OVERVIEW OF COFFEE PRODUCTION UNDER THE IMPACT OF CLIMATE CHANGE IN DAK LAK PROVINCE

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ABSTRACT

Many studies have shown that cultivating coffee in large areas has environmental impacts such as reducing the multi-layered forest structure to only 1-2 layers, depleting water sources, weakening protective functions, and increasing soil erosion. In fact, monoculture of coffee on a large scale has led to water shortages for daily living and production in the Central Highlands in general and in Dak Lak province in particular. Additionally, the effects of climate change on coffee production have become increasingly apparent, resulting in higher costs, increased water demand, and reduced yields. At this point, the adoption of agroforestry coffee production models is considered advantageous. These models provide appropriate shade for coffee plants, retain soil moisture better, and reduce irrigation needs; they also increase income and employment for farmers, and mitigate risks of soil and water resource degradation while enhancing adaptability and resilience to climate change. However, the effectiveness of the model will be enhanced if combined with forest restoration activities and intercropping woody plants within coffee-growing areas. Achieving this requires a series of synchronized solutions in policy and government support in investing in infrastructure and production facilities, engineering, modern scientific applications, capital, and integrated pest management.

Keywords: *Coffee production, Climate change, Dak Lak province*

1. INTRODUCTION

The Central Highlands has a natural area of more than 5.4 million ha, which is one of the areas with a high percentage of land and forest in use, over 81%, ranking 4th among 7 ecological regions in Viet Nam (Le Huy Ba, 2013). In the past, the rapid and uncontrolled transition of forest land use purpose with the combination of the unreasonable land use caused the vegetations, especially the area of natural forest to decrease in both area and quality, which lead to more erosion, leaching and degradation of land resources. Currently, there have been signs of the climate change (CC) in many places in the Central Highlands, including the Srepok River basin. Droughts are becoming more and more severe in the dry season and floods are unusual in the rainy season, which have a huge impact on production. These have negatively affected people's health, their daily life and the food security, as well as the environment, which increases the adverse impacts of CC (Bach Hong Viet, 2017).

In many places, forests have been cleared for land to grow coffee. This encroachment on arable land and the 38% increase in arable land were partly responsible for deforestation in many areas during the 10 years from 1990 to 2000 (World Bank, 2004). In addition, the local people have overgrown coffee trees in many areas. They cultivate massively with the method of monoculture of coffee trees on the large scale, even in areas that are not suitable for the growth and development of coffee trees (i.e. large slope, unsuitable foothold, lack of irrigation in the dry season…). That's why the problems are more serious, especially the decrease in water resources for daily life and for production in the Central Highlands.

Many countries around the world are implementing and applying the agroforestry coffee/ climate - smart coffee practices. Viet Nam is also one of the countries following this model. This type of production is considered to have outstanding advantages comparing to normal coffee growing habits and experiences. It limits the risk of the degradation of land and water resources, as well as increases the adaptability and resilience to CC. The model has demonstrated its economic, ecological and environmental efficiency and sustainability compared to other monocultures. However, the efficiency of the model will increase if it combines with the forest restoration in the upstream areas, in the adjacent zones and even in the coffee growing

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areas by the complementary crops (Nguyen Van Thuong, 2020).

The review article focuses on determining the current status of coffee production, and the risks and vulnerabilities of coffee production activities under CC conditions in Dak Lak province, based on which can prioritize applying smart farming solutions as an essential job.

2. CONTENTS

2.1. Current coffee production in Dak Lak province

Dak Lak province is located in the center of the Central Highlands, with a natural land area of 1,307,048 ha ranking the 4th in the country. Agricultural land ranks the first in the country with 655,985 ha (accounting for 50.19% of the natural area), including about 40% of the fertile basalt area that is suitable for development of industrial crops such as, coffee, rubber, pepper, cashew and fruit trees… (Dak Lak Provincial People's Committee, 2022).

Dak Lak province is known as the capital of coffee with an area and output accounting for nearly one-third of the total coffee area and output of the country. Coffee is a key agricultural product in the province's economic structure, accounting for a large proportion of the province's total social product and annual export turnover. Therefore, coffee has directly affected the income of the majority of people living in the area (Dak Lak Provincial People's Committee, 2021). The data in Table 1 shows that coffee trees are planted throughout 15 districts/cities with a total area of 212,912 ha, including the largest area in Cu M'gar district (38,457ha) and next large areas are in Ea H'leo district (31,907ha), Krong Nang district (24,886ha), Krong Buk district (20,789ha), Krong Pak district (19,840ha).

Table 1. Current state of coffee cultivation in 2022 in Dak Lak province

No.	District administrative units	Area (ha)
1	Buon Ma Thuot	11,167
2	Buoôn Ho	14,572
3	Ea H'leo	31,907
4	Ea Sup	26
5	Buon Don	4,660
6	Cu M'gar	38,457
7	Krong Buk	20,798
8	Krong Nang	24,886
9	Ea Kar	9,662
10	M'Drak	1,981
11	Krong Bong	8,497
12	Krong Pak	19,840
13	Krong Ana	9,920
14	Lak	4,908
15	Cu Kuin	11,630
	Total	**212,912**

Source: Crop Production and Plant Protection Department of Dak Lak province, 2022.

