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Rethinking Agricultural Policy in Ecuador (1960–2020): Analysis Based on the Water–Energy–Food Security Nexus

Lucía Toledo [1,*], Gloria Salmoral [2,3] and Oswaldo Viteri-Salazar [4]

1 Programa de Doctorado en Gestión Tecnológica, Facultad de Ciencias Administrativas, Escuela Politécnica Nacional, Ladrón de Guevara E11·253, Quito 170525, Ecuador
2 Cranfield Water Science Institute, Cranfield University, Swindon SN6 8LA, UK; gloria.salmoral@gmail.com
3 Department of Mechanical, Aerospace and Civil Engineering, The University of Manchester, Manchester M13 9PL, UK
4 Facultad de Ciencias Administrativas, Escuela Politécnica Nacional, Ladrón de Guevara E11·253, Quito 170525, Ecuador; hector.viteri@epn.edu.ec
* Correspondence: lucia.toledo@epn.edu.ec

Abstract: Agriculture is the principal source for satisfying the growing global demand for food. However, current production patterns and socioeconomic and demographic pressures could lead to an unsustainable, inequitable food supply. Government interventions support technical advances designed to meet future needs following international trends while overcoming biophysical constraints. Those most often used are focused on augmenting land productivity through mechanisation and increased dependence on external inputs. To that end, public policies have emerged as engines of development in agriculture and the agri-food system. This article provides a chronological analysis of the relevant milestones in the agri-food sector in Ecuador (1960–2020). At first, agrarian reform focused on land distribution and tenure. Subsequently, the focus moved to the implementation of research, technological innovation and technology transfer programmes promoted by the state with support and financing from international organisations. For this article, we chose for our approach the water–energy–food nexus. Until now, insufficient study based on this approach regarding agricultural programmes has been conducted in Ecuador. It is essential to concentrate on this sector because it represents about 10% of the gross domestic product and is a principal source of employment for more than two-thirds of the economically active population in rural areas. However, land fractioning, the lack of project continuity and the focus on the application of technological packages identified in this analysis suggest the need to rethink public policies for a sustainable agri-food system.

Keywords: sustainability; agri development programmes; Ecuador; agrarian reforms

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Citation: Toledo, L.; Salmoral, G.; Viteri-Salazar, O. Rethinking Agricultural Policy in Ecuador (1960–2020): Analysis Based on the Water–Energy–Food Security Nexus. *Sustainability* **2023**, *15*, 12850. https://doi.org/10.3390/su151712850

Academic Editors: Tiziano Gomiero, Lisa Lobry de Bruyn and Ji Li

Received: 9 April 2023
Revised: 4 July 2023
Accepted: 6 July 2023
Published: 25 August 2023

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1. Introduction

Countries throughout the world are focused on the strategic importance of food security and increasing food production [1]. Is this sustainable? Because the human population is in a period of accelerated growth [2], increasing food production could lead to numerous environmental problems [3]. Pimentel et al. [4] suggest that evaluating available land, water and energy resources is required for sustainability. Agriculture is directly related to nature [5]. It benefits from nature but threatens it as well [6]. For this reason, sustainability is a critical issue in the formulation of future agricultural policies and practices [7].

The Food and Agriculture Organization (FAO) defines food security as the condition in which all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active, healthy life [8,9].

In many countries, the state creates policies to support agricultural producers and contribute to food security [10]. Some came into being through agrarian reforms [11–13], and others through development programmes [14,15]. Agrarian reforms commonly involve changes in land tenure and related policies and tend to alter relations between agricultural production and distribution [16]. For instance, in the 1960s and 1970s, inequality in tenure included exploitative labour conditions. According to Vergara and Kay [17], agrarian policies in Latin America during those decades were influenced by programmes of social protectionism intended to involve small producers in commodity chains, a situation that does not favour peasants. They also indicate that conservative governments championed capitalism, whereas progressive regimes lacked clear development agendas or strategies. Insights into the results of past agricultural policies have been identified in several countries; however, few offer an analysis of the sustainability of these practices.

Integral food system frameworks are essential for sustainability [18]. In the context of sustainable production, a food system must be profitable (economic), socially responsible (social) and environmentally friendly (environmental) [19]. The said system promotes preserving resources for future generations [20]. In this sense, sustainable agri-food policies are urgently needed. The development of sustainable systems requires that we learn from the past.

In *Silent Spring*, Rachel Carlson [21] argues that the most alarming of all human attacks against the sustainability of the natural world is pollution, with dangerous and even lethal substances released into the air, land, rivers, lakes and seas. However, what is sustainability? Some authors, including Paoletti et al. [22], maintain that sustainable agriculture must be environmentally, economically and socially viable. Minimal inputs during production and the preservation of natural resources contribute to sustainability [23]. According to Giampietro and Pimentel [24], environmentally sound agriculture limits the use of renewable resources and respects biophysical constraints.

There are many options for the analysis of sustainability. This study has focused on the water–energy–food security nexus approach (WEF nexus), which is intended to promote and improve synergies across governance sectors [25]. Analyses of WEF nexus resources are fundamental to explaining phenomena such as equality, human well-being and sustainability [26]. The nexus takes into account biophysical constraints [27]. Inputs are examined in terms of their linkages to WEF resources and the consequences of their use in various spheres (socioeconomic and ecological) [28]. In this sense, the WEF nexus is a holistic framework that allows for an exploration of interconnections or synergies of the three components and provides ways to minimise trade-offs [29]. Three elements will be analysed—water resources, soil and agrochemicals—for the WEF nexus. The research was framed within the bioeconomy, specifically through the ontological and epistemological principles of ecological economics.

The inefficient use of water in agricultural production is a problem [26,30]. In fact, Pimentel [31] argues that insufficient water is the major constraint for world food production. It is estimated that 70% of the freshwater used by humans is dedicated to crop irrigation [32,33]. Common crops require large amounts of water. Another complicating factor is the widespread application of synthetic fertilisers causing soil salinisation. Freshwater can also be contaminated by dangerous microorganisms, as well as pesticides and fertilisers. Consumers are generally unconcerned about and/or unaware of the effects on water resources that their consumption habits have. Nor are conventional agricultural practices environmentally friendly [34]. Conflicts between the continuously increasing diversion of water for agriculture and the maintenance of terrestrial and aquatic ecosystems are constant [35], as is the demand for water to satisfy direct human needs [36] and for hydroelectric energy generation [37].

Biophysical limitations related to demographic pressure lead to the expansion of the agricultural frontier and the application of additional Green Revolution technologies [38]. This continuous search for efficiency leads to collateral effects, including overproduction, loss of biodiversity and loss of soil fertility [39]. Furthermore, modern agricultural practices can lead to erosion, degradation and the destruction of the soil [23,40]. These practices include over-tilling, tilling when the soil is too wet or too dry and the application of anhydrous ammonia, excessive nitrogen fertilisation or saline or sodium irrigation water. Other complicating factors are the degradation and abandonment of productive arable land [31] as well as the loss of biodiversity [41]. Reliance on chemical fertilisers is used to compensate for soil shortages but can produce erosion [4]. Harden's research [42] shows that soil erosion and the elimination of biomass for food and forage cause the depletion of the organic carbon content of cultivated soils. From this point of view, he analyses land abandonment and relates it to local alterations in rainfall runoff, soil erosion and effects on soil degradation. Programmes are needed to create awareness of resource (land, water, inputs) management [43]. Implementation of appropriate conservation technologies preserves soil fertility and may increase yields [41]. In light of the above, it becomes necessary to improve sustainable production through effective public intervention based on an analysis of farmers' preferences [44].

