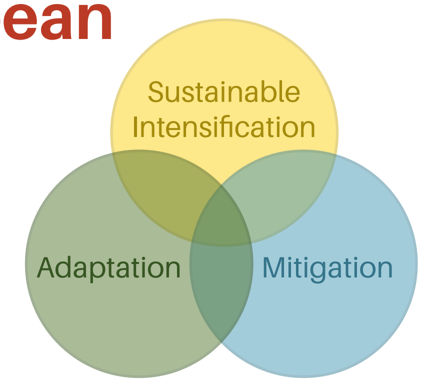
Climate Change Impacts on Cocoa Production in Central America and the Caribbean

Atlas



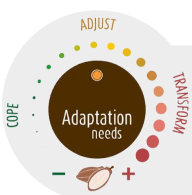
Climate-smart cocoa production sustainably increases productivity, improves resilience to climate risk, and reduces or eliminates greenhouse gases (GHGs). Interventions may be conducted at different technological, organizational, institutional, and policy levels. Furthermore, the required degree of adaptation effort for a sustainable cocoa production is associated to the degree of climate change impact. With the rise in impact, the level of interventions attains greater significance, going beyond practices at the farm level, such as changes in livelihoods or achieving an enabling environment.

To support an efficient adaptation, CIAT developed a climate change impact gradient for cocoa production. The gradient is a cocoa-specific evaluation of the results of the projected climate impact for this crop. Otherwise, identical climatic changes can result in severe or irrelevant impacts on production, depending on the historical climate conditions. For instance, a reduction in rainfall of 100 mm could be critical for cocoa in areas with low water availability, but it would be irrelevant in those areas where rainfall is heavy throughout the year. The gradient shows the most likely degree of adaptation effort needed in possible future climate scenarios.

This atlas for Central America and the Caribbean provides general information on the different degrees of adaptation efforts needed to mitigate climate change impacts on cocoa production, as well as maps of the region and of each country, agroclimatic zone maps (ACZ), and impact gradient maps. This information facilitates having a better outlook of the region regarding the effects of climate change on cocoa in the region and opens the debate about sustainable practices and necessary investments to face future risks. The map of cocoa presences helps identify cocoa production zones; maps of agroclimatic zones show future changes of agroclimatic zones suitable to grow cocoa; the maps of impact gradient help identify the level of impact in each zone, first on the region, but also by country. All the maps in this Atlas, as well as the data from which they were created can be downloaded and reused.

Download all the maps in this Atlas: maps of agroclimatic zones ideal for cocoa showing **future changes** in them; impact gradient maps that help identify the **level of adaptation effort by region and by country.**

Download the **Climate-smart cocoa in Central America and the Caribbean** brief, which, contains a detailed discussion of CSC practices for Central America, including their potential to achieve sustainable intensification, adaptation to climate hazards and mitigation of greenhouse gas emissions using the following link**:** **https://hdl.handle.net/10568/105542**



Three degrees of adaptation effort (Impact Gradient)

Incremental Adaptation, areas where the climate is most likely to remain suitable and adaption will be achieved through a change of practices and ideally improved strategies and enablers. The altered patterns of pests and diseases, uncertain rainfall, as well as drought and heat, can affect the crop, but cocoa production will remain feasible.

Systemic Adaptation, areas where the climate is most likely to remain suitable, but with substantial stress in traditional production systems; adaptation will require a comprehensive change of practices and redesigning the system, along with external support to implement changes. Without changes, the risk for production will be unsustainable. Better adapted varieties, diversification, and financial mechanisms will be necessary to reduce risks.

Transformational Adaptation, areas where climate is more likely to make cocoa production unfeasible; adaptation will require redesigning the production system or switching to new crops. External enablers will be crucial to support change, because it will likely be more feasible and cost-effective to switch to other crops than sustain cocoa production in these conditions in the future.

Note: The impact gradient mentions “Opportunities” to refer to zones, in which current climate is not suitable for cocoa, but in the future become suitable to grow this crop.

The method used a comparison of the distribution of climatic zones in which cocoa is currently produced and its distribution in future climate scenarios. Therefore, maps should be used to understand the relative differences in impacts among regions, but they should not be interpreted at the plot level. The method considered the adaptation range using current production practices, but not a likely expansion of such range through novel technologies. The adoption of Climate-smart Agriculture (CSA) practices for cocoa can lead to alternative developments. Similarly, climate was defined as an average of climate conditions through several decades. Climate variability, such as El Niño Southern Oscillation (ENSO) phenomenon, was not taken into consideration.

Agroclimatic zones are defined by different types of climate, all of which are suitable for cocoa production. The zones shown in the maps are described below. It is necessary to clarify that when the zones are described as cold or dry, those areas are not necessarily cold, but within the suitability range for cocoa, these are the areas with the lowest or highest values, as the case may be.

Agroclimatic Zones Suitable for Cocoa Production Central America and the Caribbean

Hot / Dry: Average temperature in this zone is slightly higher than 26°C, which is the highest in comparison to the rest of agroecological zones. Similarly, average temperature in the hottest quarter is above 27°C and is the highest in comparison to other zones. Regarding annual accumulated rainfall, it shows values around 2,000 mm, which is the second lowest value in comparison to other zones. Rainfall in the driest month is the lowest relative to the rest of agroecological zones, with just 20 mm, approximately. The same can be observed during the hottest quarter, with the lowest rainfall in comparison to other zones, close to 340 mm.

Temperate / Very Dry: Annual average temperature is roughly 25°C and minimum temperature during the coldest month is approximately 18.22°C, which is close to the average for the rest of agroecological zones; for annual accumulated rainfall, close to 1,900 mm are registered, which represents the lowest amount relative to the rest of agroecological zones. Concerning precipitation, during the wettest quarter, approximately 600 mm of rainfall have been registered; this is the second lowest amount, compared to other agroecological zones. In terms of rainfall during the driest quarter, around 150 mm have been observed, the second lowest amount relative to the rest of zones.

Very Hot / Dry: In these zones, annual average temperature is 25.8°C and maximum temperature during the hottest month is over 32.5°C; this is why the zone is characterized by a very hot climate. Regarding rainfall, annual accumulated amount is lower than 2,000 mm, which is the lowest observed in all agroecological zones. Regarding rainfall during the wettest quarter of the year, roughly 750 mm have been observed, and this corresponds to the lowest amount, compared to the rest of agroecological zones.

Cold / Wet: In this agroecological zone, the annual average temperature is approximately 24.7°C, the lowest in comparison to the rest of zones. In regard to average temperature during the wettest quarter of the year, 25.2°C have been observed, which is also the lowest, compared to the rest of zones. In terms of annual accumulated rainfall, over 2,600 mm have been observed, which corresponds to the second highest amount, relative to the rest of zones. Concerning rainfall during the hottest quarter, over 600 mm have been observed, which is the second highest compared to the rest of zones.

Temperate / Very Wet: Annual average temperature in this zone is 25.4°C, compared to the other zones. Regarding temperature during the wettest quarter, close to 26°C have been registered; this is also an average value relative to the rest of agroecological zones. The same applies to temperature during the driest quarter, registering 25.4°C. In terms of annual accumulated rainfall, roughly 3,000 mm have been observed, which corresponds to the highest amount relative to the rest of agroecological zones. On the other hand, rainfall during the wettest month registers amounts close to 500 mm, and rainfall during the wettest quarter exceeds 1,200 mm; the figures of the two latter variables are the highest in comparison to the other agroecological zones.

With Limitations: Most of these zones are not climatically suitable to grow cocoa; thus, cocoa will be produced in sub-optimal conditions.

Uncertain Suitability: These zones are suitable for the crop, but climate information does not allow us to clearly classify them in one of the specific agroclimatic zones. They are areas between one agroclimatic zone and the other, showing features of both zones.

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Do you need the map images and data?

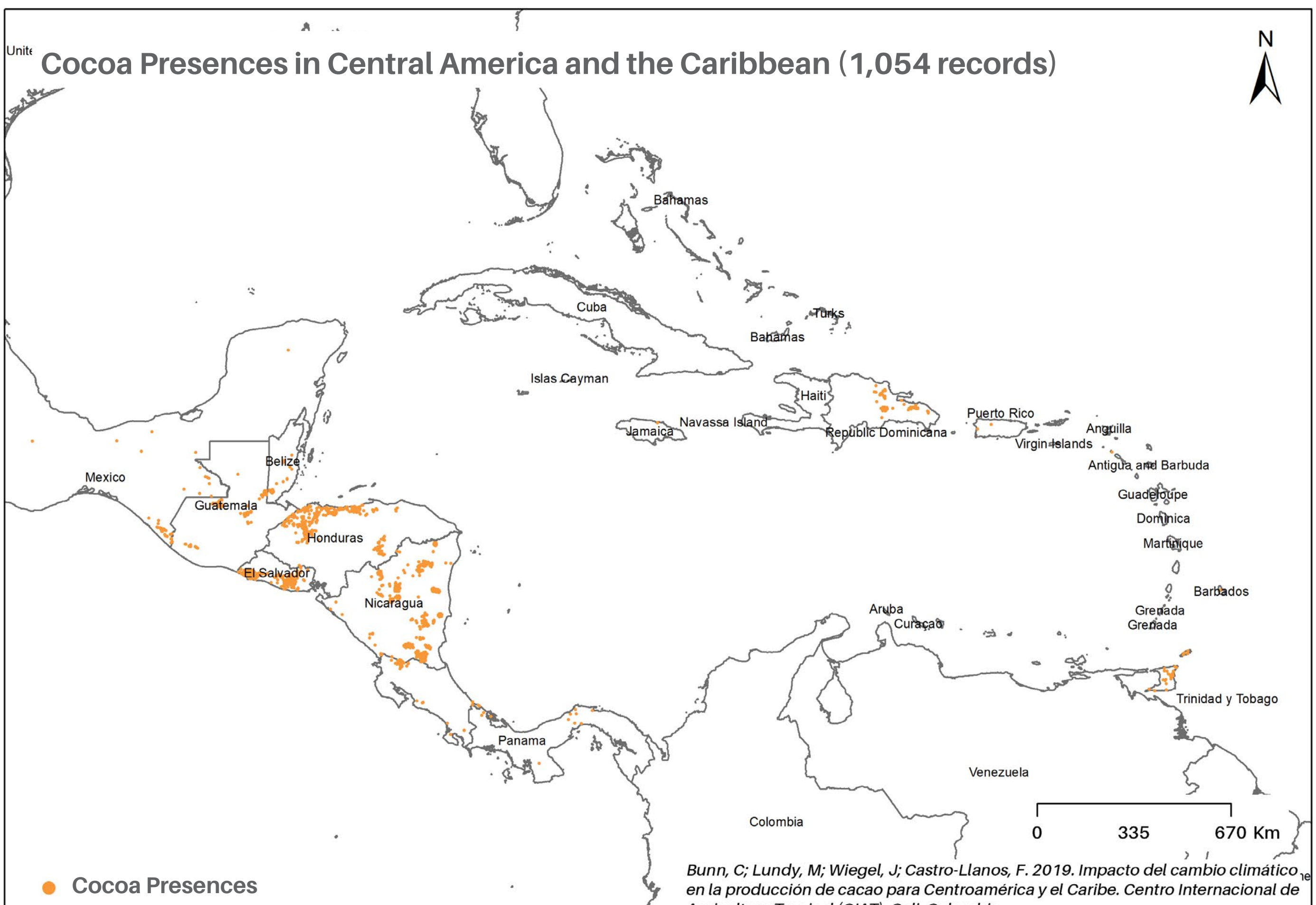
You can download, use, and share the map images you will find below in PNG format and the data in TIFF format to be used with professional software that allows editing. Follow these steps to download:

1. Visit: https://doi.org/10.7910/DVN/QUKZTO
2. In the upper part, you will find important information about the data. In the lower part, you will find two zipped files (.zip) to download. Maps.zip contains images in folders by country and region to use in presentations and documents. In Raster_Data.zip you will find editable data in folders by country and region.
3. Tell us how you will use them and download (clicking on the download button).

Central America and the Caribbean

The ACZ's for cocoa in Central America show two suitability corridors under baseline conditions. The first corridor starts in the south of Mexico and continues along central Guatemala towards Honduras (along the Caribbean), then through the center, the Caribbean coast of Nicaragua to the west, and it ends in Costa Rica and Panama. The second suitability corridor is located along the Pacific coast of Guatemala and El Salvador. These zones show climatic features that are suitable to grow cocoa in terms of rainfall, temperature, and evapotranspiration. For the future, some changes are projected: in general, the location of the areas will be similar, except that there will be an increase of areas with uncertain suitability, i.e., there will be more zones in which suitability is not sure. Some cases will be observed in the central region of Guatemala and Nicaragua, in Panama's Pacific coast, and the south of Mexico.

ACZ's for cocoa in the Caribbean show suitable areas in the baseline, mainly in the Dominican Republic, and Trinidad and Tobago, as well as small areas in the north of Puerto Rico and the north of Haiti. In the future, suitable zones increase. This means that there will be opportunity zones, i.e., new zones in which cocoa could be produced both in the Dominican Republic and Trinidad and Tobago.



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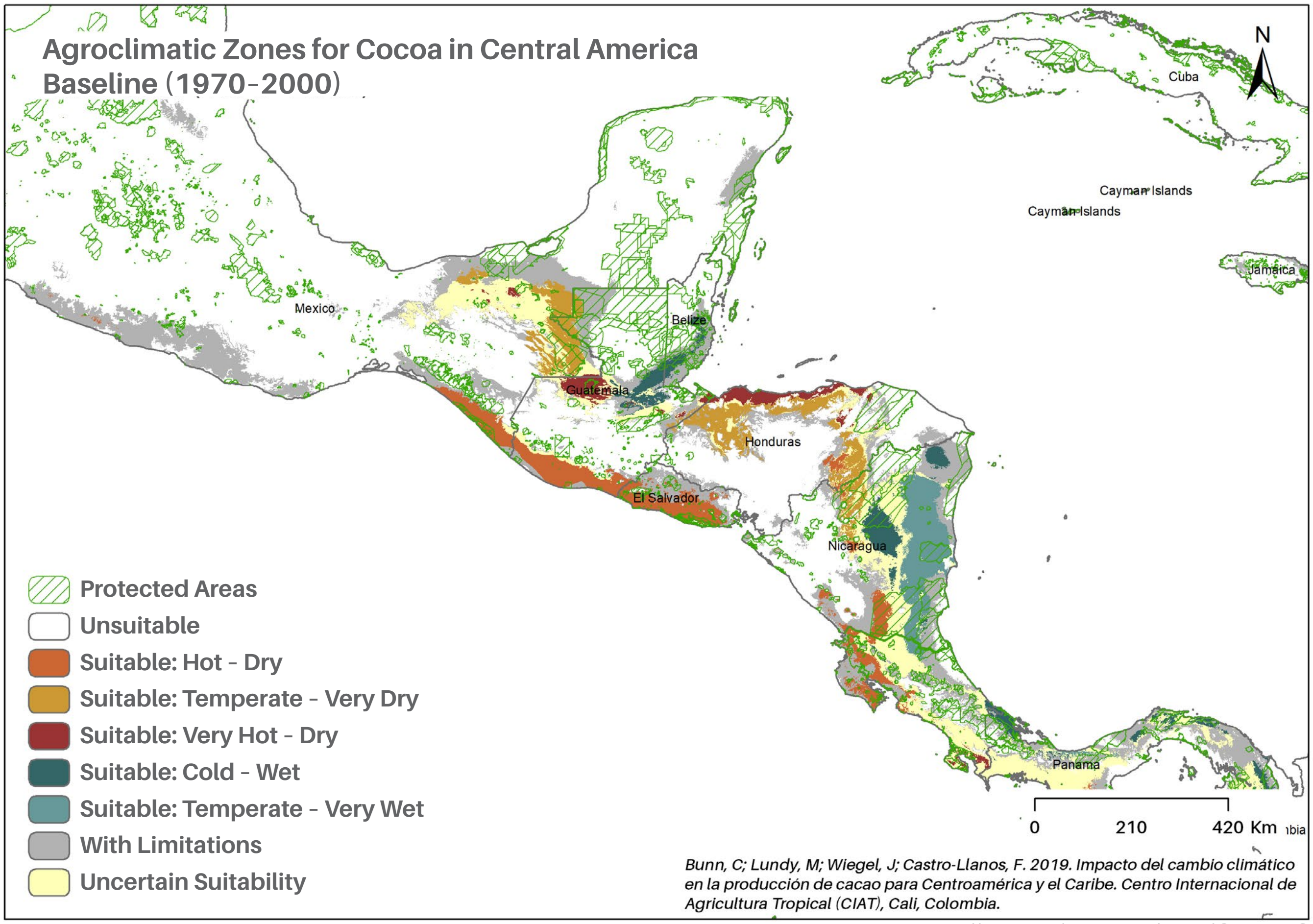

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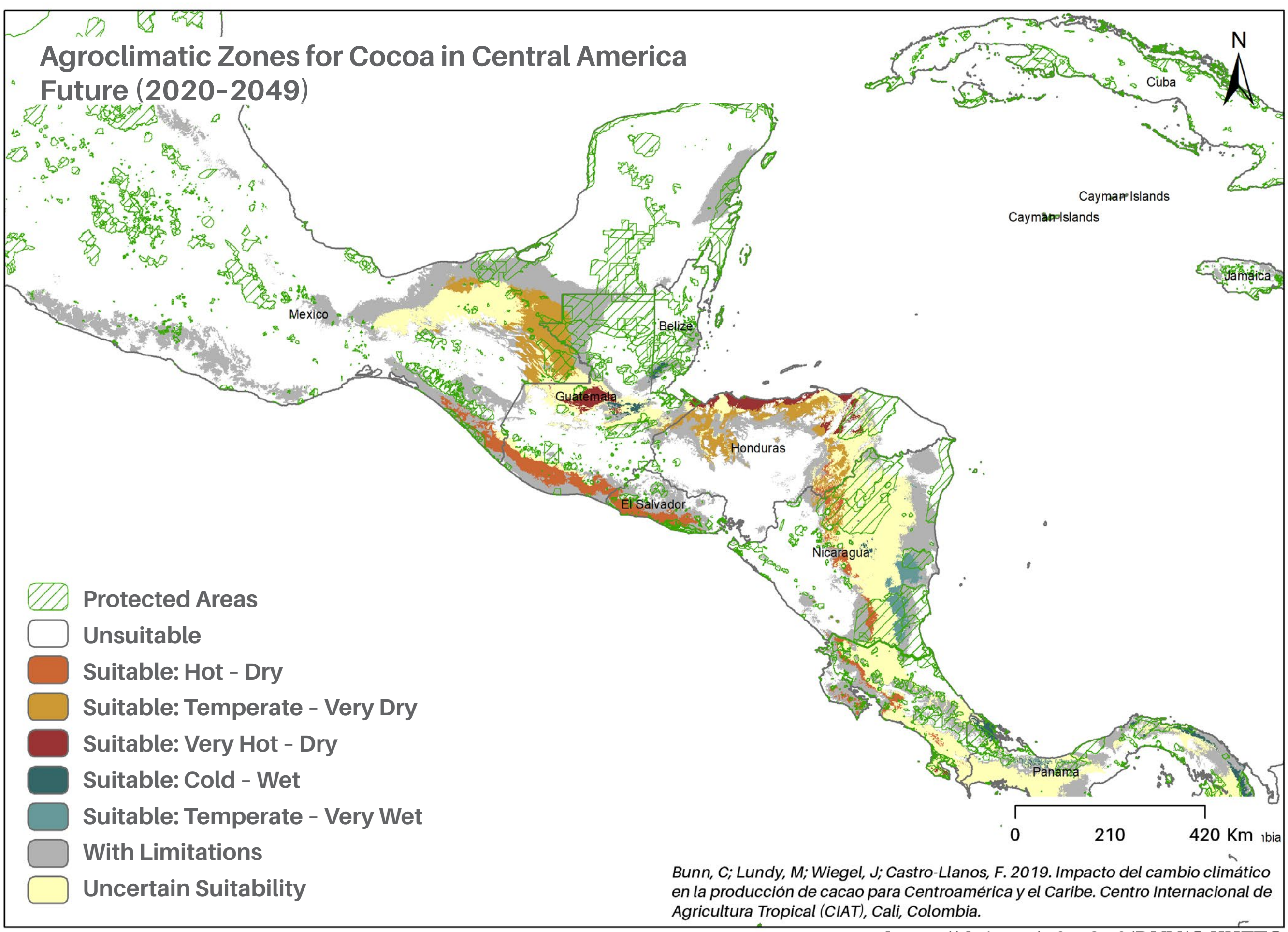

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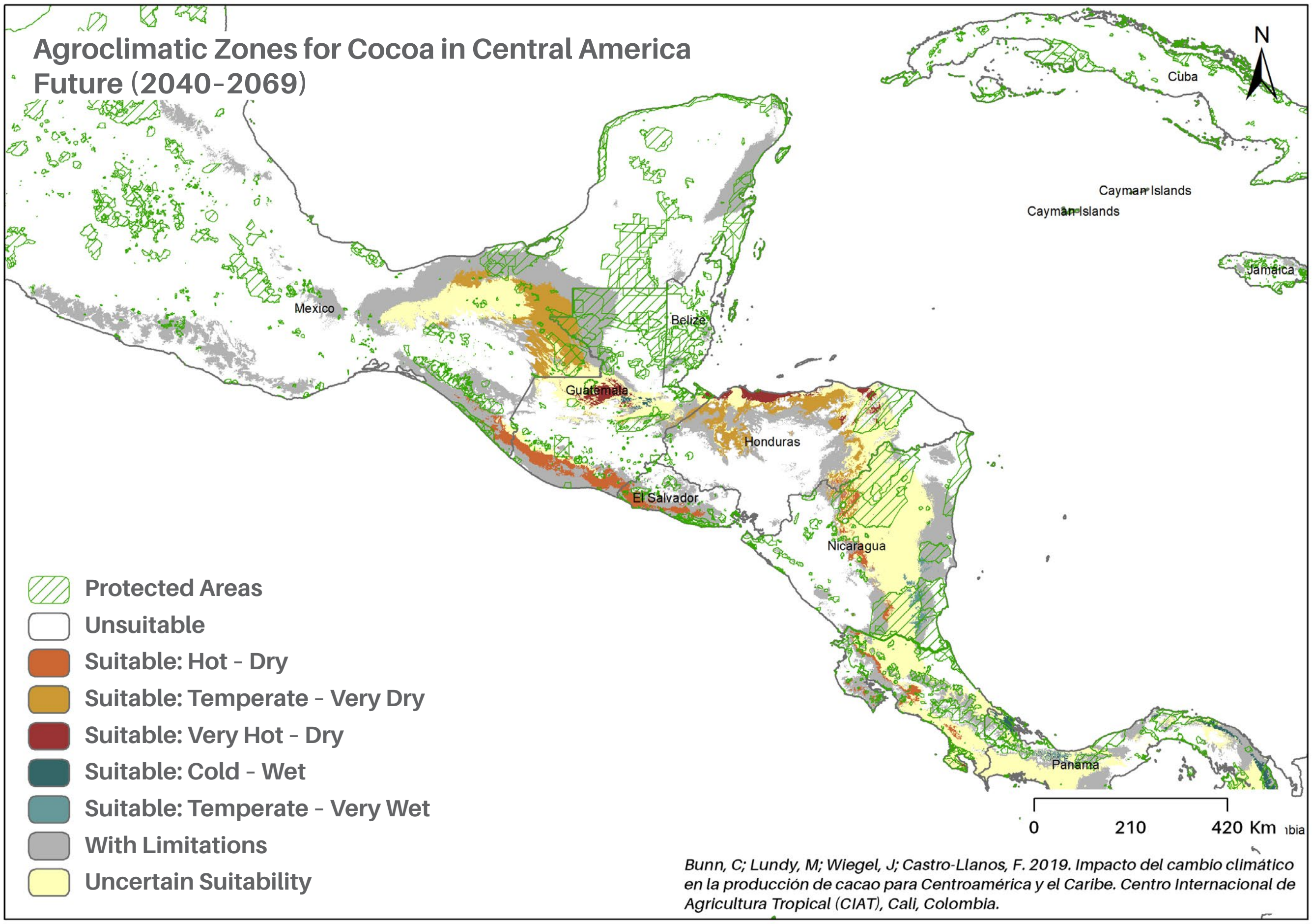

