectively meeting internal demands. In contrast, SSA faces consumption growth that surpasses its production capacity.

Table 3. Production, consumption, import, and export of grains and meats[1] (in million tonnes), 1974 and 2024

Grains

(i) 1974

	Produção	Consumo	Importação	Exportação
Asia-Pacific	124.6	137,70	8,6	2,4
Latin America	31.0	34,51	5,1	4,0
Brazil	*24.0*	*24,74*	*2,4*	*3,8*
Africa	15.0	16,69	1,7	0,6

(ii) 2024

	Produção	Consumo	Importação	Exportação
Asia-Pacific	500.8	529,98	59,01	4,6
Latin America	357.0	227,95	31,25	172,0
Brazil	*317.1*	*171,40*	*5,74*	*160,9*
Africa	92.8	129,43	17,00	1,75

Meat

(iii) 1974

	Produção	Consumo	Importação	Exportação
Asia-Pacific	1,44	1,44	0,17	0,01
Latin America	4,87	4,72	0,63	0,12
Brazil	*3,36*	*3,31*	0,05	0,02
Africa	0,03	0,04	0,03	0,05

(iv) 2024

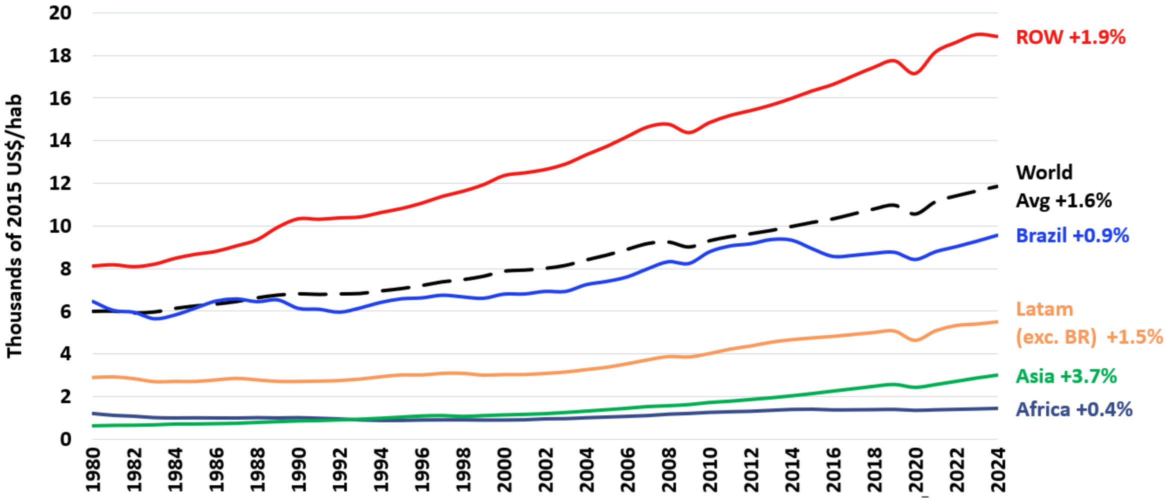
	Produção	Consumo	Importação	Exportação
Asia-Pacific	17,83	17,39	2,05	1,2
Latin America	37,91	27,89	0,85	8,7
Brazil	*31,35*	*21,35*	0,04	8,1
Africa	0,26	1,42	1,43	0,01

Source: Insper Agro Global based on USDA and FAO data. *Note: Grains include rice, maize, wheat, and soybeans; Meats include beef, pork, and chicken.

Income levels are a critical factor in food security. Higher incomes enable families to access diverse and nutritious diets while providing economic stability and resilience. Empirical studies in the scientific literature highlight a positive relationship between agricultural productivity growth and poverty reduction, showing more significant impacts than investments in other economic sectors (Thirtle et al., 2003). On the production side, farmers with more resources have greater capacity to invest in sustainable technologies and agricultural practices, thereby improving their productivity.

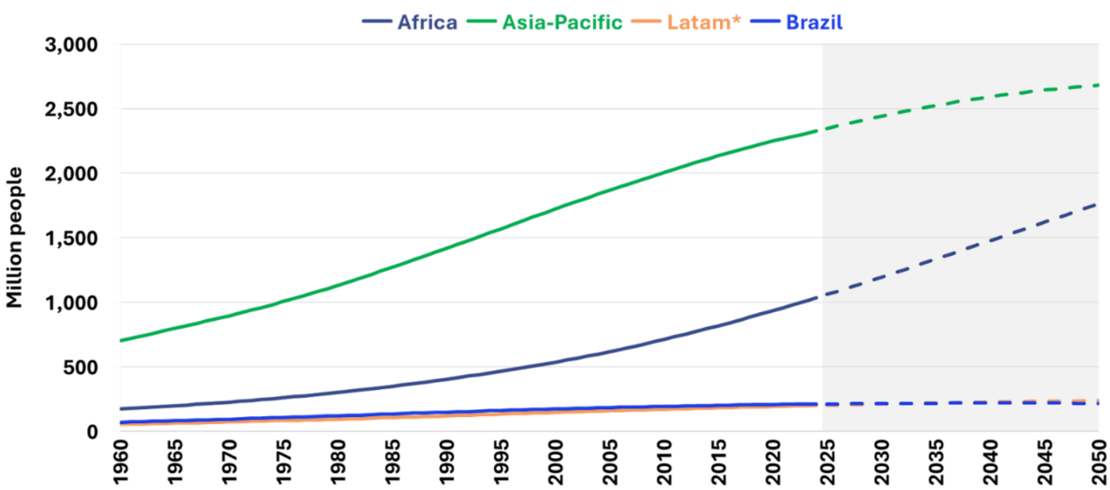
The relationship between income and malnutrition is clear: higher per capita income levels correlate with lower malnutrition prevalence. Figure 7 depicts the evolution of per capita income in tropical and global countries from 1980 to 2024, highlighting the low income levels of the Asia-Pacific and Africa regions. Furthermore, Figure 8 shows that these regions are projected to experience the highest population growth, making this relationship even more concerning.

Figure 7. Per capita income by region (in thousand US$/capita, in 2015 US$)



Fonte: Insper Agro Global based on World Bank (2025).