Part of the energy of conventional agriculture depends on fossil fuels and chemicals [33,43]; this leads to further dependence on fertilisers to maximise production [4]. Constant application of these substances contributes directly to global climate change [3] and soil erosion [4]. Thus, approved pesticides are necessary to ensure healthy crops free of plagues and diseases. When used in the right amounts and ways, these are not harmful and should not be present in final food products. Mismanagement of pesticides is indeed a problem and causes damage to agricultural and natural ecosystems [45].

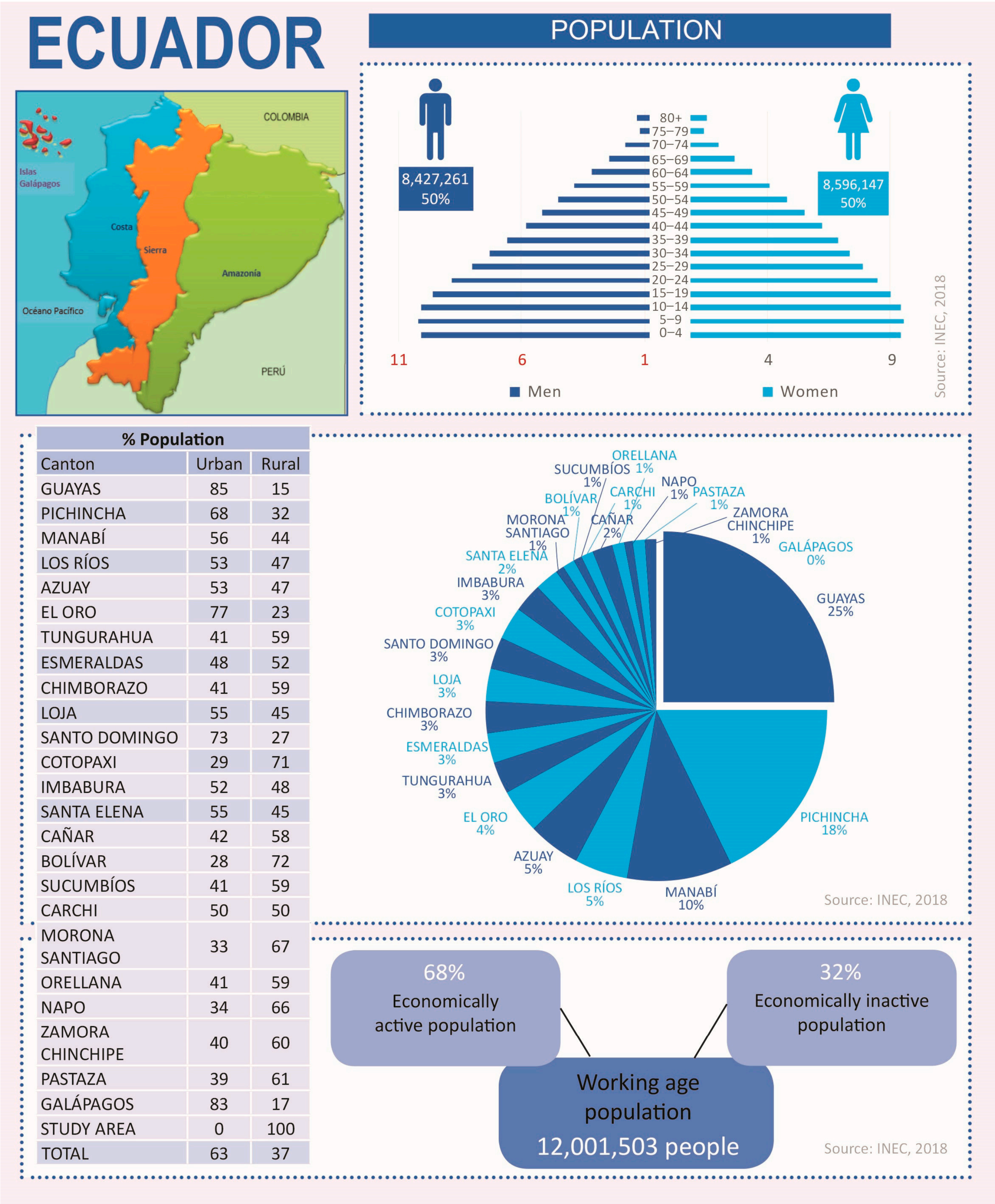
Until now, insufficient study of the WEF nexus in agricultural programmes has been conducted in Ecuador. In this paper, we assess the relevant milestones in Ecuador's agri-food system from 1960 to 2020 and analyse impacts using the WEF nexus approach. We aim to assess the effectiveness and implications of the public policies implemented in the Ecuadorian agri-food sector in supporting equitable economic growth, food security and sustainability. To achieve that, we propose these objectives:

- To analyse the timeline of public policies and interventions in Ecuador's agricultural sector;
- To apply a sustainable framework to assess the impacts and long-term sustainability of interventions in the agri-food sector on water resources and soil through use of agrochemicals;
- To provide insights on how future public policies, while preserving the environment, can support meeting food demands while leading to local economic growth and food security.

2. Study Area

The Republic of Ecuador is located in South America and covers 270,670 km^2 [46]. Of the land dedicated to production at the national level, 5.20 million hectares are used for agriculture (permanent and seasonal crops and cultivated and natural pastures) [47]. The country is divided into four regions: highland, coast, insular (Galapagos Islands) and Amazon (Figure 1a–c), with extraordinarily diverse ecosystems suitable for research and the development of a great variety of agricultural activities.