In the period of 2015-2021, the scale of coffee production in the area increased slightly, an average of 0.64% per year, from 203,000 ha in 2015 to 213,000 ha in 2021. From 2015 to 2018, the coffee area is quite stable; however, three years ago, the coffee area has tended to increase, especificially, the coffee area increased 5.046 ha in 2019, compared to 2018. It increased 1,846 ha in 2020, compared to 2019 and 3,381 ha in 2021, compared to 2020. However, by 2022, the coffee area tends to decrease slightly to 212.912ha, down 424ha due to the increased durian prices and people tend to cut down old low-yielding coffee trees to grow pure durian. Besides, although the coffee area in 2022 decreases slightly, coffee output in Dak Lak province still increases, reaching 558.729 tons and the average output per hectares of coffee is 2.62 tons. In general, in the period 2015-2022, coffee output in Dak Lak province tends to increase slightly over time. On average, coffee output in Dak Lak province increases by 3.23% per year, from 444.121 tons in 2015 to 558.729 tons in 2022 (Table 2).

Table 2. Coffee area and production in Dak Lak province from 2015 to 2022

Year	2015	2016	2017	2018	2019	2020	2021	2022
Area (ha)	203,746	203,357	203,737	203,063	208,109	209,955	213,336	212,912
Production (tons)	444,121	454,810	447,348	508,944	476,424	509,944	526,613	558,729

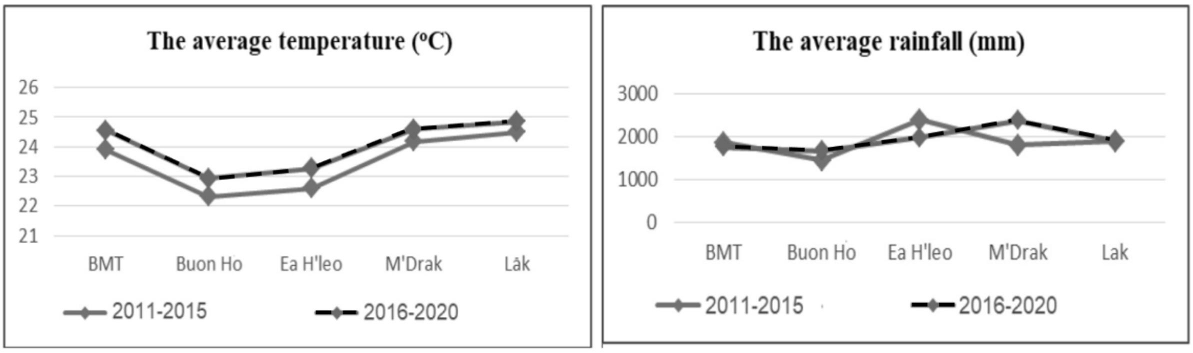
Source: Statistical report for 2015-2022 of the Statistics Department of Dak Lak province.

In Dak Lak province, the coffee production force is still limited. Coffee production and business suffers from many external challenges and risks; therefore, the current state of coffee production in the province is facing many problems. More than one-third coffee area is aged between 15-20 years old, which gives poor yield and need to be replanted. Many coffee growing areas are not planned, which lead to high production costs, low productivity, affecting the sustainable development of coffee production. More than 80% of the coffee areas is managed by smallholder farmers. Some of them have not mastered the process of caring techniques, which lead to low productivity and inefficiency investment. Because of the small-scale production, the degree of mechanization in all stages of coffee production is low, leading to low labor productivity, not saving water resources and materials… Coffee production faces many opportunities and challenges such as new coffee consumption trends, stronger international integration and impacts of CC (Dak Lak Provincial People's Committee, 2017).

2.2. Signs of climate change in Dak Lak province

2.2.1. The change of temperature and rainfall

As the statistics and charts in Figure 1 showed that the average temperature of monitoring stations in the period of 2016-2020 has increased, an average increase of 0.54^{o}C compared to the period 2011-2015. The highest temperature increase at Ea H'leo station (0.68^{o}C) with 24-27^{o}C, the lowest at Lak station (0.35^{o}C) with 17-23^{o}C; besides, the ability to adapt of plants is not only affected by temperature change but also by precipotation. Dak Lak tends to have an erratic average rainfall over the years. It distributes unevenly, depending on the region, having large fluctuations from 1,451.28 mm (Buon Ho station) to 3,202.3 mm (M'Drak station).



Source: Natural Resources and Environment Department, 2021

Figure 1. Evolution of average temperature and rainfall in Dak Lak province

2.2.2. Climate change scenarios and forecast changes of meteorological factors

The climate change scenario that is announced by The Ministry of Natural Resources and Environment in 2009 based on the climate change scenario of The Intergovermental Panel of Climate Change (IPCC) developing according to the greenhouse gas emmision scenarios (*Special Report on Emission Scenarios - SRES)* at levels: low (B1), medium (B2) and high (A2, A1F1). It is equivalent to the scenarios renamed by IPCC from 2013 until now to Representative Concentration Pathways (RCP) instead of SRES scenarios. RCP is representative of emmision scenarios and reasonably covers the range of future greenhouse gas concentrations. The RCPs are similar to SRES scenarios with the same construction criteria ((RCP2.6, RCP4.5, RCP 6.5, RCP8.5). Through the climate change and sea level rise versions and scenarios for Viet Nam oin 2020, they were updated the latest information about the signs, the trends of climate change and sea level rise in the past; Hydrological and sea level rise in Viet Nam were updated to 2018; digital elevation model data was updated to 2020.

