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Current Status and Trends in Cabo Verde Agriculture

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Abstract: With climate change, drought is expected to increase, and its negative impacts will be particularly important in developing countries, usually with rainfall-dependent agriculture. The Cabo Verde archipelago is characterized by limited resources, remoteness, vulnerability to natural disasters, and a fragile environment. In this study, we provide the first report of the current status and trends of agriculture in Cabo Verde. We present data on the current performance of agricultural production areas in these islands and discuss them in terms of their most important natural constraint, water. Also, we assess the impact of institutional strategies on crop production and evaluate recent mechanisms that have been engaged towards agrarian development in this archipelago. Our results show that, among the ten Cabo Verde Islands, Santiago has the largest area used for agriculture (52.5%), followed by Santo Antão (16%) and Fogo (15.8%), and that rainfed farming dominates in all of them. The staple crops, such as maize and beans, are produced through rainfed subsistence farming, whereas irrigated crops (i.e., sugarcane, tomatoes) are mostly grown for commercial purposes. The prolonged drought periods, exposure, erosion and soil degradation, which led to increasing desertification over the last decades, have been identified as the main constraints to agrarian development across the ten islands of the archipelago. The strategies of Cabo Verde government to mitigate water scarcity through small-scale irrigation based mainly on small dams and drip irrigation technology have a marked effect on agricultural production in the predominantly arid and semi-arid areas of this archipelago.

Keywords: agriculture resilience; climate change; drought; irrigated farming; rainfed farming

1. Introduction

With climate change, drought is expected to increase in duration and severity, and its negative impacts will be particularly important in developing countries, usually with rainfall-dependent agriculture [1]. The Cabo Verde archipelago consists of ten large islands (of which nine are inhabited) and is located off the western coast of Africa. These islands are characterized by their limited resources, remoteness, susceptibility to natural disasters, vulnerability to external shocks, and fragile environments [2,3]. With a subtropical and dry climate, Cabo Verde has been affected by serious and prolonged droughts over the past decades [4]. Moreover, the small area available for agriculture, and topographic features such as mountain peaks and steep slopes, contribute to limiting the homogenous cultivation of crops in this archipelago [5].

Cabo Verde Islands were discovered in 1460 by navigators serving the Portuguese crown, who found the islands uninhabited and apparently without evidence of previous human presence [6]. Presently, most of the archipelago's population (294,135 inhabitants in 2015) lives in the capital, Praia, Santiago Island, where the government administrative headquarters are located. Praia and Mindelo (in São Vicente Island), are the main cities of the country. The largest island is Santiago, and it was the first to be inhabited in the 15th century [6], being also the most important agricultural and economic centre of the country [7].

Cabo Verde has been recognized by the international community (governments, companies, and institutions) as one of most successful African countries regarding political, economic and social performance in recent years [8,9]. This development effort underpinned by a transformation strategy justified the middle-income country status conferred by a United Nations resolution in 2008, and also its acceptance as a member of the World Trade Organization [10] in the same year. Despite the progress made and the commitment of the government, Cabo Verde continues to struggle with macroeconomic problems arising from its insularity and archipelago configuration, fast demographic growth and insufficient production, which only covers 10%–15% of the food needs of its population [9,11]. Cabo Verde depends on key external financial flows to support and sustain its economy, with significant imports of energy (petroleum products) and food, especially through official assistance with development and the remittances of emigrants in the diaspora.

Historically, the evident aridity of the islands did not attract agricultural-oriented settlers [12]. That aridity presents numerous obstacles to a stable agricultural-based society, with drought and famine being ever-present problems for the human occupation of Cabo Verde. Typically, commercial crops have been planted in the few irrigated lands, while subsistence crops are planted in rainfed areas, thus explaining several historical records of famine resulting from droughts [13]. This recurrent event has always forced the country to import food goods. Cotton was the earliest significant crop in Cabo Verde, first in Santiago, then in Fogo, and was an important product until the end of 19th century [12]. The lichen *urzela* (*Roccella tinctoria* DC.), used to obtain orchil dye, also became an important product [14]. However, the discovery of other *urzela* sources in Angola and Mozambique, and market competition, reduced the economic importance of these agriculture commodities. The introduction and implementation of tropical crops as staple crops, namely maize, beans and manioc from the New World, bananas from Africa, and rice from Asia, occurred soon after island settlements in the 16th century [15]. Due to economic interests, and since the beginning, maize and other subsistence crops were established in rainfed areas while sugarcane, coffee and cotton occupied irrigated areas [12].