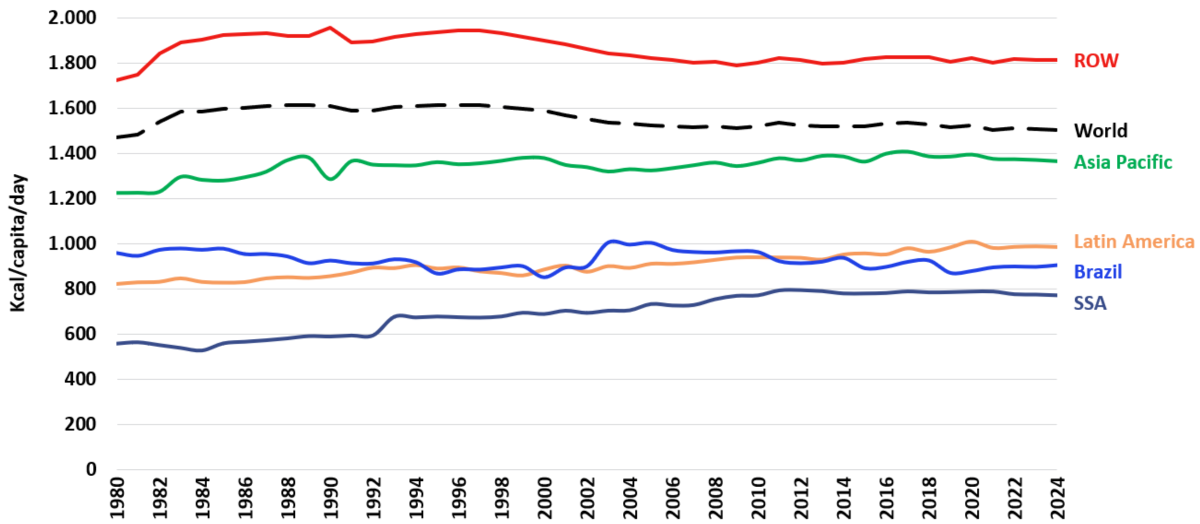
Figure 8. Population growth and projection in tropical regions, 1960–2050 (in millions of people)



Source: Insper Agro Global based on ONU (2024)

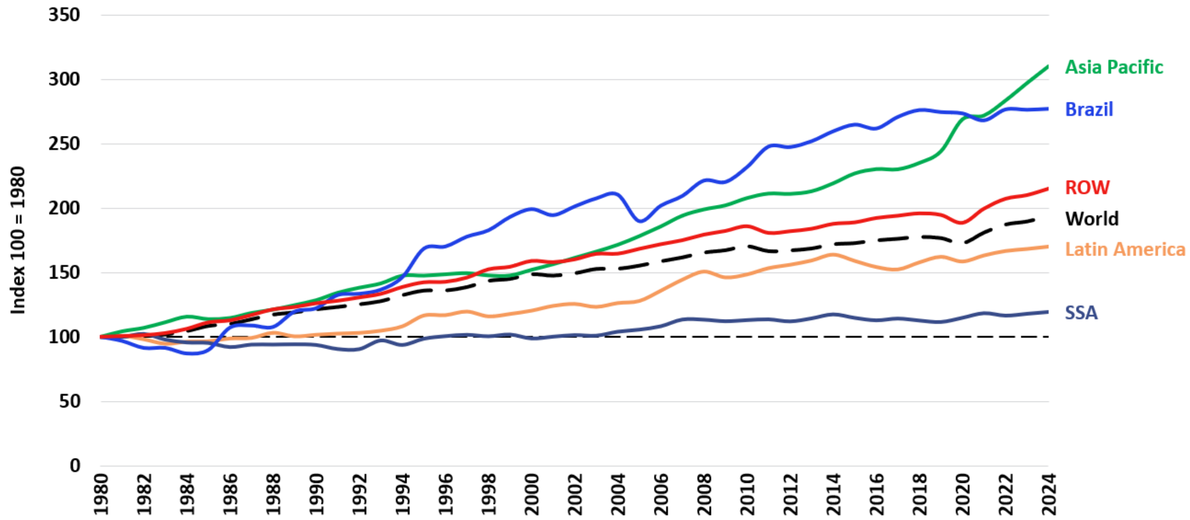
Regarding dietary diversity, higher-income countries exhibit a greater share of meat consumption, while lower-income countries predominantly rely on plant-based sources (Figures 9, 10, and 11). This dietary transition is also linked to production growth and availability, as evaluated in Table 3 and Figure 11.

FIgure 9. Per capita consumption of selected grains by region, 1980–2020 (in Kcal/Capita/Day)



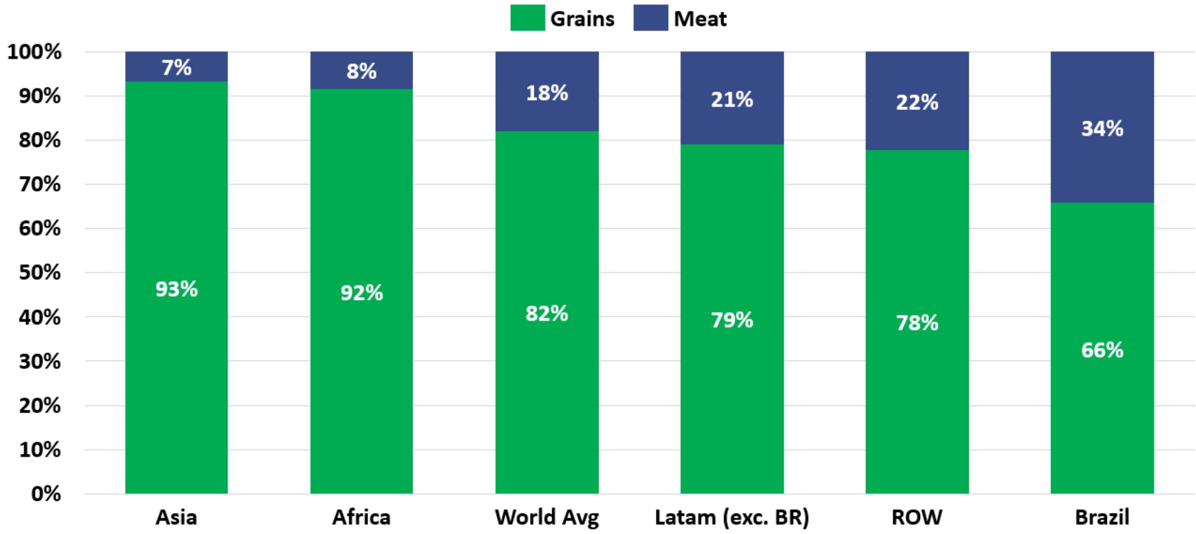
Source: Insper Agro Global based on USDA data (2025). Note: (1) Latin America excluding Brazil. (2) Grains include soybeans, maize, rice, and wheat..

