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Analysis of the environmental characteristics and impacts of agricultural production in the Western Department of the Republic of Haiti

Análise das características ambientais e implicações da produção agrícola no Departamento Oeste da República do Haiti

Análisis de las características ambientales y implicaciones en la producción agrícola en el Departamento Oeste de la República de Haití

Analyse des caractéristiques environnementales et leurs implications dans la production agricole dans le Département de l'Ouest de la République d'Haïti

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ABSTRACT

In the Republic of Haiti, agriculture is one of the main economic sectors. In the Western Department, more than half of the population lives in rural areas and relies on agriculture as their primary source of livelihood. This study analyzes the environmental impacts in the Western Department of Haiti on the suitability of agricultural land for the region's main crops. To this end, relief, pedology, and climate were considered as relevant environmental factors for determining agricultural suitability, along with the physiological characteristics of plants. Therefore, for this analysis, maps, graphs, and tables were created based on specialized scientific literature, relief data, pedology, and climate. The results show that agricultural production in the Western Department is still precarious due to unfavorable environmental conditions, resulting in a decrease in local food production for consumption. When considering the drought tolerance of certain crops, it is concluded that smaller-scale cultivation, with an emphasis on providing food for families and local commerce, is feasible for corn, beans, and cassava.

KEYWORDS: food safety; environmental conditions; physical Geography; Haiti.

RESUMO

Na República do Haiti, a agricultura é um dos principais setores econômicos. No Departamento Oeste, mais da metade da população vive em áreas rurais e usa a agricultura como principal fonte de subsistência. Este estudo analisa as implicações ambientais no Departamento Oeste do Haiti sobre a aptidão agrícola para as principais culturas da região. Para tanto, o relevo, a pedologia e o clima foram considerados como fatores ambientais relevantes para a determinação da aptidão agrícola, bem como as características fisiológicas das plantas. Assim, para esta análise, com base em literatura científica especializada, dados de relevo, pedologia e clima, realizou-se a confecção de mapas, gráficos e tabelas. Os resultados

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mostram que, devido às condições ambientais desfavoráveis, a produção agrícola no Departamento Oeste ainda é precária, resultando em menor produção de alimentos para consumo local. Ao considerar a tolerância à falta de água de algumas culturas, conclui-se que o plantio em menor escala com foco na alimentação familiar e no comércio local é viável para milho, feijão e mandioca.
PALAVRAS-CHAVE: segurança alimentar; condições ambientais; Geografia física; Haiti.

RESUMEN

En la República de Haití, la agricultura ha sido uno de los principales sectores económicos. En el Departamento Oeste, más de la mitad de la población vive en áreas rurales y utiliza la agricultura como su principal fuente de sustento. Este estudio analiza las implicaciones ambientales en el Departamento Oeste de Haití sobre la aptitud agrícola para los principales cultivos de la región. Para ello, se consideraron el relieve, la pedología y el clima como factores ambientales relevantes para determinar la idoneidad agrícola, así como las características fisiológicas de las plantas. Para este análisis se elaboraron mapas, gráficos y tablas, con base en la literatura científica especializada, datos de relieve, pedología y clima. Los resultados muestran que, debido a las condiciones ambientales desfavorables, la producción agrícola en el Departamento Oeste aún es precaria, lo que se traduce en una menor producción de alimentos para el consumo local. Al considerar la tolerancia a la falta de agua de algunos cultivos, se puede concluir que la siembra a menor escala con un enfoque de alimentación familiar y comercio local es factible para maíz, frijol y yuca.
PALABRAS-CLAVE: inocuidad de los alimentos; condiciones ambientales; Geografía física; Haití.

RÉSUMÉ

Dans la République d'Haïti l'agriculture est l'un des principaux secteurs économiques. Dans le département de l'Ouest plus de la moitié de la population vit en milieu rural et utilise l'agriculture comme principale source de revenu. Cette étude analyse les implications environnementales dans le département de l'Ouest d'Haïti sur l'adéquation agricole aux principales cultures de la région. À cette fin, le relief, la pédologie et le climat ont été considérés comme des facteurs environnementaux pertinents pour déterminer l'aptitude agricole, ainsi que les caractéristiques physiologiques des plantes. Ainsi, pour cette analyse, basée sur la littérature scientifique spécialisée, des données du relief, de pédologie et de climat, des cartes, des graphiques et des tableaux ont été utilisées. Les résultats montrent qu'en raison de conditions environnementales défavorables, la production agricole dans le département de l'Ouest est encore précaire, ce qui se traduit par

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une moindre production d'aliments pour la consommation locale. En considérant la tolérance au manque d'eau de certaines cultures, on peut conclure que la plantation à plus petite échelle en attirant l'attention sur l'alimentation familiale et le commerce local est faisable pour le maïs, le haricot et le manioc.

MOTS-CLÉS : sécurité alimentaire ; conditions environnementales ; Géographie physique ; Haïti.

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INTRODUCTION

In Haiti, agriculture has remained a key sector for the country's development since colonization. In the 2020s, still more than half of the population lives in rural areas, with agriculture as the main source of livelihood. The Inter-American Development Bank (IDB) states that the agricultural sector's participation represents more than 25% of the country's Gross Domestic Product (GDP) (IDB, 2012). However, Haiti suffers from food insecurity, which makes local agricultural production and productivity important guarantors of food availability for the population (CALIXTE; ROBERTS; BUNCH, 2019).

This Caribbean country, a mountainous territory, is located on the interaction of the North American and Caribbean tectonic plates, which explains its susceptibility to earthquakes (LORICH *et al.*, 2010). In this context, Haiti's agricultural sector is often affected by extreme events, such as erosion, as the steeper the terrain, the more surface runoff there is, which can lead to erosive processes.