Temperature change trends: According to the climate change scenario of The Ministry of Natural Resources and Environment (2020), the average annual temperature (^{o}C) compared to the base period (1986–2005) corresponds to the RCP4.5 scenarios, according to different models (0,4 ÷ 1,2), average for all models 0.8^{o}C in Dak Lak province (2016-2035). According to the RCP8.5 scenarios, the model can increase from (0.6÷1.2), average for all model (0.9^{o}C).

Rainfall change trends: In the period of 2016-2035, the average annual rainfall variations (%) compared to the base period ((1986-2005) corresponds to the RCP4.5 scenarios under different models from (2.2÷10.9%), average for all models (6.5%). According to the RCP8.5 scenarios, model can increase from (-1.0÷11.6%), average for all model (5.3%) (Ministry of Natural Resources and Environment, 2020).

2.3. The impact of climate change to coffee cultivation in Dak Lak province

The change in rain and rainfall distribution in Dak Lak in the past 10 years is very clear. The frequency of rain in December and January is quite common, which makes coffee have problems in the pollination process, the low fruiting rate, and the yield reduction. Besides, the rain in this period has affected the preliminary process of coffee such as the long drying time, the black kernel, and the low price (Center of Policy and Technology on Disaster Prevention, 2021). It can be seen that CC is posing risks to coffee production and the livelihoods of coffee growers. Changes in temperatures and precipitation, rainfall patterns, as well as extreme weather phenomena can affect the production cycle and negatively affect coffee production (Coffee & Climate, 2015).

It's can be deny that, water is one of the factors that play an important role in coffee production because coffee has a shallow root system, which is concentrated in the 0-30 cm layer, so its drought tolerance is low compared to many other perennial plants (National Agricultural Extension Center, 2018). Irrigation water not only is used for the flowering and fruiting needs of coffee trees but also increases the resistance to drought conditions and contributes to the yield of coffee trees (Trung Chuyen, 2017; Tran Danh Suu et al., 2017; Le Thua Hoai Son et al., 2018; Do Van Chung, 2019). Particularly under the CC context, irrigation demand for coffee trees becomes more and more essential. From 2017, FAO has warned that the yield of main crops, including coffee, is estimated to decrease due to water scarcity and other environmental impacts (Doan Trieu Nhan, 2011).

To see this issue clearly, several researchers tried to find evidence to confirm that the farmers should change cultivation, from traditional to smart ways. This paper concentrates on two models: mono-coffee and agroforestry coffee to prove that planting woody plants in coffee gardens will save irrigation water resources, which are scarce due to the impact of CC now.