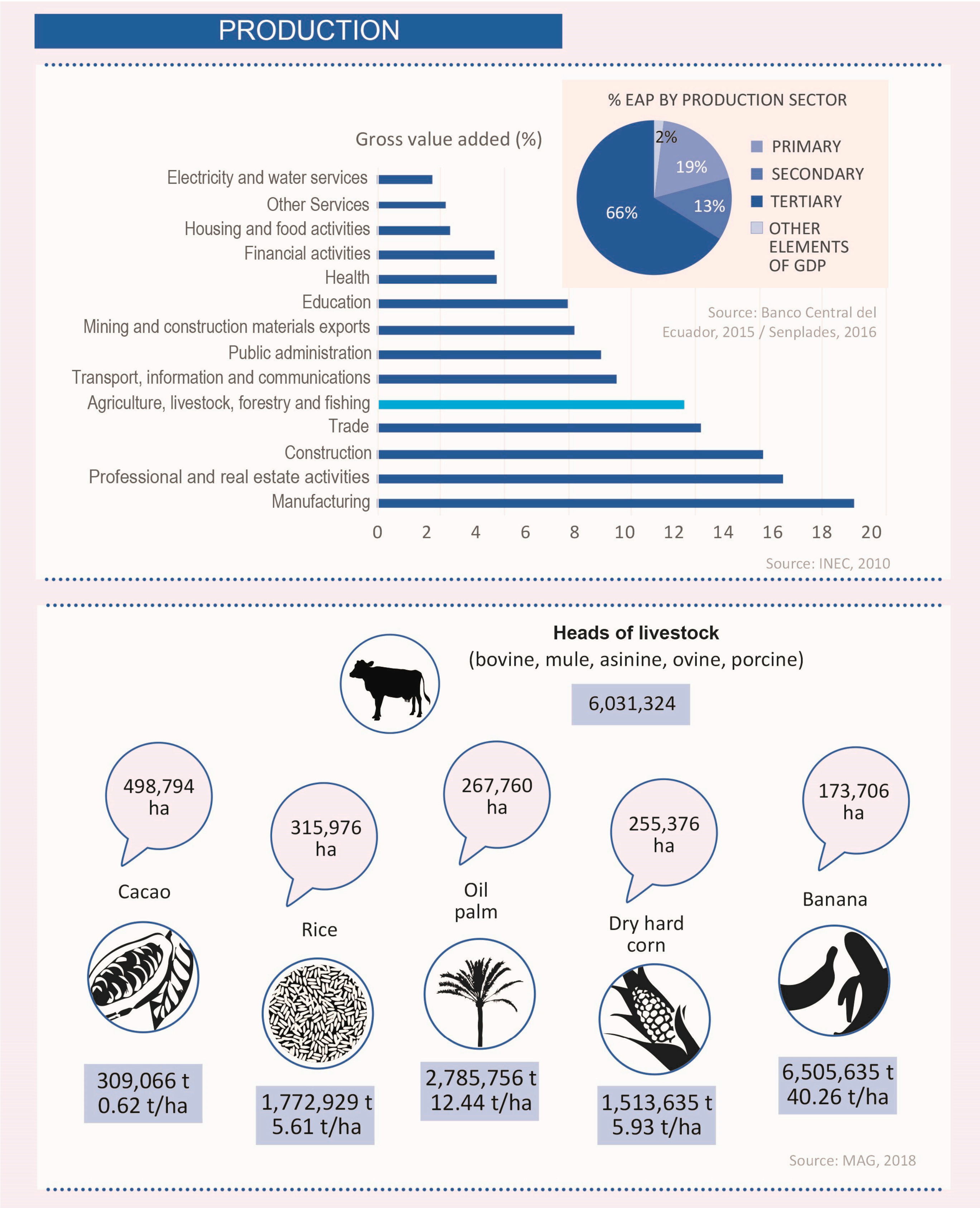
Currently, Ecuador has 17,023,408 inhabitants. According to the three-sector model of economic activities, the primary sector involves the extraction of raw materials, in which 19% of Ecuador's economically active population (EAP) is employed; the secondary sector is dedicated to manufacturing and employs 13% of the EAP; and the tertiary sector, employing 66% of the EAP, is made up of service industries that facilitate the transport, distribution and sale of goods produced by the secondary sector. The primary sector, which includes agriculture, livestock production, forestry and fishing, is among the principal activities in most provinces, has a stimulating effect on Ecuador's overall economy (Figure 1a–c) and accounts for 12% of the gross value added (GVA). The GVA is the difference between production and intermediate consumption and contributes directly to the country's gross domestic product (GDP) [48].



% Population		
Canton	Urban	Rural
GUAYAS	85	15
PICHINCHA	68	32
MANABÍ	56	44
LOS RÍOS	53	47
AZUAY	53	47
EL ORO	77	23
TUNGURAHUA	41	59
ESMERALDAS	48	52
CHIMBORAZO	41	59
LOJA	55	45
SANTO DOMINGO	73	27
COTOPAXI	29	71
IMBABURA	52	48
SANTA ELENA	55	45
CAÑAR	42	58
BOLÍVAR	28	72
SUCUMBÍOS	41	59
CARCHI	50	50
MORONA SANTIAGO	33	67
ORELLANA	41	59
NAPO	34	66
ZAMORA CHINCHIPE	40	60
PASTAZA	39	61
GALÁPAGOS	83	17
STUDY AREA	0	100
TOTAL	63	37

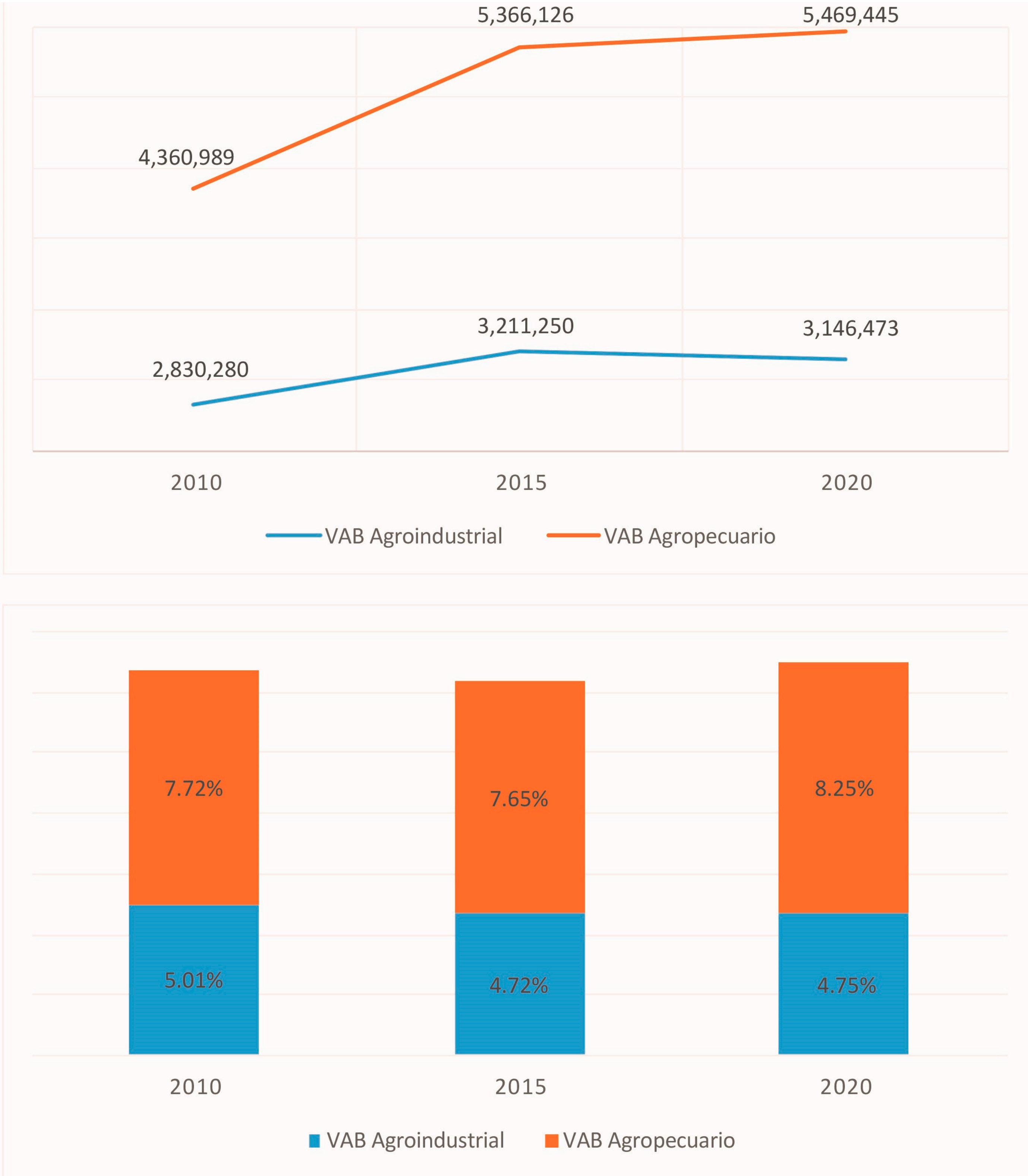
(**a**)

Figure 1. *Cont.*



(**b**)

Figure 1. *Cont.*



(c)

Figure 1. (**a**) Characteristics of Ecuador's population and production. (**b**) Characteristics of Ecuador's population and production. (**c**) Characteristics of Ecuador's population and production.