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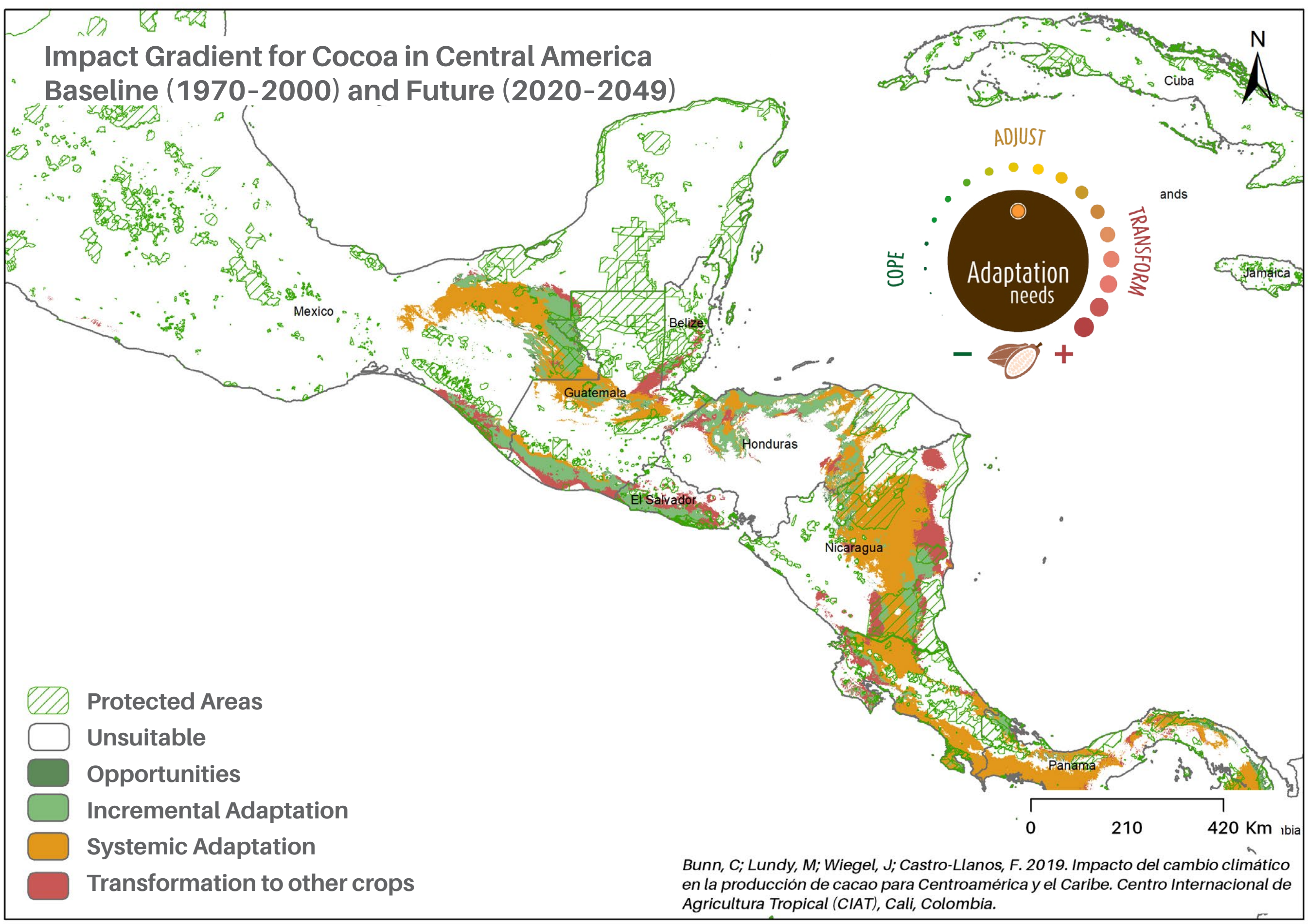

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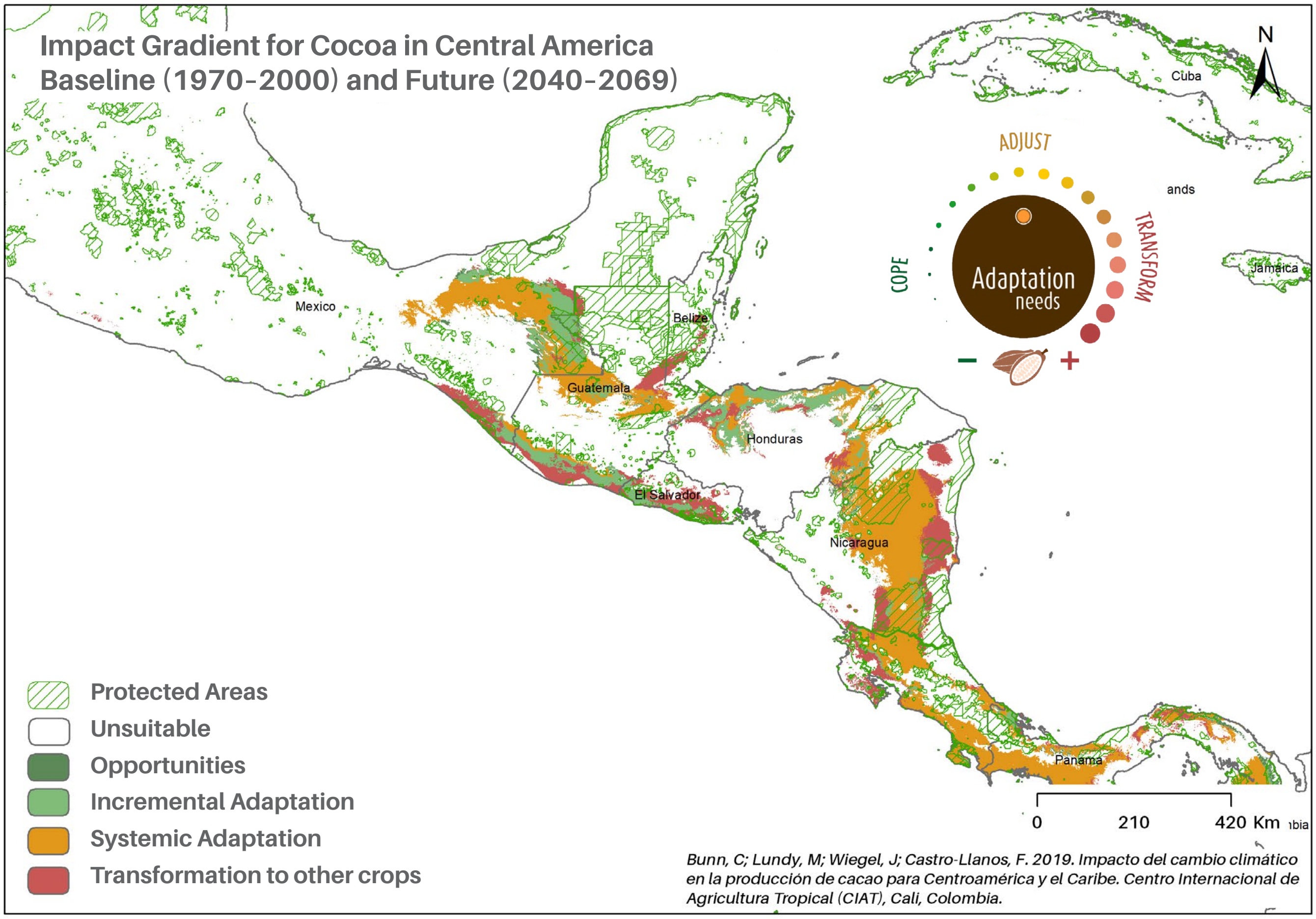

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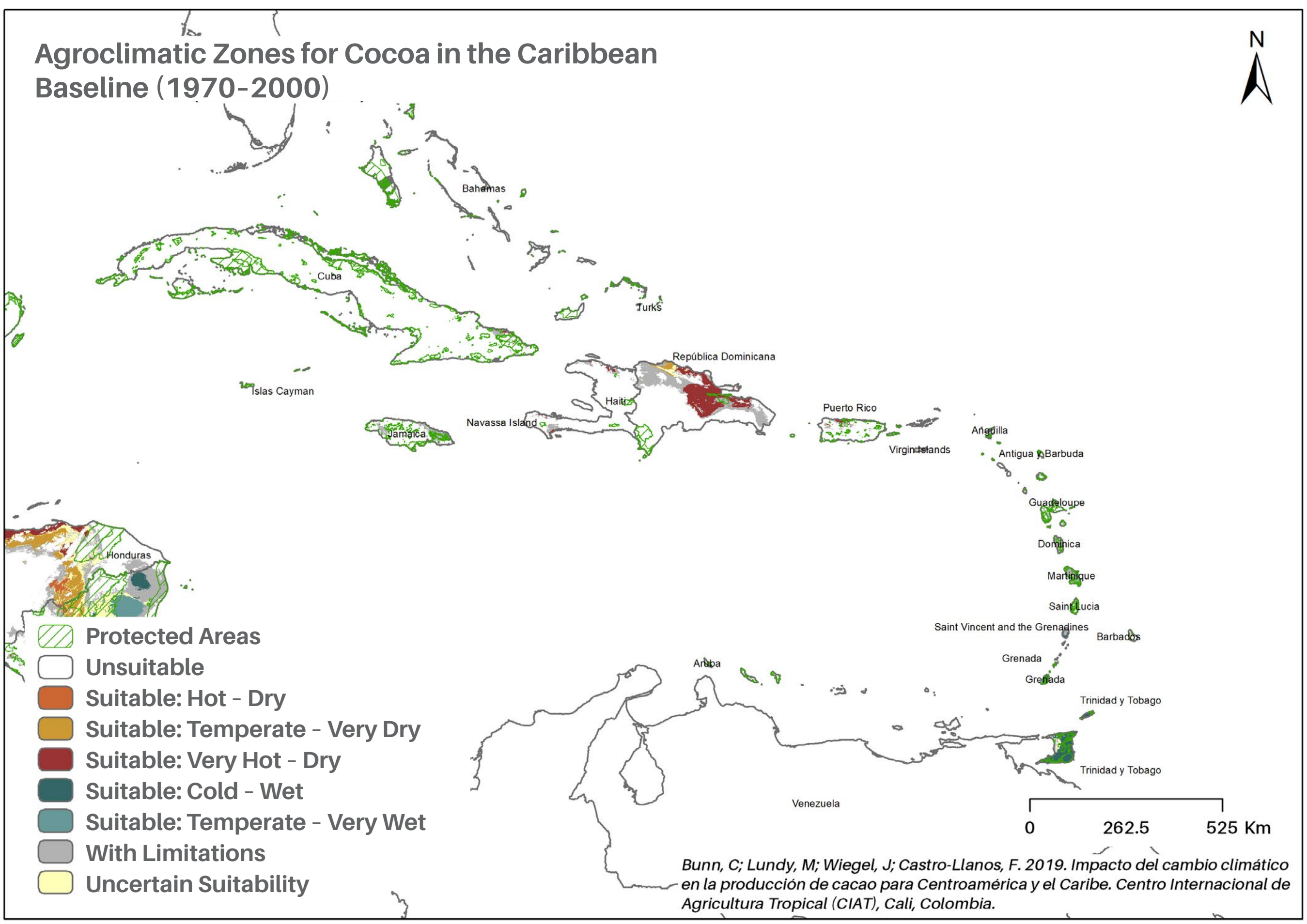

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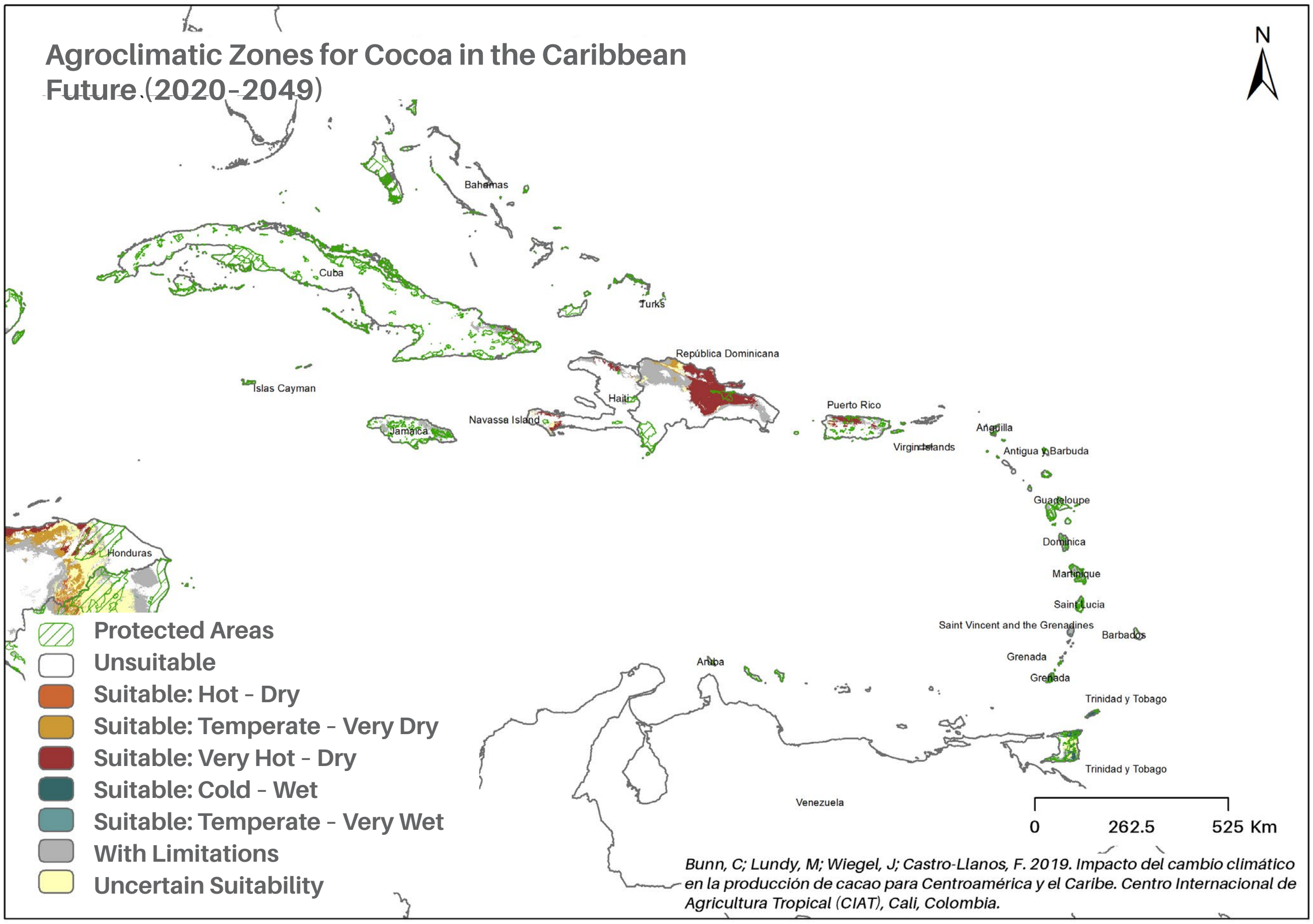

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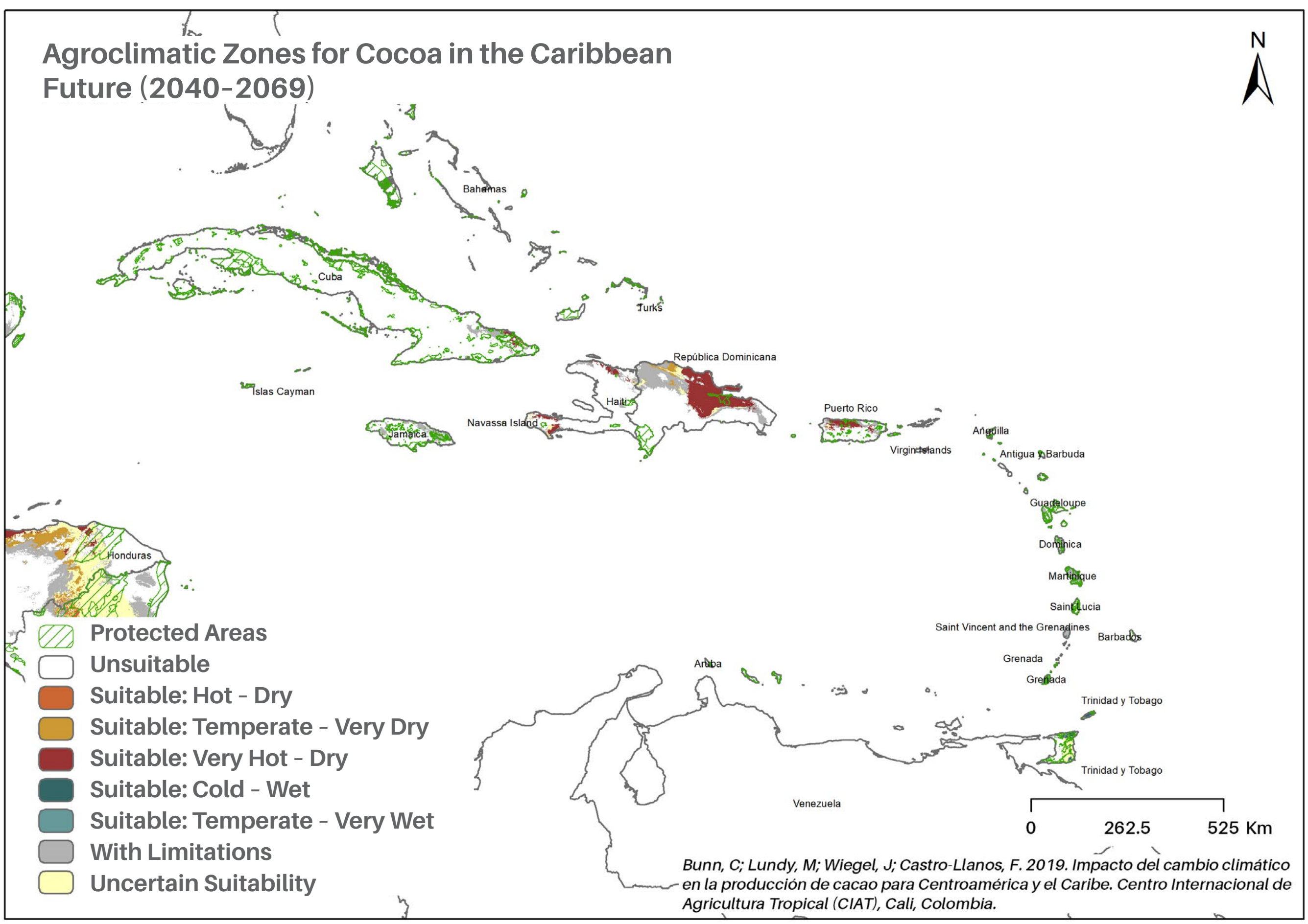

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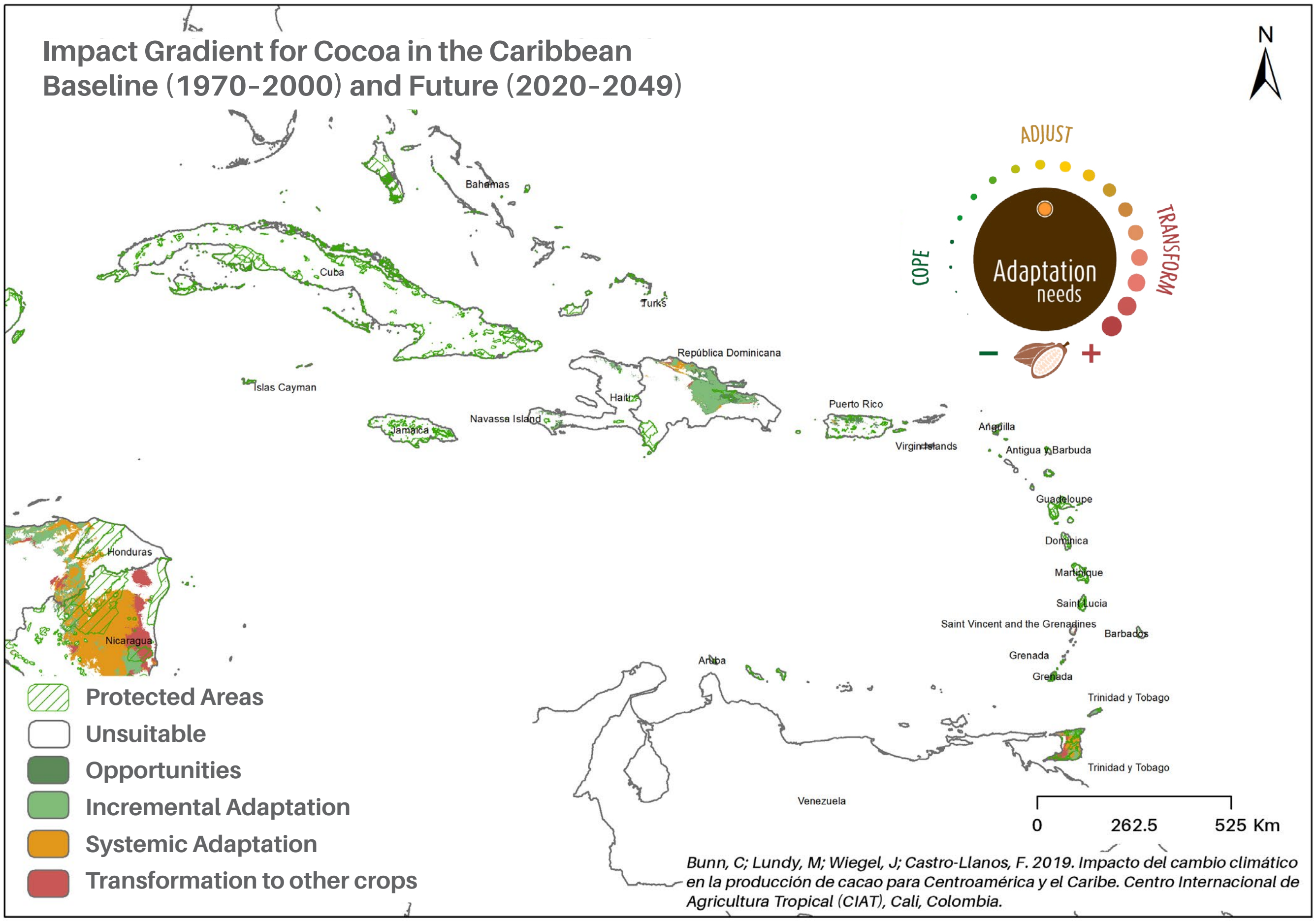

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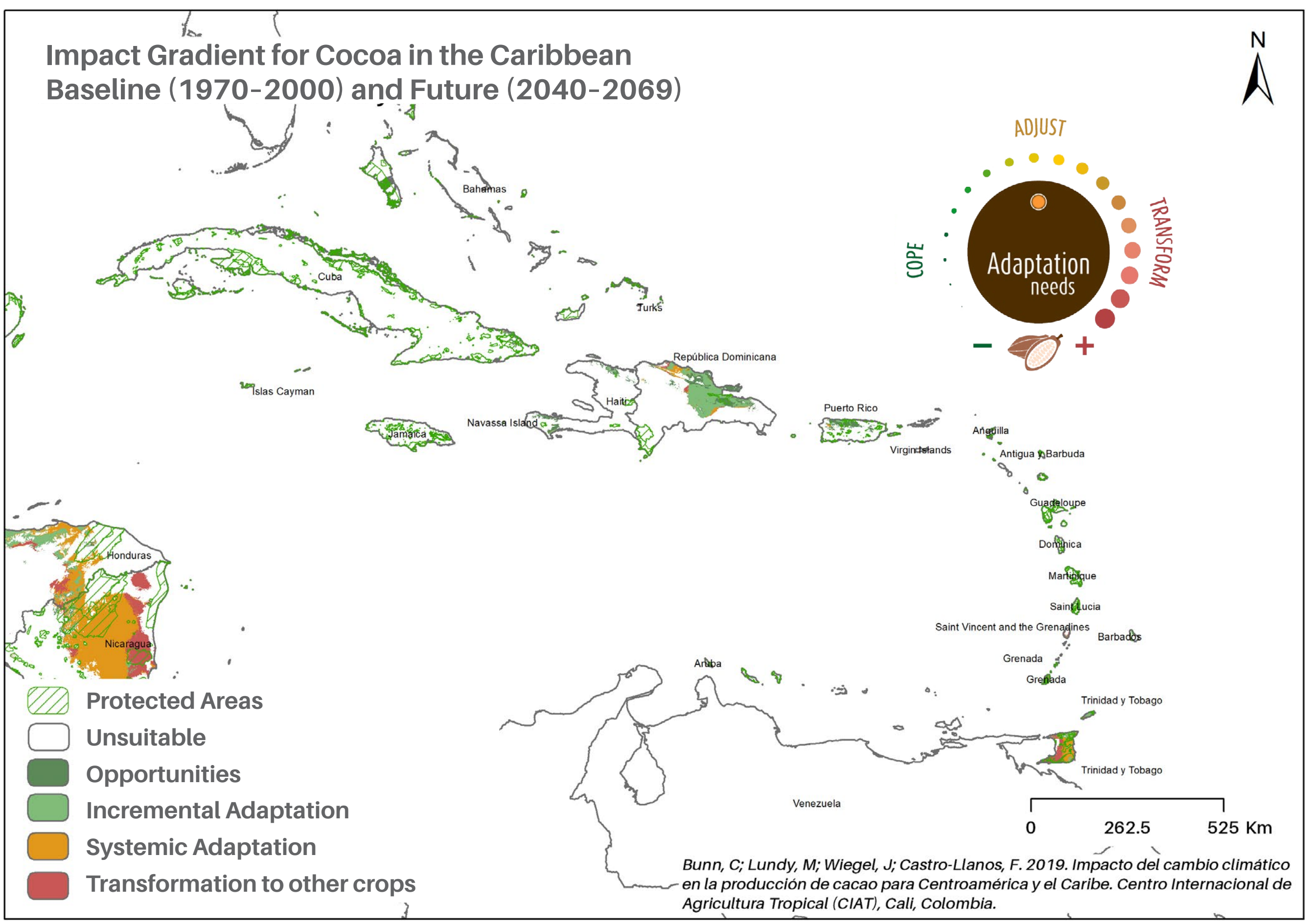

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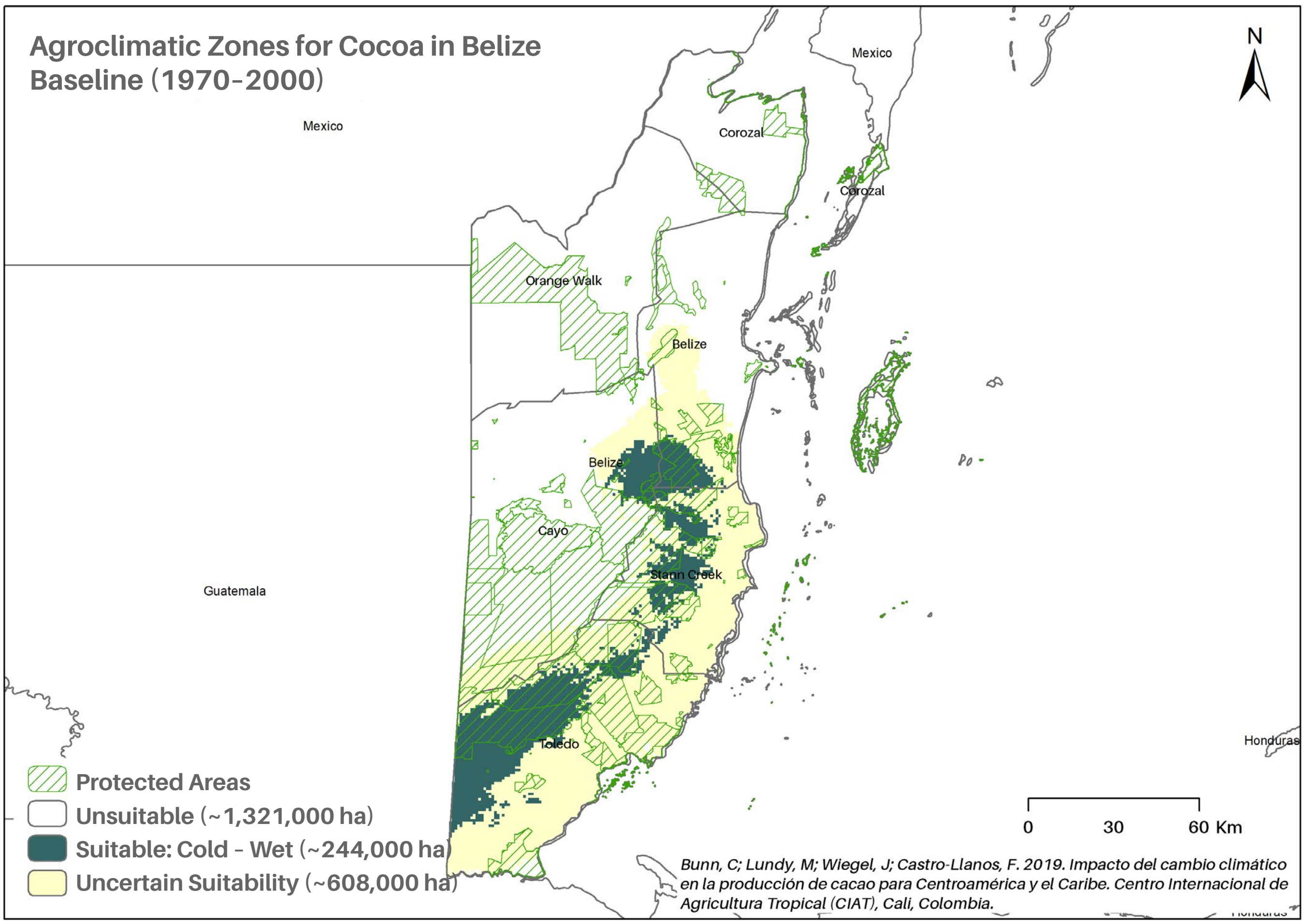
Belize

In the baseline, the suitability corridor to grow cocoa goes from the south to the center-west of the country. This cold-wet suitability corridor is surrounded by uncertain-suitability areas for cocoa. The suitable zones represent an area of 240,000 ha (hectares). Towards the north of the country, there are no suitability zones for this crop, because the climatic zones do not meet the requirements of cocoa.

