Received: 23 December 2020 | Revised: 17 March 2021 | Accepted: 29 March 2021
DOI: 10.1111/jbi.14126

RESEARCH ARTICLE

Journal of Biogeography WILEY

Two centuries of changes in Andean crop distribution

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Funding information
Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA)

Handling editor: Ana Filipa Palmeirim

ABSTRACT

Aim: Historical changes in crop distributions of tropical regions are poorly understood and rarely quantified due to the scarcity of historical records. As early as 1796, Francisco José de Caldas recorded crop distribution and drew maps depicting crop regions for eight crops. Using Caldas' crop regions, we identify changes of crop distribution in relation to latitude and elevation, as well as compare their elevational limits over two centuries.

Location: The northern Andean mountain range between Colombia and Ecuador.

Taxon: Wheat, barley, potato, maize, sugarcane, cacao, plantain and cassava.

Methods: We analysed Caldas' crop regions and compared them with a current homologous replication of the same crops. We tested whether elevational ranges and mean elevation of the crops varied between the colonial and contemporary periods and analysed the relationship between elevation and latitude.

Results: In quantifying the historical and contemporary distributions, we identified a large expansion of 740.1 meters in the elevational range over 224 years for all eight crops. We also found crops located at lower latitudes south towards Quito distributed at a higher elevation.

Main conclusions: Our findings use historical data never used before to investigate the evolution of crop distribution since the colonial period. Our analysis provides evidence to conclude that Caldas' work on climate and agriculture was essential to developing the field of tropical agriculture climatology, a discipline for which Caldas established but was never given recognition.

KEYWORDS
colonial period, elevation, Francisco José de Caldas, history of agriculture, latitude, New Granada

1 | INTRODUCTION

Mapping the distribution of organisms into regions began in the late eighteenth century (1780–1800) in Europe when Eberhard August Wilhelm von Zimmerman pioneered a map of animal distribution in different continents (Ebach, 2015). The study of biogeographical maps was driven out of naturalists' curiosity to know where organisms exist. Jean-Louis Giraud Soulavie applied some of Zimmerman's techniques for the first time on plants in 1783, showing the limits of altitude for alpine vegetation and the climates of chestnuts and vines in the Loire and Rhône region (Giraud-Soulavie, 1783; Zimmermann, 1777). Soulavie's cross-sectional map of climate regions advanced the development of plant geography but lacked several geographical details such as latitude and longitude.

Between 1783 and 1816, the Royal Botanical Expedition of the New Granada took place under the direction of botanist and priest, José Celestino Mutis, who pioneered botanical collections in the northern Andes. Following Mutis' expeditions, Alexander von Humboldt and Aimé Bonpland arrived in South America in the early 1800's to explore the geography in the New Granada (Humboldt & Bonpland, 1807). They mapped the distribution of plants at elevational gradients in Colombia and Ecuador, describing the habitats of different native vegetation zones. On this trip, Humboldt encountered Francisco José de Caldas (1768–1816), a self-taught Colombian scientist who since 1796, had been mapping the distribution of native plants and agricultural crops growing along routes in Colombia and Ecuador that he took as a travelling salesman (González-Orozco et al., 2015).

Prior to his encounter with Humboldt, Caldas had developed a series of cartographical maps of surrounding areas he had encountered along trade routes between his hometown in Popayán and Bogotá, which he made selling fabric (Appel, 1994). The complex topography and biodiversity he observed on his trips provided him with a natural laboratory to develop his understanding of plant distribution (Jaramillo Gonzalez, 2010). It was on several trips he carried out between Bogotá (Colombia) and Quito (Ecuador) between 1796 and 1802 that he documented the phytogeographical regions of eight crops (wheat, barley, potato, maize, sugarcane, cacao, plantain and cassava), including their distribution, elevation and latitude in a map (Caldas, 1803) (Figure 1).

Our study analyses the distributional changes of these eight crops by comparing Caldas' map (referred to as the colonial period) (Figure 1b), with a map covering data gathered between 2000 and 2020 (referred to as the contemporary period) (Figure 1a). We studied the latitude, longitude and elevation of these crops between the two periods, assigning elevation, latitude and longitude to the locations visited by Caldas (Method 1). To complement our analysis, we verified elevational limits using historical documents primarily