Ecuador's biodiversity is among its greatest riches [49]. Unfortunately, it is affected by deforestation [50] due to the expansion of the agricultural frontier [13], other extractive processes [51], urbanisation processes and other human interventions [52]. Another issue that has yet to be adequately addressed is soil [53] and water [54] pollution resulting from intensive agricultural practices that include the increased use of chemicals and fertilisers [55].

In the past, agricultural development was the result of two different phenomena: reform focused on land redistribution and innovative projects combined with technology transfer programmes promoted by the state with the involvement of external financing (Figures 2 and 3). It is important to keep in mind that international financing for development usually involves requirements based on the interests of the sponsoring institution [56]. During the last 60 years, the agricultural sector has undergone significant and unforeseen changes. Ecuador's situation has been similar to that of other countries in the region. Here, land distribution involved three major state-sponsored agricultural reforms, mainly promoted by de facto governments. In general terms, these reforms were carried out by the Ecuadorian Institute of Agrarian Reform and Colonization (IERAC) that was created in 1964. In 1979, Ecuador returned to democracy [57].

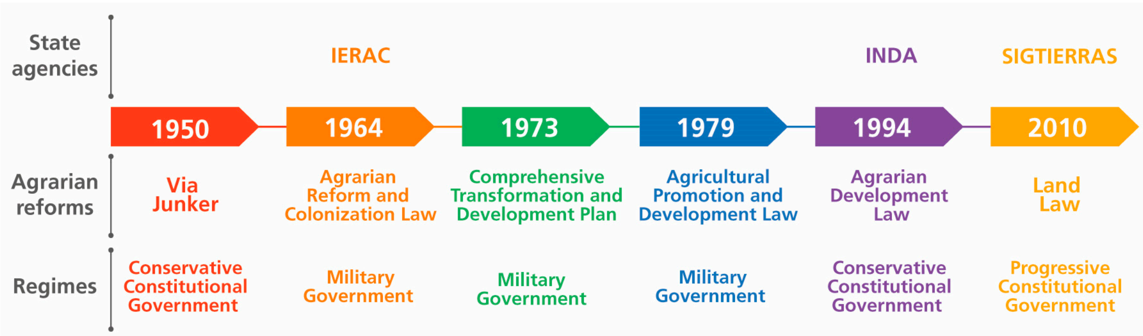


Figure 2. Milestones in the development of agri-food policies in Ecuador (1960–2020).

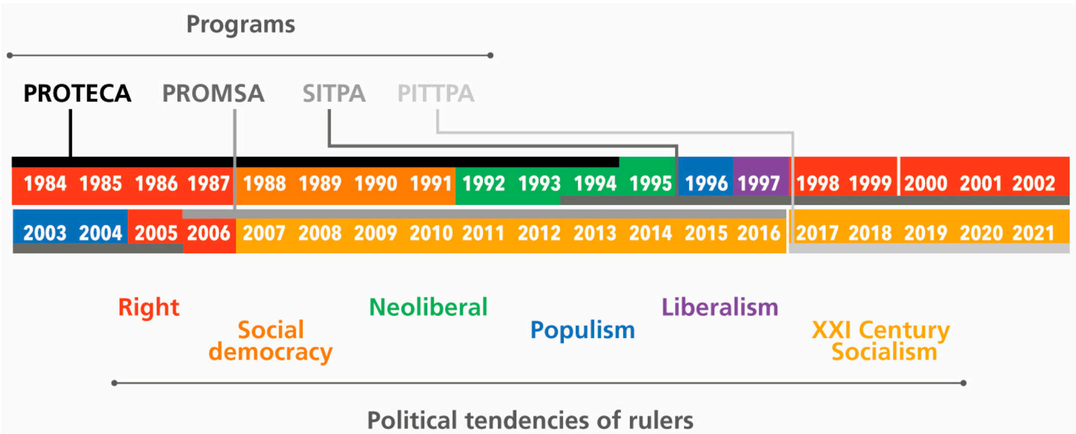


Figure 3. Agri development programmes and political tendencies of rulers.

3. Methodology

Our case study involves an examination of Ecuador's agricultural development from 1960 to 2020. A qualitative analysis illustrates the situation of the country's agricultural production sector from the standpoint of sustainability. In this research, we applied different tools to obtain data and information from primary and secondary sources.

Data Sources

The timeline is based on our review of the literature from both published and unpublished sources. It was a complicated task, since only certain information is publicly available, whereas access to other sources is restricted. We also discovered information losses due to inadequate document management as well as the destruction of material due to physical damage to the Ministry of Agriculture (MAG) library's storage facility.

After interviews with experts, we identified two major agrarian reforms and the following four programmes that marked agrarian policy: the Agricultural Technological Development Programme (PROTECA) (1984–1994), the Agricultural Services Modernization Programme (PROMSA) (1994–2005), the Technological and Participatory Innovation Programme—Agricultural Participatory Innovation System (SITPA) (2006–2016) and the Participatory Technological Innovation and Agricultural Productivity Programme (PITPPA) (2017–2021). We selected these because of their national coverage and the significant investment involved. Other development programmes identified were regional and had a limited scope or were included in other programmes and projects.

We then carried out semi-structured interviews (Appendix A) with six people who held senior management positions and were key actors in programme execution. Confidentiality agreements were signed and the participants' names were not used, though interviewees allowed us to use information they provided. We then transcribed and analysed the information in order to identify complementary and conflicting visions of the issues addressed.

Finally, using the WEF nexus as a framework, we evaluated the impacts resulting from interventions in the Ecuadorian agri-food sector. Specifically, we examined water resources, soil and agrochemicals and their influence on food production and security.

4. Results

4.1. Timeline of Public Policies and Interventions in Ecuador's Agricultural Sector

The first agrarian transformation was initiated by the private sector. It began in the 1950s and 1960s, following the example of the yunkers (reform made by the landowners themselves), and led to land redistribution, especially in the highlands, from large landowners to peasants. Some landowners handed over land, whereas in other cases expropriation was required and the land in question was handed over to charitable organisations. Subsequently, the state-sponsored 1964 Agrarian Reform and Colonization Law abolished the hacienda (this system was highly profitable for the landed elites who had controlled political and economic power since colonial times and allowed them to shape agrarian institutions in their own interests [58]) system as it then existed. The state acquired partial control over the activities of the landowners. In Latin America, this change was prompted by the Alliance for Progress to avoid social conflicts similar to those that occurred in Cuba. The purpose of this reform was to end the *huasipungo* (a Kichwa word: huasi-house, pungo-door. A plot of land loaned by landowners in a precarious way to indigenous people in exchange for labour performed in exploitative conditions [59–61]) and to initiate structural changes in land use; the reform was applied to large farms and properties owned by the Catholic clergy. This led to conflict as the land in question was not used to produce profitable crops or resources for local/family consumption and social inequality thus increased. Peasants were further marginalised and exploited by landowners.