Faced with a range of humanitarian and environmental challenges, international cooperation has helped the country by providing humanitarian assistance, food and medical supplies. But Exime et al (2021) pointed out that this international aid was not enough to fight hunger and poverty. The authors also consider that the development of family farming requires other measures, such as an anti-poverty development plan that includes investments linked to technology and the valorization of science, as well as the promotion of cooperation against hunger, with social programs to combat inequality (EXIME *et al.*, 2021). For Calixte, Roberts, and Bunch (2019), education focused on rural extension is also necessary for the development of Haitian agriculture.

The Western Department is a primary division of Haiti. It is subject to varying climatic conditions, ranging from semi-arid to humid. The region features rock formations comprising different varieties of limestone, volcanic materials, and their respective sediments. According to Jeune (2015), the region has a highly undulating terrain and a wide range of eutrophic soils. These soils are prone to intense erosion due to the significant anthropic pressure they experience.

The Western Department is particularly vulnerable to environmental erosion due to the prevalence of Neosol and significant deforestation in the study area. The natural vegetation was suppressed by the local population for housing construction without adhering to legal norms. This contributed to the initial formation of slums in Haiti, involving scenarios that entailed deforestation, soil erosion, poor urban health, the loss of biodiversity, unregulated mining, degradation of the marine ecosystem, urbanization, demographic pressure, and poverty (ROC, 2008). The effects of these activities have a detrimental impact on the environment as they are carried out in a disorganized manner

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and involve the irrational use of natural resources.

Furthermore, because of the unique geographical characteristics of the country, the agricultural sector is vulnerable to the impacts of natural disasters, such as hurricanes and frequent droughts. It is also observed that soil erosion, caused by the suppression of vegetation, was a factor that contributed to a significant reduction in agricultural production. As a result, the Western Department, along with the entire country of Haiti, became reliant on food imports (PNUE, 2011).

Describing and analyzing the environmental implications of the Western Department is of fundamental importance, due to the impact that the constitution of the natural environment has on agricultural production, and it is necessary to understand these scenarios and, in a complementary way, the anthropic interference in the studied region. In this manner, the present study aims to investigate the environmental implications of the Western Department of the Republic of Haiti on agricultural production for the most commonly cultivated crops in the region.

This study, in its initial section, took into consideration an analysis of the environmental characteristics of the Western Department, encompassing its geomorphological, pedological, and climatic aspects. Building upon these features, the second part of the study assessed the feasibility of certain crops for this Department, taking into account their suitability to the natural conditions of the area.

METHODOLOGY

CHARACTERISTICS OF THE STUDY AREA

The Western Department, the spatial focus of this present study, is situated in the Republic of Haiti, an island nation located in the Caribbean Sea, with its only land border to the east, adjoining the Dominican Republic The Haitian Office of Mines and Energy depicts the country as predominantly mountainous (80% approximately), distinguished by rugged terrain and the presence of 30 hydrographic basins More than one-third of the territory lies between 200 and 500 meters in altitude; 40% exceeds 500 meters, and 17% surpasses 800 meters above sea level. Thus, more than half of the land exhibits slopes exceeding 40%, while only a quarter of the territory consists of plains (BME, 2015).

The Western Department (Figure 1) encompasses approximately ^{4,983} km² and is situated between 18° 15 30 N and 18° '58 25 N latitude, and 71° 42 39 W and 73° 4' 22" W longitude, in the western region of Haiti. The Departments constitute the first-level administrative divisions within the four-tiered structure of the Republic of Haiti. This region encompasses the capital of Haiti, Port-au-Prince. According to the 2015 census by the Haitian Institute of Statistics and Informatics (IHSI), the Western Department has an approximate population of 4 million inhabitants, accounting for about 36% of the country's total population (IHSI, 2015).

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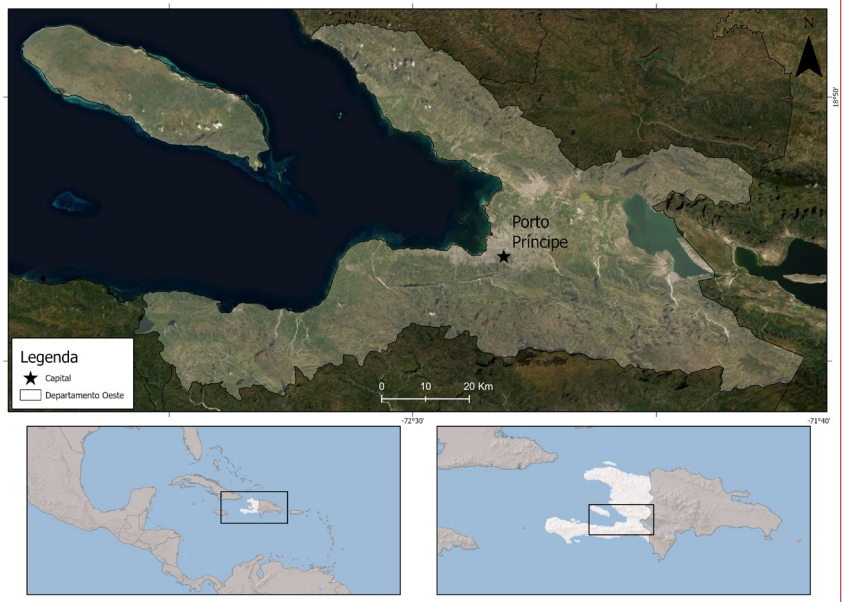
Figura 1. Location map of the study area



Source: Authors

Due to the rugged terrain, soil distribution in the Western Department, as well as throughout the rest of the country, exhibits significant variability, resulting in a high diversity of soil classes over short distances. In general, neosols and cambisols predominate, with points where it is possible to identify gelisols and planosols (WOODRING; BROWN; BURBANK, 1924; JEUNE, 2015).