Figure 10. Per capita meat consumption in tropical regions, 1980–2020 (in Kcal/Capita/Day)



Source: Insper Agro Global based on USDA data (2025). *Note: (1) Latin America excluding Brazil. (2) Meat includes all animal meats as well as fish..

Figure 11. relative internal availability in the ratio of caloric consumption between meat and grains, based on daily per capita food consumption by food group and region, 2024



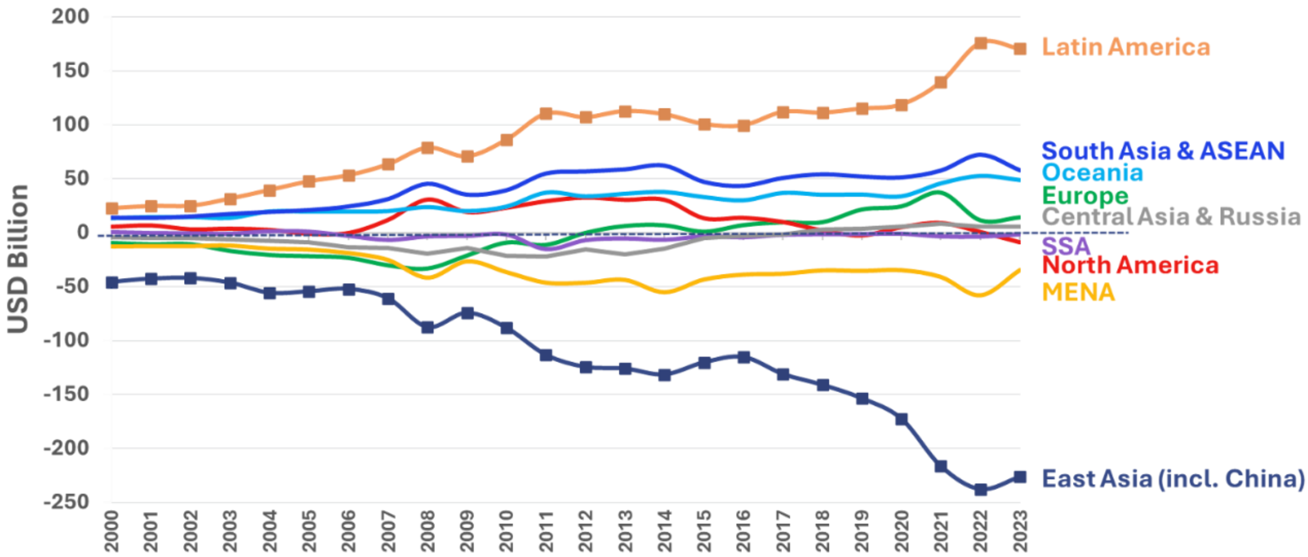
Source: Insper Agro Global based on FAO (2025).

Political instability, economic crises, and extreme climatic events are uncontrollable factors that exacerbate food vulnerability. Economic crises and disruptions in supply chains, particularly in the aftermath of the COVID-19 pandemic, have raised food production and transportation costs. Meanwhile, soaring prices for agricultural inputs like fertilizers and fuels have limited farmers' ability to sustain production (Arias et al., 2024). Concurrently, extreme climatic events such as droughts, floods, and hurricanes have severely impacted agricultural production since 2020, destroying crops, infrastructure, and increasing the vulnerability of affected communities. These data emphasize the importance of policies that promote food production and climate adaptation, combined with inclusive economic growth and rising income levels as critical strategies to improve food security and mitigate global malnutrition risks.

The role of international trade in ensuring food security is particularly noteworthy. Trade connects agri-food systems, transferring surpluses from regions with food excesses to those in deficit, promoting positive distributive effects by reducing food prices and enhancing production efficiency (Arias et al., 2024). Latin America, with Brazil as a standout, has solidified its position as a pivotal player in promoting global food security, driven not only by its production capacity but also its contributions to price stability, global food availability, and its capabilities in research and development (Díaz-Bonilla et al., 2024).

Figure 12 shows, in billions of current dollars, the food trade balance across selected regions, including tropical countries analyzed in this study. .

Figure 12. Evolution of global food trade balance by region, 2000–2023 (in Billions of Current Dollars)



Source: Insper Agro Global based on UN Comtrade and Trade Data Monitor data (2024). Note: SSA: Subsaharan-Africa; ECA: Europe and Central Asia; MENA: Middle East and North Africa.

5. ENVIRONMENTAL FACTORS AND CLIMATE RISKS

Beyond ensuring food security, the development of agricultural production now requires optimizing the use of natural resources within the context of increasing pressure from climate change. While the Green Revolution in the past emphasized productivity gains and reduced food costs, the contemporary scenario is defined by global climate risks that pose more complex challenges: maintaining competitiveness and food supply, mitigating environmental impacts, and adapting production to new climatic conditions..