The second Agrarian Reform Law was implemented in 1973, through decree 1172 that was issued during a new period of military dictatorship [61]. The Comprehensive Transformation and Development Plan consolidated the import substitution industrialisation process proposed by the Economic Commission for Latin America and the Caribbean (ECLAC). The purpose was to promote endogenous development processes that would allow countries to strengthen their economic situation and improve the living conditions of producers as well as to achieve the redistribution of income and land [59,60,62]. The idea was to resettle the maximum number of peasant families in specific regions throughout Latin America; in Ecuador, that was in the Amazon [63]. At the same time, the Green Revolution was being promoted worldwide. According to Gomiero et al. [40], during this process, the productivity of main agriculture crops increased, sometimes up to four or five times. This Green Revolution was based on the use of fossil energy for fertilisers, pesticides and irrigation [3]. In the 30 years since, the use of these technologies has led to a dependency and yields are beginning to decline [64]. As part of the Green Revolution promoted by international organisations, research organisations, such as the Autonomous Institute for Agricultural Research (INIAP), were founded [65]. Governments have also implemented agricultural policy involving objectives such as increasing agro-exports and productivity [66]. The agro-production system in Ecuador changed focus, from rural development to technology transfer. A process of production specialisation began and traditional crops were displaced by new, introduced species. Indeed, the policies implemented from the 1980s favoured grain imports and undermined cereal production in the Andean provinces [67]. However, Da Conceicao [68] indicates that Ecuadorian agricultural production continued to be a subsistence activity. For their part, Calderon et al. [69] state that attempts were made to modify the pattern of specialisation with an agro-export focus, mainly favouring the owners of capital. Thus, the national development bank (Banco Nacional de Fomento, BNF) [70], INIAP [65] and IERAC [71] were created in order to accelerate the development and expansion of the agricultural sector. For this purpose, fiscal policies, credit, financing plans and other strategies were introduced. However, Calderon et al. [69] emphasise that, as the industrial sector grew, agriculture lagged behind, creating a trade imbalance. Throughout history, the agricultural sector has been relegated to a secondary plane, independent of the political tendency of governments.

Since this transition was linked to the international division of labour, state strategies were proposed within the primary export model. The cycle of agrarian reform ends, and comprehensive rural development begins with technology transfer. Programmes included in public policies were biased towards export agroindustry. Unfortunately, most of these programmes have a clientelist approach. Several interviewees emphasise that they are limited to giving farmers kits, which eventually leads to dependence on deals with commercial houses that sell agrochemicals and supplies. Additionally, all producers are placed in the same category, rather than having their individual situations taken into account. Similarly, in certain programmes, selection of personnel is not a transparent process and thus generates mistrust. MAG area leaders tend to be political appointees who do not always have the technical knowledge related to execution, monitoring and evaluation. Another major drawback is the lack of articulation between state entities and development programmes, which leads to a duplication of efforts and inefficiency in achieving objectives.

One programme that stands out is PROTECA (1984–1994), which involved government intervention. Its main objectives were to increase productivity and expand the agricultural frontier. In addition, MAG technicians were to integrate education with research and technology transfer. The programme's sponsors were the International Development Bank (IDB) and the Inter-American Institute for Cooperation on Agriculture (IICA). This was a public policy aimed at research and technology generation, agricultural extension based on technology transfer, seed production and marketing, and monitoring the adaptation of the credit system in favour of the agriculture sector [72]. According to critics, the initial objectives were not fully met. The significant funds allocated were not properly distributed. Thus, resources did not reach producers in the amount expected; instead, funds were primarily used for operating and administrative expenses. However, some reports affirm that certain projects were successfully implemented, such as the training of technicians abroad for short periods and of producers in situ.

Based on data from the National Agricultural Censuses, policies to increase the agricultural frontier were, in fact, successful: in 1954, cultivated areas covered 5,999,700 ha; in 1974, they covered 7,955,255 ha; and in 2000, the covered 12,355,831 ha. [73,74].

PROMSA (1994–2005), another iconic programme, was a public–private effort. Its main objective was to involve the private sector in the execution and financing of technology generation, along with the transfer of processes as well as agricultural health services. The programme's executive director managed and assessed components focused on research, transfer and agricultural health. The World Bank and the IDB sponsored the programme. Public policies generated included price policy and foreign trade, land policy implementation, water and irrigation policy, public agricultural sector modernisation and rationalisation of environmental policies. The programme continued for 11 years, despite the various political ideologies of the 6 different administrations and the 17 Ministers of Agriculture who served during this period. The programme faced additional challenges, including the change in the country's official currency from the sucre to the US dollar. The significant competitive advantage the programme enjoyed was its technical–administrative structure that was independent of the state. This proposal came into being in the context of state modernisation [56]. According to Rebaï et al. [67], through modernisation, family farms went from production centred on the satisfaction of domestic and local food needs to specialised production that reflected a new form of subordination of peasant family agriculture towards capitalist interests. According to Cueva et al. [75], the labour market became more flexible in the generation of employment. Additionally, emphasis was placed on improving competitiveness for foreign exchange earnings and improving the quality of life. In 1994, the name of the institution regulating land was changed to the National Institute of Agrarian Development (INDA); its functions included the continuation of policies aimed at expanding the agricultural frontier [61]. Among the results, the increase in production and productivity stands out, as well as the reduction in post-harvest losses and the adoption of new technologies. This involved working through agricultural production chains rather than focusing on individual links. According to critics of the programme, its legitimacy was questionable, as the private sector was assigned activities that were the state's responsibility.

Another representative programme is SITPA (2006–2016). Like PROTECA, this was a programme of exclusive government intervention. It had national coverage and focused mainly on a few crops (rice, potatoes, corn, wheat, barley, cacao, bananas and soybeans) grown on family farms. The fundamental goal was the creation of agrarian revolution schools (ERA's) for members of 2834 associations. Development was focused on agricultural practices, technical assistance, affordably priced inputs, training, strengthening of associativity and socio-business management. This proposal came into being as a criticism of previous programmes that were exclusive rather than inclusive [76]. Nevertheless, the proposal included components similar to those of previous projects, including an emphasis on increased productivity and the delivery of agricultural input kits. Critics of this programme point to it as a populist indoctrinator. Additionally, the programme was part of government proposals known as Socialism for the 21st Century, whose proponents have been charged with various acts of corruption.

During this administration, proposals for agrarian reforms aimed at the redistribution of wealth were implemented. Albornoz and Machado [77] point out that the third agrarian reform was carried out in 2010 through the Land Law. This legislation mainly involved the expropriation of properties with productivity lower than the average for the area or on which only up to 20% of the total usable area was under production. It should be noted that this law was preceded by earlier legislation, including the 1979 Agricultural Promotion and Development Law aimed at protecting land tenure and property through compensation or subsidies. Furthermore, in 1994, replacement of the Agricultural Promotion and Development Law by the Agrarian Development Law was intended to increase productivity, mainly through privatisation and state service processes. In addition, the legislation encouraged colonisation and extension of the agricultural frontier based on the concept of vacant lands that, though already occupied, were considered by the state to have a low population density. The state reasoned that colonisation was an appropriate policy for absorbing demographic growth. In this sense, Jordan [78] maintains that the law was intended to protect tenure and property structures through compensation and subsidies, whereas Martin Mayoral [79] affirms that the legislation pursued production and social control through benefits that favoured only certain producers, mainly landowners. From 2010 [80] to the present [81], the state agency for the control of rural land and technological infrastructure is SIGTIERRAS, a MAG programme.

Finally, we have the PITPPA project (2017–2021), which began under guidelines similar to those of its predecessor and was mainly due to the ideological stance of Ecuador's president Rafael Correa [82,83]. However, throughout his administration, various factors affected the direction of the project. Among them, the marked distancing from the philosophy of Socialism for the 21st Century [84–86] and global restrictions due to the COVID 19 pandemic stand out [87]. Evaluations of the project are yet to be published.

4.2. WEF Nexus Approach to Assessing the Impacts and Long-Term Sustainability of Interventions in the Agri-Food Sector

4.2.1. Water Resources

In 2018, Salmoral et al. [88] studied food and water security in an Ecuadorian region. They concluded that, although the water available in the country could satisfy food production needs, water security is a problem in areas where the resource is scarce and residents are poor. This is often the case where the production of crops for export takes precedence over the equitable management of water supply.