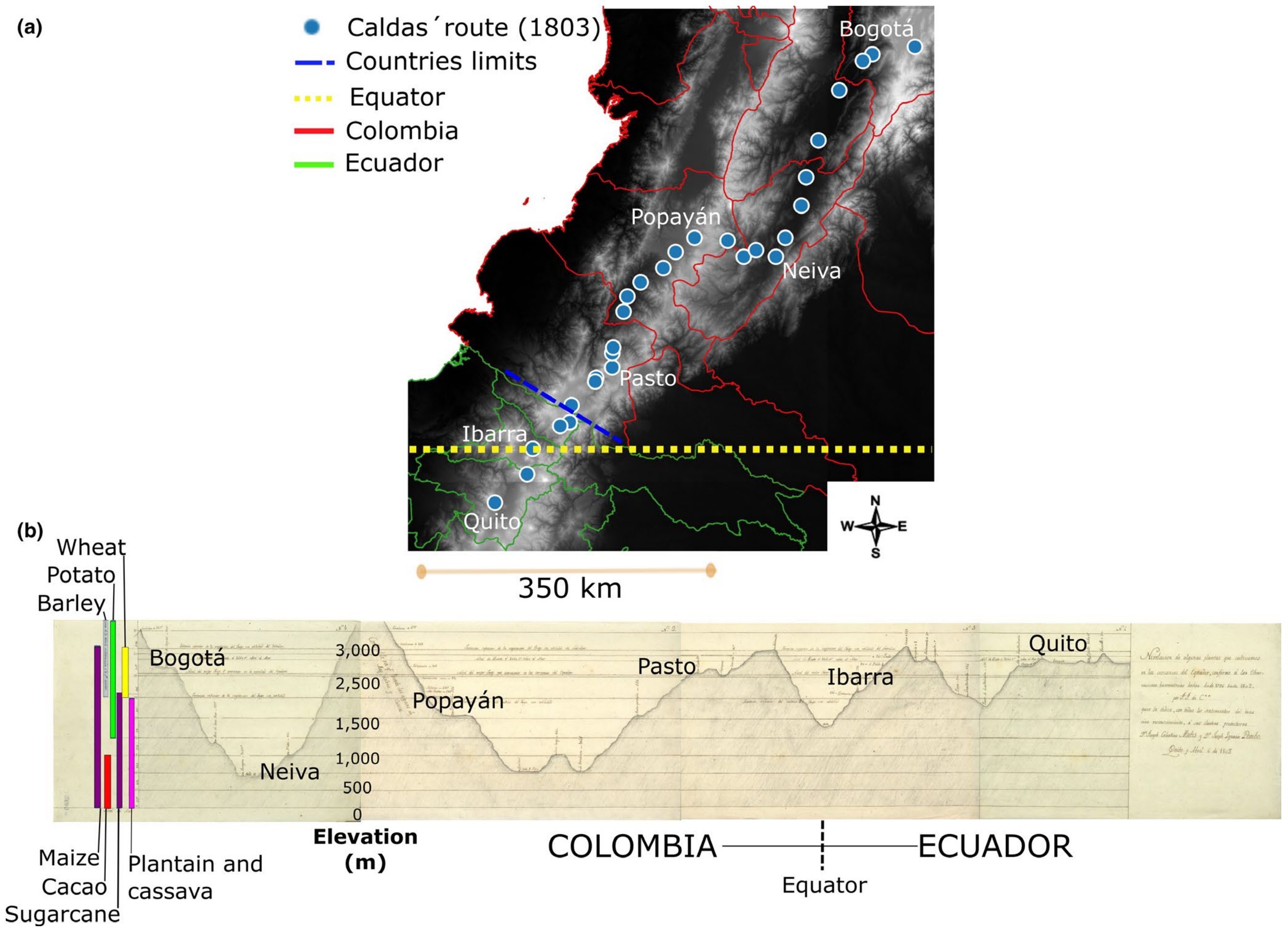

FIGURE 1 Caldas' travel route depicting the transnational transect in the northern Andes of South America from Bogotá (Colombia) to Quito (Ecuador) between 1796 and 1803 (about 1000 km) (a). High elevations in the Andes of Colombia and Ecuador on the Digital Elevation Model (DEM) are shaded in white. Original cartography of Caldas' crop regions showing the colonial profile of the travel route with vertical elevations, towns and the different crops (b). High elevations in the Andes of Colombia and Ecuador on the Digital Elevation Model (DEM) are shaded in white. The colour bars on the left of (b) represent the width of the elevational limits of the different crop regions. The title of the crop regions on the right of (b) means: 'Establishing the height of some plants that we grow in the vicinity of Ecuador, according to barometric observations made from 1796 to 1802, by Francisco José de Caldas' (Caldas, 1803). The original Spanish text used to refer to the crop regions is: 'Nivelación de algunas plantas que cultivamos en las cercanías del Ecuador, conforme a las observaciones barométricas hechas desde 1976 hasta 1802, por Francisco Jose de Caldas'. Caldas' crop regions images were obtained and authorized by the Archive of the Royal Botanic Garden. AJB, Div. III, M519, M520, M521 and M522. DEM obtained from SRTM for the globe Version 4 (Jarvis et al., 2008)

authored by Caldas in which he refers to each crop's elevational limits and compared it with contemporary data drawn from recent research (Method 2). The changes we observed cover a period of 224 years, between 1796 and 2020.