The Cabo Verde agrarian sector has always been greatly vulnerable, due to a number of constraints, such as shortage of rainfall, prolonged droughts, scarcity of resources (water and soil, low soil quality, and relatively small farmland), small territory, and poor technological knowledge [16,17]. There are no permanent surface fresh water sources in Cabo Verde, and together with the irregular and insufficient rain, this has the most important negative impact on agriculture and water supplies [18,19]. As a result, the current exploitation system is essentially oriented towards subsistence agriculture. Despite its fragility, the agricultural sector is still the support of a large number of families whose livelihoods are closely associated with land. The scarcity of natural resources and raw materials, and insufficient basic infrastructures, among others, maintain a poorly productive agricultural sector and Cabo Verde's economy relies on the development of services and trade. According to the country's National Institute of Statistics (INE) [20] and the National Bank [21], the tertiary sector accounted for more than 70% of Gross domestic product (GDP) over recent years and has been the main driver of economic growth.

In contrast, the contribution of the agricultural sector has been decreasing over the last decades. In 1992, agriculture, forestry and livestock farming accounted for only 9.9% of GDP, and in 2005, for 5.2% of GDP. More recent data from INE show that from 2000 to 2007 the weight of the subsectors of agriculture, livestock, forestry, and fisheries on GDP slowed down to around 8.2%, representing about 9% of GDP in 2010 [21] and 6.3% in 2017 [20]. Production is intended primarily for domestic consumption and has played a crucial role in ensuring food and stabilizing food prices. It is also recognized as one of the best options to reduce poverty and improve livelihood, contributing to job creation. According to [19], the agricultural sector in Cabo Verde plays an important role in the country's economic and social development, since it is not possible to predict, in the short term, another form of occupation for about 60% of the country's population, who live in rural landscapes. Data from the 2005 Household Food Vulnerability Tracking Survey (ISVAF) show that 81% of rural households in the country are involved in primary sector activities directly linked to agriculture and livestock [22].

Studies approaching the characterization of Cabo Verde archipelago agriculture are limited [19,23], despite some reports have been made in an island context, particularly in Santiago Island [24,25]. More recently, studies have sought to address the efficiency of public policies aimed at the development of the agricultural sector, especially in solving its structural problems related to the extreme dependence on rainfall and the consequences of guaranteeing food security for the population [26,27]. However, an overall evaluation of the agriculture patterns within Cabo Verde archipelago is still lacking and is of the utmost importance for directed and focused policies towards up to date agriculture systems practiced for both commercial and subsistence purposes.

With this work, we made an integrated assessment of information on the present status and trends of the agriculture sector in Cabo Verde. We present data on the current performance of agricultural production areas in these islands and discuss them in terms of their most important natural constraint, water. Also, we assess the impact of agriculture strategies on crop production and evaluate recent mechanisms that have been engaged towards agrarian development in Cabo Verde.

2. Material and Methods

2.1. Studied Area

Cabo Verde archipelago is of volcanic origin and nine of its ten islands are inhabited [6]. These islands present a total surface area of 4033 km^2 and the islands are grouped as: (i) northern group (Santo Antão, São Vicente, Santa Luzia and São Nicolau); (ii) southern group (Santiago, Fogo and Brava); and (iii) eastern group (Sal, Boavista and Maio). Topography across most of the islands is quite rugged, with steep peaks in the islands of Santo Antão, São Nicolau, Santiago, Fogo and Brava, and altitudes that easily exceed 1000 m in some islands, thus offering a wide range of habitats over relatively short distances [28].

2.2. Climatic Characterization

The climatic characterization of Cabo Verde Islands is presented in Table 1, and data was compiled from several sources [29–41]. Due to its geographical location within the vast Sahel area, strongly influenced by the northeast trade winds, the climate surrounding Cape Verde is arid and semi-arid, with a long dry season (8-10 months between November and July) and a short, sparse and irregular hot and humid rainy season from August to September (60%–80% precipitation) [42–44]. The amount of precipitation that each island receives annually varies by topography, not exceeding 300 mm in areas below 400 m and 700 mm in areas above 500 m (Table 1).

Table 1. Climatic variables (mean annual temperature, mean annual precipitation, mean annual relative humidity) for each inhabited island of Cabo Verde archipelago.

Island	Tmin: Mean Temperature (°C)	Tmax: Mean Temperature (°C)	T: Mean Annual Temperature (°C)	P: Mean Annual Precipitation (mm/year)	Mean Annual Relative humidity (%)	Maximum Elevation (m)
Santo Antão	21 °C	26 °C	22 °C	237 mm	75%	1979 m
Boavista	21.8 °C	27.2 °C	24.2 °C	68 mm	NA	387 m
São Nicolau	19.5 °C	26 °C	22 °C	142 mm	73%	1304 m
São Vicente	21.8 °C	26.5 °C	23.9 °C	93 mm	68.5%	725 m
Sal	22 °C	27 °C	23.9 °C	60 mm	72%	406 m
Santiago	18 °C	27 °C	25.1 °C	321 mm	75%	1394 m
Fogo	26 °C	20 °C	25.1 °C	495 mm	70%	2829 m
Maio	22.5 °C	27.5 °C	24.4 °C	150 mm	NA	300 m
Brava	23 °C	27 °C	25.1 °C	268 mm	NA	900 m

NA—data not available. Sources: [29–44].