The prevailing climate in this island nation retains characteristic features of the tropics, such as high temperatures. The rainy season occurs between May and July, while the hurricane season spans from June to November; during winter, precipitation is lower than in summer (UNDP, 2019). According to Köppen and Geiger, the country's climate classification is Aw, with an average annual temperature of 26.6°C and average precipitation of 964 mm. Jeune (2015) asserts that the region presents two types of climates due to altitude variation: the tropical type "Aw," which characterizes the plains and hills with low-temperature variation throughout the year; and the type "Cwb," namely, highland tropical climate, featuring a dry winter and hot summer, found in the higher regions.

MAP ELABORATION

A cartographic data inventory was conducted to establish the natural characteristics of the study area. Through a literature review, the primary physical parameters and data to be collected in this phase were determined. These included cartographic data essential for the development and organization of thematic maps (pedology, slope, hypsometry), orbital images, and maps that supported further analyses. The scale of 1:100,000 was applied as the analytical scale for the study of natural systems within the investigated area. ArcGIS 10.5 software was employed for the creation of thematic mapping units. To organize the database,

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Landast8 and Sentinel 2 data were *downloaded* from the United States Geological Survey (USGS, 2021). Subsequently, polygons representing the formations of the main soil classes in the study area were digitized and adapted.

The slope map holds significant importance in the analysis of environmental fragility, owing to its direct influence on processes determining the rate of transformation from potential energy of rainfall to kinetic energy, and consequently, on the intensity of erosive processes (CREPANI *et al*., 2001; VALE *et al*., 2016). Using hydrologically consistent digital elevation models (DEMHC), the slope model was generated using the Slope tool, which calculates the maximum value of each point. This enabled the establishment of the percentage of terrain inclination.

CLIMATE DATA

Climatological data were collected from the NASA POWER database, generated based on satellite models. The results cover the period from January 1990 to December 2020 and were used to determine the climatological normal for monthly precipitation and maximum and minimum temperatures. Following their collection and tabulation, the data were organized for the creation of a graph, employed to provide a more detailed characterization of the climate in the Western Department and the agricultural suitability of the region.

THE PREPARATION OF THE AGRICULTURAL SUITABILITY TABLE

For the analysis of environmental implications on crops, the authors compiled a synthesis table (Table 1) containing recommendations for terrain, soil, temperature, and precipitation, along with a section accounting for the crops' tolerance to water scarcity. This is particularly relevant given one of the climatic features of the Western Department, which is its prolonged dry season (FEWS NET, 2015). The analyzed crops included Arabica coffee, sugarcane, corn, beans, bananas, cassava, and oranges, with indications of whether they are advisable or not for the Western Department.

Thus, for a specific agricultural crop to receive a positive recommendation (marked with a "yes"), it would need to demonstrate suitability for four out of the five analyzed conditions (terrain, soil, temperature, precipitation, and tolerance to water scarcity). Otherwise, the recommendation would be negative (marked with a "no"). This categorization was carried out based on bibliographical sources that outline the main environmental suitability characteristics of the selected crops These sources constitute the last column of the table.

It is important to emphasize that terrain is a key parameter in the analysis, representing one of the environmental characteristics of the Western Department, as it significantly influences soil formation and other natural processes. Due to its topography, the

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Table 1. Environmental guidance of different crops

Agricultural culture	Recommended terrain relief	Recommended soil	Temperature conditions	Annual precipitation	Tolerance to water scarcity	*	References
Arabica Coffee	No specification	Latosol	20°C to 30°C	1300 to 1800 mm	Average	No	Camargo e Pereira (1994) Pereira, Camargo e Camargo (2008)
Sugarcane	The terrain ranges from flat to gently undulating	Latosol	30°C to 35°C/max.	1100 to 1500 mm	Average	No	Francisco *et al.* (2016) Townsend (2000)
Corn	The terrain ranges from flat to gently undulating	Latosol Claysoil Arenosol	25°C to 30°C	300 to 600 mm	Little	Yes	Embrapa (1982) Francisco, Santos e Lima, (2016) Francisco *et al.* (2017)
Beans	Plan	Argisol Arenosol	15°C to 30°C	300 to 600 mm	Little	Yes	Ribeiro *et al.* (2011) Marco *et al.* (2012)
Banana	The terrain ranges from flat to gently undulating	Claysoil	15°C to 35°C	1900 mm	Little	No	Menezes e Galvão (2004) Medeiros *et al.* (2013)
Cassava	No specification	Arenosol	20°C to 30°C	600 to 1200 mm	High	Yes	Alves e Modesto Junior (2014) Matos *et al.* (2019)
Orange	The terrain ranges from flat to gently undulating	Latosol	13°C to 35°C	600 to 1200 mm	Little	No	Cruz *et al.* (2005)

* Recommended for the Western Department.

Source: Prepared by the authors, based on the aforementioned references.

study area exhibits terrain with a high degree of environmental fragility to erosion, according to Ross's methodological classification (1994). This factor impacts agriculture, particularly for large-scale mechanized cultivation focused on product exportation (PEREIRA *et al.*, 2012; FRANCISCO *et al.*, 2014; HÖFIG; ARAUJO-JUNIOR, 2015; FRANÇA *et al.*, 2016). In the case of the Western Department of the Republic of Haiti, it is deemed more coherent with the country's real social needs for this study to assess the agricultural suitability of the Department, indicating the viability of crops for family consumption and local trade.