2 | MATERIALS AND METHODS

2.1 | Caldas' crop regions

We carried out a detailed analysis of Caldas' crop regions generated between 1796 and 1803 in the New Granada (Caldas, 1803). This historical cartography drawn up 224 years ago shows the elevation and latitude of each crop in the Andean mountains between Bogotá and Quito (Figure 2). The work by Caldas was titled 'Memory of the elevational zones of some plants that grow in the vicinity of Ecuador' (Caldas, 1803). The original document is deposited in the Archive of the Royal Botanic Garden in Madrid, and is cited under the codes AJB, Div. III, M519, M520, M521 and M522 (CSIC, 1995).

2.2 | Crops analysed

Caldas' crop regions were used to analyse the evolution of the crops between the colonial and contemporary periods. The crops included in our analyses were as follows: wheat, barley, potato, maize, sugarcane, cacao, plantain and cassava. Wheat and barley are foreign cereals that were introduced with the arrival of the Spaniards in the New Granada and grow at high elevations along the Andean mountain ranges. Cassava and potatoes are native tuberous crops originating in the tropics and grow in high and transitional mid-elevations. The native cacao and sugarcane and the introduced plantain are crops cultivated in lower elevations originating from humid tropical areas. Maize is native to the tropics and has a wide distribution, growing at all ranges from sea level to high mountainous areas.

2.3 | Data collection

The data collection and analysis consisted of two methods: (1) establishing latitude and (2) elevational limits. Method 1 assigned latitude