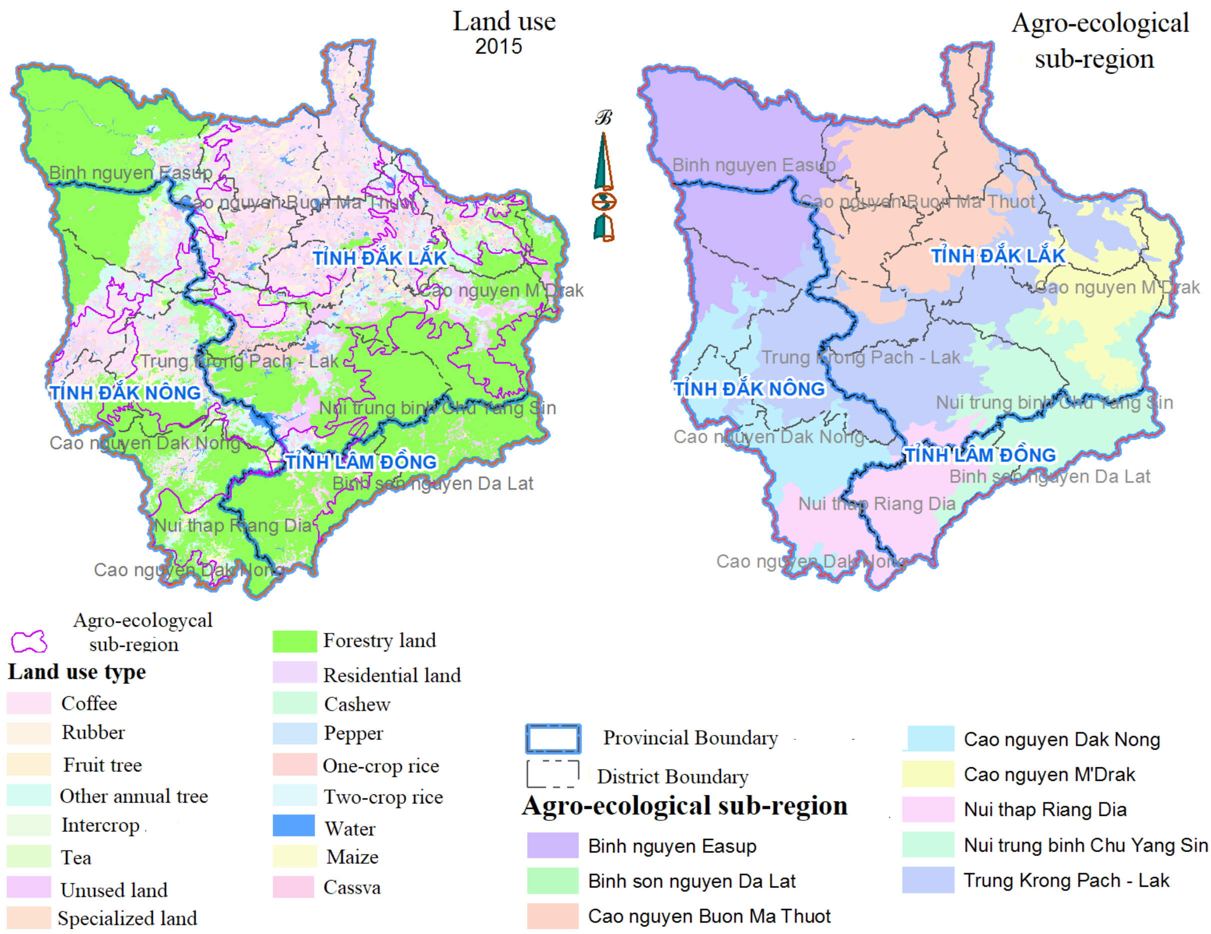
2.3.1. Mono-coffee model

According to the recommendation of the Western Agroforestry Science Institute (WASI), when the average amount of water for irrigation for coffee is about 1600-1700m^3/ha, the water requirement for coffee in the whole Central Highlands is about 800-850 million m^3/ha (Truong Hong, 2013). In 2016, in the current environmental status report of Dak Lak province in the period of 2011-2015, the water requirement for 203,746 ha of coffee was estimated at about 814.984-855.733 million m^3 (Department of Natural Resources and Environment of Dak Lak province, 2016).

Many studies have pointed out that coffee can only be grown when there is enough water to irrigate in the dry season for flowering and fruiting simultaneously and determine the coffee yield (Pham The Trinh and et al., 2013; Trung Chuyen, 2017). The evidence is that during the 2016 drought, severe droughts in the Central Highlands in general and Dak Lak province in particular made hundreds of reservoirs dry up and more than 165,000 ha of coffee were affected, of which 40,000 ha of coffee were lost, the coffee yield decreased from 15-25% on an area of more than 100,000 ha (Trung Chuyen, 2017; D'haeze, 2019).

In recent years, the effects of CC have made surface and groundwater reserve decline seriously. In highly intensive farming conditions in the Central Highlands, the water requirement for crops is very high, especially in the dry season. However, most coffee farmers use irrigation water inappropriately, which causes loss and depletion of resources (Le Thua Hoai Son et al., 2018). The traditional hose irrigation is still popular (about 74%), the overhead sprinkles is about 25%, the advanced methods such as drip systems, the root sprinkler systems have not been widely applied (under 2%). WASI also pointed out that the coffee households overwatered by using traditional hose irrigation, compared to WASI's recommendations (Truong Hong and Pham Cong Tri, 2018).

In order to have suitable adaptations to CC, a study has calculated and forecasted the water requirement for some main crops in the Srepok basin, including coffee trees. The Srepok basin is irrigated based on natural features, terrane separations, climate conditions… Inheriting the previous research on agro-ecological zoning, the basin is divided into 7 agro-ecological sub-regions as shown in Figure 2. The results have calculated the irrigation norms of coffee trees in the forecast period according to the climate change scenarious RCP 2.6, RCP 4.5 and RCP 8.5 (Table 3). It can be seen that the water requirement for coffee tends to decrease in the low scenario (12,06%) and in medium scenario (17,34%), but tends to increase in high scenario (4,25%), compared to the current status (Nguyen Thi Ngoc Quyen et al., 2020).



Source: Nguyen Thi Ngoc Quyen et al., 2020

Figure 2. Land use map (a) and agricultural land partition (b) in Srepok basin

Table 3. Irrigation norms for coffee trees in the Srepok river basin

Unit: m³/ha/crop

LUT	Current status period	Period 2013-2045			Variation compared to current status		
		RCP 2.6	RCP 4.5	RCP 8.5	RCP 2.6	RCP 4.5	RCP 8.5
Coffee	4029	3543	3330	4112	-12,06	-17,34	2,07

Source: Nguyen Thi Ngoc Quyen et al., 2020.

In 2022, a study was carried out the forecast of water requirement to 2030 for coffee-the main crop in Krong Pak district by using FAO's approach method based on CROPWAT 8.0 model. The results showed that water requirement of coffee trees has changed because of CC, in particular, water requirement tended to increase in area irrigation of 20.078 ha: forecast for 2030 (135.77×10^6 m^3) and 2030 (137.47×10^6 m^3) according to scenario RCP4.5 and RCP8.5 (138.52×10^6 m^3), compared to 2021 (121.17×10^6 m^3). In the other hand, the research showed that the temperature and precipitation were the main factors that had the strongest impact which changed the water requirement among months of coffee trees in Krong Pak district (Nguyen Thi Ngoc Quyen et al., 2022). The similar study applied in Ea H'leo district. The results showed that under the impact of CC, the water demand of coffee tends to increase. This poses a significant challenge for local managers (Nguyen Thi Ngoc Quyen et al., 2023).