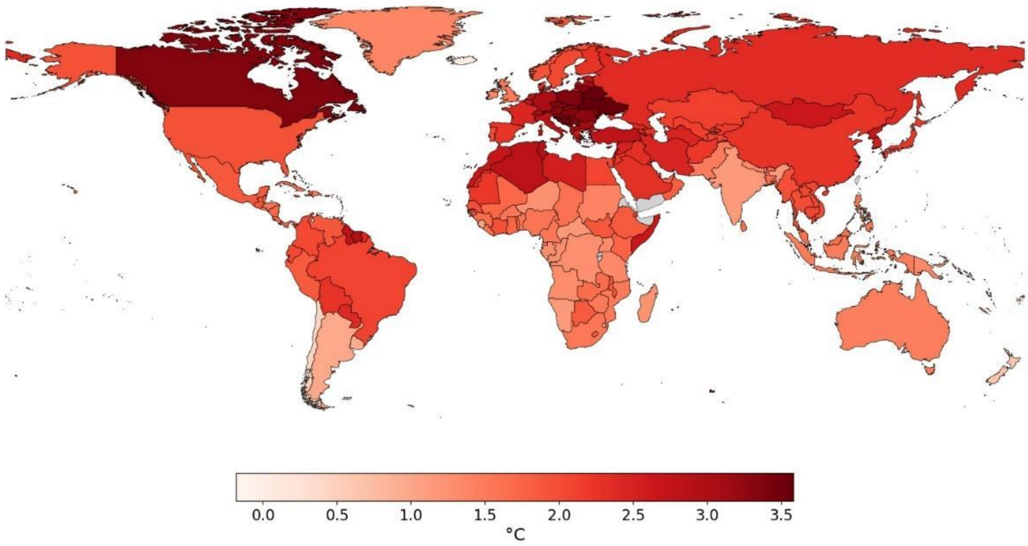
Global warming, the primary driver of climate change, is already a measurable reality. According to FAO data (2025a), tropical countries have experienced an average temperature increase of 1.7°C between 1961 and 2024 compared to the reference period of 1951–1980, with regional variations reaching up to 3.0°C (Suriname).

Brazil ranks as the sixth country with the highest temperature rise, registering an increase of 2.1°C during the analyzed period — the same as the global average in 2024, when the Earth's surface temperature reached 2.1°C above the historical baseline. This outcome confirms the trend of accelerated warming, surpassing the 1.5°C limit set by the Paris Agreement across nearly all regions, except Oceania (1.4°C) — as illustrated in Figure 13.

The rise in average temperatures in tropical regions directly impacts agriculture and aquaculture, affecting both crops and aquatic ecosystems. Even heat-adapted species, such as maize, sorghum, and millet, experience productivity declines when thermal limits are exceeded. For instance, millet yields are estimated to decrease by around 6% by the end of the century in African countries and India, with heat identified as the primary driver of this reduction (Berg et al., 2013).

In aquatic systems, warming reduces dissolved oxygen levels in rivers, jeopardizing irrigation and aquaculture. Oxygen levels near or below 3 mg/L impair growth, reproduction, and survival of species, necessitating greater use of management technologies, such as artificial aeration (Bello et al., 2017).

Figure 13. increase in annual average temperature in tropical countries – 2024 (compared to historical average of 1951–1980)



Source: Insper Agro Global based on FAO (2025a)

Water resources are critical for tropical agriculture, as tropical countries hold 22,360.7 billion m³ of renewable water resources, equivalent to 52% of the global total of 42,808.6 billion m³, according to FAO - AQUASTAT estimates (2025). This volume underscores the importance of tropical regions for global water security, even though their distribution is highly uneven across countries (Table 4).

Latin America stands out as the tropical region with the highest absolute availability, totaling 12,060.6 billion m³—roughly 28% of the world's freshwater resources. Brazil alone accounts for 5,661 billion m³, nearly half of the regional supply and 13% of the global total. The Asia-Pacific region ranks second, with 7,418.9 billion m³ (17% of the world). In contrast, Africa, despite comprising countries heavily reliant on rainfed agriculture, has only 2,881.2 billion m³, or 7% of the world's freshwater resources.

Table 4. Water resources by regions (in billion m³, 2022)

Region	Water Resources	Share in the World
Latin America (total)	12,060.6	28%
Latin America (exc. Brazil)	*6,399.6*	*15%*
Brazil	*5,661.0*	*13%*
SSA	2,881.2	7%
Asia-Pacific	7,418.9	17%
Tropical Countries	**22,360.7**	**52%**
ROW	**20,447.9**	**48%**
World	**42,808.6**	**100%**

Source: Insper Agro Global based on FAO - AQUASTAT (2025)

The limited availability of water significantly impacts agricultural productivity and sustainability in tropical African countries. Projections suggest that climate change may reduce precipitation and increase temperatures in southern Africa, potentially decreasing agricultural productivity by 15% to 50% (Nhemachena et al., 2020). Investments in water management for agriculture can reduce poverty by increasing productivity, expanding cultivated areas, and stabilizing incomes (Hanjra & Gichuki, 2008). However, institutional and resource constraints have hindered the implementation of national agricultural investment plans (Nhemachena et al., 2018). Improving water use efficiency is critical, particularly in rainfed agriculture, to respond to rising food demand amid climate change (Malmquist, 2018).

Another key feature of tropical agriculture aside from the abundant water supply is the prevalence of arable land. This factor is central to understanding both the potential for agricultural expansion and the pressures exerted on the region's natural ecosystems. According to World Bank data (2025), between 1961 and 2021, the global area of arable land increased from 1,020.13 to 1,395.96 million hectares—a 27% growth. Latin America more than doubled its cultivable area over this period, rising from 40.08 to 83.12 million hectares, reflecting rapid agricultural frontier expansion. Brazil particularly stood out, increasing its arable land from 23.63 to 58.25 million hectares—a relative growth of 59%, the highest among the countries analyzed (Table 5).

This proportionally faster expansion in tropical countries compared to other regions highlights the agricultural dynamism of the tropics. However, risks are compounded when productive land expansion is paired with low intensity and limited modernization in many developing tropical countries (Barbier, 2004). Without technical planning, expansion into deforested areas leads to biodiversity loss, soil degradation, climate changes, and threats to future productivity (Gomiero, 2016).

Table 5. Arable land availability by region

Region	1961	2021	Growth
	(Millions of hectares)		(1961/2021)
World	**1,020.13**	**1,395.96**	**27%**
Latin America	40.08	83.12	52%
Latin America (exc. Brazil)	16.45	24.87	34%
Brazil	23.63	58.25	59%
Asia-Pacific	217.65	236.11	8%
SSA	85.39	152.64	44%
ROW	677.01	924.09	27%

Source: Insper Agro Global based on Word Bank (2025)

Tropical soils, in general, exhibit low fertility and high susceptibility to degradation due to climatic conditions (Sousa et al., 2018). Moreover, the combination of fragile soils and warm climates promotes the proliferation of pests, necessitating constant integrated management (Gonçalves, 2021). In this context, deforestation combined with inadequate land management has the potential to accelerate the deterioration of key resources, such as soil fertility, water availability, and alterations in local climatic patterns (Rivero et al., 2009). Between 2001 and 2024, it is estimated that tropical agricultural countries have lost approximately 241.5 million hectares of forests, according to Global Forest Watch (2025) – Table 6.