RESULTS AND DISCUSSIONS

CHARACTERIZATION OF THE RELIEF OF THE WESTERN DEPARTMENT

The hypsometric map (Figure 2) illustrates the variation in altitude of the study area relative to sea level, with each color representing a range of altitude in meters and indicating the height or depth of the area. Upon analyzing Figure 2, it is evident that more than one-third of the territory lies between 200 and 500 meters in altitude,

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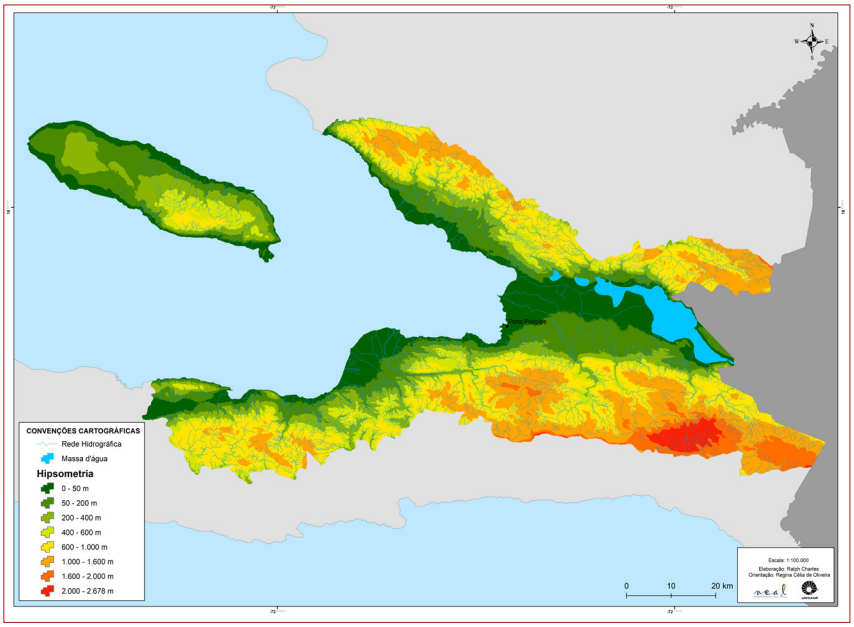
approximately 40% surpass 500 meters, and 17% exceed 800 meters above sea level. From another perspective, over half of the land exhibits slopes exceeding 40%, while a quarter of the territory consists of plains. Thus, the altitude of the Western Department displays significant variation, ranging from 0 to 2,678 meters.

The hypsometric map shows a high altimetric variation of the studied area. It is noteworthy that only 16.1% of the area lies below the elevation of 50 meters. Conversely, it has been observed that over 45% of the area has an altitude exceeding 600 meters. Among these, 18.4% fall within the range of 1,000 to 1,600 meters, and 5.9% surpass 1,600 meters. According to Jeune (2015), this significant topographic variability is a result of the diversification of the local climate, geological processes, and vegetation, thereby intensifying the region's susceptibility to erosion. Among these characteristics posing challenges to profitable agriculture development in the region, erosion stands out as a primary cause, as it leads to soil loss and consequently diminishes arable land (MARNDR, 2015).

In the case of the Western Department, concerning slope, it was observed that the terrain of the region is excessively rugged, with 50% of the area characterized by strongly undulating mountainous terrain (20% slope ≤ 75%) and only 20% featuring flat terrain. Upon analyzing Figure 3 (the relief map), it was noted that approximately 15% of the area exhibits steep terrain, primarily occurring in slopes exceeding 400 meters. Terrace farming and reforestation can be implemented in this area to mitigate the effects of erosion, as these are techniques applied in inclined terrains.

Figura 2. Hypsometry of the Western Department of Haiti



Source: Authors.

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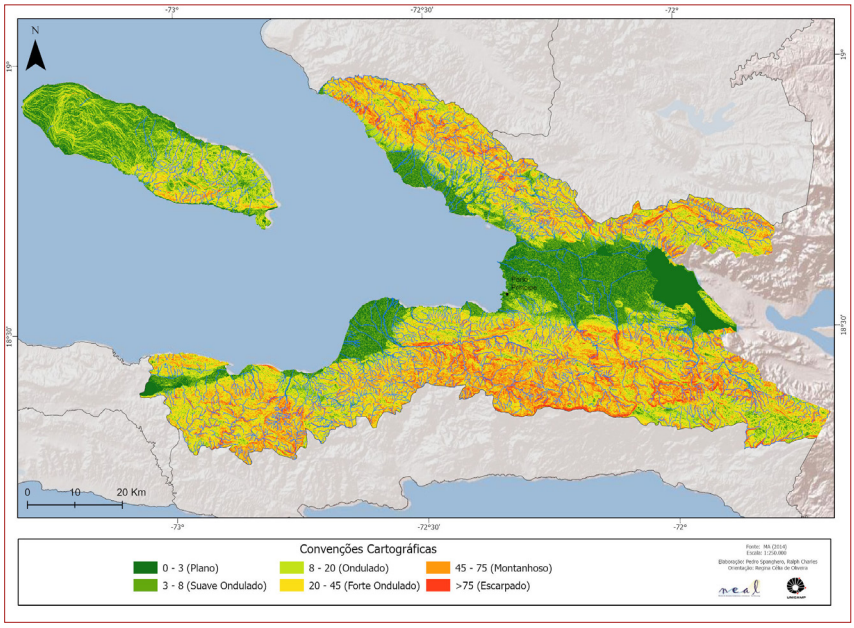
Figura 3. Clinographic map of the Western Department of Haiti



Source: Authors.

This characteristic of the terrain creates favorable conditions for erosive processes with intense denudation and sediment production. Consequently, the prevalence of steep terrains prioritizes mechanisms of soil loss with constant rejuvenation. Due to the scenario of accelerated deforestation, coupled with the natural characteristics of the region under study, MDE (2015) indicates that erosion has gradually removed, on average, 3 cm (three centimeters) of fertile soil in the study area annually over the past four decades. Thus, the same study suggests that water erosion causes an annual loss of an estimated 37 million tons of soil throughout the Haitian territory.