2.3.2. Agroforestry coffee model

The impacts of CC on the Central Highlands in general and in Dak Lak province in particular is the phenomenon of prolonged drought leading to an urgent need for irrigation water (Dao Nguyen Khoi et al., 2014; Dao Nguyen Khoi et al., 2015), (Tran Van Ty et al., 2012a; Tran Van Ty et al., 2012b). According to the forecast results, the total number of drought months will increase from 4 months in the period 1980-2012 to 6 months in the period 2013-2045 and the degree of drought tends to become more and more severe as shown by severe droughts, special droughts which appear more and more in the basin (Nguyen Thi Ngoc Quyen et al., 2016); Field survey shows that water scarcity is happening frequently in the upstream areas during the last dry months in recent years and at the peak in 2016, drought occurred throughout most of the Srepok basin. Thus, under the impacts of CC, drought and water scarcity will increase, which cause great obstacles to agricultural production and people's lives (Nguyen Thi Ngoc Quyen, 2019). Many studies have shown that coffee production in the form of intensive farming and the traditional hose irrigation in the Central Highlands has resulted in a large amount of water used for coffee which become unsuitable in arid conditions (Nguyen Phuong Le and Nguyen Hai Duong, 2020; Duyen Nhat Lam Tran et al., 2021).

At this time, agroforestry farming is a promising direction in the midland and mountainous areas in Viet Nam in order to solve the needs of forest products, people's livelihoods and protect the ecological environment. Compared with the traditional farming methods, agroforestry farming has outstanding advantages because it provides with product divesification (firewood, non-timber forest products, agricultural products …) that ensure livelihood, improve production efficiency, conform to people's farming practices and maintain the sustainability of the ecosystem. Therefore, developing agroforestry system has become an inevitable trend and consistent with social progress (Vo Hung et al., 2019). Or Climate Smart Agriculture (CSA) aims to improve the resilience of agricultural system to climate change to contribute to food security stability, combined with the needs of adaptation and mitigation of impacts of CC and build a sustainable agriculture. CSA is an intergrated approach to solve simultaneously inter-field challenges of food security and CC. CSA is recognized with 3 objectives at the same time at the levels from farming to environment, context, from local to global and from short to long time, as well as focus on prioritizing the specificities of the country. CSA combines three pillars of sustainability: Increasing productivity and income sustainably; Adapting and improving resilience to climate change; Reducing and/or eliminating greenhouse gas emissions whenever possible (FAO, 2010).

Nguyen Van Thuong *et al.,* (2001) confirmed that the moisture in soil surface 0-30cm in the dry season in the agroforestry models is always 2%-3,5% higher than that of the net coffee gardens (Table 4). Agroforestry systems based on coffee keep soil moist longer, so they can save water for irrigation

Table 4. Soil moisture of agroforestry system in the dry season

Models	Soil moisture (%db)		Difference from net coffee garden (%)	
	Before 1st batch	After 1st batch 10 days	Before 1st batch	After 1st batch 10 days
Net coffee	28,5	31,2		
coffee + durian	30,4	33,7	+1,9	+ 2,5
Net coffee	-	31,1	-	
Coffee + Black Cassia	-	34,5	-	+ 3.4
Net coffee	26,7	29,0		
Coffee + cashew	28,2	31,0	+ 1,5	+ 2,0

Source: Nguyen Van Thuong et al., 2001.

In a study comparing net coffee plantations to coffee garden with black cassia and acacia, farmers in Krong Nang district said that planting shade trees is necessary to have benefits such as creating shade, adding branches and leaves to the soil, irrigating less in the dry season, maintaining stable yield especially in drought years without irrigation. Up to now, farmers are very fond of pepper, durian and macadamia. Intercropping is also considered an effective farming method to diversify income sources for farmers and limit risks when coffee price is low. Although this form of intercropping can simultaneously satisfy the two goals of shade and economic products, but not all coffee gardens can be applied easily. In fact, coffee production in the district is not really sustainable, so in the coming time it is necessary to encourage farmers to increase shade trees or intercrop fruit trees or perennials in coffee gardens in order to ensure coffee production in a sustainable way and protect the environment (Pham The Trinh et al., 2013).

Another assessment of the effects of intercropping confirmed that coffee trees are affected when growing near of under the canopy of shading intercrops, except for the black cassia used as a living pillar for pepper trees, which have been thinned and determined to have no effect on adjacent coffee trees (Table 5). The intercropping that has the least effect on the adjacent coffee trees is the black pepper trees on the black cassia in the coffee intercropping model. Most of the intercropping has an effect on the water consumption of coffee trees. The coffee garden models with shade trees and windbreaks will limit water evaporation on the coffee garden. Therefore, the water requirement for coffee trees will less and less watering is required for coffee trees during the dry season (Nguyen Xuan Hoa et al., 2016).

Table 5. Intercrop effect on adjacent coffee trees and coffee water consumption (%)

No.	Plant	Effect on adjacent coffee trees		Effect on coffee water consumption	
		Yes	No	Yes	No
1	Coffee				
2	Durian	85.71	14.29	91.67	8.33
3	Pepper	22.22	77.78	25.00	75.00
4	Avocado	66.67	33.33	85.71	14.29
5	Macadamia	42.86	57.14	100.00	0.00
6	Mangosteen	100.00	0.00	100.00	0.00
7	Black Cassia	0.00	100.00	100.00	0.00

Source: Nguyen Xuan Hoa et al., 2016.