The implementation of agrarian reforms, mainly in the highlands, as well as progressive colonisation of lands together with deforestation, led to risks of water shortages and reduced water quality [89]. In this way, the increase in the peasant population at ever-higher altitudes has generated intense conflicts between uses and users [37].

Herrera et al. [90] present an analysis of water management in the Santa Elena Peninsula, highlighting that state intervention unleashes socially and economically inefficient results. On the other hand, Mena-Vásconez et al. [91] analyse the problem that arises from power relations in the face of industrial production dedicated to export. They point out that government policies for the expansion of water-intensive crops have often led to an accumulation of water rights by large agricultural companies, causing environmental degradation and legal, extralegal or illegal dispossession [92]. According to Rivadeneira and Wilhelmi [93], in Ecuador there are conflicts in the defence of water against extractivism and dispossession. These conflicts involve communities threatened by industrial mining projects [94] and violent agrarian dispossession that forces the adoption of technological packages [95].

In Ecuador, greenhouse floriculture has expanded in the highlands [96], leading small landholders to implement adaptative strategies [97]. According to Knapp [96], Ecuador is the world's third largest flower exporter; expansion of the sector took place from the beginning of the 1980s. The demand for water for greenhouse flowers is normally around 0.5 L per second per hectare, peaking at 1 L per second per hectare during the dry season. Plantations can be inserted into pre-existing irrigation networks, with water rights paid for under the table, a practice that has gone on for years because Ecuadorian law prohibits the sale of water rights. To meet the water needs of the crop, groundwater can also be pumped.

4.2.2. Soil

In Ecuador, two types of agricultural systems are recognised by the MAG. On the one hand, there is the industrial system focused mainly on monocultures such as banana [98]. On the other hand, we have peasant family farming involving diversified crops but facing various problems [99].

The MAG provides agroecological zoning maps by crop (Figure 4). The characteristics used to illustrate climatic ecosystems that determine the suitability of crops were altitudinal floors, climatic zones and types of soil. However, interviews conducted by the authors indicate that the majority of producers do not use this information, making decisions, instead, based on factors that do not necessarily respond to the technical guidelines. One reason may be that producers are unaware of the tool's existence because of a lack of socialisation by the ministry.

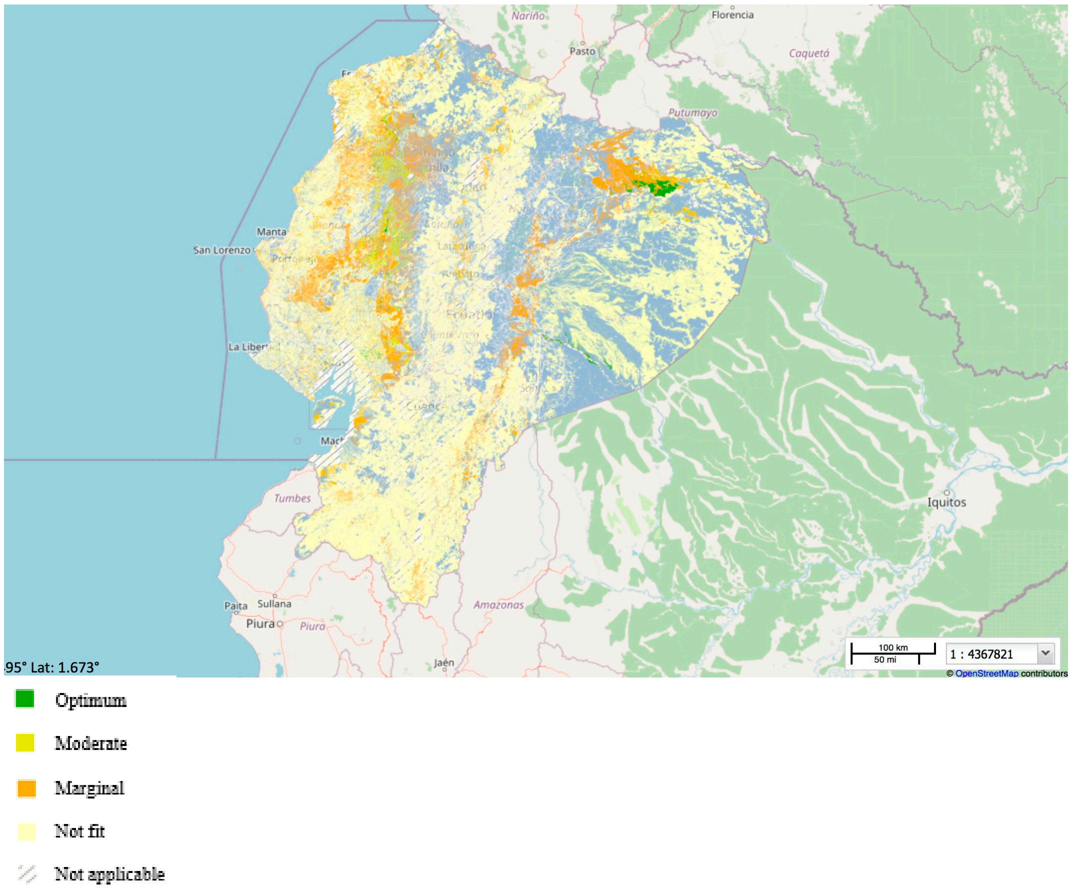


Figure 4. Agroecological zoning of cacao 1:25,000. Note: Classification according to the degree of aptitude.

According to the IDB [80], Ecuador's agricultural sector represented 10% of the gross domestic product (GDP) in the last decade and was the principal source of employment for more than two-thirds of the rural sector's EAP. Based on data from national agricultural censuses, agricultural policies extended the agricultural frontier. Figure 5 shows the increase in cultivated land from 1954 to 2020.

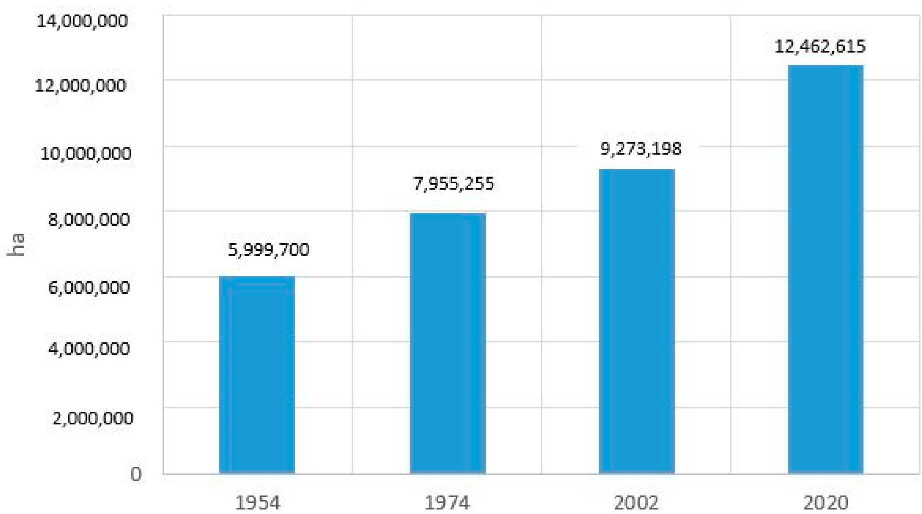


Figure 5. History of the increase in cultivated area in Ecuador. Adapted from [73,74,100–102].