The average annual temperatures are usually moderate, around 25 °C, due to maritime influence, with the highest monthly average temperatures in September (warmest season, 26.7 °C) and the lowest in the cool season (January / February, 18.4 °C) (Table 1). The average annual relative air humidity varies from 75% in the arid lowlands to more than 80% in the highest areas. Depending on the terrain, climate, and type of vegetation, the following bio-climatic zones are considered today: (i) Arid coastal zone, at altitudes 0–200 m, with an annual rainfall below 300 mm; the vegetation is usually of the herbaceous steppe type; (ii) Semi-arid zone, at 200–400 m altitude, with an annual rainfall of 300–400 mm; natural vegetation, although more diverse, differs little from that in the arid coastal zone; (iii) Sub-humid zone, at 400–600 m altitude, with a rainfall of 400–600 m; this area is rather occupied by agriculture, and several shrubs and tree species can be found; and (iv) Humid zone, above 700 m, with average rainfall greater than 600 mm, particularly in north-facing slopes.

2.3. Data Collection

The characterization of the agriculture profile of Cabo Verde Islands was based on four complementary sources: (1) in-country available agricultural data from the Ministry of Agriculture and Environment [45,46] and the National Institute of Statistics (INE) [39]; (2) grey literature [12,28–47]; (3) an expert-wise approach based on the authors' (A.F., V.F., A.M.C. and M.M.R.) extensive fieldwork in Cabo Verde over a 10 year-period; and (4) data retrieved from FAOSTAT on the top six agriculture commodities in terms of production (tons) and harvest area (ha) [48]. The first step was to compile the scattered information on the agriculture areas of each island and to complement it with results from a detailed survey of in-country available data from Agriculture delegations and the Ministry of Agriculture (Cabo Verde). In order to evaluate the agriculture areas per island, we investigated: (a) extant rainfed and irrigated crops; (b) the crop species, namely for local market trade and household consumption. Agriculture area data for each island was compiled from in-country published source to undertake a longitudinal assessment and reconstruct agriculture profiling patterns, which allowed to prospect an in-depth study of agronomical sources of the country, as detailed in Table 2. Additionally, in order to determine the role of irrigation facilities supporting agriculture in Cabo Verde, data compilation was performed using FAOSTAT restricting for cropland and land area equipped with irrigation under a 10 year-timespan (2006–2016) [49].

Table 2. Data compiled from Cabo Verde islands concerning agriculture areas (total, rainfed and irrigated) and type of crops under each farming system (rainfed or irrigated).