For the 2040-2069 period (which we approximate to 2050), a significant reduction of suitable areas for cocoa is projected. Thus, the substitution of this crop with other better adapted to the climatic features projected for this region is recommended. As seen in the maps, the most affected areas by 2050 are located in the southern part of the country, on the border with Guatemala. Around 6,000 ha are projected to be suitable for cocoa production.



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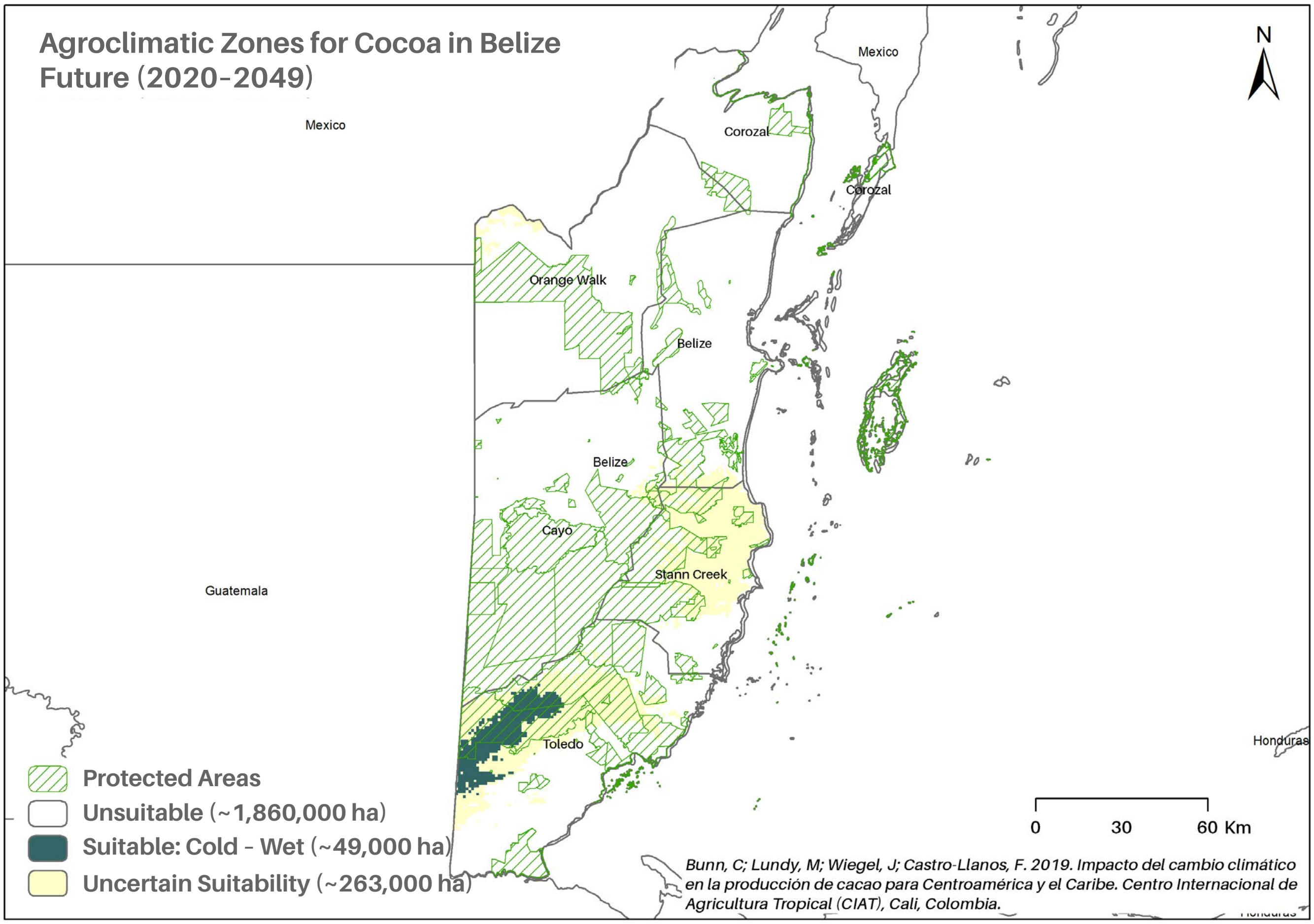

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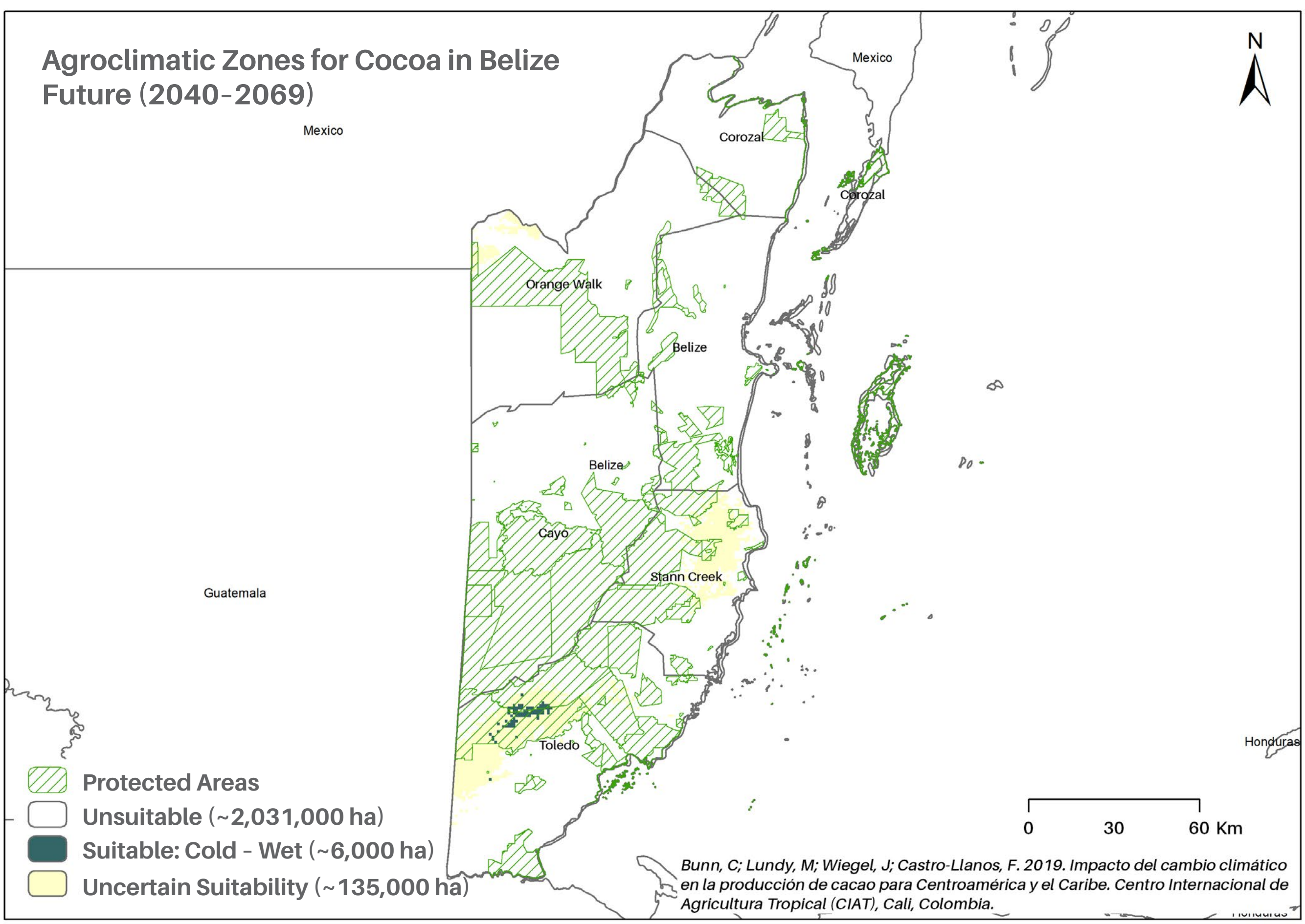

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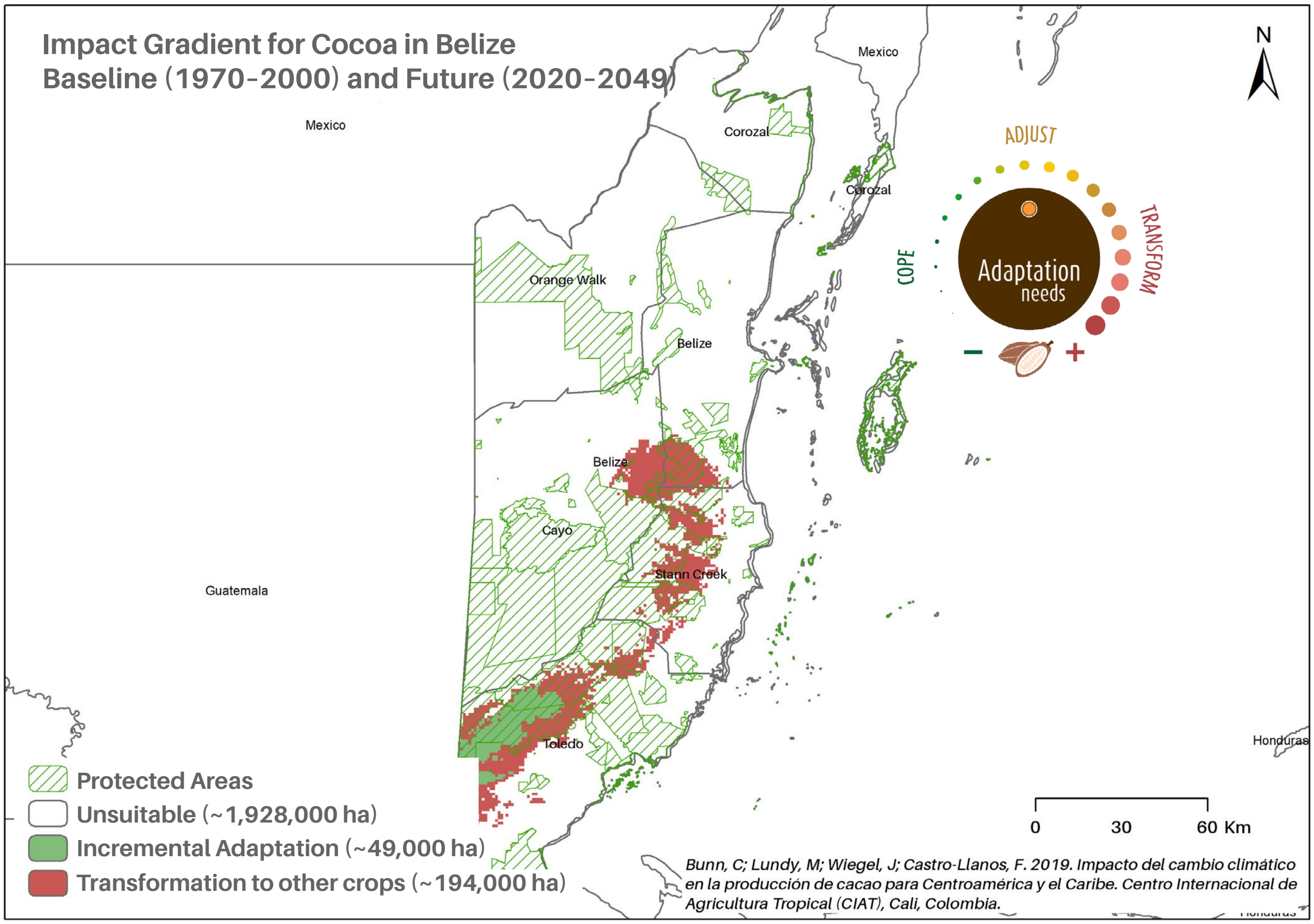

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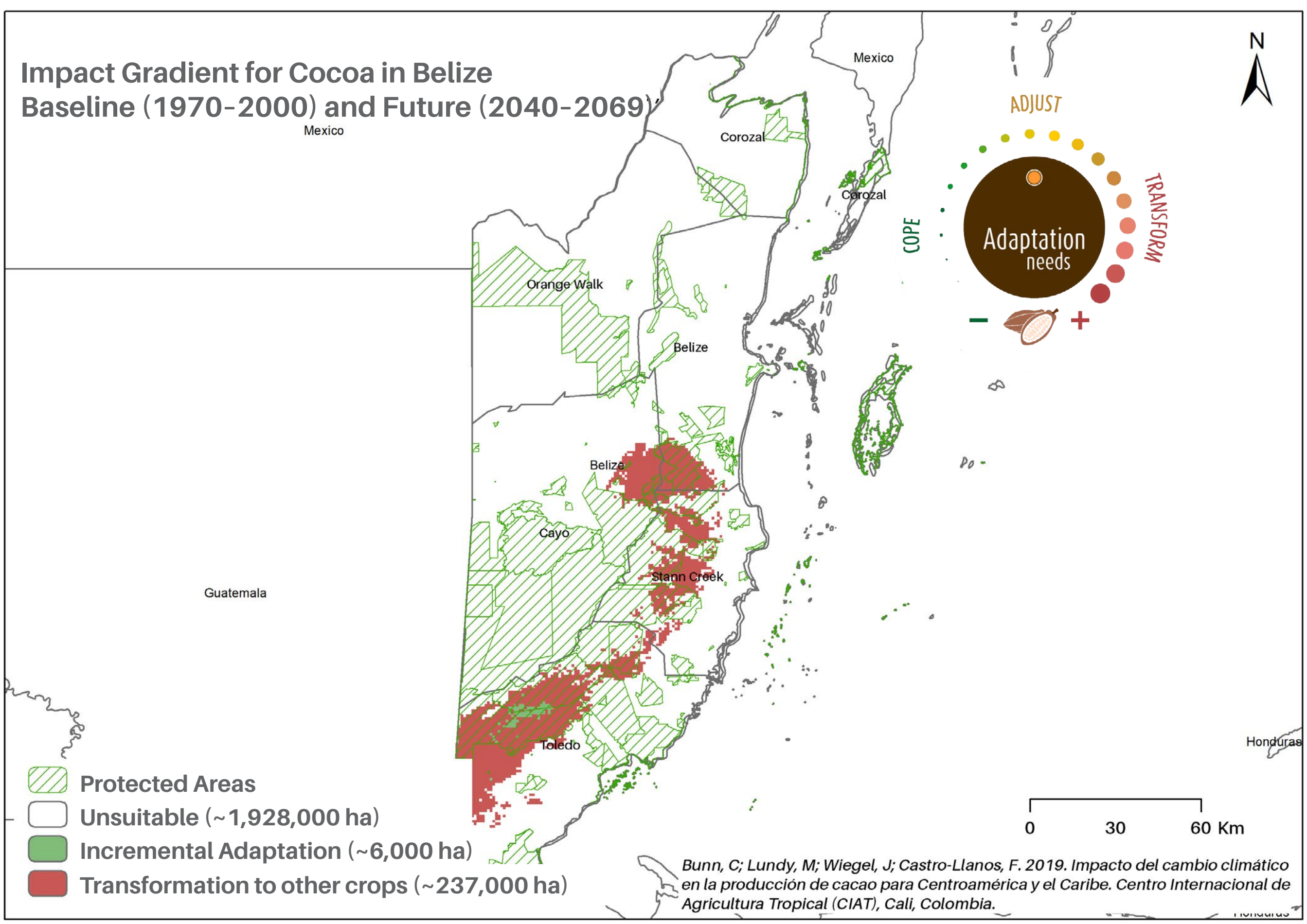

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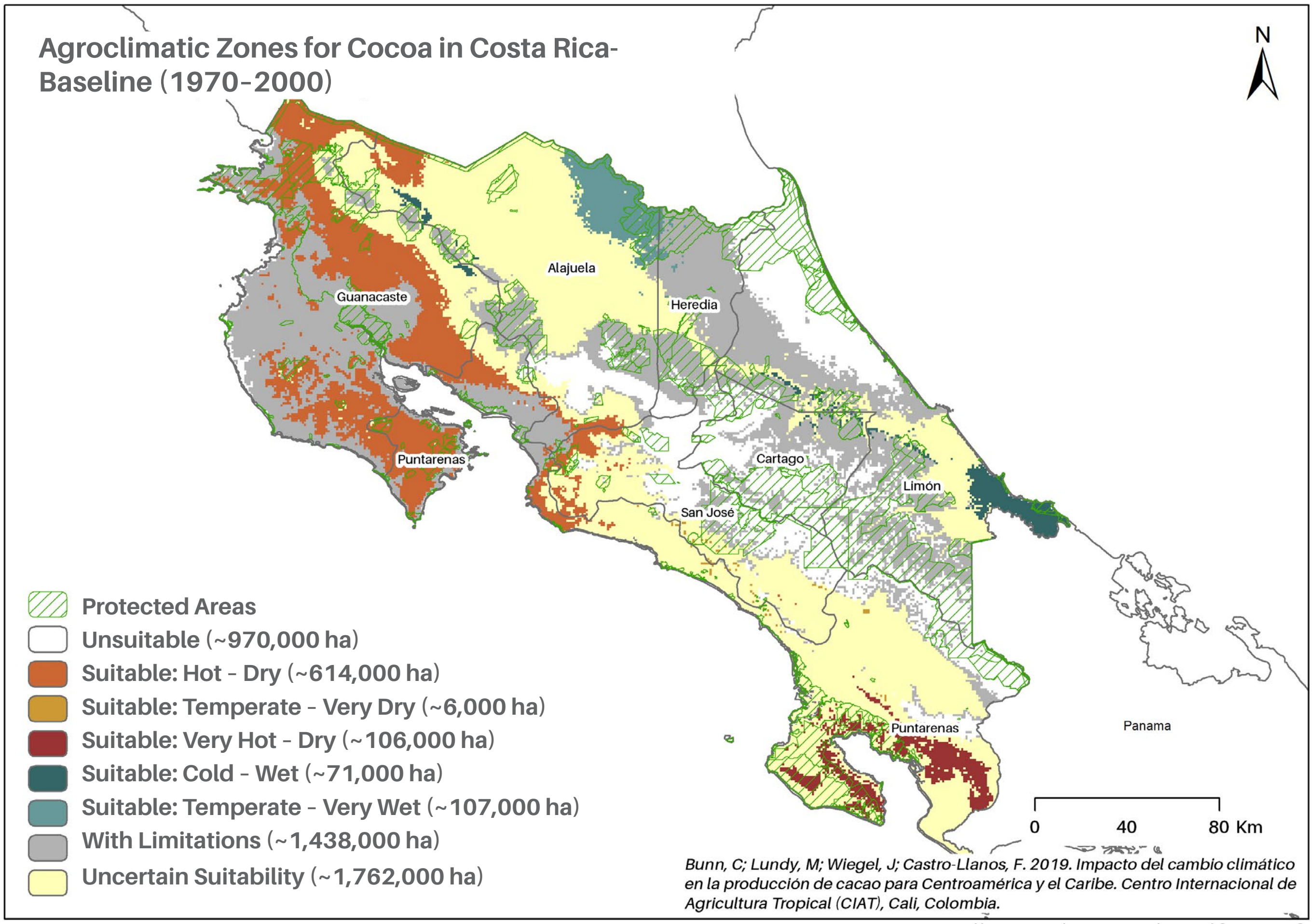
Costa Rica

This is the only country showing all types of agroclimatic zones. The hot-dry zones show the largest area, with more than 600,000 ha located mainly in the northwest of the country. The other types of suitable areas are found in the southern part of the country, on the border with Panama; these are suitable areas under baseline conditions.

For the 2050 period, a significant reduction of suitable area is projected for the hot and temperate zones, and the disappearance of suitable zones with cold and temperate features. Therefore, it is estimated that the level of adaptation efforts needed for the west of the country is mostly systemic. In some zones a transformation of the crop is considered necessary.