Through testing by WASI, many new coffee varieties with high yield, quality, adapting to climate change and extreme weather have been put into production such as late-ripening varieties that are suitable for areas with difficult in water resources ((TR14, TR15) or high rust resistance (TRS1). In the intercropping solution, WASI has proven that intercropping avocado, durian, pepper, acacia, black cassia… increases the income per orchard by 40-120% (depending on the type of crop). Especially, intercropping increases water use efficiency by nearly 18%; To produce 1 ton of coffee in an intercropped garden requires only 500 m^3 of water, compared to a net coffee garden that requires 600m^3 (Trung Chuyen, 2017). Or another study showed that in net coffee model with 533 liters of water/irrigation time, with 4 irrigation times the coffee yield reached 3.9 tons of kernels/ha (Table 6). The amount of water needed to produce 1 ton of kernels in agroforestry models intercropped with durian, pepper and avocado is lower than that of net coffee, with only the type of cashew intercropping, the amount of water to produce 1 ton of coffee kernels is higher than that of the net planting of 49 m3/ha. The amount of water required for the production of 1 ton of coffee kernels in the intercropping with pepper is the lowest with 365 m3/ha nad the highest in the cashew intercropping with 582 m^3/ha (WASI, 2017).

Table 6. Water consumption to make 1 ton of coffee kernels (m^3/ha)

Type of intercropping	Water requirement to make 1 ton of coffee kernels	Irrigation water increase/decrease to make 1 ton of coffee kernels
Mono-coffee	533	-
Coffee + durian	462	-71
Coffee + pepper	365	-169
Coffee + avocado	384	-149
Coffee + cashew	582	49

Source: WASI, 2017.

In 2019, IUCN conducted a rapid assessment of the costs and benefits of switching from coffee monoculture to a coffee agroforestry model with higher value, more divesity and less water use. The study was conducted in Dak Lak province (wher one-third of Viet Nam's coffee production) and proposed to convert about 200,000 ha of coffee monoculture into a coffee intercropping, pepper, durian and avocado that have the ability of drought tolerance and the yield of 2.5 times the value of the crop, maintain coffee production and save about 150 million m^3 of water per year by reducing irrigation. IUCN has compiled WASI studies and summarized water requirements for intercropping in suitable areas and in unsuitable areas due to water scarcity (Figure 3). The data in Table 7 show that the coffe model intercropped with pepper, avocado and durian has saved significant irrigation water, compared to the monoculture model. Specifically, in Dak Lak province, coffee monoculture under irrigation conditions currently consumes about 405 million m^3 of water per year. If using economical irrigation for mono-coffee, it will reduce about 105 million m^3 of water (-26%). In the agroforestry model scenario, water use decreases gradually until the year 19 as coffee is gradually remove from water scarce lan units. In this case, 149 million m^3 of water is saved by the year 19, compared to the baseline scenario (-37%). It can be affirmed that the environmental benefits of agroforestry coffee model are water saving and climate change mitigation (D'haeze, 2019).

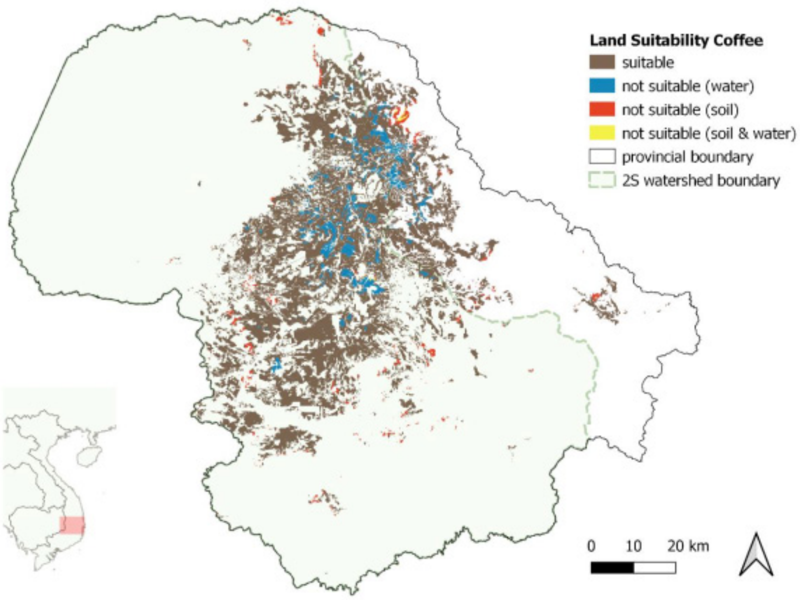


Figure 4.1 Land suitability for coffee production

Source: D'haeze, 2019.

Figure 3. Suitable partition of land for coffee trees map

Table 7. Water requirements of intercropping crops

Model	Amount (tree/ha)	Irrigation requirement (m^3/ha/year)
- Net coffee		
- hose	1,110	2,043
- saving water	1,110	1,515
- Coffee (intercrop) in suitable land		
- Coffee	887	1,211
- Pepper	336	134
- Avocado	28	34
- Durian	28	21
- Intercrop (no coffee) in unsuitable land, water scarcity		
- Pepper	1,362	545
- Avocado	35	42
- Durian	35	26

Source: D'haeze, 2019.

Nguyen Van Thuong (2020) evaluated the impact of intercroping of woody plants in coffee gardens in Krong Bong, Lak, Krong Pak, Cu Kuin districts. The results show that there 3 effects of woody plants in coffee gardens that are highly appreciated by agricultural managers in 4 districts: Improving household income, increasing land area prevented from degradation and increasing cover density on coffee garden (Table 8). The remaining effects are disagreed. However, district officials form Krong Bong and Cu Kuin both highly appreciate the role of woody plants in the field of environmental protection (impacts 5-9).