According to BME (1992), the Western Department is comprised of a basaltic Cretaceous basement, exposed in the La Selle massif, and covered by a series of Eocene and Miocene limestones. These geological features are located in the northern part of the Matheux mountain range and the Trou d'Eau mountains (BME, 1992). As stated by Woodring, Brown, and Burbank (1924), the region is situated within a geological complex with various rock formations.

PEDOLOGICAL CHARACTERIZATION OF THE WESTERN DEPARTMENT

According to White (2013), the prevailing minerals in highly weathered tropical soils belong to the kaolinite group, with the common presence of iron, aluminum, and titanium oxides. Muhs et al. (1987), in their study of soils developed on limestone in islands of the Caribbean and the Western Atlantic, including Haiti, found them to be quite clayey, sometimes attaining significant depth with the presence of thick bauxite deposits.

In the study area, there was a predominance of various types of Neosols. However, calcareous

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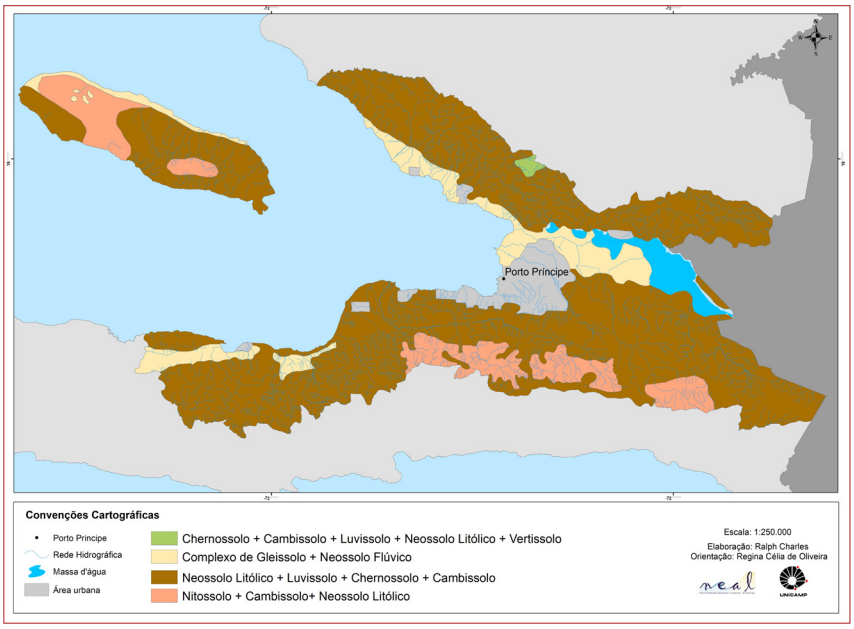
soils from rocks prevail in the country, covering more than 80% of the territory. The depth and chemical characteristics of calcareous soils vary greatly. Often, it is hard calcareous, little-evolved limestone due to the low rate of decomposition of the parent rock and its slope (WOODRING; BROWN; BURBANK, 1924).

The generalization regarding the advanced degree of weathering in tropical soils may not apply to the entire region, as the variability of factors, mechanisms, and processes sometimes leads to the formation of highly heterogeneous soils, dependent on prevailing local conditions (CHARLES, 2020).

Hence, Lithic and Fluvic Neosols, Chernozems, Gleysols, and Cambisols are the types of soils with the greatest geographic extent, especially in the western region of the country. The soils in the western region of Haiti have developed in a complex geomorphological context that allows for the operation of the removal-deposition mechanism. These soils, formed under the influence of calcareous and basaltic materials, rugged terrain, and spatially variable climate, have been relatively under-studied regarding the mechanisms and processes that conditioned their genesis. Figure 4 exemplifies the main soil classes in the western sector of Haiti.

The pedological map reveals a predominance of Neosols, characterized by low pedogenetic development, with shallow depth or dominance of sandy loams and the presence of distinct layers inherited from the parent material. All these features indicate low *in situ* soil development, due to conditions of low depth (Lithic Neosols or Regolithic Neosols), low water retention (Quartzarenic Neosols), or high susceptibility to flooding (Fluvic Neosols) (EMBRAPA, 2013; CHARLES, 2020).

Figura 4. Pedological map of the Western Department of Haiti



Source: Authors.

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The Gleysol class was also observed in the study area. According to Embrapa (2013), Gleysols are mineral soils, hydromorphic in nature, developed from recent unconsolidated sediments, with a clayey, clayey-sandy, or sandy composition from the Holocene period. They may have some organic matter accumulation, but the gley horizon starts within 50 cm from the surface, or between 50 and 125 cm, provided it is preceded by horizons with abundant mottles and reduction colors. Consequently, they encompass poorly to very poorly drained soils, reflecting characteristics resulting from the influence of excess permanent or temporary moisture, due to the presence of the water table close to the surface during a specific period of the year.

Gleysols are characterized by a gray horizon (glei horizon) immediately below the A horizon. The gray color indicates formation in a reducing environment, due to water saturation for a prolonged period of the year. They have a medium to clayey texture in all horizons, with fertility ranging from low to high, and do not feature a B horizon associated with an abrupt textural change, distinguishing them from Planosols.

Regarding the Chernozem class, these are characterized by high-activity clay and high base saturation. Previously, they were referred to as Reddish Brown Brunisols (EMBRAPA, 2013). These soils are moderately deep to shallow, with distinct differentiation between horizons, typically featuring medium texture in surface horizons and clayey texture in subsurface horizons They exhibit moderate permeability in the surface horizon and slow permeability in the Bt horizon, making them highly susceptible to erosive processes.