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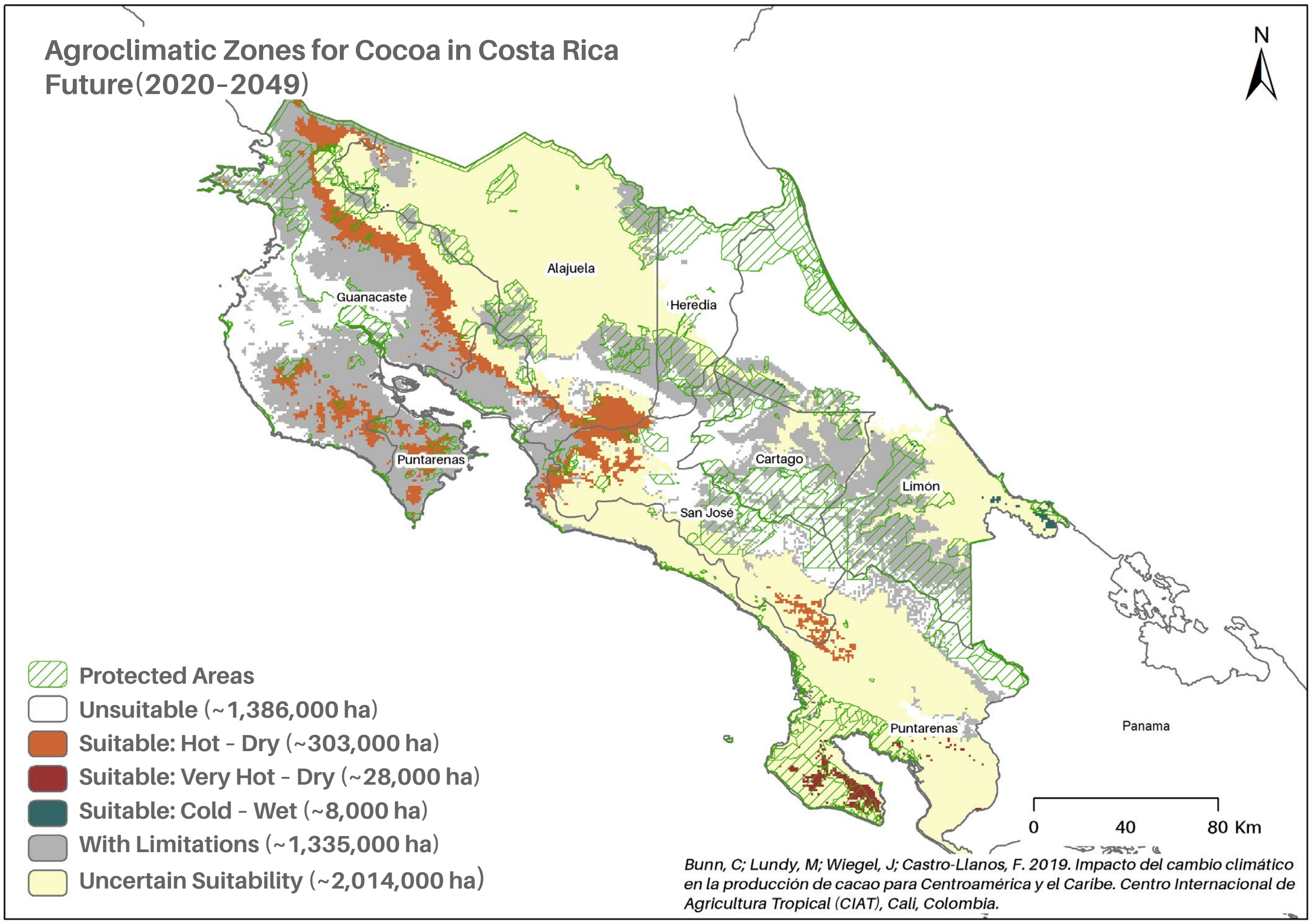

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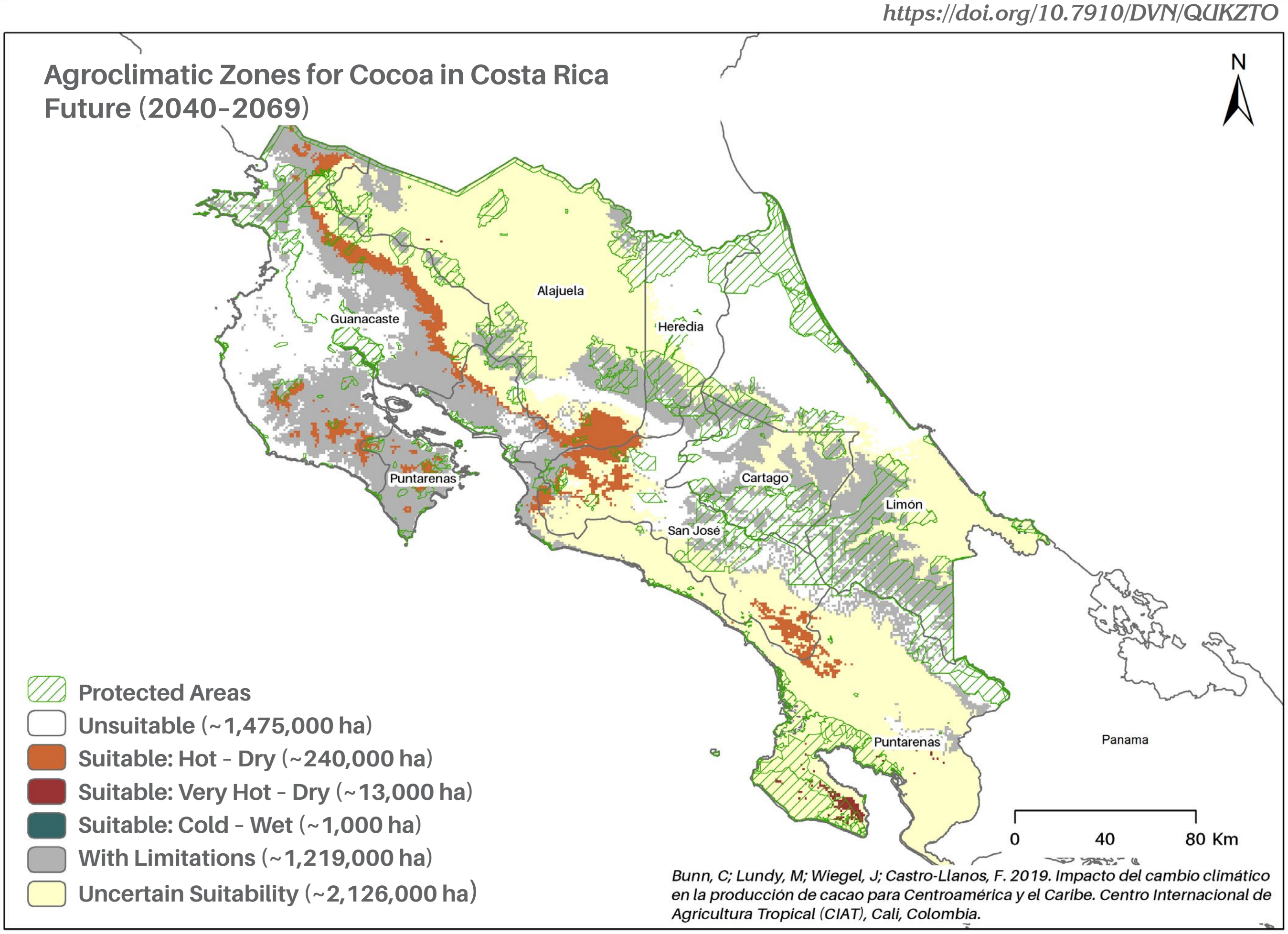

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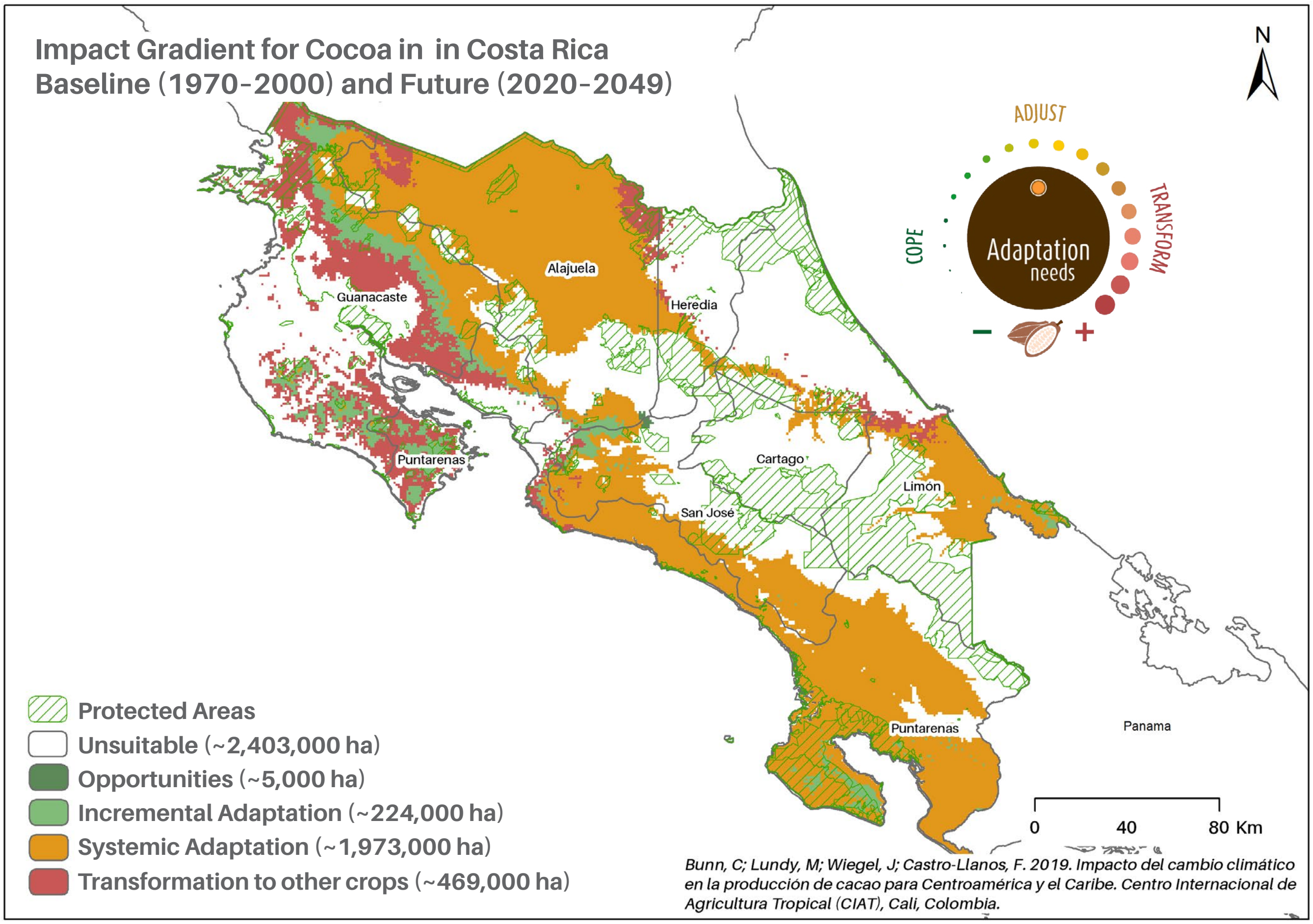

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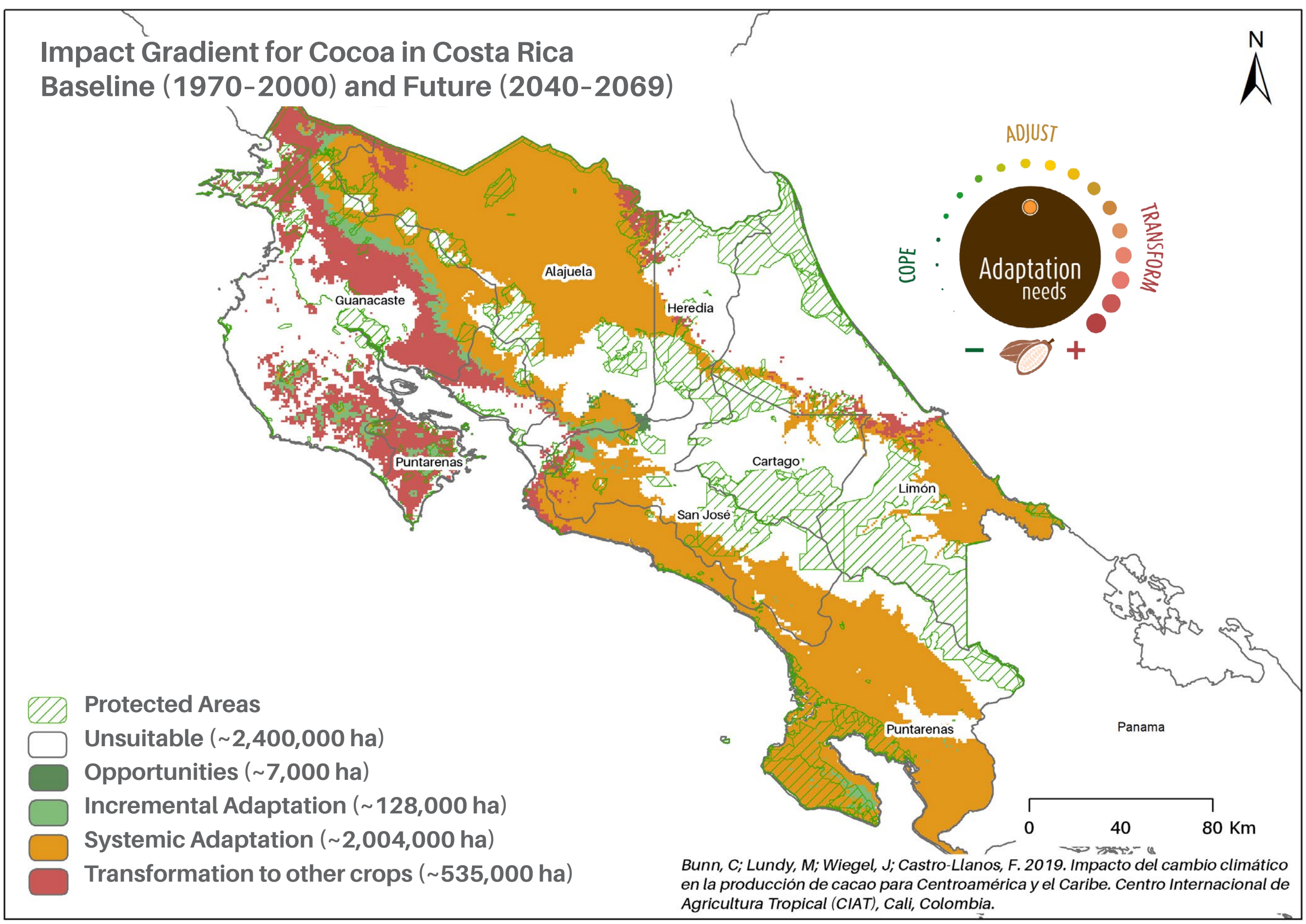

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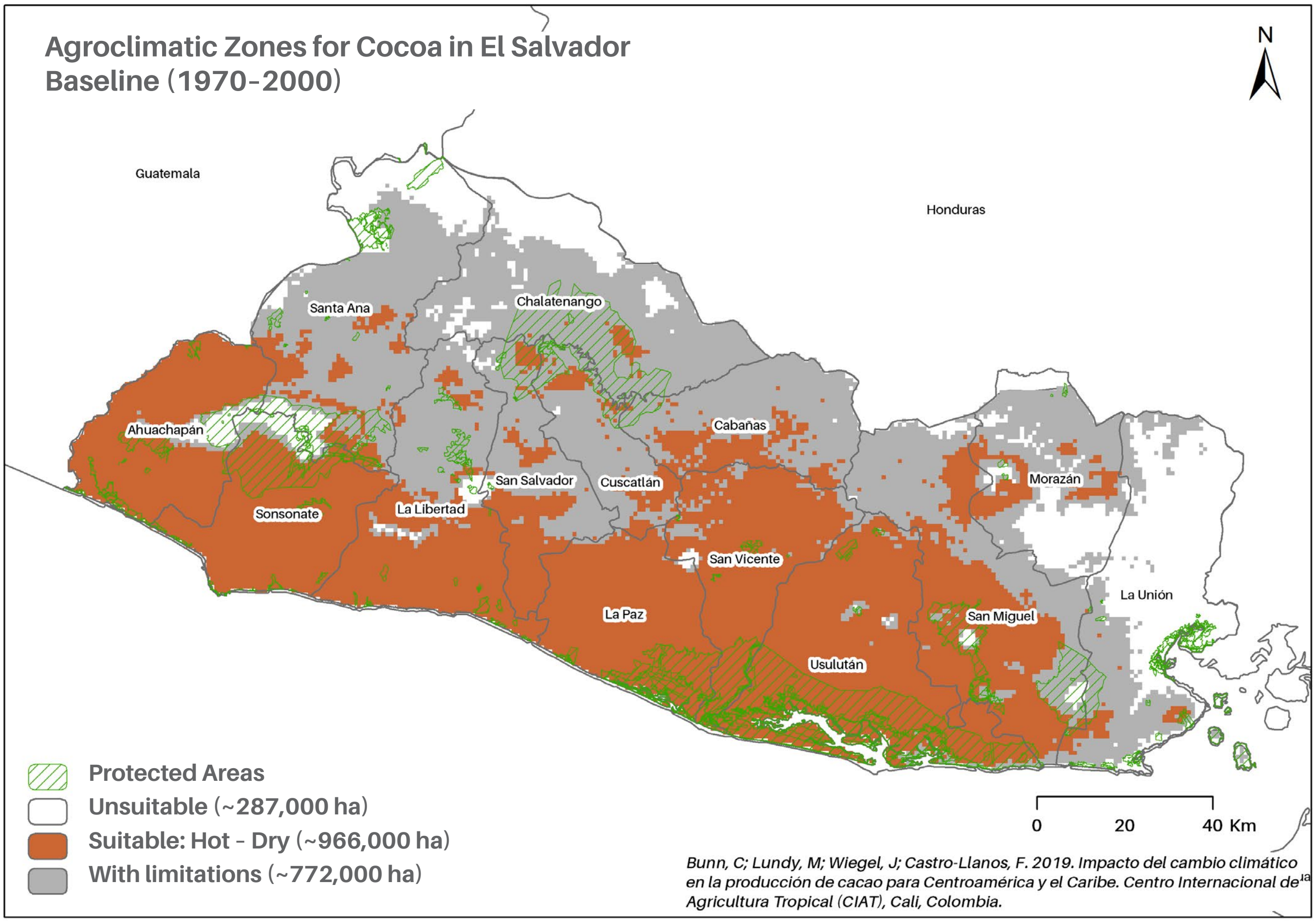
El Salvador

In the baseline, the suitability corridor for cocoa stretches from the southwest to the center-south of the country. These zones are suitable under the hot-dry climate; it is also the only suitable area for this crop.

For the 2050 period, a significant decline in suitable area for cocoa is projected. Therefore, it is estimated that the level of adaptation efforts needed for the country is mostly transformational. However, an incremental adaptation effort is recommended for some zones mainly surrounded by transformational areas.



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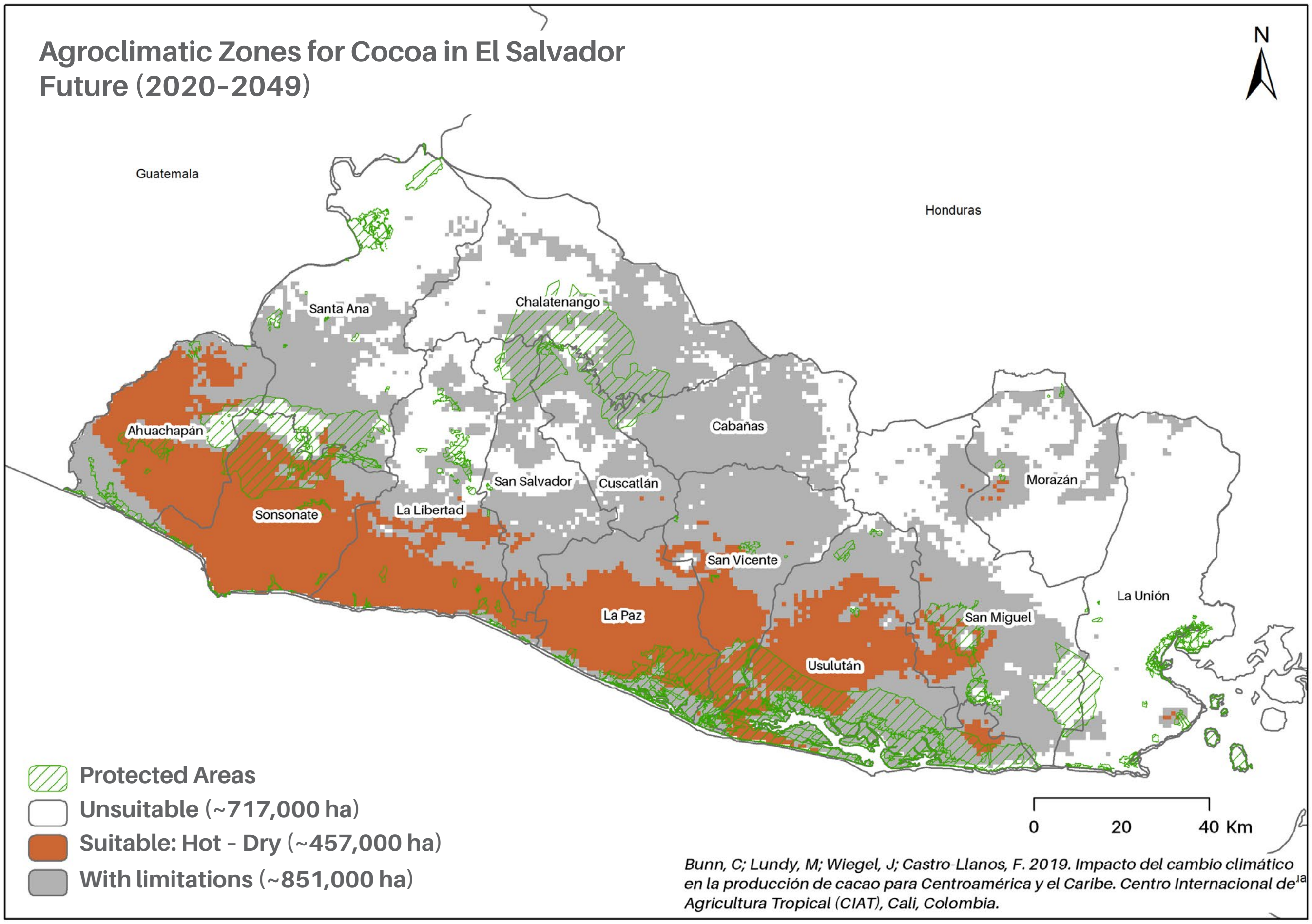

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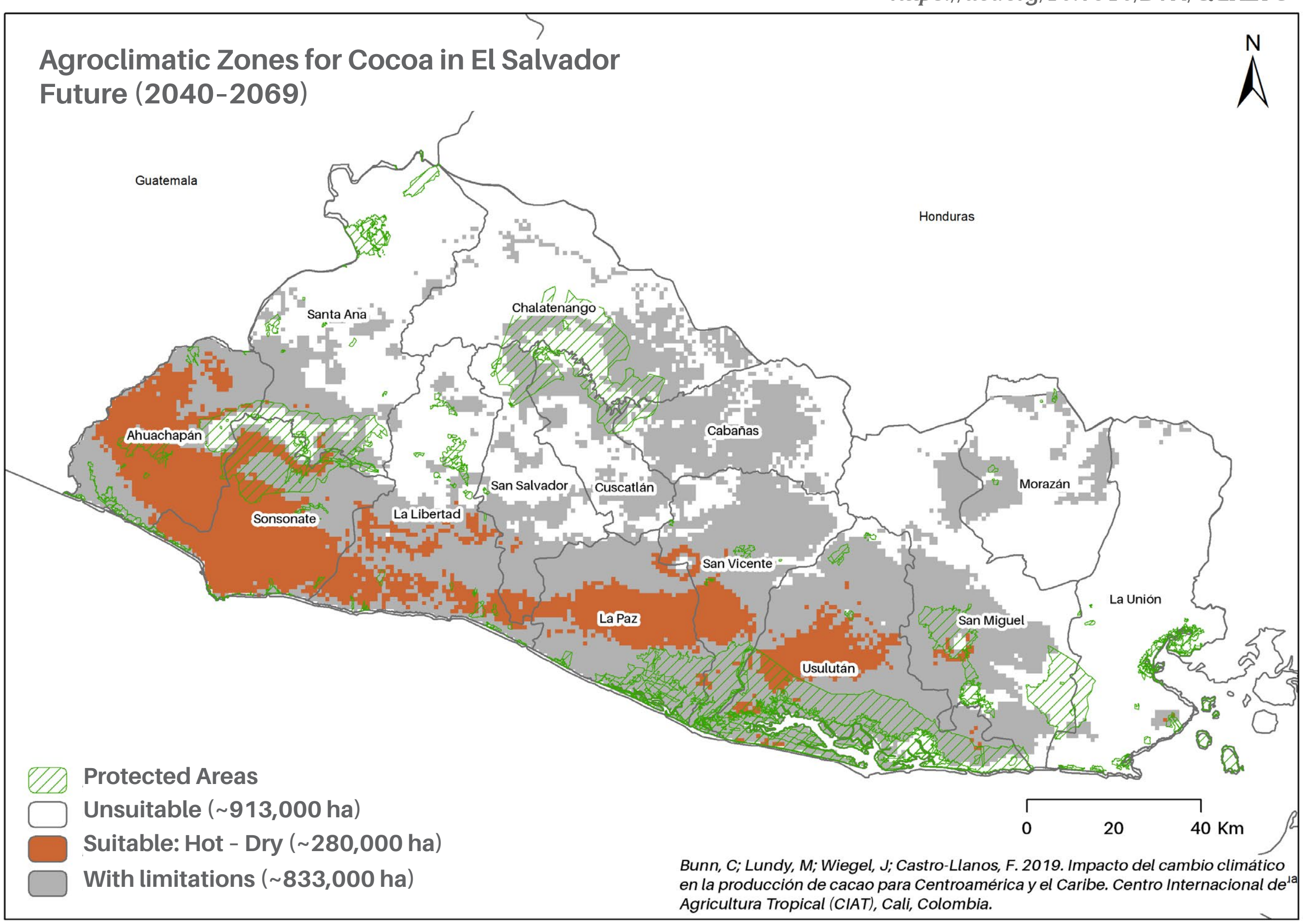

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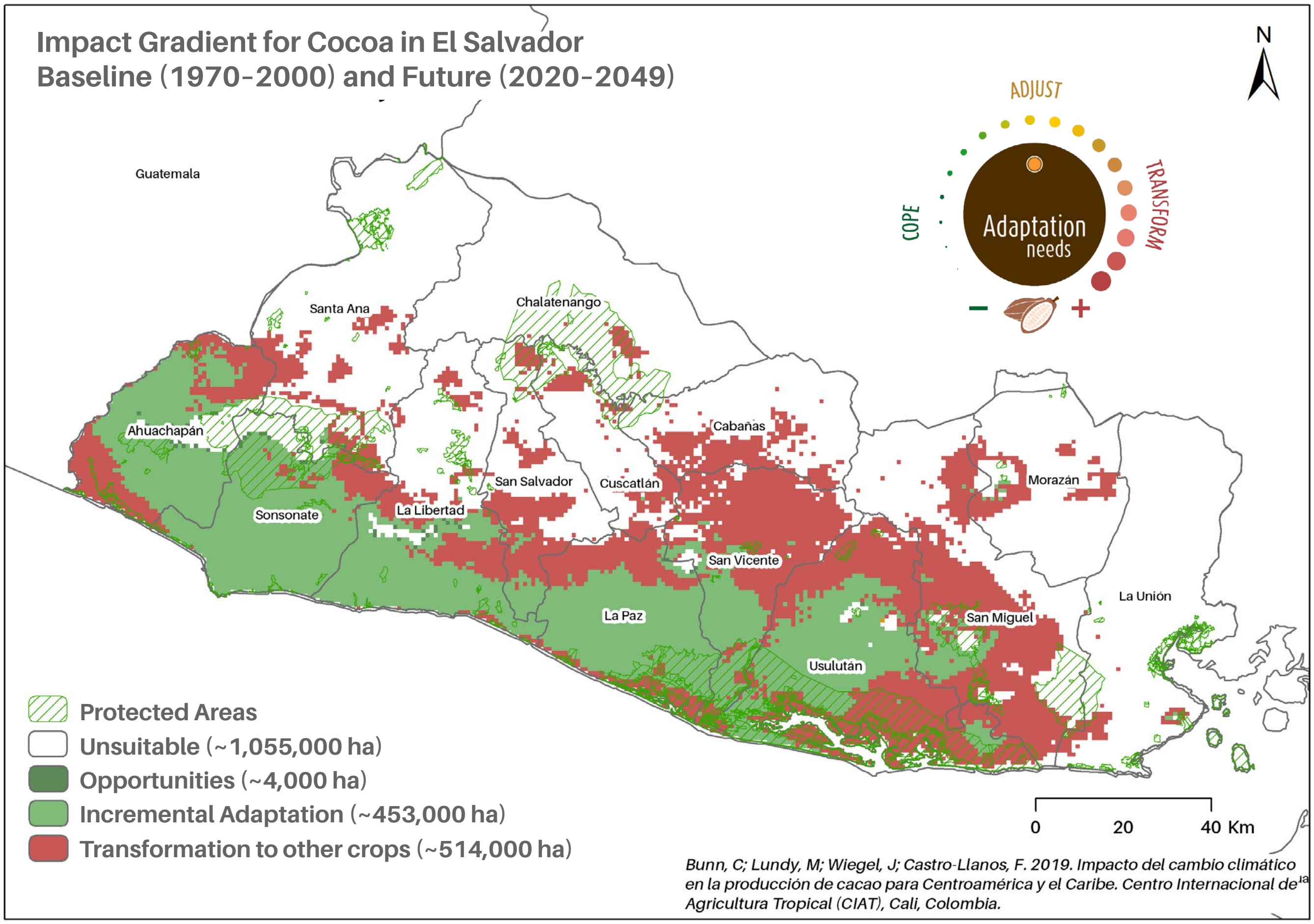