Table 8. Evaluation of the impacts of woody plants in coffee gardens

No.	Impact	Level				
		Krong Bong	Lak	Krong Pak	Cu Kuin	Aver-age
1	Increasing local competitiveness thanks to stable product supply	4	4	2	2	**3,00**
2	Improving household income	1	1	1	2	**1,25**
3	Increasing the number of smallholders with/without land	4	4	1	4	**3,25**
4	Attracting more workers	3	3	1	4	**2,75**
5	Increasing the number of hectares of restored land and/or reforested land	3	4	1	1	**2,25**
6	Reducing water pollution levels in major water sources in the region	4	4	1	1	**2,50**
7	Increasing or stabilizing the amount of water in groundwater in surface water in the area	2	3	1	1	**1,75**
8	Increasing the area of land prevented from degradaa-tion	2	2	1	1	**1,50**
9	Increasing the cover density on the coffee gardens	1	1	1	1	**1,00**

Note: Impact level: (1) High, (2) Medium, (3) Low, (4) Unclear

Source: Nguyen Van Thuong, 2020.

Figure 4. Acacia shade model

Figure 5. Black cassia shade model

Source: Nguyen Van Thuong, 2020

In fact the activities of planting woody plants in coffee gardens in Dak Lak province are practices of farmers that have existed for a long time and are quite diverse in types (Figure 4 and 5). The models of coffee intercropping with pepper/wood trees and with durian bring much higher economic efficiency than that with cashew trees and black cassia to block the wind. The woody plants in the coffee gardens have ecological support for coffee trees in the hot dry season: reducing wind speed; reducing radiation intensity to coffee trees; reducing garden temperature and helping garden soil keep moisture better. Legumes such as acacia and black cassia planted as perennial shade trees for coffee help soil fertility improve and reduce watering needs in the dry season, so reducing investment costs (Nguyen Van Thuong, 2020).

Recently IUCN has updated data (in 2022) on drought in Ddak Lak province and recalculated the water requirements of the monoculture coffee model and the agroforestry model. The results show that coffee monoculture under over-irrigated conditions consumes about 1.12 billion m^3 of water per year. If irrigation management is optimized for coffee monoculture, about 290 million m^3 of water will be saved (-26%). In the intercropping scenario, the water requirement decreases gradually until the 19th year as coffee trees are gradually removed from the water-scarce land units. In this case, 407 million m^3 of water will be saved by the 19th year compared to monoculture (-36%). Thus, once again, IUCN affirms that converting monoculture coffee production to a diversified crop production model increases the ability to save water significantly (D'haeze, 2022).

2.4. Some solutions for sustainable coffee cultivation under the CC context in Dak Lak province

On the basis of an overview of studies with theoretical and practical backgrounds combined with consultation with experts in the filed of coffee production, a number of solutions are synthesized and proposed based on the researches of World Bank (2004), WASI (2017), Nguyen Thi Ngoc Quyen et al., (2020), D'haeze (2019; 2022), Vo Hung et al., (2019), Nguyen Van Thuong (2020) and orientations of agencies and departments such as the Ministry of Agriculture and Rural Development, the Dak Lak People's Committee, the Department of Agriculture and Rural Development, the Dak Lak Sub-Department of Cultivation and Food Protection... The development and expansion of agroforestry coffee model requires a long-term roadmap and close coordination of stakeholders.

According to agricultural experts, in the near future, CC may not be able to "eliminate" coffee trees in the Central Highlands, but it makes production costs increase and profit decrease, so coffee may no longer prevail over other crops. A number of solutions have been responded to CC and continue to hold this position of the strategic crop.

- To live with CC, coffee trees need supporting by a series of synchronous solutions in terms of planning, new variety application, water-saving irrigation, intercropping, integrated pest management…

- In the current context of CC, it is possible to produce more coffee with less water when applying low-cost drip irrigation or sprinkler systems. In large coffee-growing regions in Dak Lak, it is possible to supplement artificial groundwater through a system of filter tanks (containing sand and small stones) and wells. This system collects water from natural flows, leads to a filter tank before putting it into farmers' wells to replenish groundwater, helping people overcome water shortages and make use of excess water flowing in nature…

- Compared with the traditional hose irrigation in the basic construction period and the business period, the amount of water uesed/ha of the economical irrigation method is much less than that of the traditional method and the T-test shows that this difference has a 99% confidence.

If calculated for the whole region, the amount of irrigation water saved thanks to the new technology will be huge. Drip and sprinkler irrigation technologies not only help households save water but also help them use other resources more efficiently, especially labor.

Besides the economic benefits, economical watering contributes to environmental protection and production stability: (i) Using water resources more rationally and economically. Especially in the context of increasingly severe climate change and droughts; (ii) Better conserving water resources through rational and economical water use, having more opportunities to use water for more people. The sharing of water resources for community members is more effective and practical. This is the core solution contributing to a positive and effective response to climate change. (iii) Saving water for coffee also reduces competition for irrigation water between coffee and other crops that need irrigating in the same area. As a result, it is not necessary to reduce the area for irrigated coffee trees, but still ensure the irrigation area for other crops, contributing to the diversification of product lines, stability and production development.