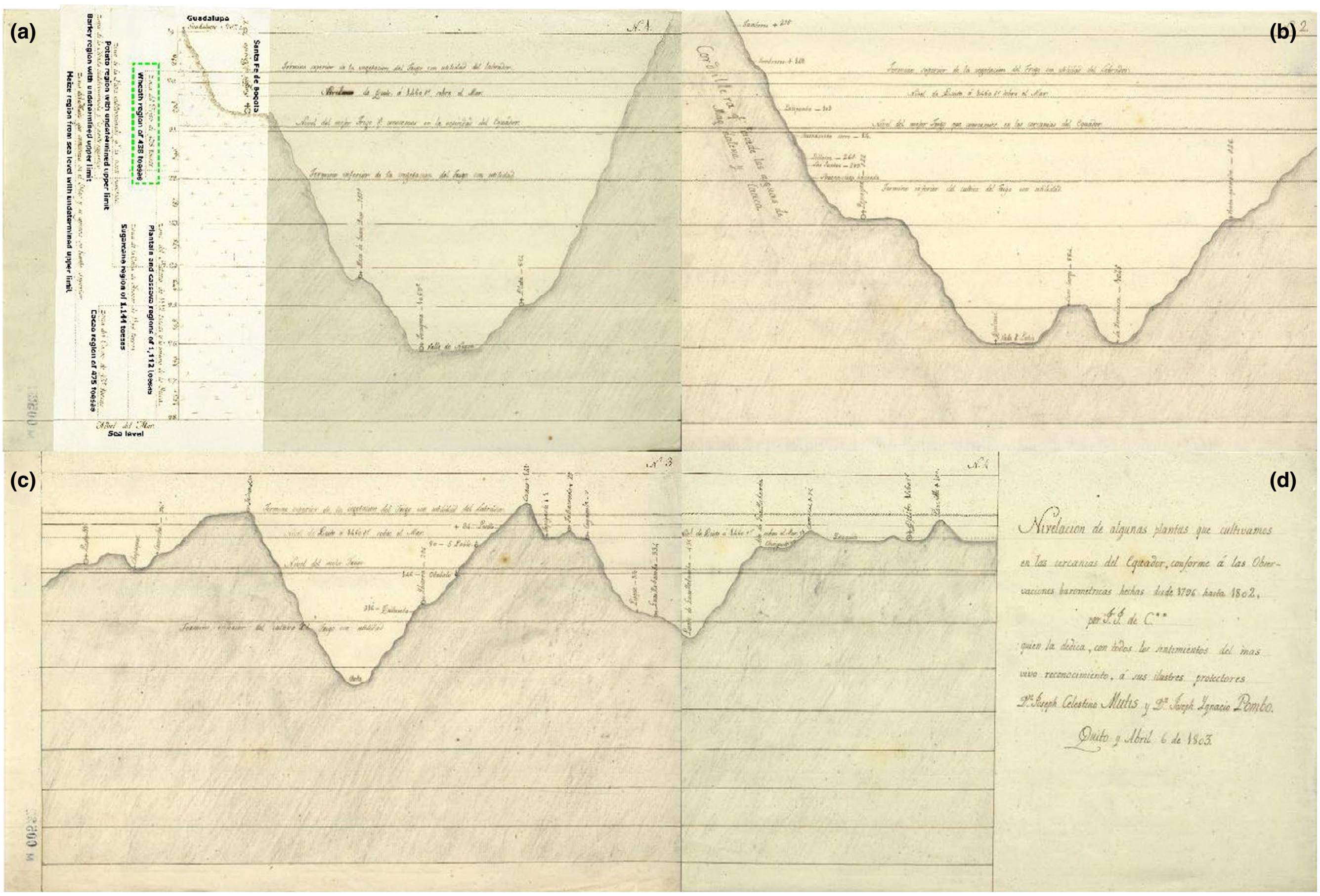

FIGURE 2 A closer view of Caldas' crop regions showing elevational boundaries of the crops displayed in four sheets (a–d) ordered latitudinally from north (Bogotá) to south (Quito). The levels shown in sheet (a) are highlighted in different colours in Figure 1b. The x-axis shows the barometric pressure from sea level to Guadalupe peak in the vicinity of Bogotá. The elevation intervals for each crop are also shown in the x-axis measured in toises (an old French unit of length; 1 toise = 1.95 m). Images authorized and obtained from the Archive of the Royal Botanic Garden. AJB, Div. III, M519, M520, M521 and M522

and longitude for a point in space, whereas Method 2 assigned single elevational limits for each crop. Method 2 complements Method 1 because it validated our interpretations using historical documents.

Using Method 1, the process to assign spatial coordinates to the modern crops based on Caldas' crop regions consisted of three steps: (i) reconstructing Caldas's route; (ii) comparing Caldas's route with the contemporary distribution of crops and (iii) assigning elevation, latitude and longitude to the location of the crops. In step 1, we conducted a detailed study of Caldas's crop regions, specifically looking at the names of towns and localities reported by Caldas along his route. This process required a review of the original description he made about the regions, which Caldas included in an attached document to support the visual picture in his map (Caldas, 1803). Step 2 consisted of establishing the specific geographical locations of crops along Caldas' route. For step 3 we used Google Earth to verify the latitude and longitude of each town reported in Caldas' map.

Using Method 1, we produced a spatial dataset of 541 entries representing crop locations along the transect (Dataset SI1). Our dataset consists of an approximation to the original route followed by Caldas, but it is not an exact reconstruction. The majority of the entries are within the transects' latitudinal extent (from 4.6°N in Bogota to −0.22°S in Quito), however, there are also a number of entries outside the transect (2°N from Bogota and 2°S from Quito following the Andean ranges) which complement the spatial distribution of crops currently present. The dataset generated using Method 1 contained country, crop type, locality, period, elevation, departments or provinces, latitude and longitude. The number of entries per country in Method 1 was the following: barley (total: 94; 85 in Colombia; 9 in Ecuador); wheat (total: 131; 88 in Colombia; 43 in Ecuador); cacao (total: 47; 45 in Colombia; 2 in Ecuador); plantain (total: 51; 48 in Colombia; 3 in Ecuador); cassava (total: 36; 34 in Colombia; 2 in Ecuador); maize (total: 44; 40 in Colombia; 4 in Ecuador); potato (total: 74; 54 in Colombia; 20 in Ecuador) and sugarcane (total: 64; 61 in Colombia; 3 in Ecuador). All data are available in supplementary information (Dataset SI1).

2.4 | Statistical analysis

For Method 1, two statistical analyses were conducted using R v. 3.5.3 (R Core Team, 2020). First, a linear model (LM) was used to establish the change in average elevation of the crops between historical periods and the relationship of elevation and latitude. For the elevation and latitude analysis, the model included elevation as the response variable, period and crop type as categorical variables, and latitude as a covariable. The interaction between latitude and period was discarded from the model based on the Akaike Information Criterion (AIC). We found that average elevations of all crops did not differ significantly between the two time periods (LM, $F = 0.6$, $p = 0.427$). This exploratory result suggested that elevational ranges are the best candidates to be explored. In the second analysis, the calculation of the distribution ranges for each crop was made by subtracting the minimum elevation recorded for each historical period from the maximum elevation. The difference between elevation ranges between the periods was analysed using a Student's *t*-test based on the range for each crop ($N = 8$). The assumptions of both analyses were corroborated using Levene's test and by visually inspecting the histogram of residuals. The findings shown in Figures 3 and 4 are based on the statistical analyses conducted for Method 1. Data from Method 1 were used to draw the main results and conclusions of the study.