According to Embrapa (2013), these soils possess excellent chemical characteristics for agricultural use, primarily due to their good fertility, high base saturation, and cation exchange capacity, in addition to having virtually no acidity. However, they occur in areas where the terrain is more rugged, with limitations primarily stemming from steep slopes, posing a high risk of erosion. They are more commonly used for pasture.

In the study area, Cambisols are also found. This order encompasses mineral soils with highly variable characteristics, but they consistently have a medium or finer texture and a lack of significant pedogenetic development These soils have shallow depth, high content of primary minerals (minerals inherited from the parent rock), significant presence of rock fragments in the soil mass, and other indicators of incipient soil weathering.

Cambisols predominate in mountainous areas, which are also prone to erosive processes due to surface runoff, classifying them as highly vulnerable to erosive agents. In some cases, the higher quantities of primary minerals in Cambisols contribute to a greater nutritional reserve for plants, particularly important in

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forest and perennial crops. These soils also have a livelier color, higher clay content, and more developed structure in subsurface horizons compared to materials purely inherited from the rock. This, in many cases, renders them suitable for agricultural use, provided some limiting factors such as rockiness, shallow depth, and excessive slope are mitigated (EMBRAPA, 2013).

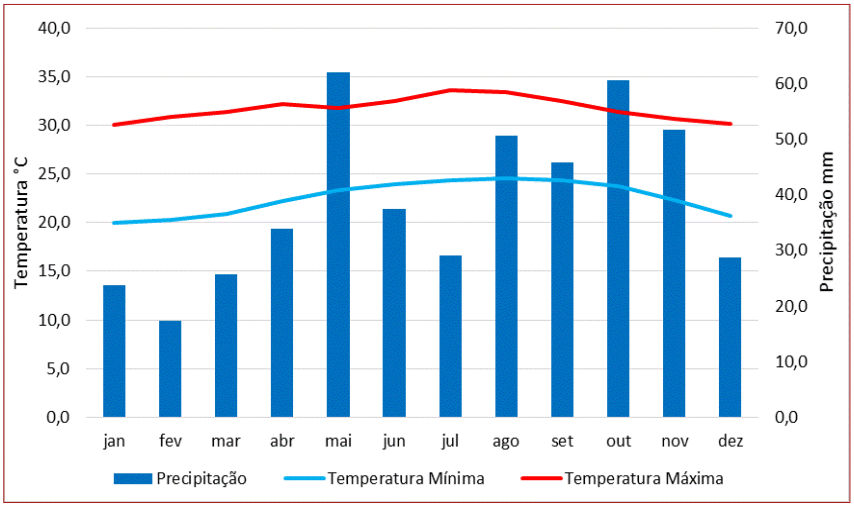
CLIMATIC CHARACTERIZATION OF THE WESTERN DEPARTMENT

As mentioned above, climate plays a crucial role in shaping the main characteristics of the terrain and soil in the region. Atmospheric dynamics are primarily responsible for the input of energy into the environment, setting off various interrelations that define the local landscape (ROMARIZ, 1977; AMORIM, 2012).

The climate in the Western Department of the Republic of Haiti is significantly influenced by the maritime conditions of the Caribbean Sea. Annually, the region experiences extreme precipitation events that coincide with the hurricane season (FAO, 2019). Hurricanes commonly form, during specific times of the year, in regions of low pressure over the warm waters of tropical oceans (TORRES *et al.*, 2021). These favorable atmospheric and oceanic conditions for their formation are found in regions of Asia and Central America, particularly over the Caribbean Sea.

Despite the extreme events that characterize the country's climate, it can be observed (Figure 5) that the Western Department of Haiti generally experiences monthly average precipitations ranging from 10 mm in the drier months to 70 mm in the wetter months. The difference between maximum and minimum temperatures indicates the low thermal amplitude of the area, along with consistently high temperatures throughout the year.

Figura 5. Monthly climatological normal for the Haiti's Western Department



Source: Based on data provided by NASA POWER.

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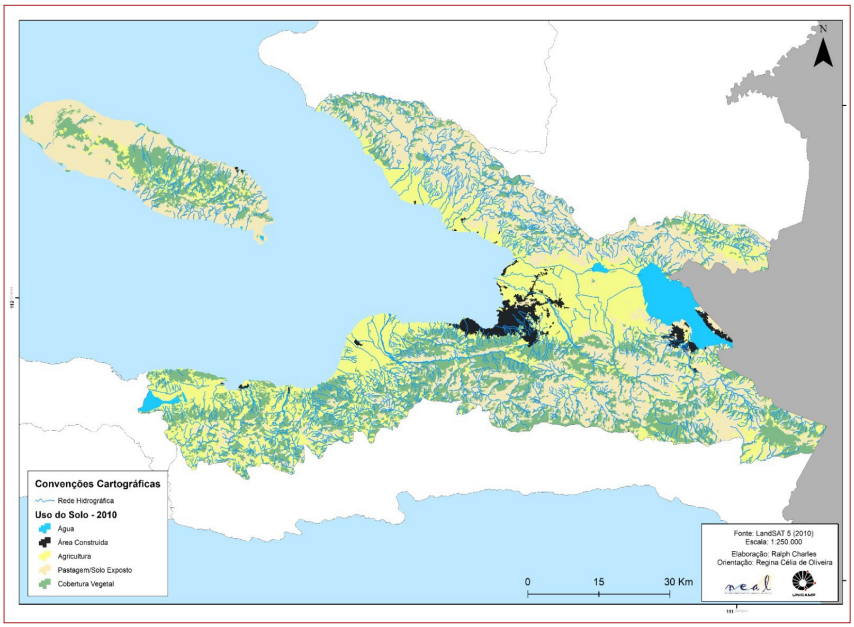
Figura 6. Map of land use and occupation in the study area