Latin America experienced the highest loss, totaling 110.7 million hectares, corresponding to nearly half of the deforestation observed in tropical countries. Brazil alone accounted for 73.3 million hectares, equivalent to about two-thirds of Latin American losses and nearly one-third of the global total. In Africa, deforestation reached 63.3 million hectares. The Democratic Republic of the Congo accounted for over 21 million hectares, representing one-third of the continent's deforestation. In Asia, 67.5 million hectares of forests were lost. Indonesia led this process, with 31.9 million hectares, nearly half of the native vegetation loss in Asia.

Table 6. Cumulative deforestation, by region, in hectares, from 2001 to 2024

Regions	Accumulated deforestation 2001 - 2024	Share (%)
Latin America (exc. Brazil)	37,425,234	7%
Brazil	73,317,081	14%
Africa	63,331,831	12%
Asia-Pacific	67,480,745	13%
Tropical Countries	**241,554,891**	**47%**
Rest of the World	**274,876,863**	**53%**

Fonte: Elaborado pelo Insper Agro Global com base nos dados da Global Forest Watch (2025)

In Latin America, agroforestry systems, such as live fences and silvopastoral systems, provide multiple benefits alongside high production, including soil conservation and increased productivity (Budowski; Russo, 1993; Montes-Londoño, 2017). Simultaneously, biotechnology has enabled the development of crops resilient to both biotic and abiotic stresses (Cockcroft et al., 2004). However, the broader adoption of these practices requires overcoming socioeconomic barriers, adapting techniques to local conditions, and integrating traditional knowledge with new technologies (Picado, 2024).

In Asia and the Pacific, agroforestry systems, nutrient management, and erosion control have yielded positive results, particularly in coffee-growing areas (Kiup et al., 2025). Laser land leveling, which involves achieving a uniform soil surface to enhance water-use efficiency, has proven effective in sustainable rice cultivation, reducing emissions while boosting yields (Nguyen-Van-Hung et al., 2022). Additionally, Low External Input Sustainable Agriculture (LEISA), which emphasizes ecological management practices and minimization of external input use, has emerged as a viable alternative for resource-limited farmers (Thanh, 2011).

In Sub-Saharan Africa (SSA), strategies such as crop rotation, intercropping, conservation agriculture, agroforestry systems, and fertilizer microdosing have also been implemented (Kuyah et al., 2021; Sithole & Olorunfemi, 2024). These practices have contributed to improved soil fertility, enhanced productivity, and greater climate resilience. However, their adoption remains constrained by factors such as land tenure insecurity, limited technical support, and restricted access to credit and agricultural inputs (Sithole; Olorunfemi, 2024). The need for increased use of fertilizers and pesticides also persists to achieve significant productivity gains, given the typical challenges of tropical soils (Gowing; Palmer, 2008).

The adoption of sustainable and regenerative agricultural practices in tropical countries is not merely a response to climate and soil challenges—it represents a strategic opportunity to align productivity with conservation. These initiatives should be regarded as cornerstones of a developmental model capable of addressing climate risks and ensuring food security.

6. DISCUSSION AND RECOMMENDATIONS

Tropical agriculture faces the dual challenge of expanding food production and ensuring food security while navigating specific physical and climatic conditions and global pressures for sustainability. On one hand, it offers advantages such as high solar radiation, crop diversity, relative availability of land and water resources, the potential for adopting integrated production systems, and a strategic position in international trade. On the other hand, it deals with challenges such as low-fertility soils and higher pest and disease incidence, which make the region heavily reliant on significant quantities of inputs, the majority of which are under external technological and productive control. Furthermore, the progression of deforestation (notably throughout the 20th century) and unequal access to efficient technologies increase the vulnerability of tropical agriculture to climate change (see Box 2).

Box 2. Strengths and Weaknesses of Tropical Agriculture

	Strengths	**Weaknesses**
Environmental Issues	Solar radiation and rainfall enabling multiple harvests; biological diversity; potential for system integration and greater adoption of regenerative practices; relative abundance of land and water resources.	Pests, diseases, and soil degradation; loss of biodiversity; deforestation and water scarcity in certain regions.
Adaptation and Innovation	Experience in integrated adaptive systems, such as crop-livestock-forest integration and agroforestry, as well as regenerative practices.	Limited technological dissemination; restricted access to credit and inputs, particularly for small-scale farmers.
International Integration	Relevance in the global trade of agricultural commodities.	Vulnerability to trade barriers; strict sanitary and environmental standards; and technological and productive dependence on imported inputs.

Source: Authors

Considering the diagnosis provided, it is possible to advance a set of recommendations to strengthen the productivity and sustainability of tropical agriculture. The heterogeneity among tropical countries—in terms of natural conditions, institutional capacities, and development levels—demands that strategies be tailored to local realities while being articulated around common axes. In this sense, three central fronts stand out: environment, adaptation and innovation, and international integration.

In the environmental axis, the priority should be effectively integrating conservation and productive efficiency, not merely as rhetoric but as a structuring criterion for tropical agricultural models. This requires robust programs for recovering degraded areas, supported by clear productivity goals per hectare, and territorial planning mechanisms to discourage agricultural frontier expansion into sensitive areas. To scale these initiatives, it is essential to mobilize innovative financial instruments, particularly blended finance, which combines public, private, and philanthropic capital. Initiatives like Eco Invest in Brazil, aimed at pasture recovery, demonstrate how such approaches can be replicated and adapted, reducing dependence on resources from non-tropical economies and strengthening the financial autonomy of the region.