2.5 | Validation of elevational limits

Data collection for Method 2 consisted of a literature search to compare maximum and minimum elevational limits per crop. This method was designed to verify the elevational limits of the crops found in Caldas' map. In some cases, historical documentation was less detailed and as a result we were not able to verify all the elevation limits. We referred to literature mostly authored by Caldas and other available sources such as books, journals, historical archives, online mapping tools and online crop databases. Caldas reported the elevation in toise, a unit originating in pre-revolutionary France (1 toise =1.95 m), which we converted into meters above sea level. Tables 1, SI1 and SI2 list the elevational limits in Colombia and Ecuador, respectively, as well as the source of information. (Álvarez & Chaves, 2017; Caldas, 1809; Lasso Espinosa, 1991; Riley et al., 2001). Table SI3 provides the links to the general source of information for each crop. The data from Method 2 was not analysed statisticallly because there were few values, only 8 elevational limits per crop for each country.

3 | RESULTS

Our study found that over the past two centuries, the elevational ranges of all eight crops along the Bogotá to Quito transect and surrounding areas experienced a significant expansion which can be observed in Figure 3a and b. Figure 3a provides the absolute values of altitude showing the maximum and minimum elevations during both the colonial and contemporary periods. Figure 3b, on the other hand, indicates the elevational range, which is the difference between the maximum and minimum elevation. We found an overall change of 740.1 meters above sea level (masl) (Figure 3b). Each crop region expanded in elevational range by the following: Sugarcane—1426 masl; barley—1020 masl; potato—866 masl; cassava—750 masl; plantain—735 masl; cacao—430 masl; maize—235 masl and wheat—284 masl.

We also found that the elevational distribution of crops between Bogotá and Quito was affected by latitude: as latitude decreases the crop elevation increases (Figure 4).

Using Method 2, we verified the elevational limits of each crop during the colonial and contemporary periods, which supports the findings in the statistical analyses (Table 1, Table SI1–2).

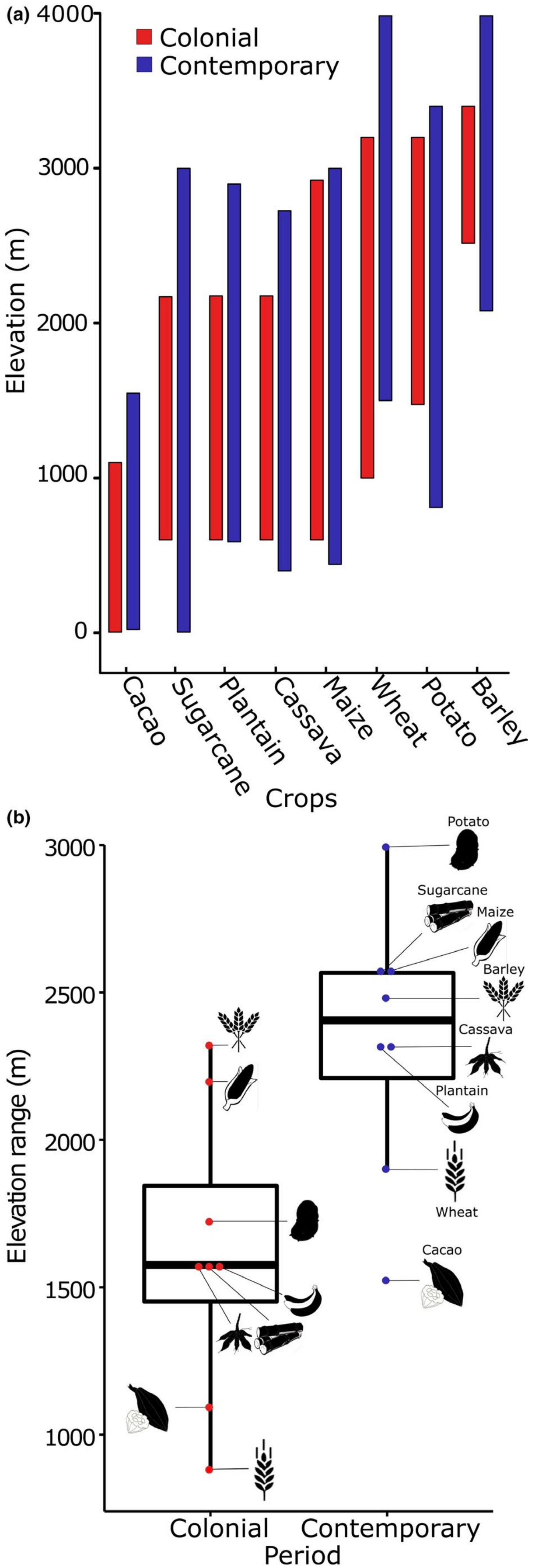

FIGURE 3 (a) Range between maximum and minimum elevations of Caldas' crop regions in the colonial and contemporary periods and (b) box and whiskers plot of the elevational ranges (maximum–minimum elevations) for both periods. Crop ranges were significantly different between periods (Student's *t*-test, $t = 3.1$, $p = 0.008$). This dataset was generated through Method 1