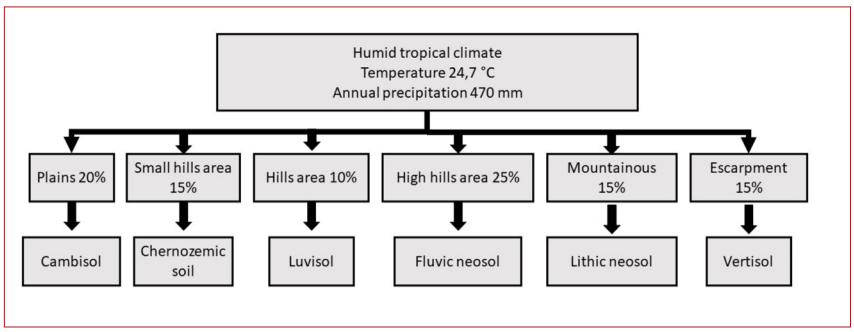


Source: Authors

The observed conditions in the climatic dynamics of the Western Department pose challenges to the profitability of certain crops that are sensitive to high temperatures or have low tolerance for water scarcity. Moreover, the recurring bouts of intense rainfall caused by hurricanes in the country can result in damage to vital components of the agricultural production process, including storage facilities and transportation channels used for product distribution. This latter point is one of the major long-term challenges to be addressed by authorities, aiming for the country to autonomously meet its food demands in the future. Figure 6, a map of land use and occupation, illustrates the extent of agricultural land.

Figure 6 shows that 36.6% of the total study area is occupied by agriculture. However, even with limitations imposed by the climate and other environmental characteristics of the Western Department, some crops have the potential for productivity, which can contribute to improving the quality of life for the population.

Figura 7. Flowchart of the environmental conditions of the Western Department



Source: Based on Jeune (2015).

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Figure 7 illustrates the synthesis of environmental conditions found in the Western Department. The relationship between the types of terrain and the predominantly encountered soil in each formation can be observed. For example, there is a predominance of strongly undulating terrain, accounting for about 25% of the total region; predominantly, Fluvic Neosols are found in this terrain. In contrast, undulating terrain accounts for a smaller percentage of the territory (10%) and is predominantly occupied by Luvisols.

AGRICULTURAL CAPACITY OF THE WESTERN DEPARTMENT

Certain crops, such as arabica coffee, sugarcane, and maize, have a high volume of transactions in international markets, making a significant contribution to the trade balance of countries like Brazil, Mexico, and the USA (FAO, 2019). In less developed countries, nonetheless, these same crops hold great importance in the daily feeding of the population. Others, like beans, bananas, and cassava, also play a crucial role in the eating habits of rural populations in some regions of these countries (CALLE; CONDE; BAENA, 2015; SÃO JOSÉ *et al.*, 2020).

Based on the analysis of the environmental conditions characterizing the Haitian Western Department, and some of the crops produced by local farmers, Table I presents the relationship between natural resources found in the study area and certain crops, also underlining their environmental requirements.

In general, the agricultural crops analyzed, which were classified as not recommended, face restrictions primarily due to climatic factors. Another point to consider is the environmental compromise of soil quality in the region, posing challenges to profitable agricultural development (CHARLES, 2020). Furthermore, since the majority of the analyzed crops have a short/annual growth cycle, an agricultural year is required for soil preparation, which can accelerate erosion processes and exposure. However, an individual analysis of each crop is necessary for a better understanding of the challenges to be addressed in future agricultural development projects, conditions that can be improved with agricultural technological innovations.

Arabica coffee

Some Arabica coffee cultivars exhibit high tolerance to water scarcity; however, the average annual precipitation distribution over the months is not conducive to coffee plant development (TORRES *et al.*, 2021). The predominant soil type in the Western Department is not Latosol (see section 1.2.), which provides the necessary depth and physical and chemical conditions for plant growth (CAMARGO; PEREIRA, 1994). Nevertheless, it is worth mentioning that the coffee crop can adapt to various types of terrain, potentially enabling cultivation

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in different areas depending on the management techniques employed. Even with suitable temperature conditions, therefore, the practice of Arabica coffee cultivation is not recommended in this locality, as it does not meet the other environmental requirements of the coffee plant.

Sugarcane

For the planting of sugarcane, it is recommended that the sugarcane plantation area has a flat to slightly sloping topography, since, if it is rugged, soil conservation practices should be adopted to reduce the risks of erosion (MARIN *et al.*, 2015). Based on the predominant soils in the Western Department and its mostly rugged topography, sugarcane production would yield minimal returns compared to the high production costs to be invested. Additionally, the required average annual precipitations for sugarcane, coupled with its moderate tolerance to water scarcity (*FRANCISCO et al.*, 2016), further discourage its cultivation in the Western Department.

Corn

The corn crop showed great potential for viability in the environmental conditions found in the study area. Given its low requirement for an average annual precipitation (*FRANCISCO et al.*, 2017) and its ability to thrive in various soil types, the Western Department considers it suitable for cultivation due to its potential for high yields. Planting is recommended during the rainy season, which, according to Figure 5, would be between August and November. It is important to note that the viability of seeds in different soil types is related to the depth at which they are planted. Seeds should be placed at a depth that allows for good contact with moist soil. Therefore, when planting in sandy soils, it is recommended to plant the seeds deeper (5 to 8 cm) to optimize the utilization of moisture in the lower layers of this soil type. In clayey soils, on the other hand, the seed should be placed more superficially (4 cm), as deep planting in this type of soil hinders germination (EMBRAPA, 1982). Additionally, the terrain conditions in the area are also conducive to maize cultivation.