Cabo Verde	Geographical Area (km^2)	Agriculture Area (ha)	Rainfed Area (ha)	Rainfed Crops	Irrigated Area (ha)	Irrigated Crops
	4033 Km^2	**44531**	**40434**		**4097**	
Santo Antão	785	7139	5356	Maize (*Zea mays*), beans (*Cajanus cajan*, *Phaseolus vulgaris*, *Vigna unguiculata*, *Lablab purpureus*), coffee (*Coffea arabica*), mango (*Mangifera indica*), citrus fruits (*Citrus reticulata*, *C. limon*, *C. x sinensis*), breadfruit (*Artocarpus altilis*)	1783	Sugarcane (*Saccharum officinarum*), banana (*Musa* sp.), horticulture crops (tomatoes- *Solanum lycopersicum*, carrots- *Daucus carota* subsp. *sativus*, onions -*Allium cepa*, pepper- *Capsicum annum*, cabbage- *Brassica oleracea*), yam (*Colocasia sculenta*)
Boavista	631.1	188.8	138.8	Maize (*Zea mays*), beans (*Cajanus cajan*, *Phaseolus vulgaris*, *Vigna unguiculata*, *Lablab purpureus*)	50	Pepper (*Capsicum annum*), onions (*Allium cepa*), tomatoes (*Solanum lycopersicum*), eggplant (*Solanum melongena*)
São Nicolau	344.61	1509	137.2	Maize (*Zea mays*), beans (*Cajanus cajan*, *Phaseolus vulgaris*, *Vigna unguiculata*, *Lablab purpureus*), mango (*Mangifera indica*), almond tree (*Prunus dulcis*)	136.8	Sugarcane (*Saccharum officinarum*), roots and tubers (cassava- *Manihot esculenta*, sweet potato- *Ipomoea batatas*, yam- *Colocasia sculenta*), banana (*Musa* sp.) and horticulture crops
São Vicente	226.7	144.3	97.1	Maize (*Zea mays*), citrus fruits (*Citrus reticulata*, *C. limon*, *C. x sinensis*), date palm (*Phoenix dactylifera*)	47.2	Sugarcane (*Saccharum officinarum*), roots and tubers (cassava- *Manihot esculenta*, sweet potato- *Ipomoea batatas*, yam- *Dioscorea* sp.), beetroot- *Beta vulgaris* subsp. *vulgaris*, lettuce- *Lactuca sativa*, tomatoes- *Solanum lycopersicum*, onions -*Allium cepa*, turnip -*Brassica rapa* subsp. *rapa*, parsley- *Petroselinum crispum*, coriander- *Coriandrum sativum*
Sal	219.8	2.7	0.9	Maize (*Zea mays*), beans (*Cajanus cajan*, *Phaseolus vulgaris*, *Vigna unguiculata*, *Lablab purpureus*), watermelon (*Citrullus lanatus*)	1.8	Coriander (*Coriandrum sativum*), tomatoes (*Solanum lycopersicum*), lettuce (*Lactuca sativa*), cabbage (*Brassica oleracea*)
Santiago	991	23378	22121	Maize (Zea mays), beans (Cajanus cajan, Phaseolus vulgaris, Vigna unguiculata, Lablab purpureus), horticulture crops, mango (Mangifera indica), roots and tubers (cassava- Manihot esculenta, sweet potato- Ipomoea batatas, potato- Solanum tuberosum)	1257	Sugarcane (*Saccharum officinarum*), horticulture crops (tomatoes-*Solanum lycopersicum*, carrots -*Daucus carota* subsp. *sativus*, onions- *Allium cepa*, beetroot- *Beta vulgaris* subsp. *vulgaris*, cabbage- *Brassica oleracea*, eggplant- *Solanum melongena*), banana (*Musa* sp.), roots and tubers (cassava- *Manihot esculenta*, sweet potato- *Ipomoea batatas*, potato- *Solanum tuberosum*, yam- *Colocasia sculenta*)
Fogo	471.2	7014	6986	Maize (Zea mays), beans (Cajanus cajan, Phaseolus vulgaris, Vigna unguiculata, Lablab purpureus), roots and tubers (cassava- Manihot esculenta, sweet potato- Ipomoea batatas, potato- Solanum tuberosum), citrus fruits (Citrus reticulata, C. limon, C. x sinensis), coffee (Coffea arabica), grapevine (Vitis vinifera), avocado (Persea americana), guava (Psidium guajava), mango (Mangifera indica), apple (Malus domestica), figs (Ficus carica), and pomegranate (Punica granatum), cashew (Anacardium occidentale)	28	Cabbage (*Brassica oleracea*), banana (*Musa* sp.), yam (*Colocasia sculenta*).
Maio	274.5	277.8	236.2	Maize (Zea mays), beans (Cajanus cajan, Phaseolus vulgaris, Vigna unguiculata, Lablab purpureus), watermelon, pumpkin (Cucurbita pepo), sweet potato (Ipomoea batatas)	41.6	Onions (Allium cepa)
Brava	62.51	503.8	467	Maize (Zea mays), beans (Cajanus cajan, Phaseolus vulgaris, Vigna unguiculata, Lablab purpureus)	36.8	Pepper (*Capsicum annum*), roots and tubers (cassava- *Manihot esculenta*, sweet potato- *Ipomoea batatas*, potato- *Solanum tuberosum*, pumpkin- *Cucurbita pepo*), banana (*Musa* p.), lettuce (*Lactuca sativa*), tomatoes (*Solanum lycopersicum*), carrots (*Daucus carota* subsp. *sativus*)

Sources: [28–47].

3. Results and Discussion

3.1. Characterization of Cabo Verde Agriculture Sector

According to the general agriculture 2015 census [50], the agricultural population represents 34.8% of the population of Cabo Verde (182,396). The total arable land area is 36,450 ha, of which 81.9% is rainfed, 16.8% irrigated and 1.3% has both dry and irrigated agriculture [45]. Cabo Verde's agriculture is family-oriented, based on small, unorganized small units (micro-owners), not exceeding 1–1.5 ha. About 11% of the total area of Cabo Verde is used for agriculture (Table 2). About 71% of the cultivated areas have less than 1 ha and, of these, more than a half has less than 0.5 ha, and only 11% is larger than 2 ha [45].

Overall, the gathered data allowed an overview of the current agriculture profiles and patterns in Cabo Verde Islands. The largest one, Santiago (991 km^2), is also the major agriculture centre, accounting for 52.5% of Cabo Verde's total agriculture area (Figure 1). Significant areas are also found in Santo Antão (16%) and Fogo (15.8%). Conversely, Sal has the smallest agricultural area (0.01%), and Boavista, with a larger geographical area than Fogo (471.2 km^2), has a very small share of the total agriculture area (0.4%). The main reason relates to its climate and landscape, markedly influenced by dry and hot Saharan winds, since it is the closest island to the African continent.