The censuses carried out throughout Ecuador's history illustrate population increase, as evidenced in Figure 6. Similarly, the increase in population is directly proportional to the increase in urban settlement.

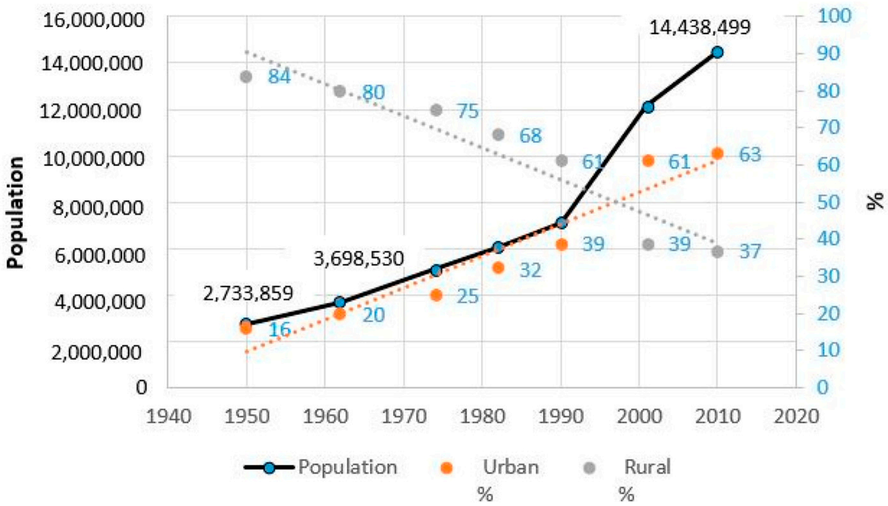


Figure 6. Ecuador's population from 1940 to 2020. Adapted from [103].

We were unable to compare information regarding land use between 2002 and 2013 and 2014 to the present due to changes in the methodology regarding measurement/description. The main land use data available are for pasture for milk and meat production, permanent and temporary crop lands and forested lands [102] (Figure 7).

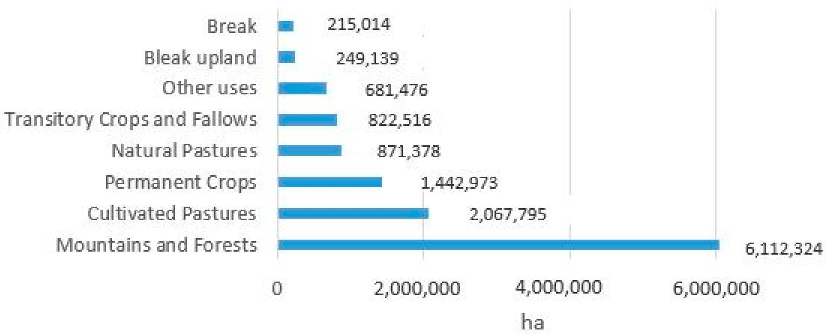


Figure 7. Land use by category—2020. Source: [102].

4.2.3. Agrochemicals

According to the Gobierno de la República del Ecuador et al. [104] (Figure 6), the average availability of kilocalories/100 g per capita is approximately 2700. Under this assumption, with 3,698,530 inhabitants in 1960, 8,765,516,100 kilocalories/100 g were required, compared with 2010 when 14,438,499 inhabitants had a requirement of 34,219,242,630 kilocalories/100 g.

Vallejo [105] states that Ecuador is a country with abundant natural resources. Moreover, part of the economy is based on agriculture [106], more specifically, export-oriented [107]. Thus, according to Vallejo [105], conflicts are inevitable due to the use of agrochemicals in plantations designed to increase food production causing water pollution, for instance, metal pollution due to industrial and agricultural activities in mangrove wetlands in river basins [108,109]. In the Guayas River Basin, Deknock et al. [110] found pesticide and chemical fertiliser residues used in banana and rice plantations. Sanchez-Mateos et al. [111] found heavy metal contamination in highland rivers due to floriculture residuals.

In Ecuador, according to interviewees, less than 1% of the national budget goes to technical assistance programmes in general, including agricultural training. All the agro-development programmes mentioned in this article promote the delivery of kits that include agrochemicals (Gran Minga Agropecuaria delivers property deeds so that farmers can obtain credit, irrigation, seed kits, agricultural and livestock insurance, technical assistance and agricultural mechanisation, as well as access to markets [112]).

According to Almutairi et al. [113], in Ecuadorian export banana containers, residues of nine pesticides were detected (azoxystrobin, carbendazim, chlorpyrifos, imazalil and thiabendazole were the most frequently found). The presence of agrochemicals threatens food safety and security. Orozco et al. [114] present the most recent information we were able to find; the authors point out reports of cases of mild pesticide poisoning per year increased from 363 in 1990 to 2163 in 2000.

Promoting a crop requiring extensive inputs among small farmers does not necessarily guarantee a higher income even though there is a greater cash flow; instead, income may be similar to that of a farmer who uses fewer inputs and/or plants a crop for which demand is lower [115].

4.3. Floriculture in Ecuador: A Case Study of a Non-Food Crop Requiring Resources That Could Be Used for a Food Crop

Ecuador is among the world's most biodiverse countries [13]. However, it allocates considerable land to monoculture production by agribusiness and is classified as a primary exporting country [116].

According to Rebaï et al. [67], a legal framework favourable to the "modernization" of the primary sector allowed the national and international private sectors to appropriate land and water resources for agroindustrial and mining development. For Ospina et al. [95], post-neoliberal Ecuador has only deepened the commodification of its primary resources, minerals and biodiversity, reinforcing its primary export sector and weak competitiveness. The floriculture sector falls into this category; its activities expanded in the 1990s thanks to international trade agreements [96].

As of December 2021, according to Ecuador's Public Agricultural and Livestock Information System (SIPA [102], floriculture accounted for 13.4% of the agriculture sector. This translates to 1,730,089 tons of flowers, which generated USD 9.6 billion in export earnings. The species produced included roses (73%), gypsophila (8%), carnations (2%) and others (16%). According to the National Finance Corporation [117], in 2020 the sector employed 28,775 people on 4930 ha. At the start of the decade beginning in 2010, around 7000 hectares were dedicated to floriculture.

Although floriculture generates employment and foreign exchange income [117], it uses water–soil–energy resources that could be used for food production. Land currently dedicated to flower production used to contribute to food security and sovereignty through the production of dairy cattle, grains and vegetables [118].

In the case of water, average consumption can be about 0.75 l/s/ha. If crops are irrigated five days a week for one hour/day, a total of 26,771,472 m^3 of water would have been used on the total area dedicated to floriculture between 2016 and 2020 (Table 1).

Table 1. Floriculture water and land use per year.

Year	ha	m^3/Year
2016	8006	5,620,212
2017	9612	6,747,624
2018	6961	4,886,622
2019	8627	6,056,154
2020	4930	3,460,860

Floriculture is a commercial activity with a production model that includes a specific technology. It uses agrochemicals constantly [119]. Unfortunately, the health of workers is at risk due to prolonged exposure to toxins and the misuse of personal protective equipment (PPE) [120]. Moreover, the spraying of these components also affects populations close to the crop, with significant variations in the levels of acetylcholinesterase [110]. On the other hand, the use of soluble fertilisers could cause salinity in soils and the presence of heavy metal contamination in rivers [111].