In the adaptation and innovation axis, the agenda should prioritize investments in science and technology tailored to tropical conditions, focusing on developing crop varieties resistant to water and biological stress, low-carbon systems, efficient input management, and regenerative practices. However, knowledge generation only translates into impact when supported by a robust rural extension network capable of transferring these practices to farmers, particularly small-scale producers who form the backbone of production in many tropical countries. This process must be accompanied by institutional innovation through public policies that ensure differentiated credit, climate-based agricultural insurance, and incentives for cooperative arrangements, thereby expanding access to technology and reducing regional inequalities. Furthermore, strengthening networks of cooperation among tropical research institutions—such as Embrapa, the Indian Council of Agricultural Research (ICAR), the Indonesian Agency for Agricultural Research and Development (IAARD), and the Kenya Agricultural & Livestock Research Organization (KALRO)—can create an ecosystem of shared innovation, accelerating endogenous solutions and reducing dependence on technologies developed in temperate-climate countries.

Finally, in the international integration axis, tropical agricultural countries must increase their connectivity in the global food trade. By reducing tariff and non-tariff barriers, this integration could improve trade flows connecting surplus regions, like Latin America, to deficit areas, primarily Africa, promoting food security and joint development.

7. FINAL CONSIDERATIONS

Tropical agriculture is characterized by abundant natural resources and occupies a strategic position for global food security. However, it faces structural, institutional, and environmental limitations. In Latin America and Asia, these barriers have been transformed into development levers through sustained investment in research, extension, and innovation tailored to tropical conditions, combined with consistent public policies and suitable financing tools. This scenario contrasts with Sub-Saharan Africa, where low productivity levels persist.

The future of tropical agriculture can benefit from greater integration among countries in the region. The exchange of environmental and regenerative conservation practices, technological dissemination, and commercial flows holds the potential to stimulate the establishment of a sustainable and competitive production model that addresses local food security needs while meeting international pressures for sustainability. As the region with the highest relative poverty globally, sustainability strategies should emphasize economic efficiency to maximize resource utilization in scarcity contexts and social approaches to eliminate hunger, malnutrition, reduce poverty, and ensure basic well-being and inclusion. These efforts align with the focus on environmental conservation, adopting practices with proven minimal ecological impact.

Two successful transformation models for tropical agriculture can serve as examples, focusing on productivity growth, local availability, and the generation of exportable surpluses, illustrated by reduced hunger and poverty and increased nutrient consumption: the Asian model and the Latin American model. The common element in both is the enhancement of technological capacity through the development of local techniques and competencies and the ability to extend this knowledge to producers. The Asian model, labor-intensive, retained its social and land structure, achieving productivity increases through technological advancements and higher input usage. The Latin American model, exemplified by Brazil, is capital-intensive, characterized by economies of scale and larger production units, with specialization and extension. In both cases, productive modernization, increased income, and higher productivity in rural areas have been accompanied by the development of conservationist techniques that preserve fragile tropical soils, discouraging overexploitation of natural resources.

Tropical regions lagging in productivity improvements can benefit from the successes of Asia and Latin America. A pragmatic sustainability dynamic can be defined based on the immediate sensitivities of directly affected populations—primarily hunger relief, poverty reduction, improved nutrition, and basic public services—while respecting local social and land structures. Rural extension schemes and easier access to inputs and technologies that increase productivity, leading to larger consecutive harvests, can initiate a virtuous cycle similar to those seen in Latin America and Asia. Over time, this process can encourage the adoption of more sustainable practices regarding natural resources. International governance for tropical agriculture—research and extension institutions, international organizations supporting agricultural production and fighting hunger, and multilateral development agencies—should collaborate on adopting and disseminating the successful productivity growth models of Asia and Latin America over the past six decades to other developing tropical countries. Including the concept of Tropical Agriculture and its need for evolution in diplomatic narratives may also help reduce negative perceptions that could hinder investment and trade relationships.

Domestic autonomy in production and increased productivity capacity are essential in today's transforming world. Climate change uniquely impacts tropical regions, making them particularly vulnerable to temperature shifts and water regime alterations, while also offering significant productive potential due to the year-round cultivability of these soils. As these regions are projected to experience population growth in the coming decades, ensuring nutritional security for these populations is crucial for internal stability within these societies and for reducing migration pressures toward developed countries. Finally, global geopolitical instability, increased trade protectionism, and the declining effectiveness of international cooperation reduce reliability in the production and logistics of food-supplying regions, further emphasizing the urgent need for tropical developing countries to ensure their own food supply and produce other essential agricultural goods such as textiles and energy sources.

REFERENCES

ALVES, E.; SILVA, G.; BRANDÃO, A. S. P. Por que os preços da cesta básica caíram? Revista de Política Agrícola, v. 19, n. 2, p. 14-20, 2010.

ALVES, H. K. M. N. ; JARDIM, A. M. R.F.; ARAÚJO- JÚNIOR, G. N.; SOUZA, C. A. A.; LEITE, R. M. C. ; SILVA, G. I. N.; SOUZA, L. S. B; SILVA, T. G. F. Uma abordagem sobre práticas agrícolas resilientes para maximização sustentável dos sistemas de produção no Semiárido brasileiro. Revista Brasileira de Geografia Física, v. 1, n. 01, p. 373-392, 2022.

AMEEN, A.; RAZA, S. Green Revolution: a review. International Journal of Advances in Scientific Research, v. 3, n. 12, p. 129-137, 2017.

ARIAS, J.; JANK, M. S.; CARDOSO, V.; UMAÑA, V.; GILIO, L. The role of international trade of promoting food security. IICA/INSPER, set. 2024. Disponível em: https://agro.insper.edu.br/storage/papers/September2024/INTERNATIONAL%20TRADE.pdf. Acesso em: 26 ago. 2025.

BARBIER, E. B. Explaining agricultural land expansion and deforestation in developing countries. American Journal of Agricultural Economics, v. 86, n. 5, p. 1347-1353, 2004.

BARROS, G.C.S. O agronegócio brasileiro no pós-Segunda Guerra Mundial: o processo de transformação e seus resultados. In: BARROS, G.C.S.; NAVARRO, Z. (Org.). Brasil rural contemporâneo: interpretações, 2022. p. 122-187.

BELLO, A. D.; HASHIM, N. B.; HANIFFAH, M. R. M.. Predicting impact of climate change on water temperature and dissolved oxygen in tropical rivers. Climate, Basel, v. 5, n. 3, p. 58, 2017.