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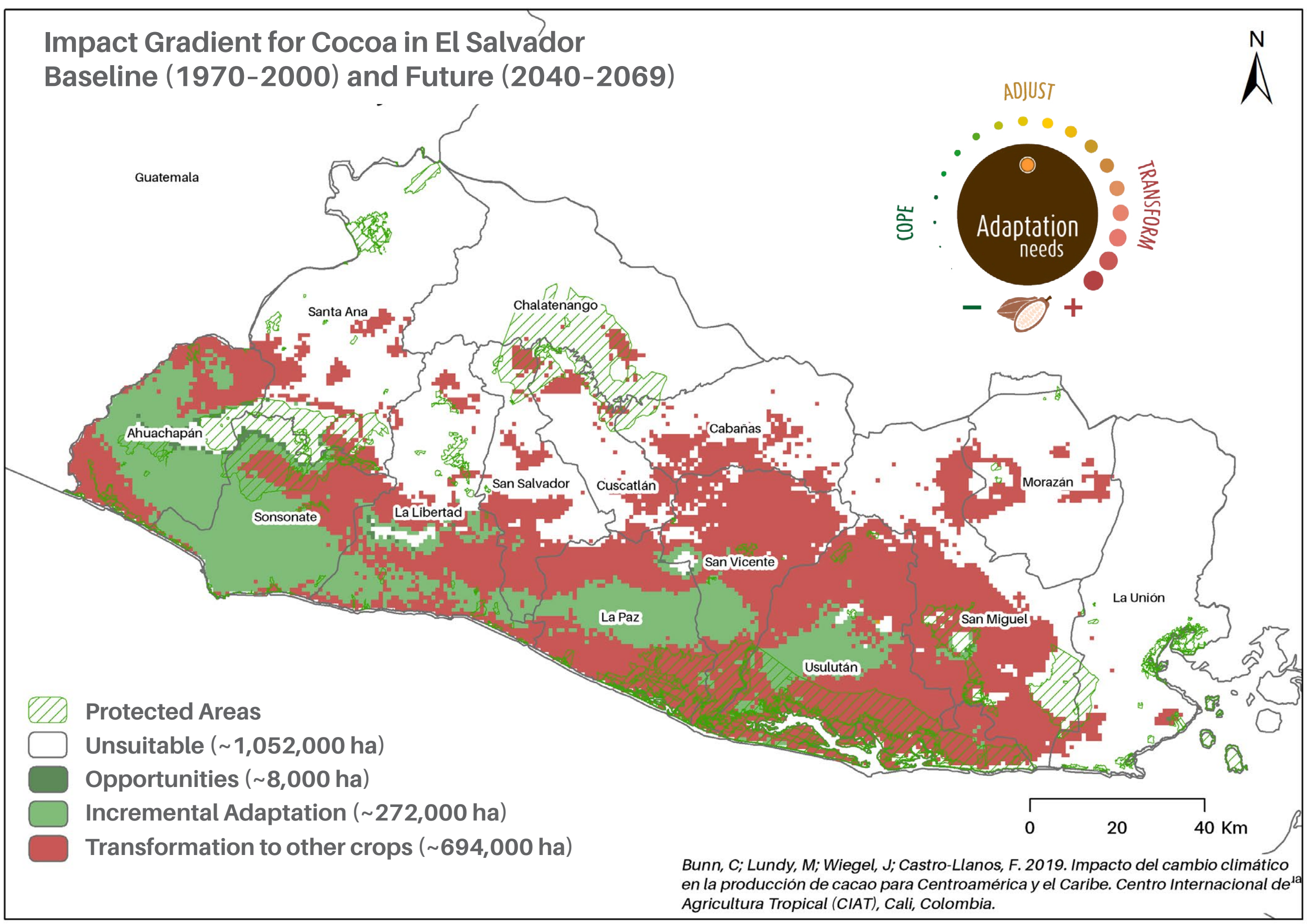

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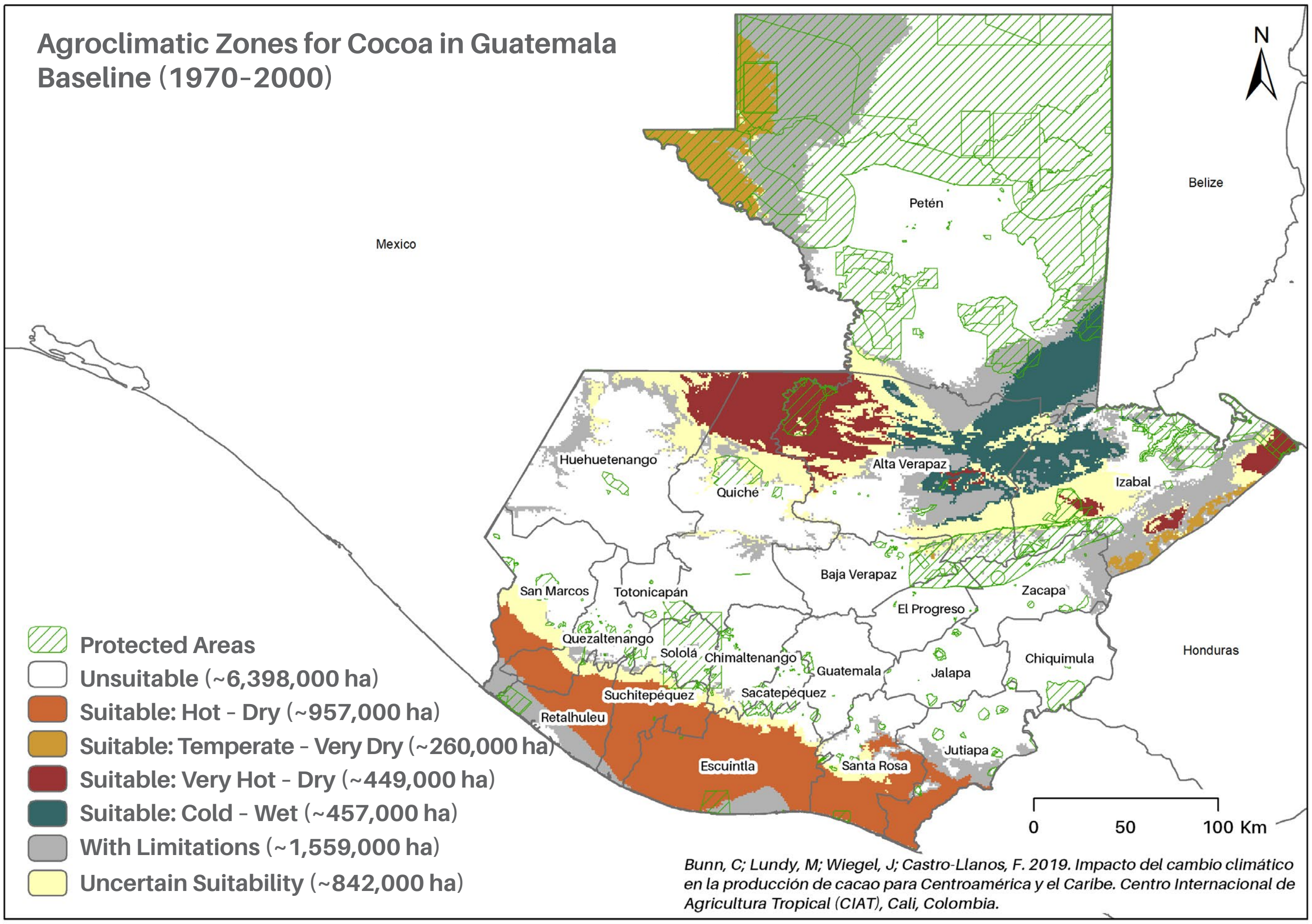
Guatemala

Under baseline conditions, the temperate, hot, and very hot zones in the country suitable for cocoa are located on the west side of the country. On the other hand, cold zones are found in the central-eastern region.

For 2050, a significant reduction in area is projected for temperate, hot, very hot, and cold zones suitable for cocoa. In some zones, a transformation of the crop is considered necessary, but most suitable areas for cocoa will require an incremental and systemic adaptation effort.



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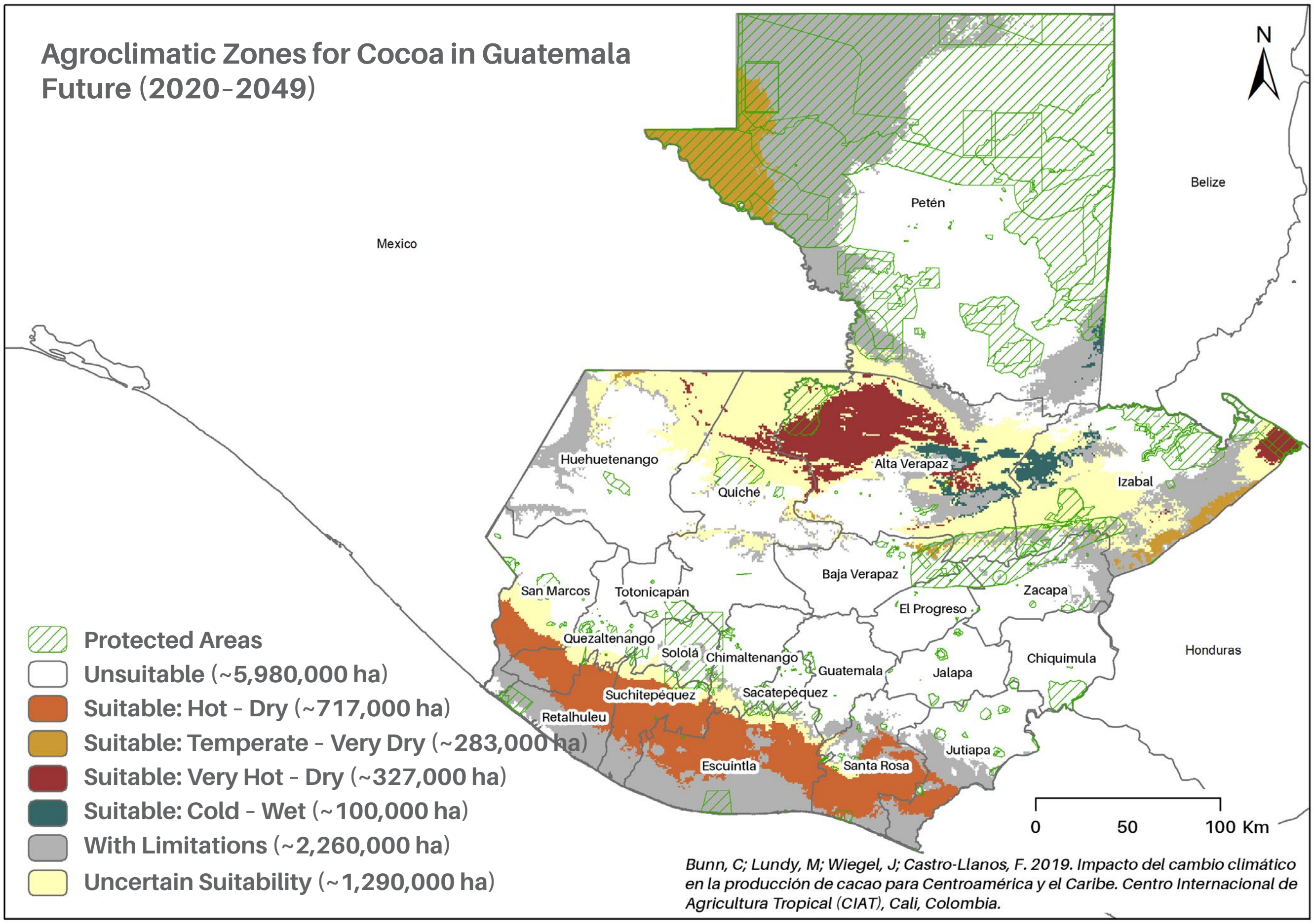

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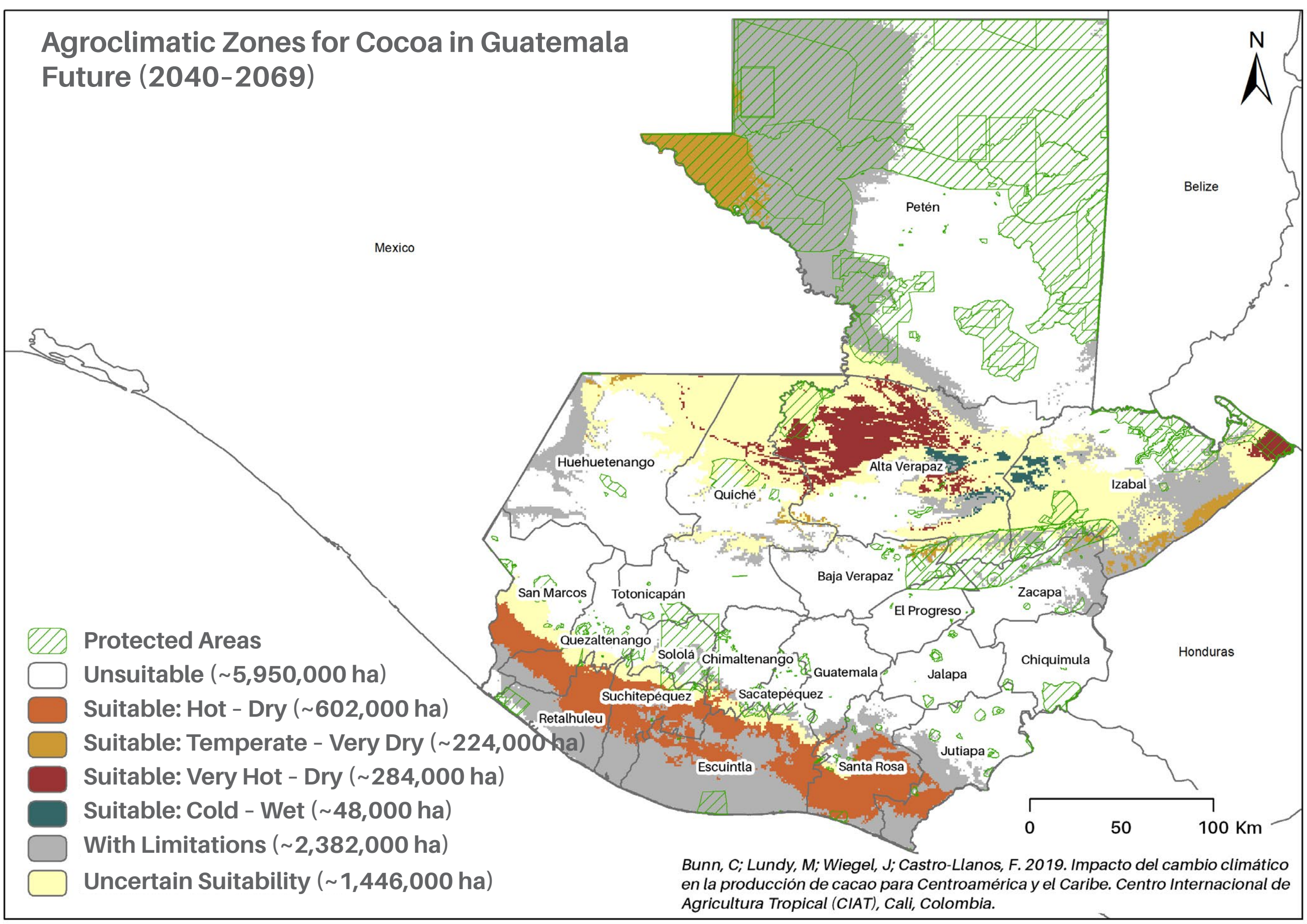

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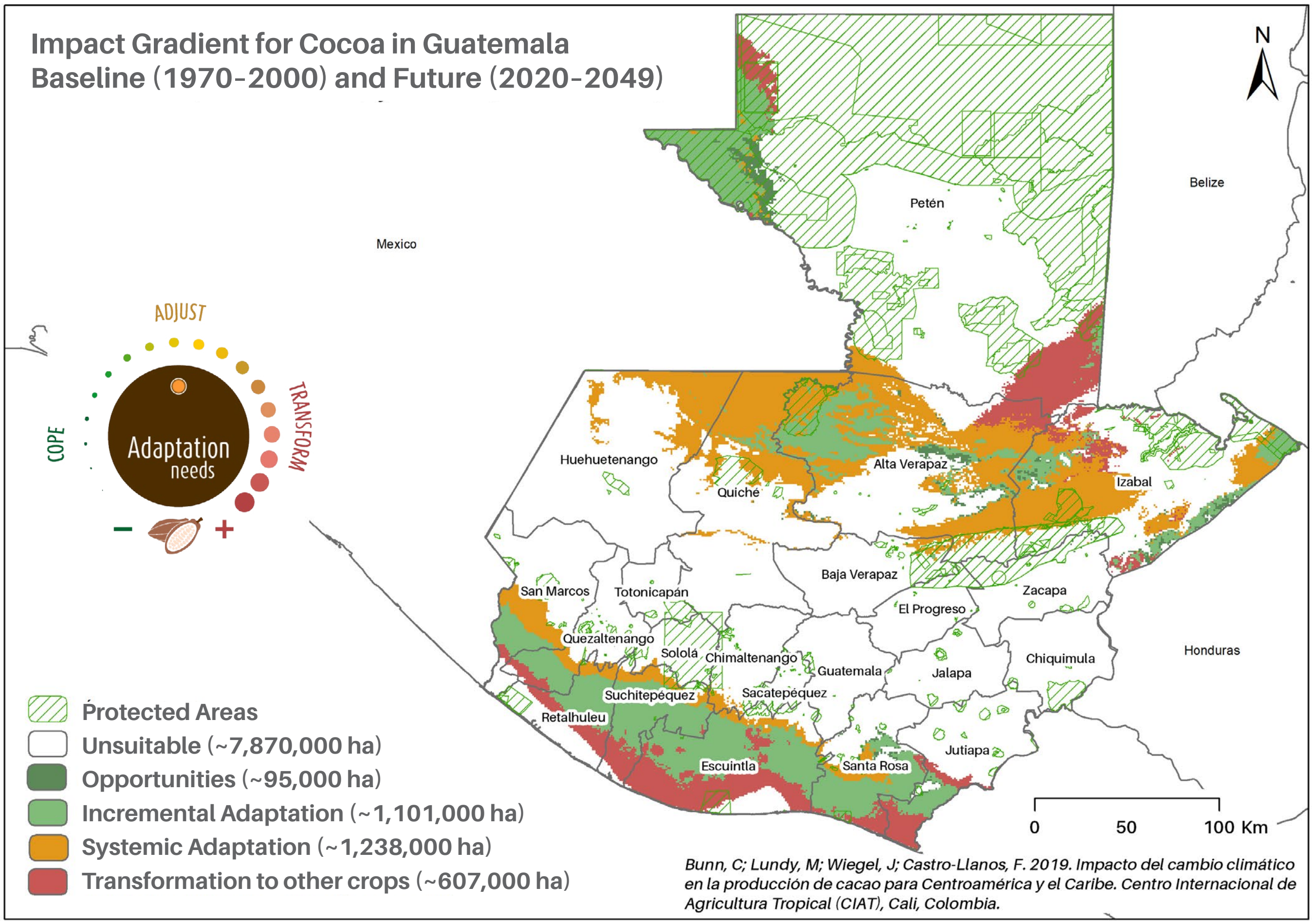

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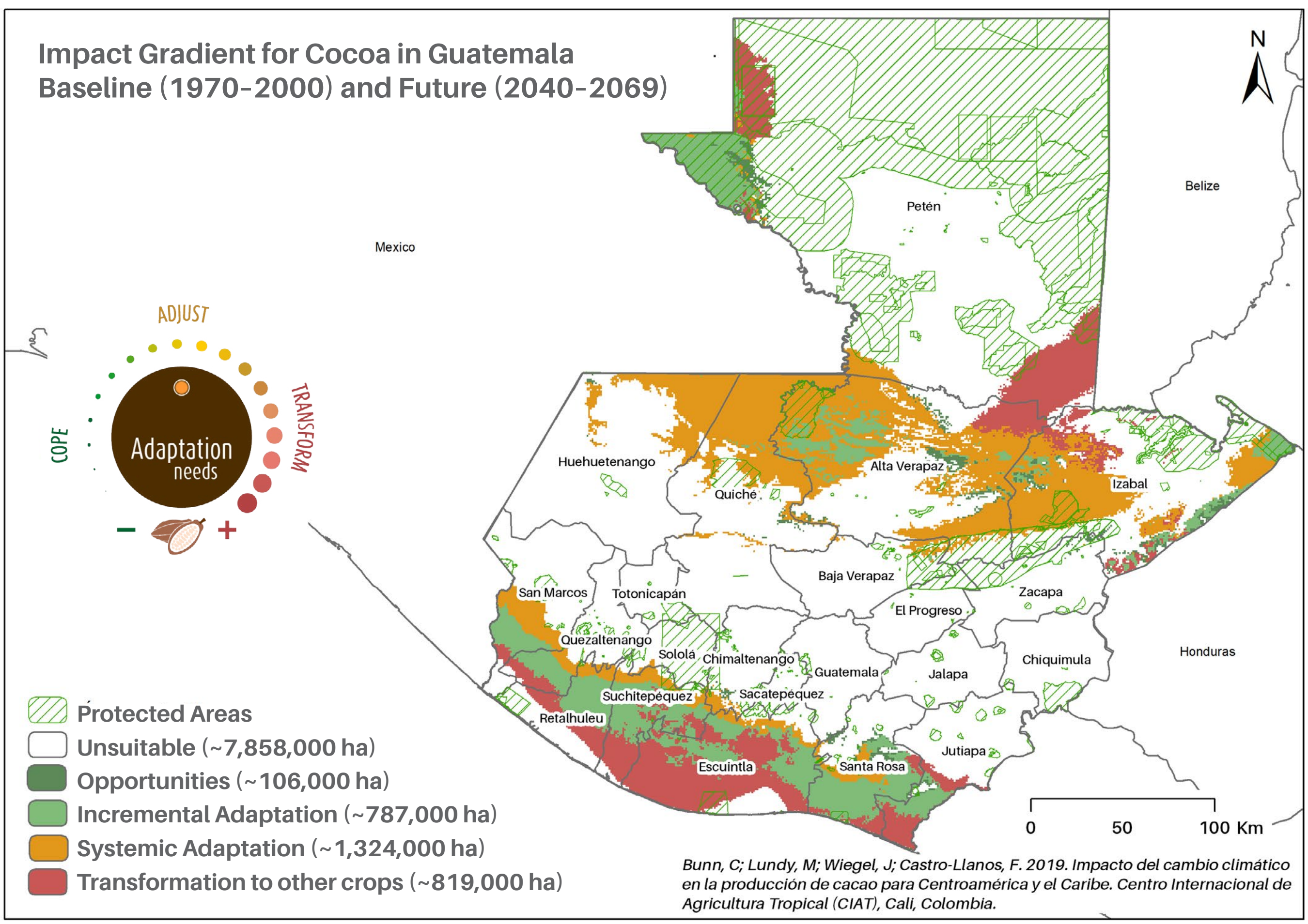

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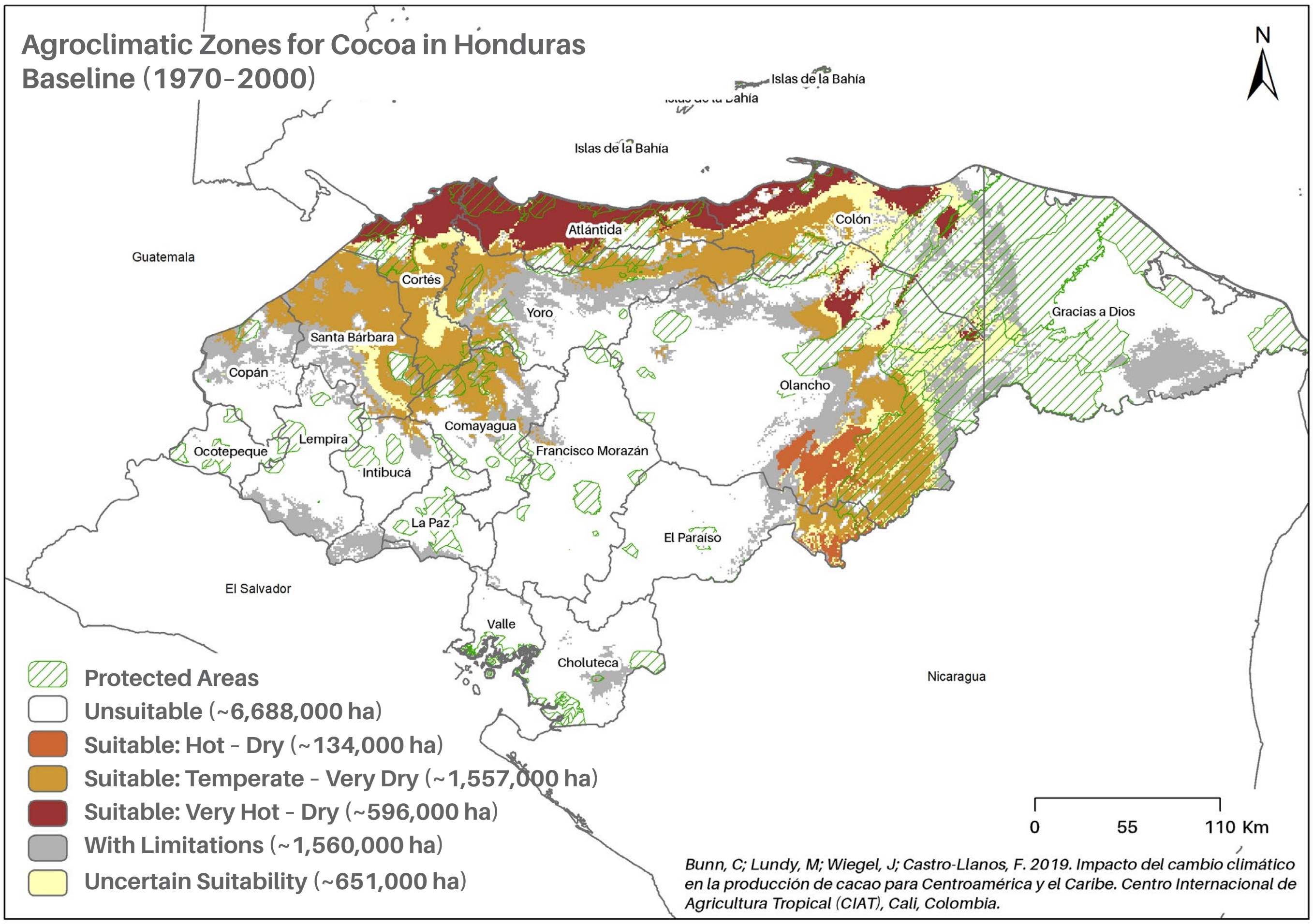
Honduras

Under baseline conditions, the suitable region for cocoa is located in the north of the country, in temperate, hot, and very hot areas. To the east, suitability is mostly uncertain for cocoa production.