Beans

Despite the common bean being sensitive to water scarcity, it has low requirements for average annual precipitation and favorable temperature conditions (MARCO *et al.*, 2012), making it suitable for the Western Department. Argisols and Arenosols are the most recommended soils for beans, provided that certain precautions are followed. Planting at a depth of 3 to 4 cm in clayey or moist soils, and 5 to 6 cm in sandy soils, is recommended, as the common bean has a shallow root system (*RIBEIRO et al.*, 2011). The recommendation of planting beans in flat areas also contributes to their viability in the Western Department, as approximately 20% of the terrain in this area is considered flat.

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Banana

The recommendation of planting bananas in Argisols (MENEZES; GALVÃO, 2004), combined with the high average annual temperatures found in the Western Department, does not meet the additional environmental conditions required for the profitable development of banana cultivation. This is mainly due to the high precipitation required for its growth, as well as its low tolerance to water scarcity (Medeiros *et al.*, 2013), which would compromise the physiological development of the plant. The planting of banana trees is not recommended in areas with steep slopes. These trees retain a significant amount of moisture in the root area, which can contribute to mass movements. This is particularly problematic in regions with high erosion potential, like the one in question.

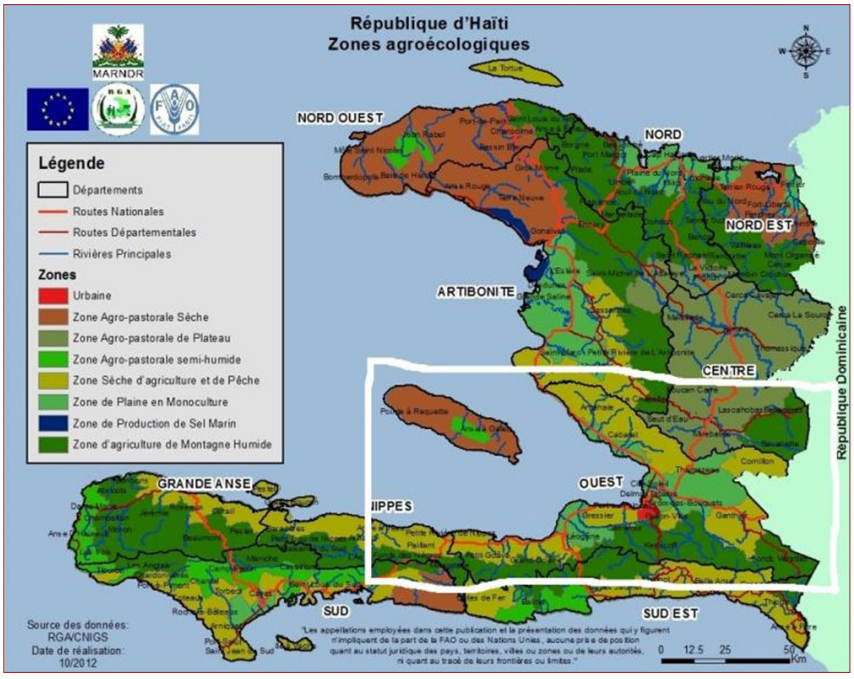
Cassava

Cassava agriculture shows high potential for development when considering its environmental requirements about the characteristics found in the Western Department. Due to its high tolerance to water scarcity and viability in soils with sandy characteristics (ALVES; MODESTO JUNIOR, 2014), it is recommended for the studied region. And its temperature and precipitation requirements do not deviate significantly from those found in the Western Department. Furthermore, the recommended terrain for this agricultural crop demonstrates its adaptability.

Orange

The development of oranges requires a significant amount of water during the fruit development period, which is marked by its filling (*CRUZ et al.*, 2005),

Figura 8. Agroecological Zoning for the Republic of Haiti, highlighting the West department with a white square



Source: MDE (2015)

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making it less tolerant of water scarcity. The soils found in the Western Department are not recommended for planting orange trees, making this agricultural crop one of the least viable options for the locality, despite the suitable terrain for this plantation.

In addition, Figure 8 shows the agroecological zoning carried out for Haiti in 2012 and its general provisions for activities related to agriculture and livestock. Highlighted in the white square is the Western Department, where it is possible to observe a wide range of agriculture developed in humid mountains (shown in dark green), as well as another strip (shown in light green) with monocultures developed in flat areas. Additionally, there are areas dedicated to other forms of agriculture and fishing.

It is possible to point out that these areas have a tradition of agricultural cultivation, which suggests the potential for developing these crops in this region. The development and environmental planning of the area would enhance crop productivity, as a more comprehensive understanding of the natural resources in the area can lead to better agricultural management.

CONCLUDING REMARKS

Based on the analysis of the environmental conditions in characterizing the Western Department of the Republic of Haiti, it is concluded that the agricultural sector holds significant importance for both subsistence and the local economy. However, its viability has been heavily impacted by erosion and recurrent droughts in the region, which have led to increased food insecurity among the population. In addition to natural factors affecting agriculture, environmental degradation resulting from unplanned urbanization has made potentially profitable arable land unsuitable for cultivation.

The analysis of environmental characteristics and their implications on agricultural production in the studied region revealed that the majority of crops grown by local farmers are not viable for cultivation there. Coffee, sugarcane, banana, and oranges face restrictions primarily due to the climatic conditions of the Western Department. However, maize, common bean, and cassava have a higher likelihood of yielding profitable returns in their production, provided they are cultivated with proper agricultural management.

Based on the results, it is recommended to develop a comprehensive master plan for integrated environmental planning. This scheme will serve as a foundation for regulating land use and occupancy in the region, assigning appropriate uses to each area. Besides reducing the erosive effect, which will have a positive impact on the environment, it can significantly increase agricultural production, thereby benefiting the country's agricultural sector.

On the other hand, it is imperative to implement policies that promote investment in Haitian small agricultural businesses and the sector, as a whole, to enhance

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climate resilience. Finally, it is crucial to promote an agricultural model adapted to the reality of the study area, ensuring food security both for the local and national populations. ●

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