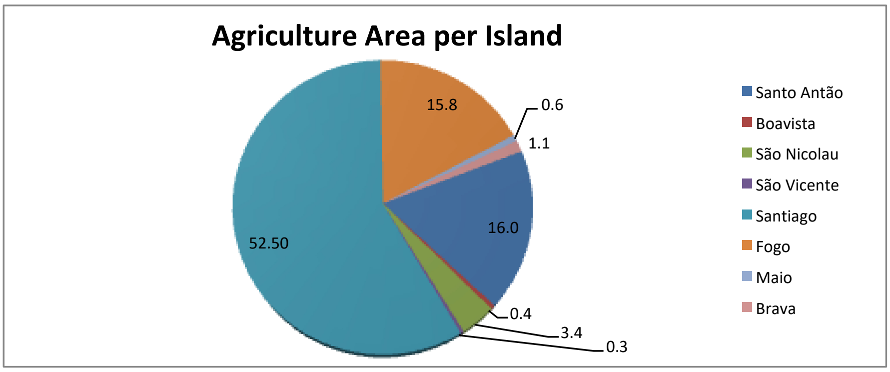

Figure 1. Agriculture area per inhabited island of Cabo Verde archipelago (in percentage). Data not represented for Sal Island, with only 0.01% of agriculture area.

Two types of agriculture systems are identified: rainfed agriculture, practiced on the slopes during the rainy season, and irrigated agriculture, practiced year-round mainly in valleys, on the lower slopes and on small plateaus. Agriculture patterns of rainfed and irrigated crop production clearly show the former as the most important farming system in the archipelago, corresponding to 91% of its total agriculture area (Table 2). In each island, rainfed agriculture generally accounts for more than 50% of total agricultural area, the exception being São Nicolau, with a fair share of irrigated areas (50%) (Figure 2). Specifically, 90% of the agriculture practiced in Santiago, the major agriculture centre of the country, is rainfed, while in Fogo only residual irrigated agriculture is found. This overall trend of large rainfed agriculture areas in Cabo Verde shows a high dependence on rainfall for agriculture production.

The arable area is concentrated on the main agricultural islands, with about 58% of the soils suitable for agriculture located in Santiago, followed by Santo Antão, Fogo, and São Nicolau. Approximately 68% of the total arable land is occupied with rainfed crops, 26% with agroforestry and 6% with irrigated crops, mostly restricted to moist slopes.

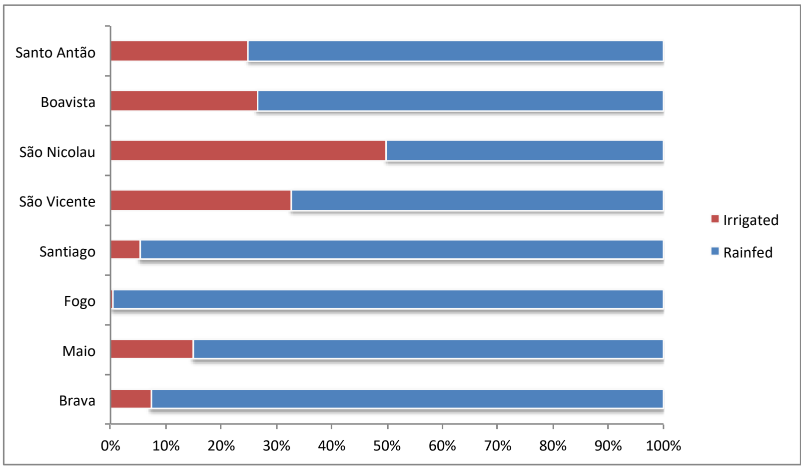

Figure 2. Rainfed and irrigated agriculture areas in Cabo Verde Islands.

Most West African agriculture is essentially rainfed, and Cabo Verde is no exception, ever struggling with a key limiting natural resource, water. As shown in Figure 3, the area used for crops (Cropland) is not supported by irrigation (Land area equipped for irrigation), and no significant increase of area with irrigation infrastructure and equipment was observed over the latest 10 years (2006–2016). This highlights the fact that even the irrigated areas risk collapsing, due to the scarcity of water supply infrastructures, despite the construction of dams with the ultimate goal of providing water for irrigated agriculture areas.

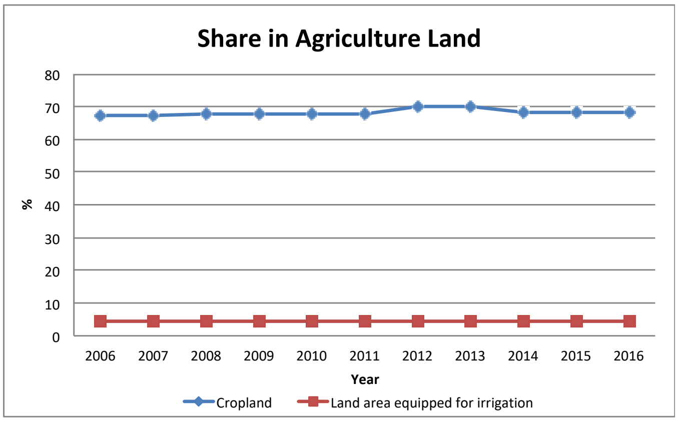

Figure 3. Share in agriculture land regarding Cropland and Land area equipped for irrigation in Cabo Verde, from 2006 to 2016. Source: [49]. Cropland is the land used for cultivation of crops; Land area equipped for irrigation refers to the area prepared with irrigation infrastructure and equipment for crops.