For 2050, a significant decline in the hot-dry area is projected, especially in departments such as Santa Bárbara and Olancho. Departments such as Atlántida y Colón are expected to continue being suitable to grow cocoa; the zones requiring incremental adaptation are high. Towards 2050, on the border between Olancho-Colón and Gracias a Dios (eastern Honduras), the emergence of uncertain-suitability zones and zones with limitations stands out, as model results do not show a high degree of certainty.



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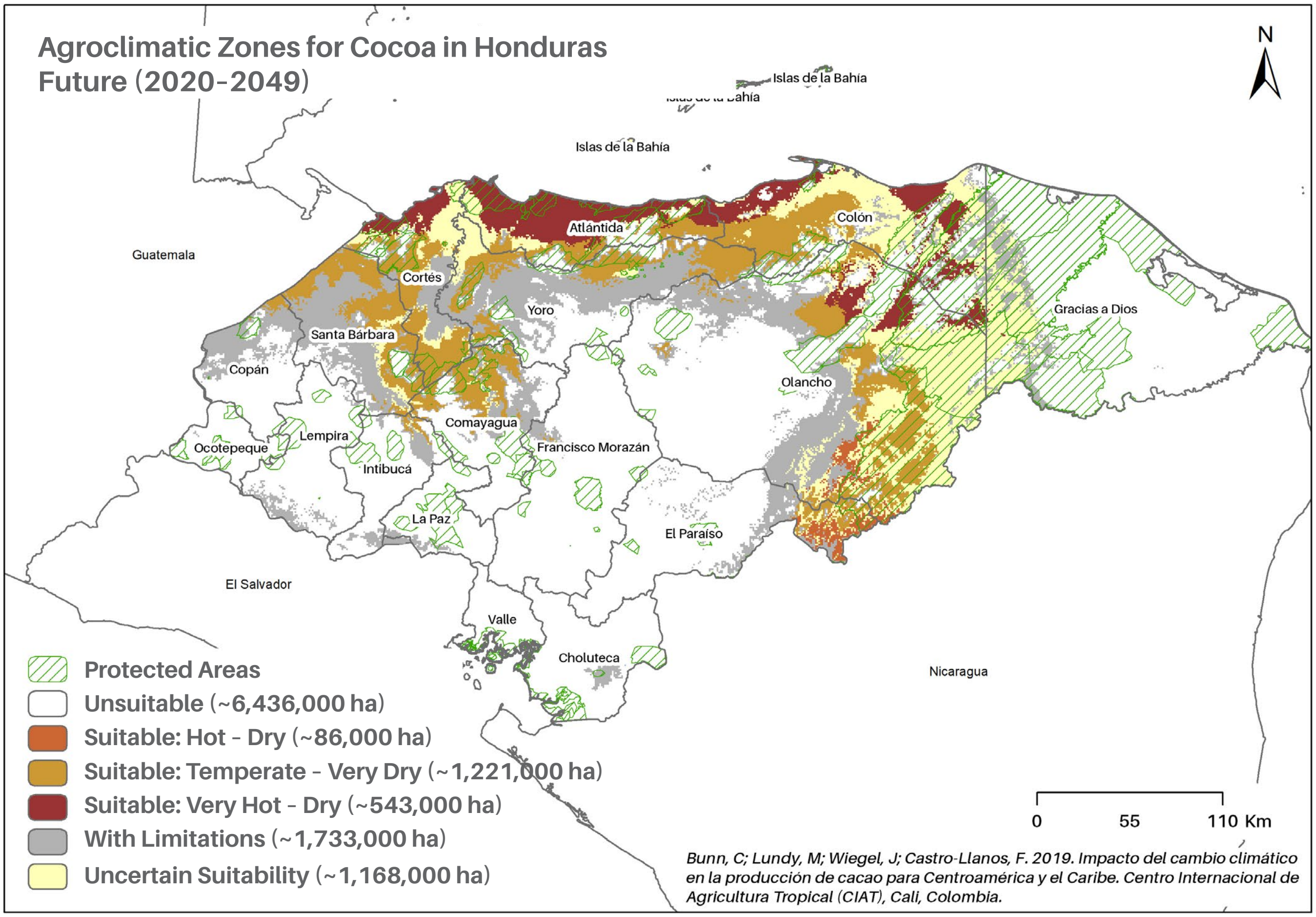

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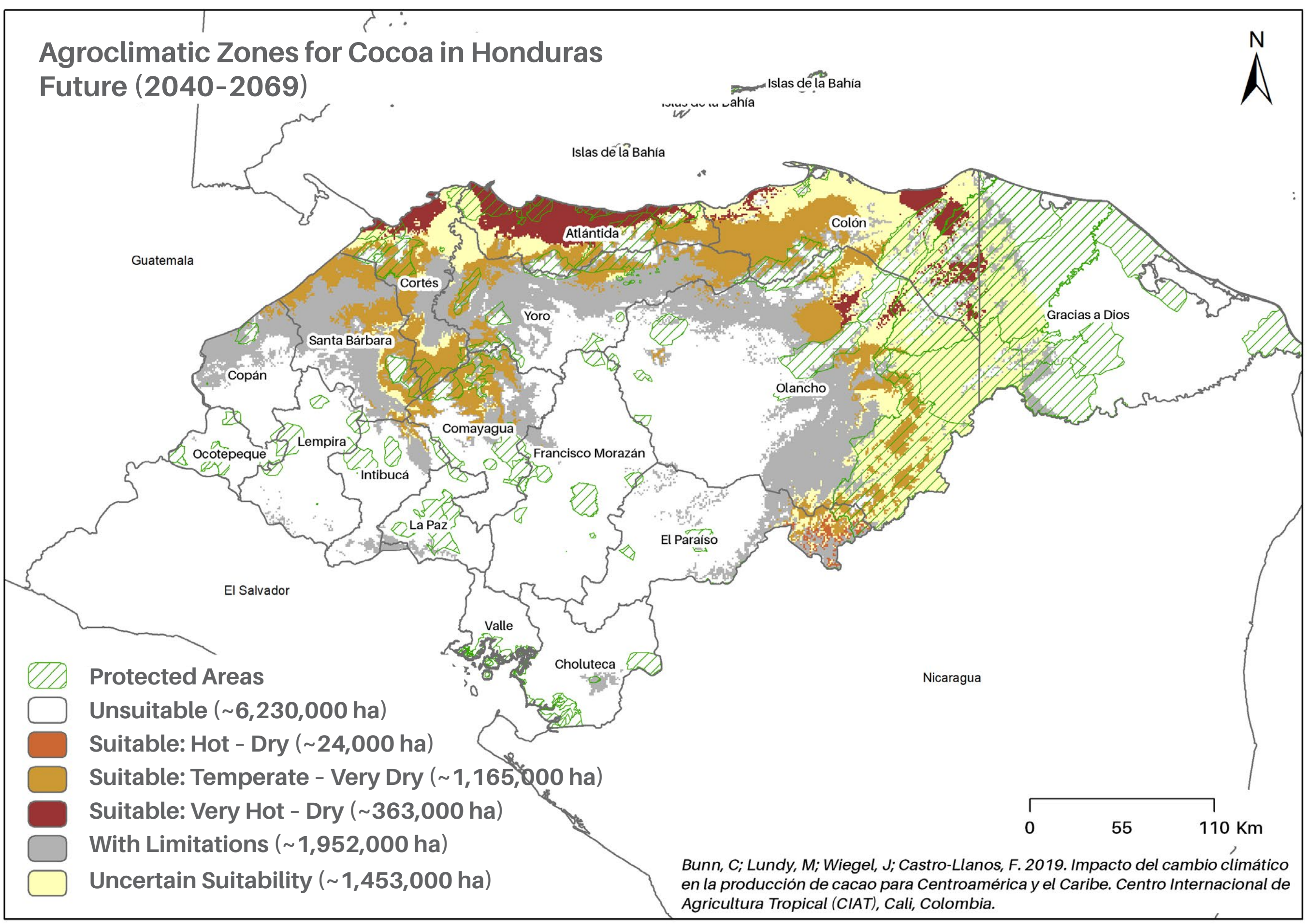

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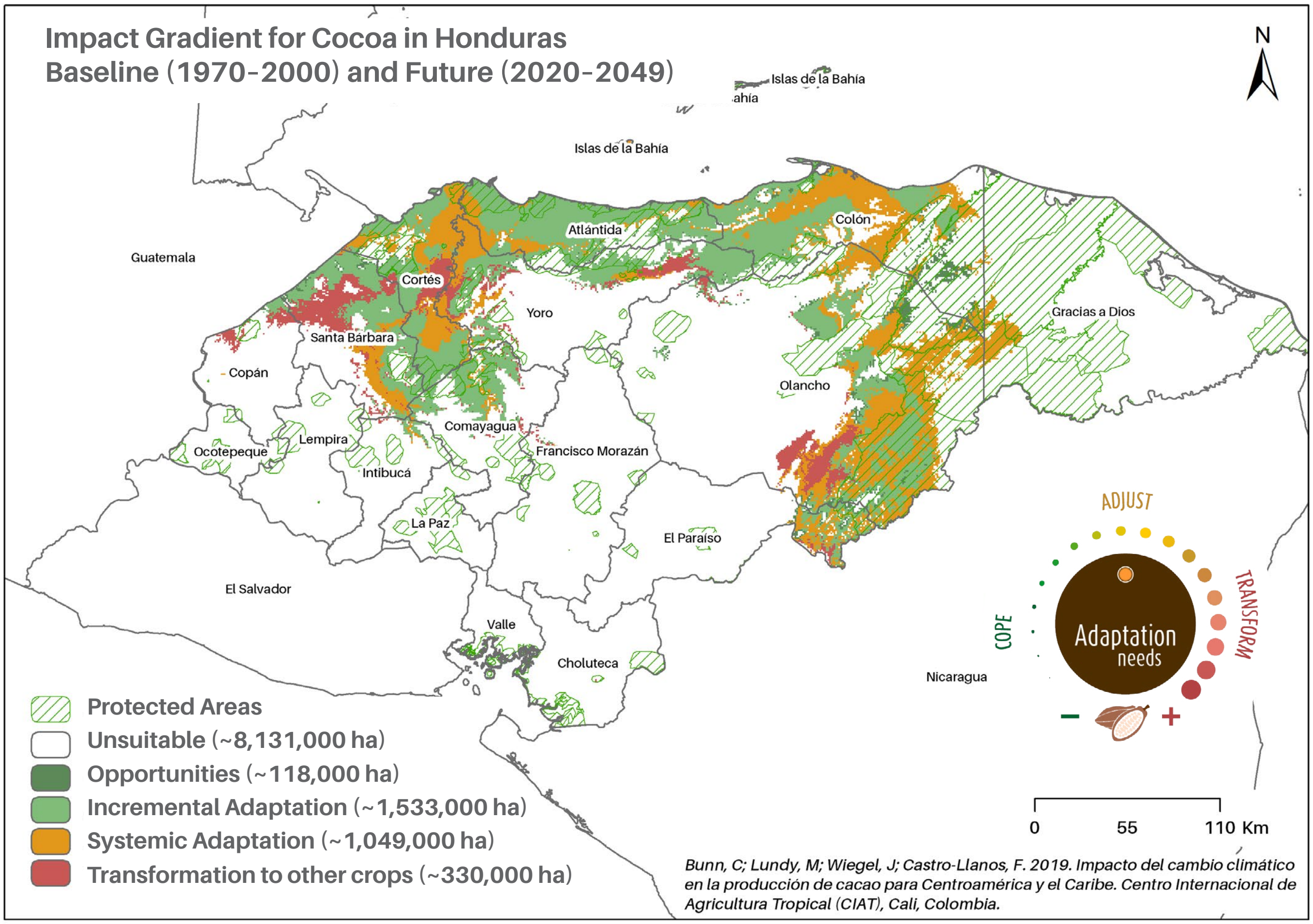

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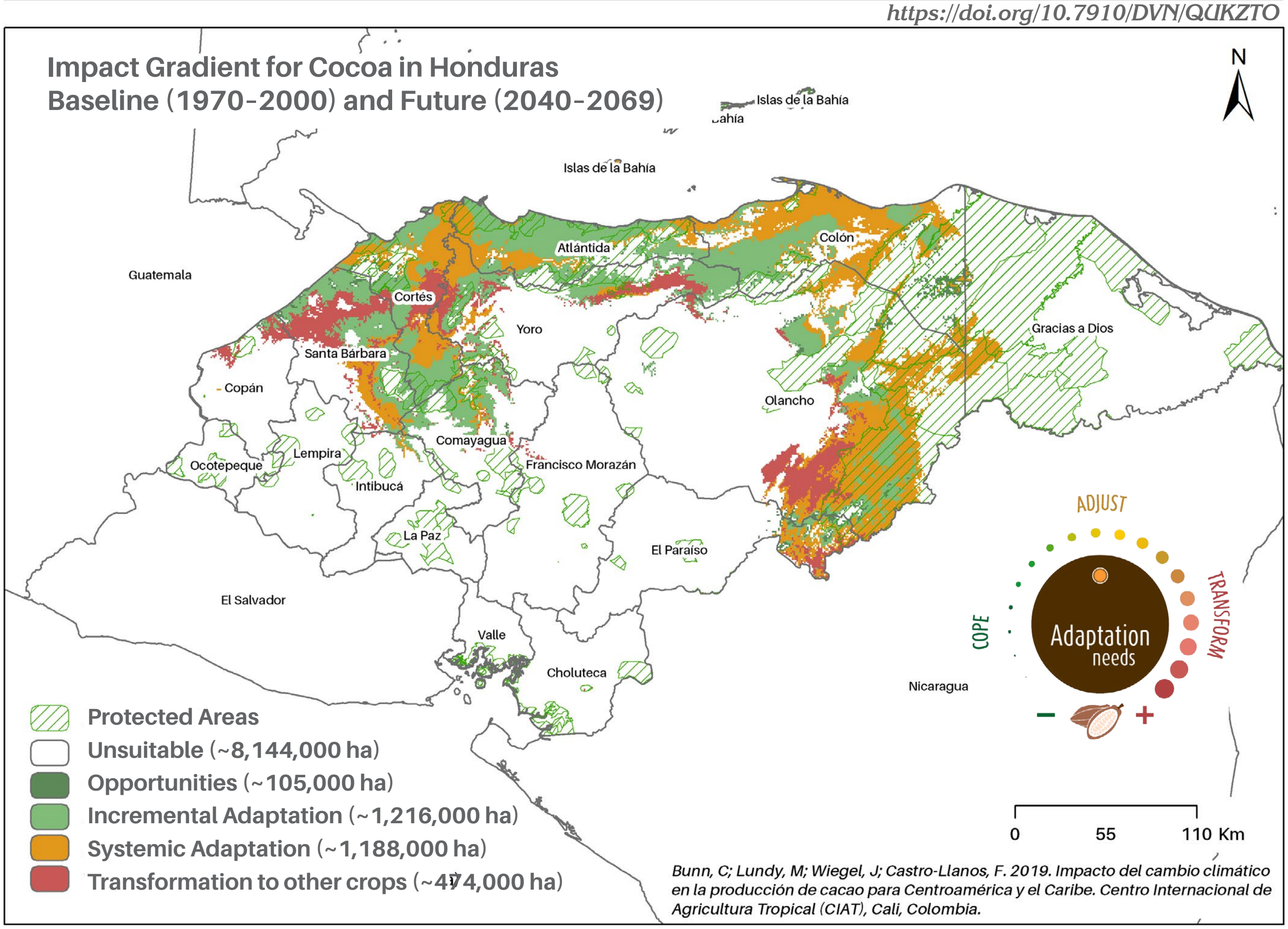

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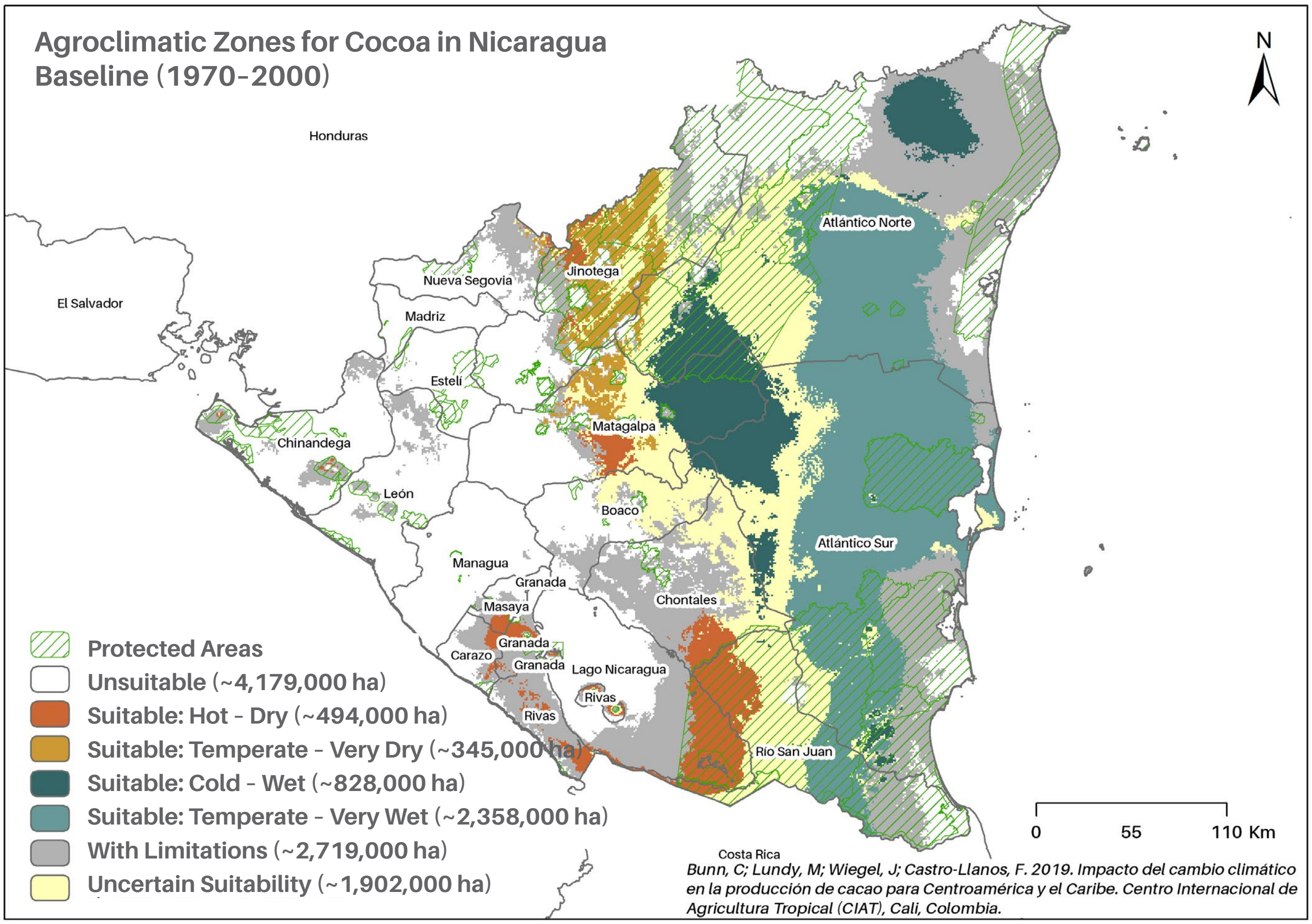
Nicaragua

In the baseline, the temperate-wet suitability corridor for cocoa is found in the east of the country. Cold zones are found in the central and northwestern regions, while suitable hot and temperate-very dry zones are located in the central-northern and southeastern parts of the country. Thus, here we can find a wide variety of agroclimatic zones for cocoa. The center of the country shows uncertain-suitability zones to grow cocoa.

For the 2050 period, a significant reduction in suitable area for cocoa is projected. Therefore, it is estimated that the level of adaptation efforts needed for the country is mostly systemic. In some zones a transformation of the crop is considered necessary.