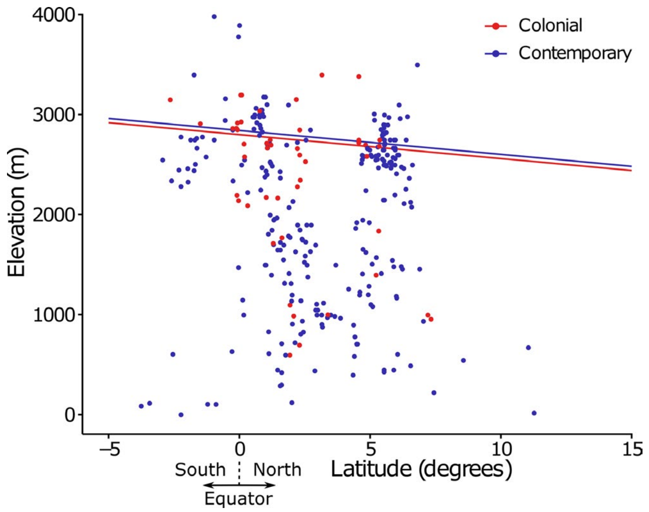

FIGURE 4 Linear model (adjusted $R^2 = 0.634$) showing the relationship between elevation and latitude of the crops described in Caldas' crop regions (all crops) in the transect Bogotá to Quito in the colonial and contemporary periods ($n = 541$). No difference was found in mean elevation between periods ($F = 0.6$, df = , $p = 0.427$). Crop elevation was affected by latitude across the transect ($F = 6.0$, df = 1, $p = 0.014$) and crop type ($F = 132.0$, df = 7, $p < 0.001$). This dataset was generated through Method 1

4 | DISCUSSION

There are studies on the elevational distribution of native flora in some parts of the Andes of Ecuador (Kidd, 2020; Moret et al., 2019; Morueta-Holme et al., 2015). However, the historical information for a larger portion of the northern Andes is deficient. The northern Andes is rich in climatic zones for agriculture (Rahbek, 2019), but there is limited information about how crop distributions have evolved over time. Despite his little exposure to the botanical advances occurring in Europe and limited resources, Caldas successfully documented detailed latitudinal and elevational distribution of eight crops in the Andes in his map. Here, we conducted the first detailed analyses of Caldas crop regions with the aim of comparing crop distributions between the colonial and contemporary periods.

4.1 | Crop changes in elevation and latitude

Although we did not detect a change in mean elevation between each period (Figure 4), a significant expansion of elevational breadth was

TABLE 1 Minimum and maximum elevational limits of Caldas' crop regions in Colombia and Ecuador comparing the colonial and contemporary periods. This dataset was generated using Method 2

		Elevation limits (m) (Colonial period)		Elevation limits (m) (Contemporary period)	
Country	Crop	Min	Max	Min	Max
Colombia	Cacao	0	925	0	1600
Ecuador		0	925	0	1000
Colombia	Sugarcane	0	2229	0	2500
Ecuador		0	2229	20	2500
Colombia	Plantain	0	2229	0	1500
Ecuador		0	2229	0	2300
Colombia	Cassava	0	2229	0	2000
Ecuador		0	2229	0	2400
Colombia	Maize	0	2339	0	2800
Ecuador		0	2339	0	3200
Colombia	Potato	1455	3000	1500	3500
Ecuador		1455	3900	1900	4000
Colombia	Wheat	1800	3000	2200	3000
Ecuador		1800	3000	2200	3200
Colombia	Barley	2167	2800	2500	3000
Ecuador		2167	3300	2000	3800

detected (Figure 3). These changes could be attributed to population growth in the Andean region. Spanish settlement first occurred at elevations of 1000–2000 masl and expanded to include higher elevations (2000–4000 masl) over time. The new colonies cleared much of the midlands for cattle grazing and as a result crop cultivation expanded into the highlands (Etter et al., 2008). Expansion also occurred into the lowlands, albeit at a slower pace, as settlement was laborious due to humid and harsher conditions and the thick Amazon rainforest (Etter et al., 2006). The effect of latitude on crop elevation is likely to be attributed to the higher elevation of Quito compared with Bogotá. In addition, crop distributions may also be affected by the higher temperatures in Quito which is closer to the equator.

4.2 | Elevational limits of each crop

In this section, we detail the elevational limits of each crop and compare their differences during the colonial and contemporary periods (Table 1).