3.2. Drought as the Main Variable of Agriculture Patterns

Drought occurs when either the amount or distribution of rainfall prevents a successful agricultural harvest. Extended drought has many negative consequences, including a drastic reduction of animal herds (particularly cattle and goats), environmental degradation driven by erosion processes, reduction of groundwater supplies, and the loss of human capital through emigration. The first drought crisis in Cabo Verde was between 1580 and 1583, and "many people died" [12,13]. Such crises periodically mark Cabo Verdean history: from 1903 to 1948. there were four major drought-related famines, with the last catastrophic drought of 1947–1948 immortalized in "Fomi 47", a song by the Cabo Verdean musician Codé di Dona about drought, famine, and emigration to São Tomé Island in 1947. After independence in 1974, the national government made great efforts to develop and modernize the agricultural sector, and thus provide the country with food products and avoid food deficits.

Rainfall in Cabo Verde is characterized by its strong intensity, often in the form of heavy short-term rainfall [51]. This type of precipitation considerably aggravates erosion due to the high velocity and energy of runoff, a phenomenon favoured by the type of agriculture practiced on unsuitable land, by soil shallowness and little vegetation cover, preventing adequate infiltration [5]. In fact, the soils are generally poorly evolved, thin, and very stony, covering more than half of the country's surface [52,53]. Moreover, only 10% of the total surface area is considered potentially arable (Table 2).

Rainfed agriculture is a farming system that depends solely on rainfall. In Cabo Verde, it is characterized by extensive land use by a diverse workforce and is generally practiced on steep slopes. Despite its limited productivity, rainfed farming is an important activity for the rural population, guaranteeing part of their food. However, this subsistence farming does not fully meet local needs in terms of cereals and pulses [19,23]. This traditional farming system does not contribute much to development, as its production capacity is low and most of the output is consumed locally, limiting the expansion of producers' gains. Yields are random due to the variability of precipitation, resulting in unsteady agriculture productivity values. The main rainfed crops that form the basis of the country's diet include maize (*Zea mays*) and several beans: congo beans (*Cajanus cajan*), bongolon (*Vigna unguiculata*), slipper (*Phaseolus vulgaris*) and stone bean (*Lablab purpureus*). They are grown in all climatic strata regardless of their agricultural potential. On average, the yield for maize, the only cereal produced in Cabo Verde, is 600–700 kg/ha [54] and, for beans, around 90 kg/ha [46]. Roots and tubers such as cassava (*Manihot esculenta*) and sweet potato (*Ipomoea batatas*) are rainfed crops grown in sub-humid areas.

Among the irrigated crops, sugarcane (*Saccharum officinarum*) is the most important one, besides tubers like potato (*Solanum tuberosum*) and various tropical fruits such as banana (*Musa* spp.) and papaya (*Carica papaya*). Various vegetables such as tomatoes, carrots, kale, onions, and peppers are grown in irrigated areas. Most of the irrigated land is still used for sugarcane production, particularly in Santo Antão and Santiago, occupying between 45%–80% of their agricultural areas. Coffee (*Coffea arabica*) is grown as a cash crop in the wetlands. With the exception of bananas and papaya, fruit production is mainly under rainfed conditions and yields are still far below their potential. The importance of the fruit-production sector in Cabo Verde agriculture sector is growing about 8600 tons per year, namely of banana, papaya, mango, citrus, avocado and grapes, which contributes to a per capita consumption of 84 kg [46].

An analysis of the agriculture commodities in terms of production and harvested area was also performed. When looking for top agriculture commodities in Cabo Verde, sugarcane is clearly the most marketable crop, followed by tomatoes and then pulses, maize, cassava, and coconuts (Figure 4).

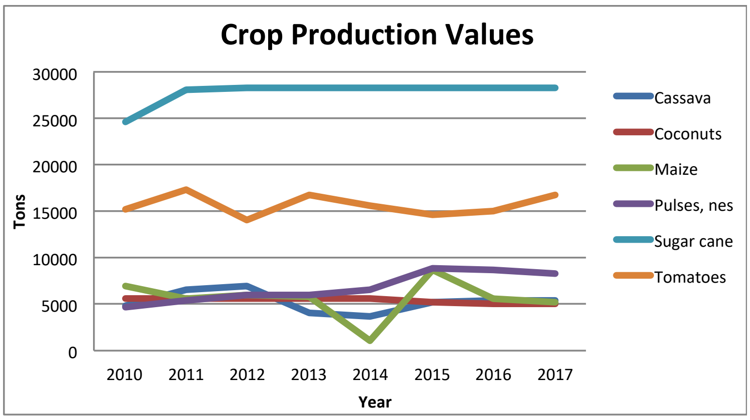

Figure 4. Production (in tons) of the top six agriculture commodities in Cabo Verde, from 2010 to 2017. Source: [48]. "Pulses, nes", pulses that are not identified separately by species according to FAO [48].