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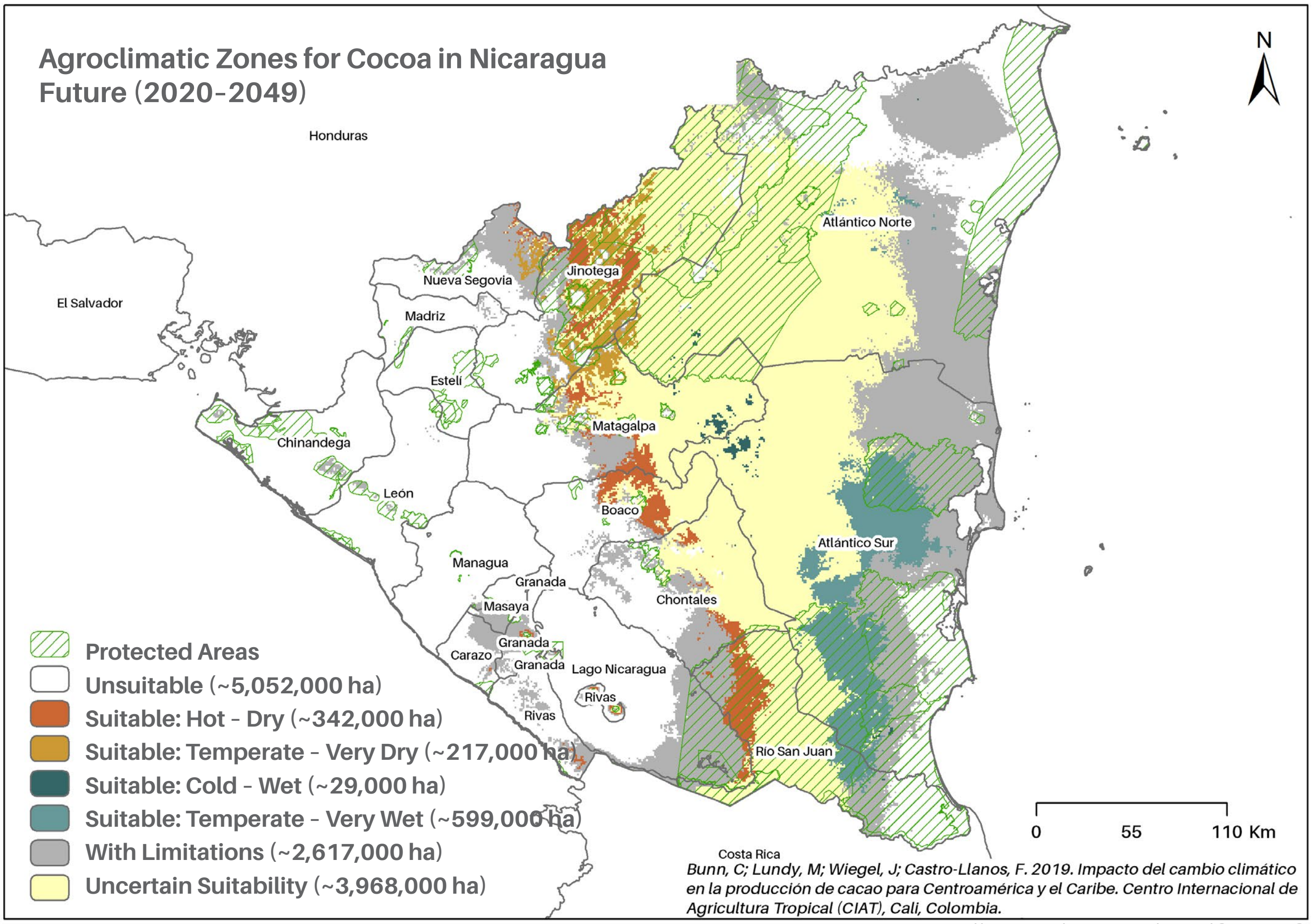

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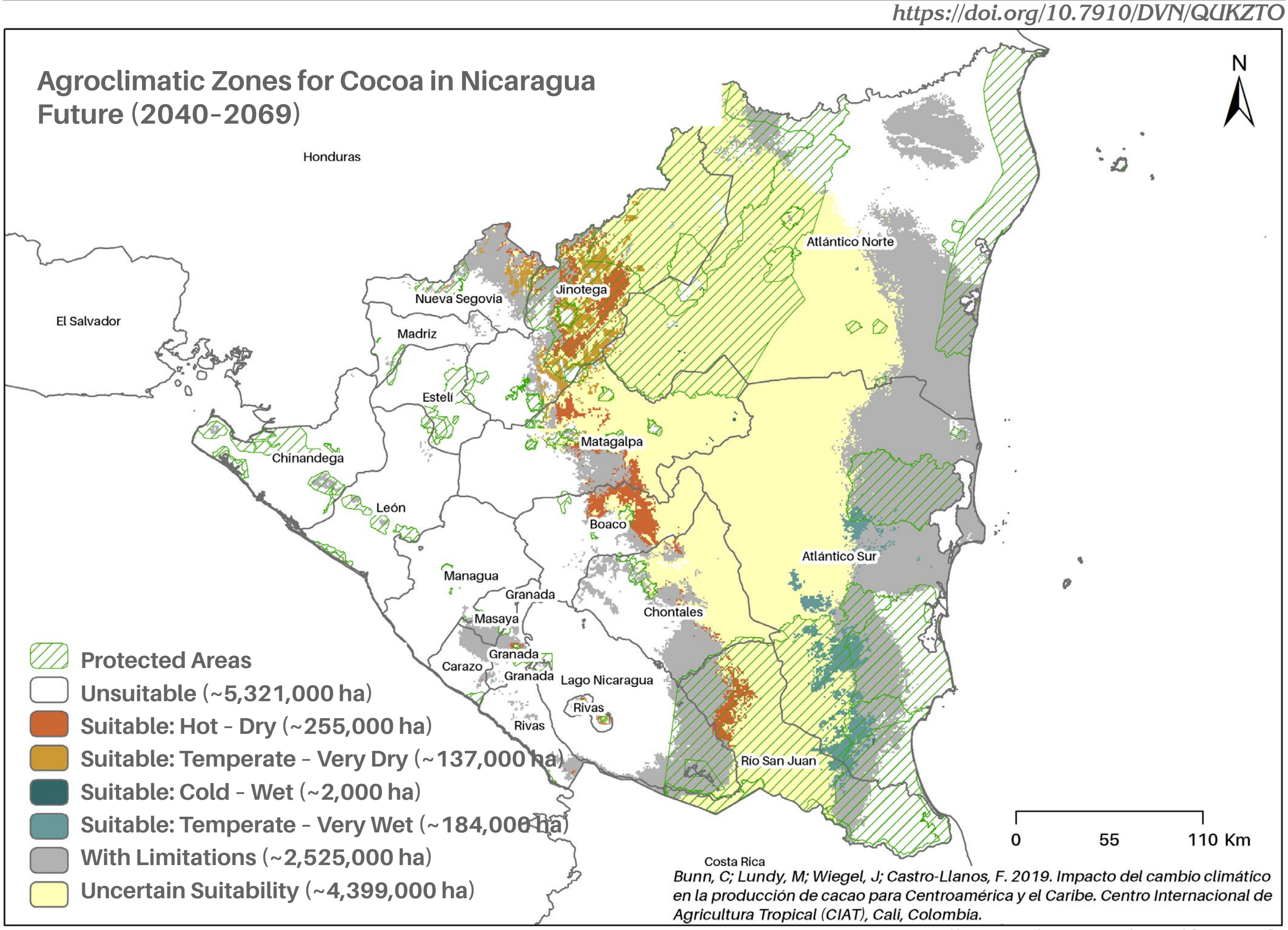

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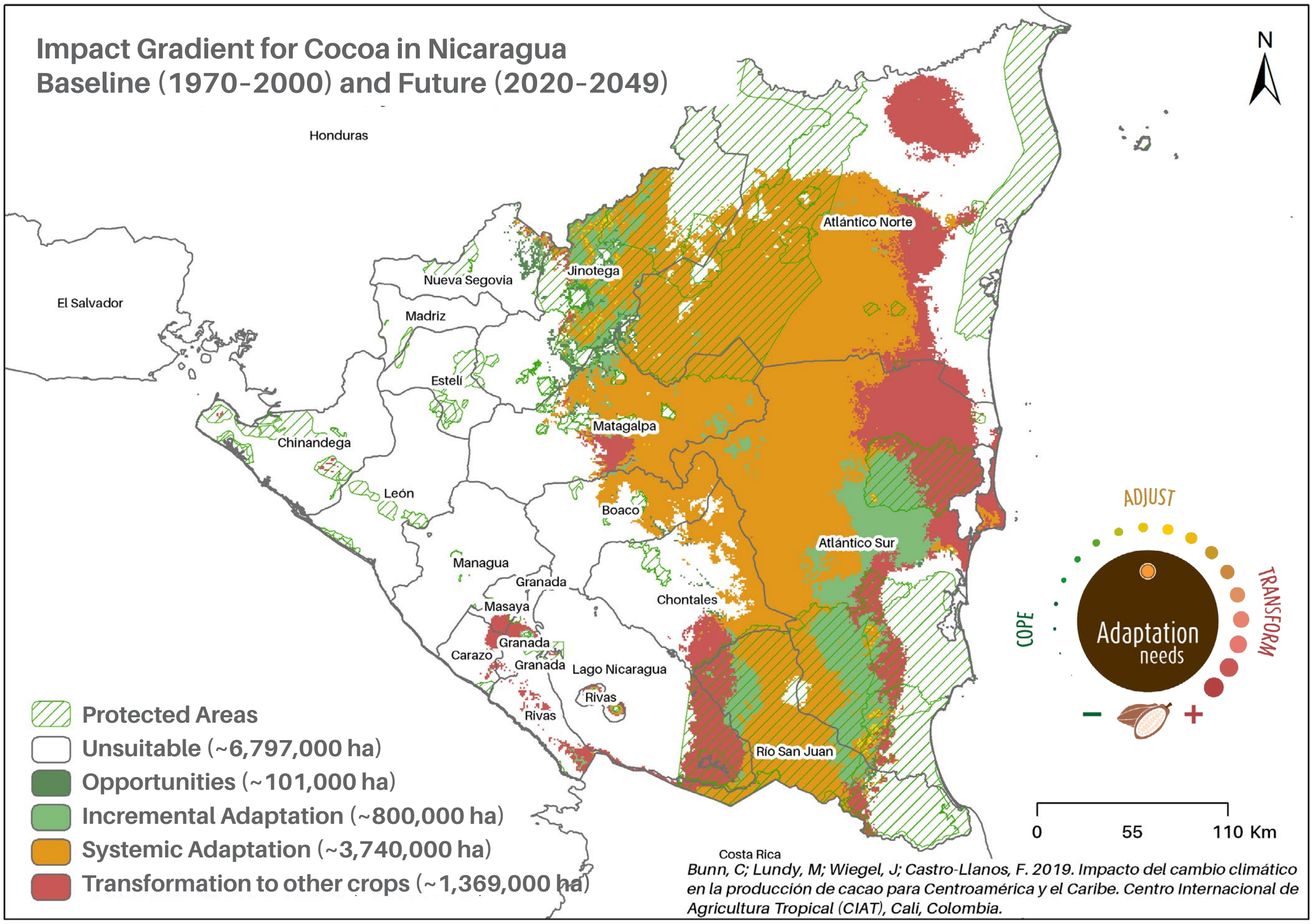

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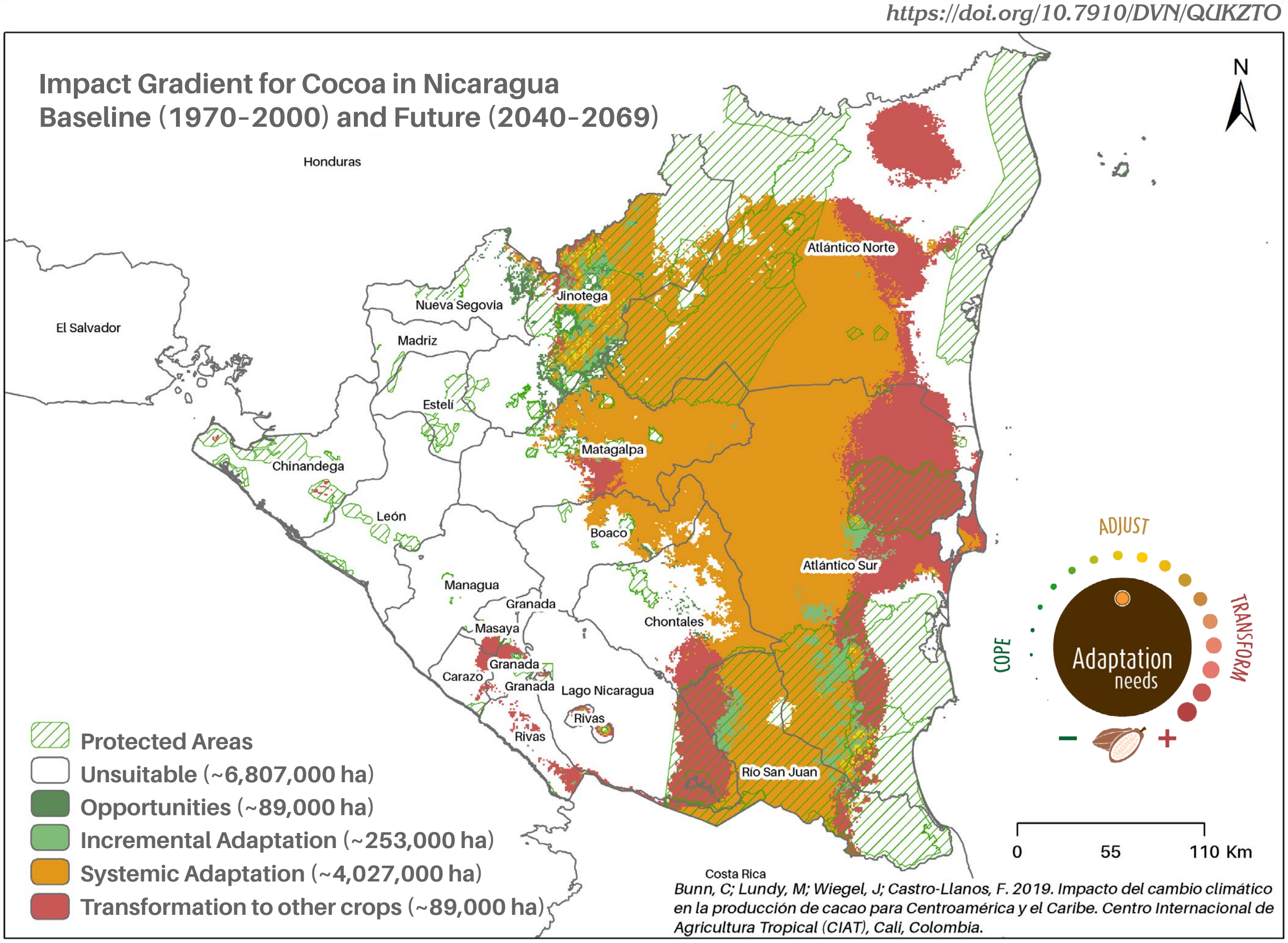

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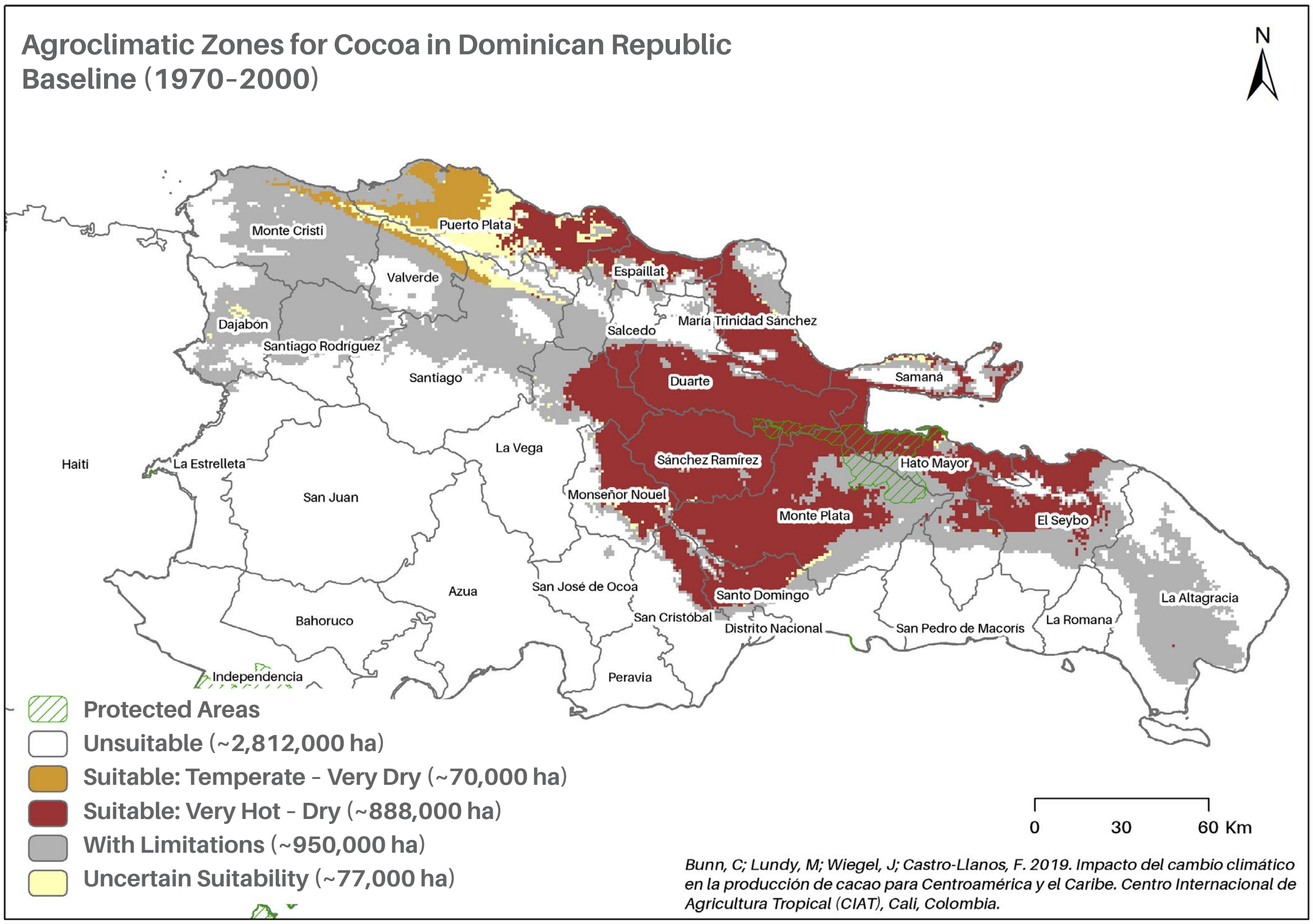
Dominican Republic

Under baseline conditions, the suitability corridor for cocoa is found in the center and north of the country. The northwest and center-south of the country shows some uncertain-suitability zones to grow cocoa.

For the 2050 period, an increase of suitable area for cocoa is projected, as well as uncertain-suitability areas. Therefore, it is estimated that the level of adaptation efforts needed for the country is mostly incremental. However, for some zones in the northwest, a systemic adaptation or even a transformation to other crops will be necessary. In comparison to the rest of countries, this is the only one that shows large increases in suitable areas for cocoa between the baseline and 2050.



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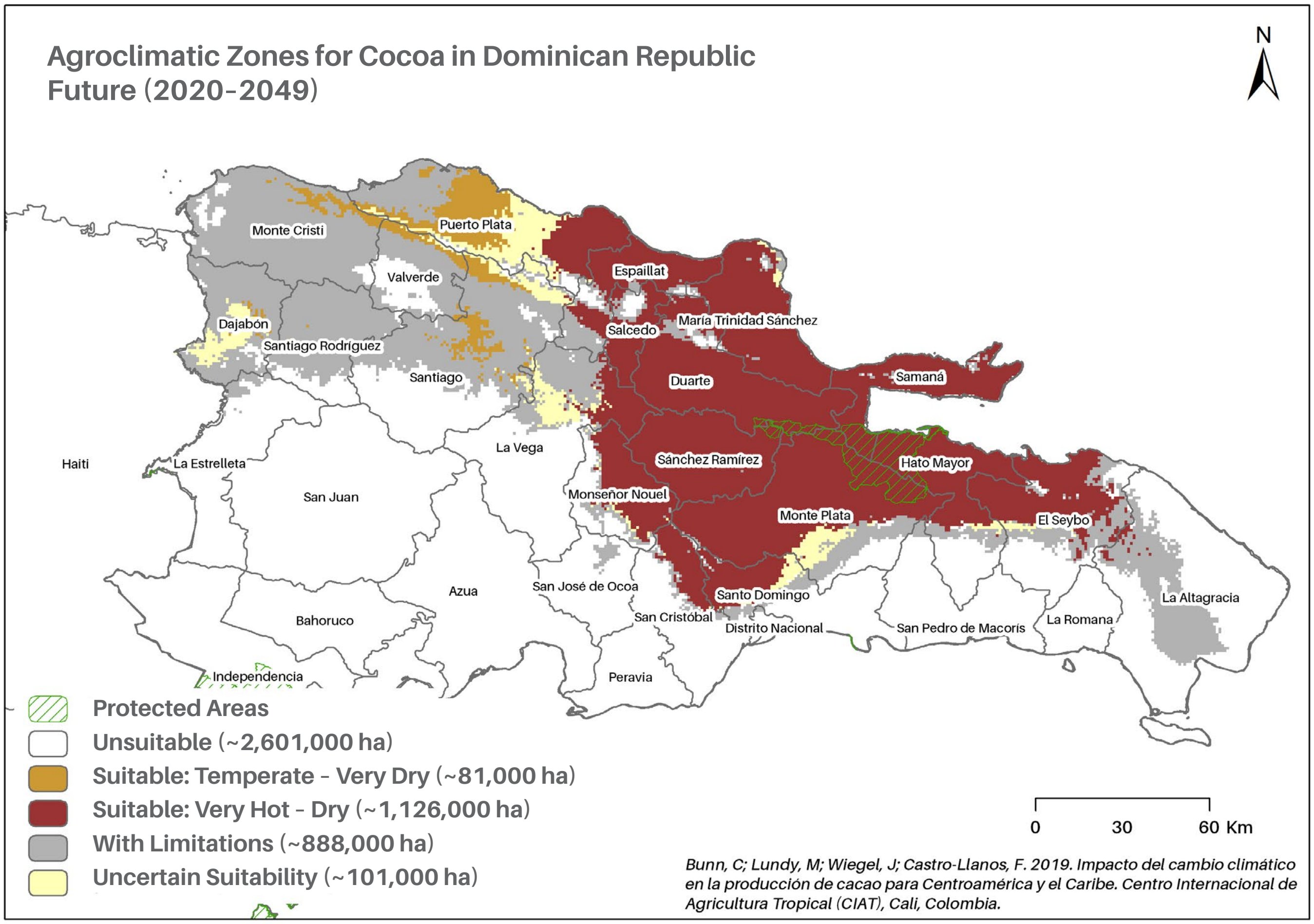

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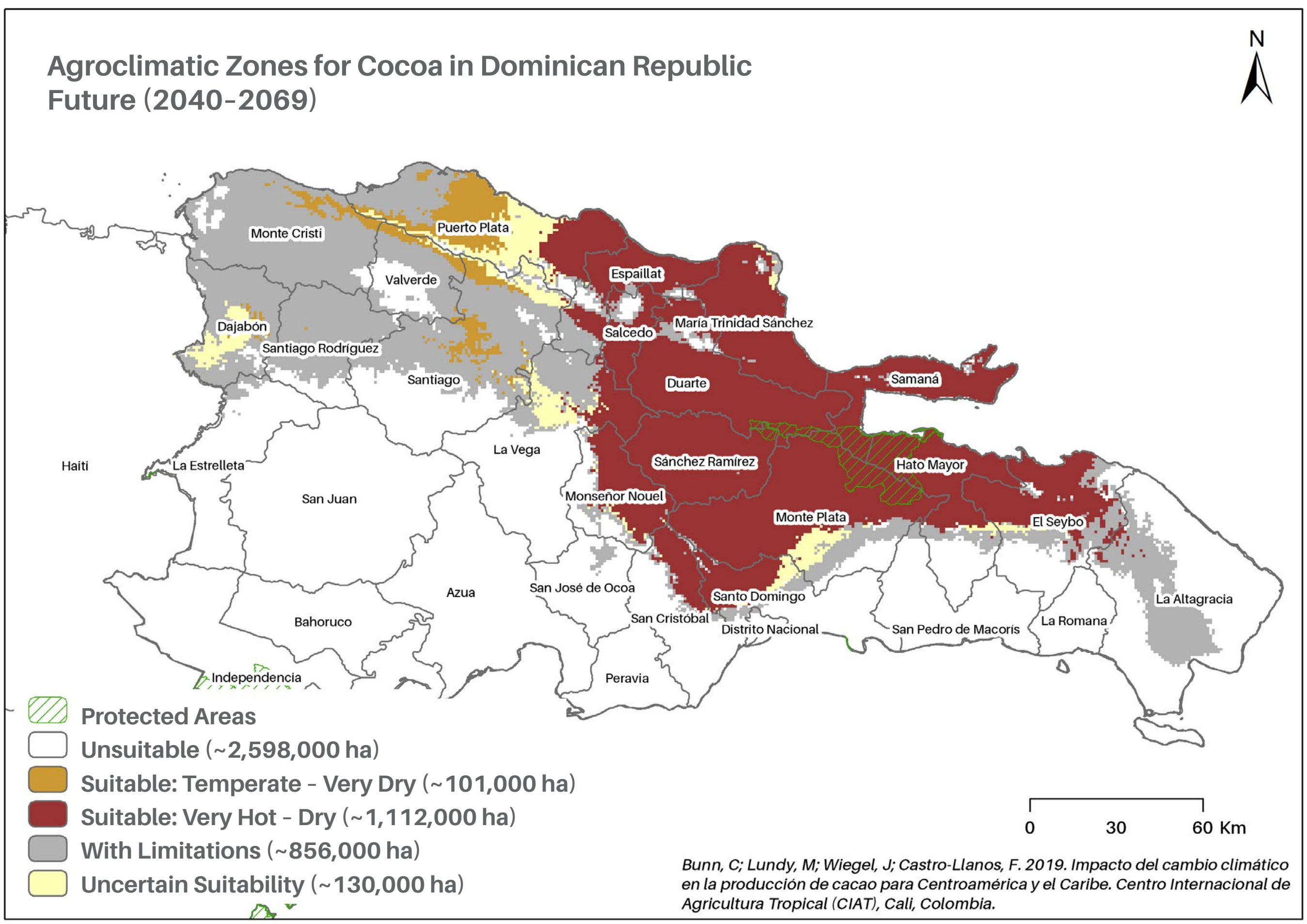

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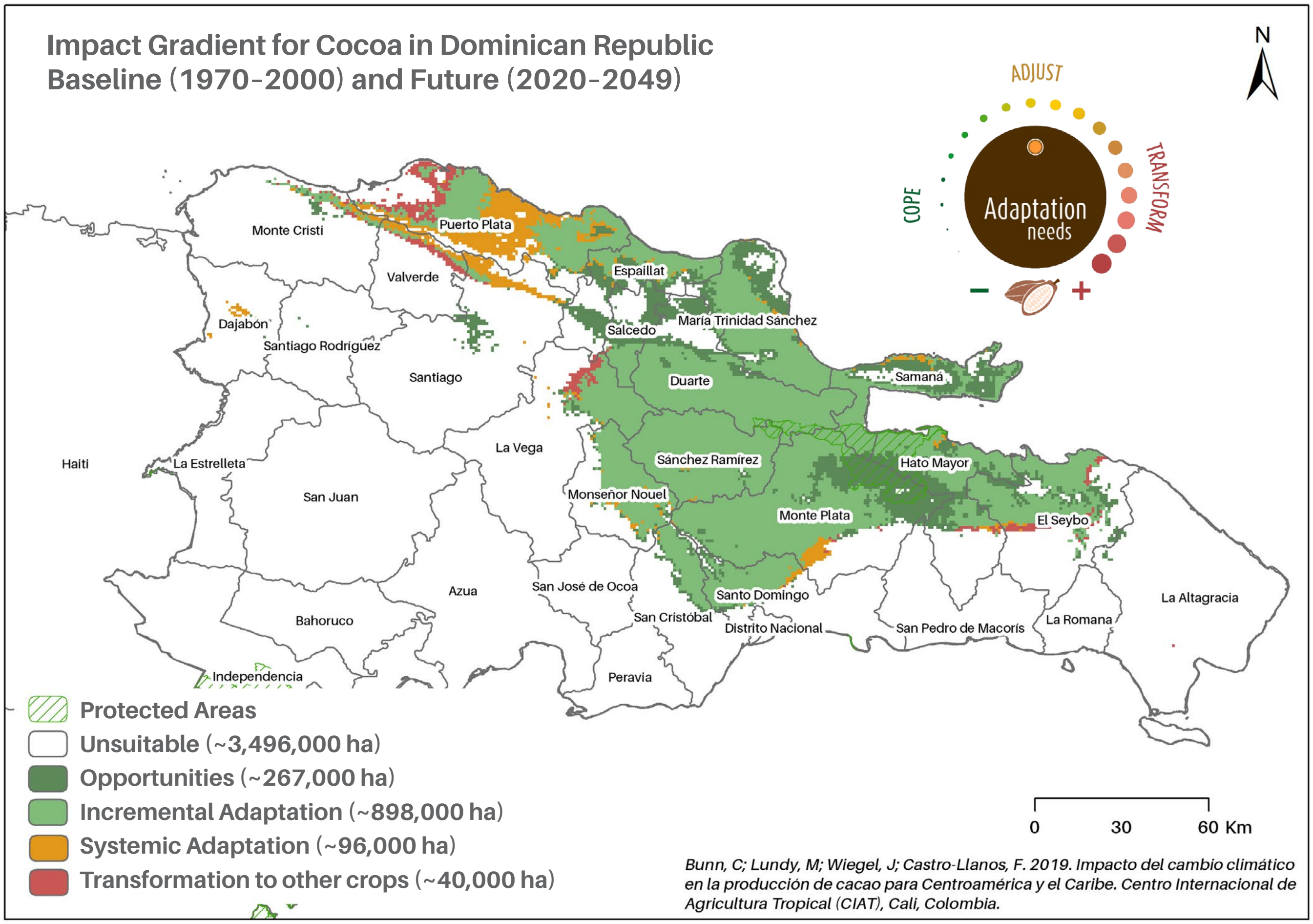