However, the reality shows that, although economical irrigation technology has many advantages, the number of households and the scale of coffee production area applying them in the Central Highlands is still very small. According to the Agricultural Extension Center of Dak Lak province, the coffee growing area applying advanced technology and water – saving irrigation in the whole province has only reached about 400ha (accounting for 0.2% of the total of coffee area). Most of the coffee areas irrigated with advanced technology are demonstration models implemented by agricultural extension projects and programs or sponsored of businesses trading in irrigation equipment. The main reason is that the majority of people do not understand the effectiveness of water – saving irrigation technology, so they have not invested in the initial investment cost for the high irrigation system, the small size of the coffee garden, and the incomplete infrastructure such as traffic, electricity and water sources. Therefore, it is necessary to have a long-term strategy to be able to comprehensively change the traditional irrigation method with modern water-saving methods.

In term of theory and practice, agroforestry coffee systems have proven to be economically and environmental sustainability, adapt to climate change due to biological interactions between plants and animals in the system, as well as the variety of products produced by the system per unit of properly used land (Nguyen Van Thuong et al., 2001). According to some studies, in the Central Highlands in general and in the Srepok basin in particular, over the past few years, people planted and developed a lot of land use systems as agroforestry coffee model which gives much higher economic efficiency than other monoculture farming. Production as agroforestry coffee has also contributed to improve soil moisture and fertility as well as limited the harshness cuased by lack of water for irrigation in the dry season (Nguyen Van Thuong et al., 2001; Pham Cong Tri et al., 2017).

It can be seen that, to live with CC, coffee plants need to be supported with a series of synchronous solutions in terms of planning growing areas, applying new drought-resistant varieties, applying economic irrigation water measures, intercropping of woody plants, and integrated pest management.

4. CONCLUSION

In Dak Lak province, coffee trees are planted throughout 15 districts and cities with a total area of 212,912 hectares, of which the largest coffee cultivation area is Cu M'gar district with 38,457 hectares, followed by Ea H'leo district (31,907ha), Krong Nang (24,886ha), Krong Buk (20,798ha), Krong Pak (19,840ha). Due to the CC, the climate of Dak Lak province has changed erratically. Specially, heat waves prolonged more frequently than the past. Following the climate change scenarios in Dak Lak province, the temperature trends to increase 0.8-0.9^{o}C and the rainfall had the same trend with 5.3% - 6.5% in 2035. Under the impact of CC, the phenomenon of drought in Dak Lak province is gradually becoming more frequent with major impacts on the coffee production industry, specifically the problem of irrigation water. Studies that take into account climate change factors show that water demand for coffee plants tends to increase in scenarios RCP 4.5 and RCP 8.5. At this time, agroforestry coffee farming is a promising guide along with traditional farming methods, agroforestry farming has outstanding advantages because it provides product diversification, ensures livelihoods, improves production efficiency, is consistent with people's farming practices, and maintains the sustainability of the ecosystem. Production practices in many localities in recent years have proven that agroforestry coffee has been effective in all three aspects of the economy, society, and environment. It must be admitted that no model is suitable for all study areas with differences in natural characteristics (soil type, terrain, climate...) and socio-economic conditions (income, capital, farming practices, knowledge and experience...). However, to be able to develop and replicate the agroforestry coffee model requires a long-term roadmap as well as close coordination of relevant parties and the simultaneous and flexible combination of Policy solutions and State support; planning solutions; agricultural extension solutions, application and transfer of science and technology; strengthen experimental research; technical solutions; capital solutions.

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TỔNG QUAN HIỆN TRẠNG SẢN XUẤT CÂY CÀ PHÊ TRONG BỐI CẢNH BIẾN ĐỔI KHÍ HẬU TRÊN ĐỊA BÀN TỈNH ĐẮK LẮK

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TÓM TẮT

Nhiều nghiên cứu đã chỉ ra rằng, cà phê được trồng thành những khu vực lớn đã ảnh hưởng đến môi trường như: kết cấu của rừng từ đa tầng giảm còn 1-2 tầng, nguồn nước cạn kiệt, khả năng phòng hộ kém, mức độ xói mòn đất lớn... Thực tế, canh tác độc canh cây cà phê trên diện rộng đã làm suy giảm nguồn nước cho sinh hoạt và sản xuất ở vùng Tây Nguyên nói chung và trên địa bàn tỉnh Đắk Lắk nói riêng. Thêm vào đó là tác động của biến đổi khí hậu đến sản xuất cà phê ngày càng rõ ràng hơn với việc làm gia tăng chi phí, tăng nhu cầu sử dụng nước và giảm năng suất. Lúc này, việc áp dụng mô hình sản xuất cà phê nông lâm kết hợp là loại hình sản xuất được xem có những ưu điểm vượt trội, tạo độ tàn che hợp lý cho cà phê, giữ độ ẩm đất tốt hơn, giảm lượng nước tưới; gia tăng thu nhập và việc làm cho nông dân; hạn chế được các nguy cơ suy thoái tài nguyên đất, tài nguyên nước cũng như tăng khả năng thích ứng và chống chịu với biến đổi khí hậu. Tuy nhiên, hiệu quả của mô hình sẽ tăng cao nếu được kết hợp với các hoạt động phục hồi rừng và trồng xen các loại cây thân gỗ vào trong diện tích đang trồng cà phê. Điều này chỉ có thể đạt được khi thực hiện một loạt giải pháp đồng bộ về chính sách và sự hỗ trợ của nhà nước trong đầu tư phát triển kết cấu hạ tầng và cơ sở vật chất cho sản xuất, kỹ thuật, áp dụng khoa học công nghệ hiện đại, vốn, quản lý dịch hại tổng hợp.

Từ khóa: *Sản xuất cà phê, biến đổi khí hậu, tỉnh Đắk Lắk.*

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