4.2.1 | Cacao

Caldas mentions the presence of cacao in Colombia and Ecuador at elevations as high as 925 masl in the colonial period (Table 1) in his map, but according to the Method 1 this crop reached a maximum elevation of 1100 masl. Caldas visited several towns where cacao was growing along his travel route, for example, he mentioned the dry and hot Patía river Valley in the Cauca department, and the town of Timaná in the upper Magdalena River in the department of Huila in southern Colombia, a main cacao-producing region during the colonial period. The Magdalena River was the main trading route of cacao during the colonial period, known as 'cacaos del Magdalena', and allowed trade to occur between Timaná to Cúcuta in the department of Norte de Santander.

In Ecuador, the main cacao-producing areas during the colonial period and today are located in the surroundings of the coastal city of Guayaquil, in the western Pacific region between 0 and 500 masl.

In Colombia, the elevational limits of cacao have increased since the colonial period. Nowadays cacao can be found at elevations of up to 1600 masl. Currently, the main cacao-producing region of Colombia is in the department of Santander at elevations between 200 and 1200 masl. This change is likely due to climate warming and the opening of pastures used for cattle grazing (Sheldon, 2019).

4.2.2 | Sugarcane

Sugarcane is a staple crop abundantly present in Andean agriculture. Caldas reported sugarcane growing at an upper limit of 2229 masl in the Andean region of Colombia and Ecuador (Caldas, 1803). In Colombia, Caldas mentioned that the Valley of the Patía River in the Cauca department was an ideal place for growing sugarcane. The Patía valley region still has similar environmental conditions today, but it only generates a small-scale sugarcane production for local markets. It is also produced on a small scale at elevations of 2500 masl. The main sugarcane-producing region of Colombia today is in the Cauca valley located around 1000 masl. The Ecuadorian region of Guayas, in the south-western Pacific coast, was the main producing region of sugarcane during the colonial period and still is today.

4.2.3 | Wheat

Wheat was the most detailed crop documented by Caldas during his field trips because it was widely distributed during his time. Caldas observed wheat growing as high as 3000 masl in Colombia and 3200 masl in Ecuador (Table 1) but noted that the best cropping elevation for wheat cultivation was at 2200 masl due to lower humidity and cooler temperatures. He argued that changes in these environmental factors could affect crop yield as well as quality. Caldas noticed that the physical properties of wheat quality were reduced with an increase in elevation. Today, the most suitable regions for growing wheat are at 3000 masl in the highlands of Nariño in the southern part of Colombia and northern Ecuador (Doolittle, 1990). The fact that today's wheat upper limit is higher than during the colonial period suggests that increasing temperatures have potentially shifted wheat growing in the higher elevations where temperatures are lower.

The productivity of wheat and other crops might also be affected by diseases which are exacerbated by climate variations. During the colonial period, the effect of disease on wheat was evident to Caldas. He observed that 'in low hot and humid areas such as Neiva, Cali and the Patía river valley there were also wheat fields before, but they were exterminated due to leaf rust attacks' (Caldas, 1803). He also reported the effects of rust attack on wheat cultivation in Cartagena on the Caribbean coast, resulting in the depletion of the crops altogether (Text SI1). Nowadays there is no evidence of wheat growing in the Caribbean region.

4.2.4 | Plantain and cassava

Plantain and cassava are major food sources in the Andean region of Colombia and Ecuador. We found that their distributional limits have changed since the colonial period. Caldas found plantain and cassava growing at upper elevational limits of 2229 masl, although observed that their productivity decreased at higher elevations which he attributed to changes in climate conditions (Etter et al., 2006). In fact, this remains the same today with the most suitable cropping regions for plantain and cassava located at elevations below 1000 masl. Nevertheless, there has been an expansion of small-scale cropping reaching the upper limits as high as 2400 masl in Colombia and Ecuador during the last century (Doolittle, 1990).

4.2.5 | Barley and potatoes

Barley and potatoes are high elevation crops in the Andean region. In the colonial period, barley and potatoes were grown at upper limits reaching 3300 masl in Colombia and 3900 masl in Ecuador. Today those limits have increased to 3800 and 4000 masl respectively (Table 1). These highland regions experienced earlier colonial settlements and the introduction of foreign crops. In the period between 1600 and 1800 in the mountain areas of the New Granada, human population increased by 50% and the expansion of the livestock industry followed with the arrival of major crops such as barley and wheat drastically transforming land use (Caldas, 1966). Caldas mentioned potatoes growing from 1455 masl to the lower limits of the glaciers (Caldas, 1803). He states that in Ecuador, potatoes were cultivated at an upper limit of 3900 masl, however, today this limit is up to 4000 masl. Pasture opening and expansion of the agricultural frontier were the main drivers for upper limit changes of potato cultivation, causing environmental damage to the Páramo ecosystem. Today, these environmental impacts have been exacerbated by human growth in the middle-upper Andean region and as a result is the most environmentally threatened region in the Andes.