BERG, A., DE NOBLET-DUCOUDRÉ, N., SULTAN, B., LENGAIGNE, M., ; GUIMBERTEAU, M. Projections of climate change impacts on potential C4 crop productivity over tropical regions. Agricultural and Forest Meteorology, Amsterdam, v. 170, p. 89-102, 2013.

BLANCO, C.; RAURICH, X. Agricultural composition and labor productivity. Journal of Development Economics, v. 158, p. 102934, 2022.

BUELENS, F.; FRANKEMA, E. Colonial adventures in tropical agriculture: new estimates of returns to investment in the Netherlands Indies, 1919–1938. Cliometrica, v. 10, p. 197–224, 2016. Disponível em: https://doi.org/10.1007/s11698-015-0128-z. Acesso em: 06 ago. 2025.BUDOWSKI, G.; RUSSO, R. O. Live fence posts in Costa Rica: a compilation of the farmer's beliefs and technologies. Journal of Sustainable Agriculture, v. 3, p. 65-87, 1993.

BYERLEE, D.; SCOONES, I.; CABRAL, L. M. Knowledge, science and politics: the role of agricultural research in Africa's Green Revolution. IDS Working Paper, n. 213, 2002. Disponível em: https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/3905. Acesso em: 25 jul. 2025

CHADDAD, F. The economics and organization of Brazilian agriculture: Recent evolution and productivity gains. Academic Press, 2015.

COSTA, C. G.; LOPES, J.; CRUZ, G. M. Regenerative agriculture in Brazil: challenges and opportunities. Rio de Janeiro: CEBDS, 2023. Relatório técnico. Disponível em: https://cebds.org/wp-content/uploads/2023/11/CEBDS_CTALIMENTOS-ING.pdf. Acesso em: 10 ago. 2025.

COCKCROFT, C. E.; HERRERA-ESTRELLA, L. R.; NORDELO, C. G. Agricultural Biotechnology in Latin America and the Caribbean. 2004. Disponível em: https://www.semanticscholar.org/paper/Agricultural-Biotechnology-in-Latin-America-and-the-Cockcroft-Herrera-Estrella/2ca986a7cfbd904dc2f20e2a2e354fb649048767. Acesso em: 20 ago. 2025.

DÍAZ-BONILLA, E., TRIGO, E.; CAMPOS, R. Acerca de los sistemas alimentarios 'fallidos' y otras narrativas. Instituto Interamericano de Cooperación para la Agricultura (IICA). San José, Costa Rica. 2024. Disponível em: https://repositorio.iica.int/bitstream/handle/11324/22073/BVE24034040e.pdf?sequence=14;isAllowed=y Acesso em: 25 de ago. de 2025.

EDENS, A. The Green Revolution's Alignments with American Agribusiness. Rockfeller Archive Center Research Reports, número 14, 2021.

Organização das Nações Unidas para Alimentação e Agricultura (FAO). FAOSTAT – Temperature change on land. Rome: Food and Agriculture Organization of the United Nations, 2025a. Disponível em: http://www.fao.org/faostat/en/#data/ET. Acesso em: 06 de ago. 2025.

FAO. The Tropical Agriculture Platform (TAP). 2025b. Disponível em: https://www.fao.org/in-action/tropical-agriculture-platform/en Acesso em: 20 de agosto de 2025

FAO. Policy Brief, 2006, Issue 2: Food Security. Disponível em: https://www.fao.org/fileadmin/templates/faoitaly/documents/pdf/pdf_Food_Security_Cocept_Note.pdf Acesso em 25 de agosto de 2025.

FAO. AQUASTAT Dissemination System. Roma: Food and Agriculture Organization of the United Nations, 2025. Disponível em: https://data.apps.fao.org/aquastat/?lang=en. Acesso em: 01 jul. 2025.

FORTINI, R. M., BRAGA, M. J., ; FREITAS, C. O. (2020). Impacto das práticas agrícolas conservacionistas na produtividade da terra e no lucro dos estabelecimentos agropecuários brasileiros. Revista de Economia e Sociologia Rural, 58(2), e199479. https://doi.org/10.1590/1806-9479.2020.199479. Acesso em: 19 ago. 2025.

GARCIA, J. R. Trabalho rural: tendências em face das transformações em curso. In: BUAINAIN, A. M.; ALVES, E.; SILVEIRA, J. M.; NAVARRO, Z. (Orgs.). O mundo rural no Brasil do século 21: a formação de um novo padrão agrário e agrícola. Brasília, DF: Embrapa, 2014. p. 559-590.

GLOBAL FOREST WATCH. Global Dashboard. Washington, DC: World Resources Institute, 2025. Disponível em: https://www.globalforestwatch.org/dashboards/global/. Acesso em: 15 ago. 2025.

GOMIERO, T. Soil degradation, land scarcity and food security: reviewing a complex challenge. Sustainability, v. 8, p. 281, 2016.

GONÇALVES, P. A. S. Manejo de solos e a nutrição de plantas e sua relação com a ocorrência de pragas. Scientific Electronic Archives, v. 13, n. 6, 2021.

GOWING, J.; PALMER, M. Sustainable agricultural development in sub-Saharan Africa: the case for a paradigm shift in land husbandry. Soil Use and Management, v. 24, 2008.

GUIMARÃES, Lara Nascimento; KARAM, Décio; GONÇALVES, Adenilson Henrique; BORGHI, Emerson; GUIMARÃES, Nathália Nascimento; PEREIRA, Caike de Sousa; INOUE, Tiago Yukio; CUSTÓDIO, Isabela Goulart. A importância das práticas agrícolas para estabilidade de produção e resiliência de sistemas agrícolas. *Observatorio de la Economía Latinoamericana*, v. 23, n. 5, p. 1-?, 2025.

HAZELL, P. B. R. The Asian green revolution. IFPRI Discussion Paper, n. 911, International Food Policy Research Institute, Washington, D.C., 2009.

JAYNE, T. S.; RASHID, S. Input subsidy programs in sub-Saharan Africa: a synthesis of recent evidence. Agricultural Economics, v. 44, n. 6, p. 547–562, 2013.

KÖPPEN, W. P. Das geographische system der klimate: mit 14 textfiguren. Borntraeger, 1936.

HANJRA, M. A.; GICHUKI, F. Investments in agricultural water management for poverty reduction in Africa: case studies of Limpopo, Nile, and Voltariver basins. Natural Resources Forum, v. 32, n. 3, p. 185-202, 2008.