Sugarcane is an important crop in Cabo Verde, mainly for its by-product "*grog*", a highly alcoholic drink, very much appreciated by locals and tourists, also exported as a national product. The horticultural production, which includes tomatoes, shows an increasing trend and could occupy an important place in the agricultural economy of the country. Other crops such as pulses, maize, and cassava are mainly produced for local consumption and are considered staple crops. When analysing harvest area devoted to agriculture crops (Figure 5), maize and pulses occupy a great share, which is not translated into high production, namely in the case of maize (Figure 4), which is one of the Africa's most important food crop [55,56]. Maize production, however, is risky because of unpredictable rainfall, a most relevant uncertainty in Cabo Verde. Also, the current maize production does not meet the internal demand, and the cereal must be imported for food and fodder. Pulses also occupy a great share of harvest area in Cabo Verde, mainly in an intercropping system with maize. Intercropping with pulses, such as common bean, cowpeas and other native beans, is relatively common where landholdings are small and there is less pressure on the land. Thus, the importance of pulses in local eating habits should also be noted.

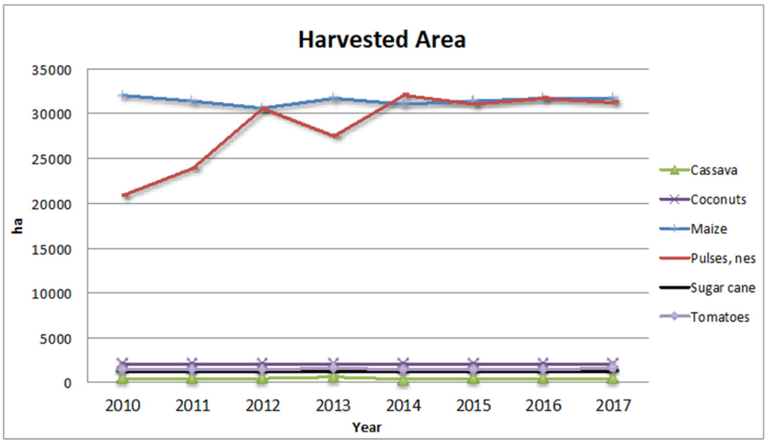

Figure 5. Harvest area (ha) of the top six agriculture commodities in Cabo Verde, from 2010 to 2017. Source: [48].

The small harvested area of sugarcane and tomatoes, with high production shares must be highlighted (Figure 4), as it emphasizes the adaptation of these crops to the extreme conditions of agrarian systems in Cabo Verde. Also, it is noteworthy that both maize and pulses are rainfed-cropping systems, whereas sugarcane and tomatoes have irrigation.

3.3. Challenges to the Agriculture Sector

Cabo Verde's topography creates different types of land tenure, soil, and climate variations, leading primarily to subsistence production on very small plots with rainfed or dryland farming [23]. The key for success in the agricultural sector has been, and will be, the combination of several agricultural related-technologies and infrastructures [57]. Managing water for agriculture, including drip irrigation techniques, seems to be a key adaptation strategy for intensive and sustainable agriculture [26]. The government's strategy includes the construction of dams, embankments and wells to capture and store water, especially rainwater [58], which, together with irrigation technologies (low-head drip, sprinkler, furrow and basin, micro systems), contribute to an efficient water use and management.

Land scarcity generates intense competition between different possible land uses – urbanization, agriculture, extractive industries, forestry, tourism and other infrastructures [59]. The annual growth rate of agricultural GDP highlights the random nature of production, especially due to rainfed agriculture. The production of the horticultural sector has been increasing from 2007 to 2010, accumulating 42,908 tons, with horticultural production reaching 29,887 tons and roots and tubers totalling 13,000 tons. In recent years, the production of vegetables that had not been cultivated before indicates that they may occupy an important place in Cabo Verde's agricultural economy. As a result of hydroponic cultivation experiments (water, gravel, and soil), the supply of fresh vegetables to hotels has been encouraging the emergence of a new type of agriculture.

Together with the scarce harvesting area, there is instability in production, driven by extreme rainfall fluctuations. Despite all these constraints, Cabo Verde's agricultural sector has successfully expanded over the last decade, growing at an annual rate of 4.6% (2007–2016) [60] and leading to a growing supply of domestically produced fresh food in the markets [61,62]. Further expansion and intensification of agricultural production (especially horticultural, fruit farming, and vegetable production) will require the introduction of more sustainable and efficient production techniques, ensuring the protection of natural resources such as water, soil, and biodiversity.