4.2.6 | Maize

Maize is a widely distributed crop in Colombia and Ecuador, cultivated across most ecosystems but mainly in the hot lowlands of the Caribbean region where productivity is the highest. Caldas noticed that maize presented a wider climatic breadth. He mentions that the crop has a wide elevational range in both Ecuador and Colombia from 0 to 2339 masl (Caldas, 1803). Today this upper elevational limit has increased to 2800 masl in Colombia (Table 1) and 3200 masl in Ecuador. Caldas found that at high elevations with colder temperatures, maize was ready to harvest in 12–13 months, and in 6–8 months below 1500 masl (Caldas, 1803). Currently, maize can be harvested after 5 months in ideal conditions.

4.3 | Potential causes of changes in Andean crop distribution

Although our study does not investigate the causes of crop changes, we suggest that the expansion of crop regions towards the upper limits of the Andes (Figure 3) could be attributed to the warming climate that drives the displacement of species (Chen et al., 2016; Cheng et al., 2019; Feeley et al., 2011; Wilson et al., 2006). In particular, an increase in temperature has been found to be the main cause of species or crops shifting (Barberan et al., 2019; Moret et al., 2019; Morueta-Holme et al., 2015; Román-Palacios and Wien, 2020; Tessema and Patt, 2019).

Settlements during the colonial period in Colombia and Ecuador occurred at high elevations (>1500 <3500 masl) due to milder climates. Lowland (<1000 masl) climates were hotter and wetter and thick with forest and, therefore, not as ideal for human settlement. Human impacts such as forest clearing and pasture opening for cattle farming during the colonial period, and even today, are the major drivers of landscapes modifications in the tropical Andes (Balthazar et al., 2015; Beller et al., 2020; Bush et al., 2004; Dearing et al., 2015; Etter et al., 2006, 2008; Feeley, 2012; Gustavsson et al., 2007; Nowak et al., 2019).

4.4 | Inaccuracies in the methodologies

Although historical maps are valuable tools to investigate changes in land use over time, inconsistencies must be considered (Beller et al., 2020; Moret et al., 2019). We found inaccuracies in our methodology due the lack of accurate and complete data. Firstly, some spatial locations assigned in Method 1 were inaccurate. This is because most of the routes taken by Caldas during the colonial period no longer exist because of land use transformation, and, even if they existed, revisiting these routes would be unfeasible under the current conditions. Secondly, some data on lower elevational limits during the colonial times were missing because most settlements were high in the mountains rather than in the forested lowlands.

For the collection of crop data in the contemporary period, there could also be certain biases. In our search, we observed that some of the crop areas that Caldas visited no longer exist today because land use has changed drastically making it difficult to compare the two periods. For example, wheat is no longer cultivated in the surrounding areas of Popayán where Caldas reported its occurrence. We also found limitations in using Google Earth to verify the presence of crops. In some cases, the spatial resolution of the Google Earth image was not fine enough to confirm the type of crop. In order to compensate for this, we used national agricultural databases to establish the type of crop present (Table SI3).

To build the dataset, we verified that each period (colonial and contemporary) had a proportional distribution of records for each crop. However, for the colonial period some crops did not have a sufficient number of records to establish this distribution. For example, available information on cassava, maize and plantain during the colonial period was scarce.

5 | CONCLUSIONS

In this study, we provided quantified evidence of crop distribution changes in the Andean tropical region along elevational and latitudinal gradients over a period of 224 years. Caldas' crop regions were highly detailed and technically sophisticated, with assigned elevations and latitudes for eight crops (Gómez-Gutiérrez, 2016; Nieto Olarte, 2006). As well as delineating crop regions, Caldas also studied the interactions with climate, crops and other organisms in these regions (Diaz-Piedrahita, 1992; Valencia Restrepo, 2016). Unfortunately, his contributions to the study of plant geography and climate have to this day been given little credit.

This is the first study to quantify the historical changes in the distribution of agricultural crops along latitude and elevation in the northern Andes of South America. Based on the evidence, we consider Caldas' work on climate and agriculture as essential to the development of tropical agriculture climatology (Caldas, 1803; Figure 2; Text SI), a discipline for which Caldas established its foundations, but was never given recognition.

ACKNOWLEDGEMENTS

The authors would like to thank the Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA) for providing funding. The authors thank Jose Luis Fernández Alonso and Esther Garcia Guillén from the Royal Botanic Garden of Madrid. The manuscript was proofread and edited by Julia Alice Veronica de Raadt. Caldas' crop regions images were obtained and authorized by the Archive of the Royal Botanic Garden. AJB, Div. III, M519, M520, M521 and M522.

DATA AVAILABILITY STATEMENT

All distributional data are available in the additional supporting information.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

How to cite this article: González-Orozco CE, Porcel M. Two centuries of changes in Andean crop distribution. *J Biogeogr*. 2021;00:1–9. https://doi.org/10.1111/jbi.14126