KIUP, E.; SWAN, T.; FIELD, D. J. Soil management practices in coffee farming systems in the Asia-Pacific region and their relevance to Papua New Guinea: a systematic review. Soil Use and Management, v. 41, 2025.

KUYAH, S.; SILESHI, G. W.; NKURUNZIZA, L.; CHIRINDA, N.; NDAYISABA, P. C.; DIMOBE, K.; ÖBORN, I. Innovative agronomic practices for sustainable intensification in sub-Saharan Africa: a review. Agronomy for Sustainable Development, v. 41, n. 2, p. 16, 2021.

MONTES-LONDOÑO, I. Tropical dry forests in multi-functional landscapes: agroforestry systems for conservation and livelihoods. 2017. Disponível em: https://www.semanticscholar.org/paper/Tropical-Dry-Forests-in-Multi-functional-Systems-Montes-Londo%C3%B1o/ccba5a99fe7f75c4f253a754e4fe4327b8665d21. Acesso em: 20 ago. 2025.

NGUYEN-VAN-HUNG; BALINGBING, C.; SANDRO, J.; et al. Precision land leveling for sustainable rice production: case studies in Cambodia, Thailand, Philippines, Vietnam, and India. Precision Agriculture, v. 23, n. 5, p. 1633–1652, 2022.

NHEMACHENA, C.; NHAMO, L.; MATCHAYA, G. C.; NHEMACHENA, C. R.; MUCHARA, B.; KARUAIHE, S. T.; MPANDELI, S. N. Climate change impacts on water and agriculture sectors in Southern Africa: threats and opportunities for sustainable development. Water, 12, n. 10, 2020.

NHEMACHENA, C.; MATCHAYA, G.; NHLENGETHWA, S.; NHEMACHENA, C. R. Exploring ways to increase public investments in agricultural water management and irrigation for improved agricultural productivity in Southern Africa. Water SA, v. 44, n. 3, p. 474-481, 2018.

JOHNSON, D.; BAKSI, S. Sethu C. A. Green Revolution in India: making sense of the qualitative and quantitative aspects of change. Economic and Political Weekly, v. 59, n. 52, 2014.

PARODA, R.; WOODHEAD, T.; SINGH, R. B.; FAO REGIONAL OFFICE FOR ASIA. Sustainability of rice-wheat production systems in Asia. 1995.

PICADO, H. V. Cultural management in agro-ecological practices, the cases of Nicaragua, Costa Rica, and Panama. Mercator, Fortaleza, v. 23, e23034, out. 2024.

PINGALI, Prabhu L. Green revolution: impacts, limits, and the path ahead. Proceedings of the National Academy of Sciences, v. 109, n. 31, p. 12302-12308, 2012.

POULTON, C.; KYDD, J.; DORWARD, A. Overcoming market constraints on pro-poor agricultural growth in Sub-Saharan Africa. Development Policy Review, v. 24, n. 3, p. 243–277, 2006.

RODRÍGUEZ-SÁENZ, D.; BIANCHI, E.; CAMPOS, A. El comercio internacional de productos agroalimentarios de América Latina y el Caribe y la transformación de los sistemas alimentarios. San José: Instituto Interamericano de Cooperación para la Agricultura (IICA), 2021.

RIVERO, Sérgio; ALMEIDA, Oriana Trindade de; ÁVILA, Saulo; OLIVEIRA, Wesley Pereira de. Pecuária e desmatamento: uma análise das principais causas diretas do desmatamento na Amazônia. Nova Economia, v. 19, p. 41-66, 2009.

SHEAHAN, M.; BARRETT, C. B. Review: food loss and waste in Sub-Saharan Africa. Food Policy, v. 70, p. 1–12, 2017.

SITHOLE, A.; OLORUNFEMI, O. D. Sustainable agricultural practices in Sub-Saharan Africa: a review of adoption trends, impacts, and challenges among smallholder farmers. Sustainability, 2024.

SOUSA, R. M.; FURTADO, M. B.; ARAÚJO, D. R.; OLIVEIRA, C. M.; CASTRO, R. D. Eficiência no uso dos nutrientes em solos tropicais propensos à coesão: alternativas de manejo. Acta Tecnológica, 2018.

THANH, D. N. Low external input sustainable agriculture (LEISA) in selected countries of Asia: regional workshop report and case studies. Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, ago. 1996. Vietnã, 2011.

THIRTLE, C.; LIN, L.; PIESSE, J. The impact of research-led agricultural productivity growth on poverty reduction in Africa, Asia and Latin America. World Development, v. 31, n. 12, p. 1959-1975, 2003.

TORLESSE, H.; KIESS, L.; BLOEM, M. W. Association of household rice expenditure with child nutritional status indicates a role for macroeconomic food policy in combating malnutrition. The Journal of Nutrition, v. 133, n. 5, p. 1320-1325, 2003.

UNITED STATES. Agency for International Development (USAID). USAID's legacy in agriculture development: 50 years of progress. Washington, DC: Bureau for Food Security, 2016. Disponível em: https://policycommons.net/artifacts/4749854/usaids-legacy-in-agriculture-development/5574385/. Acesso em: 25 ago. 2025.

VAN ASSELT, J. D. I.; BATTISTA, F.; KOLAVALLI, S.; UDRY, C. R.; BAKER, N. Performance and adoption factors for open pollinated and hybrid maize varieties: evidence from farmers' fields in Northern Ghana. Washington, DC: International Food Policy Research Institute (IFPRI), 2018.

VIEIRA-FILHO, J. E. R.; FISHLOW, A. Agricultura e indústria no Brasil: inovação e competitividade. Brasília, DF: IPEA, 2017.

YOU, L.; RINGLER, C.; WOOD-SICHRA, U.; ROBERTSON, R.; WOOD, S.; ZHU, T.; SUN, Y. What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach. Food Policy, v. 36, n. 6, p. 770–782, 2011.

WORLD BANK. Arable land (hectares). DataBank: Metadata Glossary. Disponível em: https://databank.worldbank.org/metadataglossary/world-development-indicators/series/AG.LND.ARBL.HA. Acesso em: 1 ago. 2025.

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