3.4. Strategies for Coping with Water Scarcity

Dams provide increased water availability, indispensable for agricultural development and allowing the extension of the irrigated area. In 2006, the first dam was built, in the inner part of Santiago island (São Lourenço dos Órgãos), the Poilão dam (Figure 6) [59]. Despite its importance as a water resource for human consumption and agriculture, Poilão dam still depends on rainfall, and it is not functional during the dry season (Figure 6B). Given that Cabo Verde's water resources originate exclusively from precipitation [61], and due to the potential of surface water use, Shahidian et al. [63] point out that the government's current investment in dams and large dams is a correct bet to meet agricultural needs. The option for dams in Cabo Verde is a positive one, since it was imperative to adopt policies for the use of surface water, avoiding the overexploitation of groundwater in some regions [26,41,62], along with diversification of income-generating activities.

(**A**) (**B**)

Figure 6. Poilão dam in São Lourenço dos Órgãos at the Santiago Island (**A**) Rainy season; (**B**) Dry season). Photos taken by the authors (MMR and APE).

By increasing the available water resources and therefore favouring irrigated areas and reducing poverty, dams are extremely important in a country that relies mostly on rainfed agriculture, contributing to the transition to irrigated agriculture [51]. Irrigation allows independency from seasonal rains and offers the possibility of much higher yields, because production can be sustained throughout the year [62]. Drip irrigation, investments in water mobilization, and gravity irrigation schemes have expanded fast, with an increase of 11% from 2014 to 2015. In 2015, 19% of the farms used irrigation and 14% of all plots were irrigated [62]. Further expansion of agricultural production to ensure food security and commercial development will require more efficient water management technologies, such as capturing and mobilizing water from different sources, including rainwater, surface water, groundwater and wastewater. The effective management of water from all these sources can translate into better crop and livestock production. Managing water also includes strategies in crop production and soil conservation. Although drip irrigation has contributed to the growth of the agricultural sector, it has some limitations in a country where most of the land has accentuated slopes. If not well planned, drip water irrigation leads to soil salinization, groundwater contamination, and soil degradation [64,65]. Groundwater is easier to operate and use, although associated with high investments. The exploitable technical potential is between 44 and 65 million m^3/year. The capacity to mobilize irrigation water has increased in recent times with the construction of more catchment (dikes) and storage (small dams) infrastructures. However, the estimated overall exploited volume directed to agriculture and livestock is around 36.28 million m^3/year [43]. To this volume, springs contribute about 61%, wells 24% and holes 15% [66].

As mentioned before, the scarcity of natural resources, namely arable land, soil fertility, water and also rugged terrain are extremely challenging to consider the shift from traditional low intensive and farming systems to more intensive and irrigated farming systems by the government and public policies. Given the adverse context that favours increasing poverty, the government has been taking steps to increase productivity through sustainable agriculture with more profitable dynamics by mobilizing and efficiently managing water from alternative sources. Examples of these are water desalination, capture and storage of surface water through new infrastructures (dams), expansion of irrigated area, drip irrigation massification, and the conversion of rainfed agriculture, which have paved the way for new strategies to maximize the efficient usage of water resources in agriculture [67].

4. Conclusions

Cabo Verde has experienced periodic drought throughout its history and currently is going through a particularly severe 20-year period of subnormal rains. Such harsh conditions have long posed serious challenges to agricultural activities, resulting in irregular crop output. Nearly all the rural land is engaged in subsistence farming, for which the basic productive resource needs are land and labour. However, the heavy reliance on imported food products has long been a necessity. Strategies must include the diversification of cropping systems, such as rotation, multicropping, intercropping, and agroforestry, taking advantage of ecological synergies. One important factor to consider is the preservation of local biodiversity, without compromising the yields, using improved agronomic varieties. Another strategy that has been taking form in Cabo Verde is the investment in new agricultural production processes, such as hydroponics, to produce fresh vegetables, fruits, herbal teas, herbs, and flowers. Private and government investment as well as capacity building among farmers concerning such new production processes can boost the percentage of the agricultural sector participation in the country's GDP, and orient the sector market primarily to tourism [68,69], without threatening local livelihoods.

Over the past decade, the government has adopted a proactive policy framework to augment domestic agricultural productivity, extend the available arable land for farming, and invest greatly in water resources mobilization. Our study reveals that small dams can contribute to agricultural development, since the availability of water to farmers will allow for the development of agricultural activity and increase both production and income. Although the construction of small dams represents a positive governmental option, rainfall variability leads to unpredictable variations of water availability, as demonstrated by many dams that are presently dry, and therefore they do not solve the problems of agriculture in Cabo Verde.

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