5. Discussion

According to von Bennewitz [58], based on the Gini coefficient for land, the Latin American agriculture sector is characterised by inequality. Agrarian reforms, similar to those in Ecuador, have been implemented in other Latin American countries [121–123] under the guise of state development programmes [124]. Most were inspired by the Green Revolution [125,126]. Even the latest so-called land reform was, in fact, a strategy designed to facilitate the appropriation of land by individuals with capital. Despite the huge sums invested in land reform and development programmes, the reality in Ecuador is similar to that in other Latin American countries [127], that is, the results have been uninspiring. The authors cited also state that some agricultural development programmes were executed over short periods and lacked continuity, a fact that has made the monitoring process difficult.

Analysis of Ecuador's development programmes demonstrates that, independent of the political ideology of its promoters, the objective is increased production and improved productivity. Such is the case for PROTECA, which retained the same structure despite its implementation by 17 different Ministers of Agriculture. As for development programmes, all that changed was the discourse, whereas the fundamental underlying elements remained the same. From the literature review, it is evident that, although on paper the importance of water and soil resources for food production are included, no project has dealt with these basic elements according to the WEF nexus approach. For projects implemented before 2011, this may be due to the fact that the approach was developed in those terms in that year [28].

The WEF nexus is an important analytical framework to assess security challenges [128] that allows for an understanding of the interrelations between water, energy and food [129]. Designing public policy according to the WEF nexus could be a fundamental key to economic growth and progress [130]. Adequate application requires strengthening monitoring and standard information gathering programmes [26]. More broadly, the nexus can be used to address the considerable challenge of global food security [131].

We have some additional reflections on the water resource. According to Pimentel et al. [132], agricultural runoff threatens the world's drinking water because it contains animal and chemical waste. For instance, the Guayas River Basin contains excessive nutrients, especially ammonia, due to pesticide pollution [110]. Another complicating factor is the pressure on the water used for energy generation in hydroelectric dams that impacts on the environment in general and agriculture in particular [133]. There is also a risk due to the water use in biofuels threatening food safety [116]. All of these threats indicate the need to work towards water security for the sake of food security [134]. Mora-Bernal points out that Ecuador's 2008 Constitution guarantees the human right to water and identifies the various uses of water and the need to avoid conflicts over its use [135].

The use of agrochemicals is an energy issue requiring attention. Krausmann et al. [136] point out that, as a result of population growth and economic development, the demand for food increases. Some authors [137] note that continuous exposure to pesticides produces serious health concerns, some of which are irreversible and/or affect the central nervous system [137,138]. According to Orozco et al. [114], this situation is related to the unequal distribution of public resources, with limited investment in rural areas and gender relations. Mistaken beliefs among small farmers include the notion that wearing PPE while applying agrochemicals is unnecessary and that getting sick while doing so is a sign of weakness.

Finally, care of the soil resource is an urgent matter. Censuses carried out throughout Ecuador's history demonstrate an increase in the population, as evidenced in Figure 6. This phenomenon could lead to shortages of food and energy [3] and has produced the extension of the agricultural frontier, causing deforestation at an approximate compound annual rate of 3.3% [13]. Similarly, in a directly proportional relationship, a population increase (Figure 6) produces an increase in urban settlement. This situation leads to land use transformations and pressure on natural resources [139]. As Stini [140] notes, Ecuador has a tremendous range of biodiversity. In this sense, Jimenez et al. [141] suggest that understanding local knowledge and soil management practices contributes to maintaining sustainable ecosystems. Marraccini et al. [142] maintain that agronomic diversity is a strategy that reduces the impacts on systems. Thus, assessing soil suitability for crops provides information for land use choices. This is an important matter, as the potential for soil loss is great in 47.9% of continental Ecuador [143], especially in the highlands [144]. Soil maps are consistent with the conventional methods used to evaluate soil and climate suitability according to Jimenez et al. [141], but the fact that technical land use maps are seldom utilised may be due to cultural issues.

Finally, Ecuadorian farmers are leaving rural areas for the city. Why? Southgate and Whitaker [143] maintain that causes may include displacement due to expansion of the agricultural frontier, land tenure policies and economic crises. For their part, Blackmore et al. [145] argue that mobility from rural to urban areas due to the displacement of populations towards poorer lands is linked to a combination of population growth, land scarcity and overexploitation of that resource. Stini [140] emphasises that the variety of technological innovations introduced and the imposition of inappropriate management techniques eventually produce irreversible effects on the soil [42]. All of the situations mentioned are produced or influenced by socioeconomic and production policies.

Based on this analysis of agricultural development in Ecuador, it is evident that, despite the discourse of an ideological range of governments, agriculture programmes have not always been directed towards supporting equitable economic growth and a healthier environment. A large portion of resources from development projects has been directed towards producers of crops for export. Thus, for importing countries, problems are externalised. We need to rethink how future public policies, while preserving the environment, can satisfy food demands and promote food security and local economic growth. One option is through the WEF nexus approach.

6. Conclusions

This study made it possible to identify key factors in the development of agri-food policies in Ecuador. They include environmental unsustainability due to the direct effects on the elements of the nexus approach (water–energy–food). The implementation of different public policies from the 1960s to 2020, with the application of land reform and state programs, has produced negative influences on the environment. In Ecuador, the public policies presented are aimed at guaranteeing food security, but the goals have not been achieved, mainly due to a lack of continuity and follow-up in state program implementation and corruption. There is evidence of a lack of decision making in the generation of public policies focused on the agricultural sector. There is a divide between the interests of programme promoters and the logic of producer demands. Current policies focus on agro-exports, a fact evidenced by promotion of the country's exports and investments in order to achieve strategic insertion in international trade, in addition to the search for international trade agreements and bilateral free trade agreements. Much work remains to be conducted to achieve sustainable production. It may also not be feasible due to the country's continuing political instability. By way of an overall conclusion, Ecuador's policies have been aimed at increasing production, sometimes disguised by other discourses. However, these policies have been unable to integrate other variables (the nexus) that are important to achieving sustainable agricultural production. Thought has never been given to reducing losses, for example those involving resources, or reducing the links in the market chain. Consequently, poverty remains with no solution in sight.

Author Contributions: Conceptualization, O.V.-S.; Validation, G.S.; Investigation, L.T.; Writing—original draft, L.T.; Writing—review & editing, L.T., G.S. and O.V.-S.; Supervision, G.S. and O.V.-S.; Funding acquisition, O.V.-S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Escuela Politécnica Nacional, grant number PIGR 19-15.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Written informed consent has been obtained from the interviewees to publish this paper.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Semi-Structured Interviews

The information obtained from the semi-structured interviews was used for further analysis. Some of the questions posed were:

What have been the most important projects developed by MAG?

From what perspective did each of the agrarian development programmes emerge?

In what years were they developed?

What were the main objectives initially set?

How were programmes financed?

How much was allocated for each programme?

What agencies were working on the projects?

What sectors benefited?

What premises were used to determine the distribution of impact zones?

In which links of the chain was project implementation concentrated?

How did producers respond to the programmes?

What was the scope of the programmes?

What were the most important achievements?

What, in your view, has been the impact of the programmes?

Do you believe that this programme has contributed to food sovereignty and food security? Why or why not?

How were decisions made regarding research and technology transfer?

Is the programme in question linked to the principles of the Green Revolution?

What do you think were the main limitations of the programmes?

Was an ex-post evaluation of each programme carried out?

Do you believe that lack of project continuity has delayed the development of Ecuador's agricultural sector?

In your view, do the agrarian programmes implemented respond to a long-term agrarian policy?

Do you believe that family farming is viable?

What agrarian model do you consider viable in economic, environmental and social terms?

Do you think there is a link between food, water and energy production?

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