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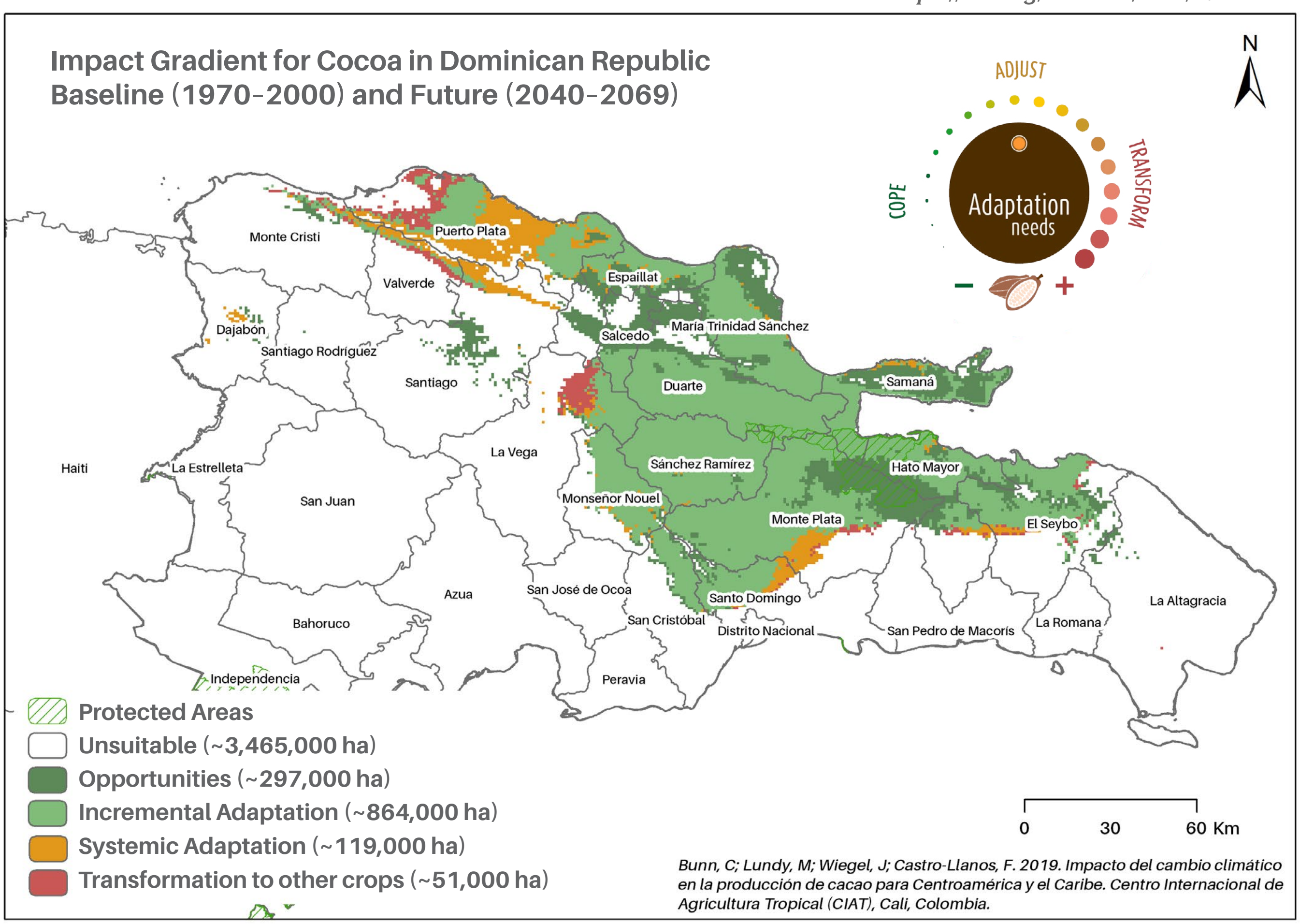

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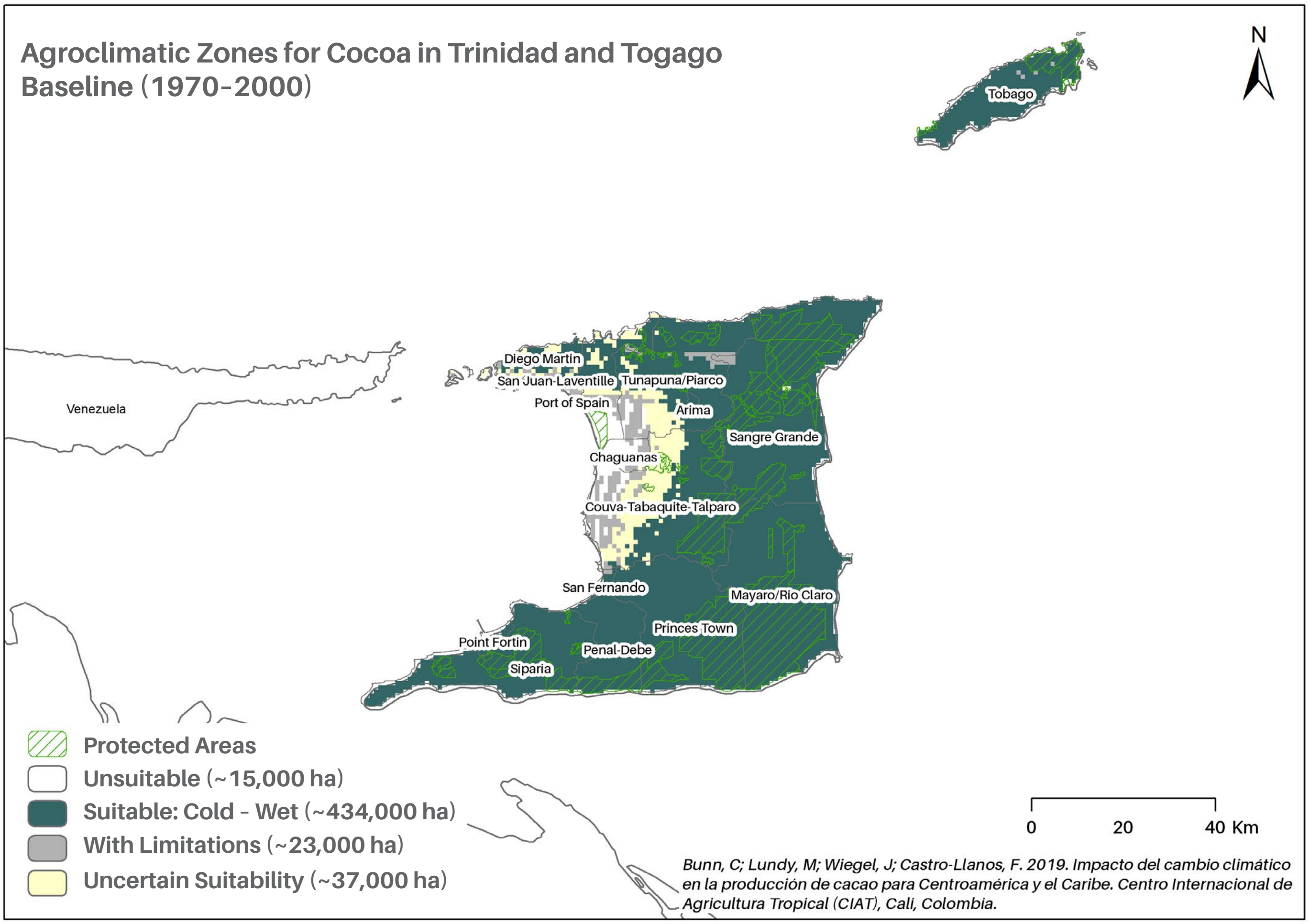
Trinidad and Tobago

In the baseline, a large part of the territory shows suitability for cocoa production. These suitable zones fall mainly under the category of cold-wet climate, with a few hectares under the category of areas with limitations and uncertain suitability.

For the 2050 period, a significant decline in suitable area for cocoa is projected. Therefore, it is estimated that the level of adaptation efforts needed for the country is mostly transformational and systemic. However, an incremental adaptation effort is recommended for some zones located mainly in the north of the country.



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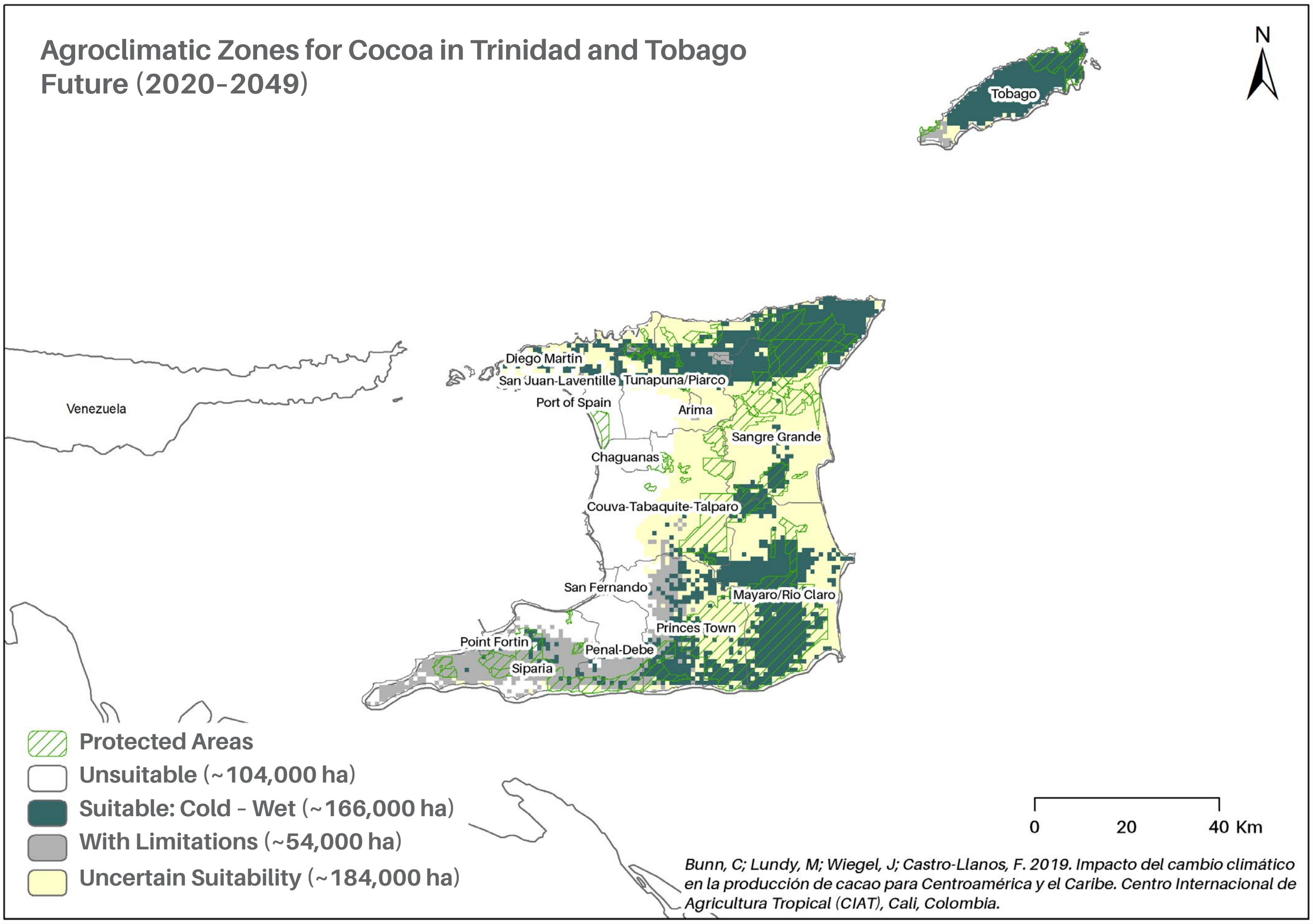

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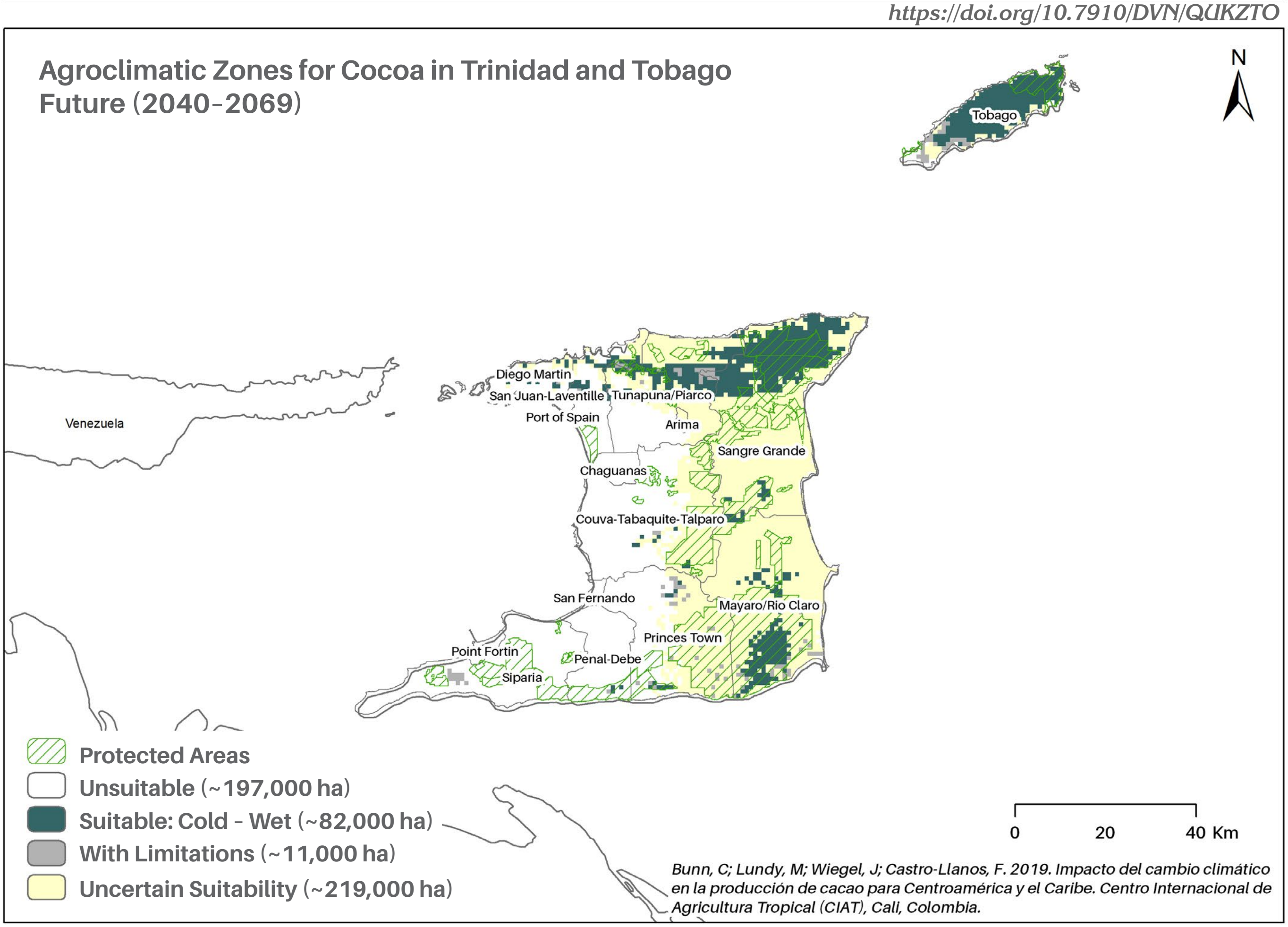

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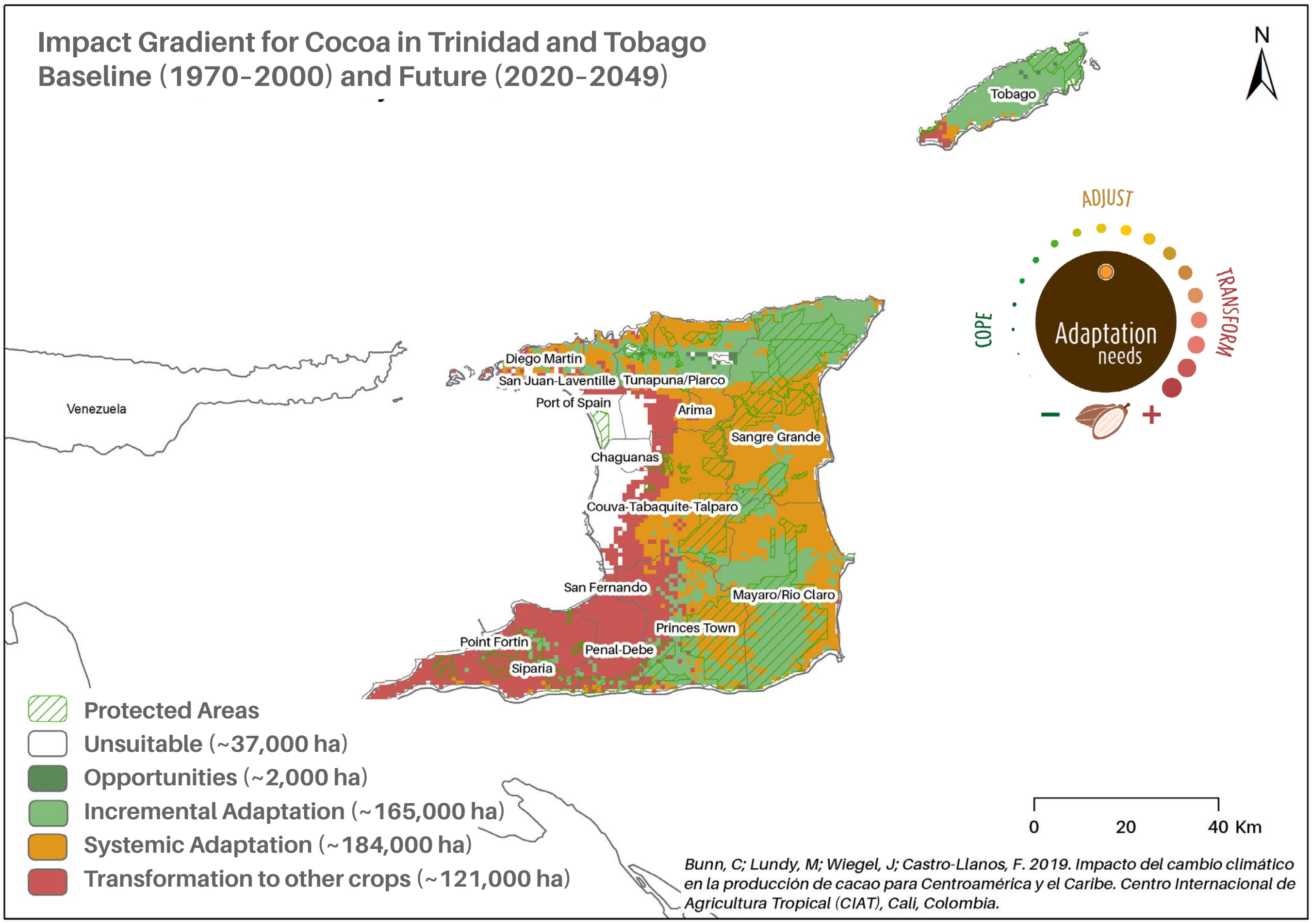

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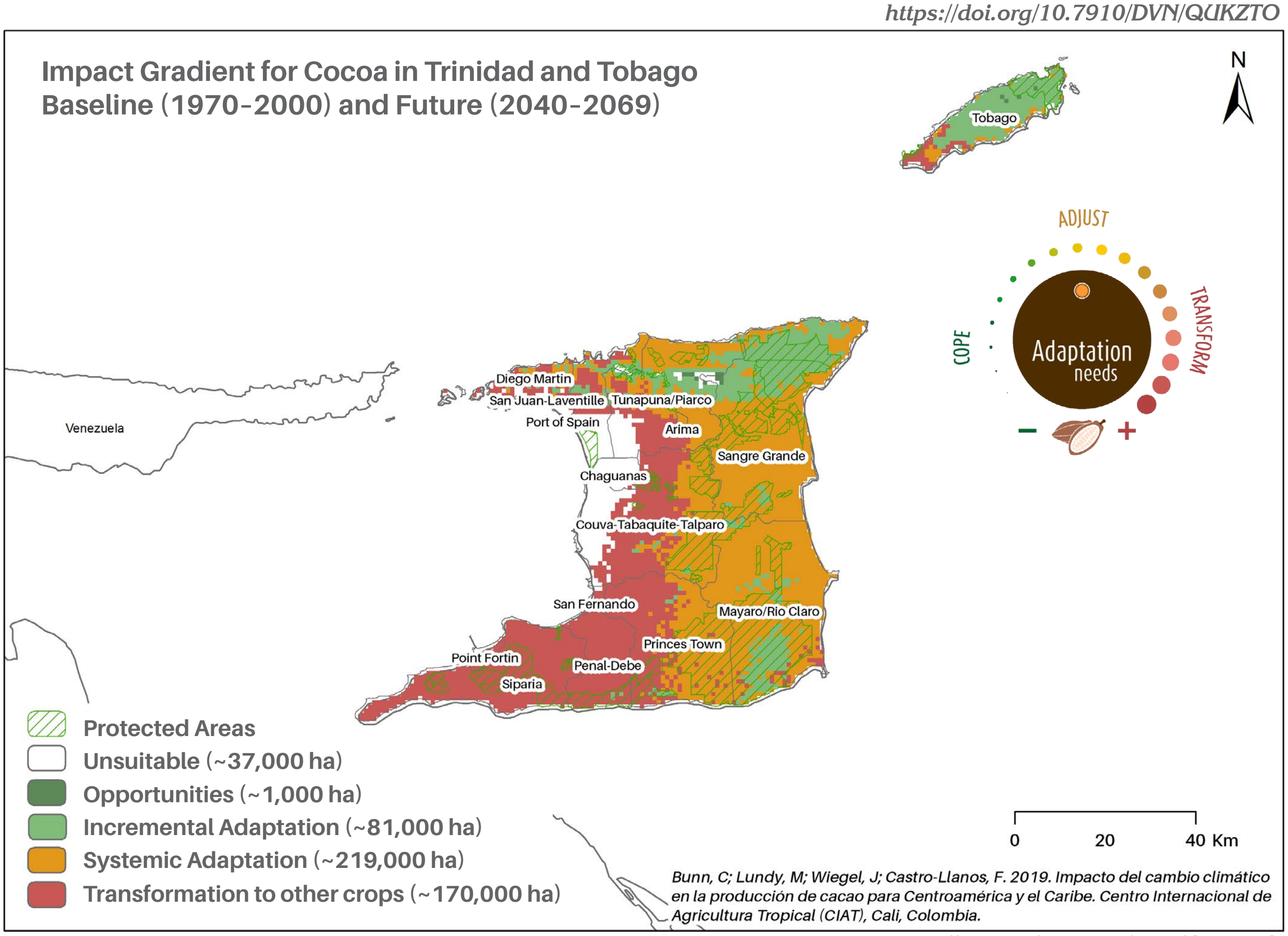

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How are future climate projections generated?

A climate projection is the simulated response of the climate system under a future scenario of emissions or concentration of greenhouse gas (GHG), usually derived from global climate models. A Global Climate Model (GCM) is a representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions, and feedback processes. Climate projections are contingent on the emission scenario used, which in turn is based on assumptions concerning future socio-economic and technological developments. GCM outcomes have a coarse resolution of 100 or 200 km, which is **not practical to assess agricultural landscapes.** Therefore, we use downscaled climate projections. The key assumptions of this approach are that changes in climate only vary over large distances and that the relationship between variables in the baseline is maintained in the future.

Which emissions scenario was used?

Emission scenarios are a plausible representation of the future development of GHGs. Optimistic scenarios assume that net carbon emissions become zero in the near future (RCP 2.6), while in the pessimistic RCP 8.5 scenario, GHG emissions keep growing, resulting in extreme warming. Several publications show that in this scenario cocoa would struggle to survive. In this study, we used RCP 6.0, because it is an appropriate option (intermediate scenario) to guide adaptation.

How was the impact gradient determined?

To determine zones with different degrees of climate impact, we modeled changes in bioclimatic suitability for cocoa under present conditions (between1970 and 2000) and those in the period between 2020 and 2049 (which we approximated to 2030) and the period between 2040 and 2069 (which we approximated to 2050) using a machine learning classification model. First, we assembled a database of locations where cocoa is currently grown. Second, we interpolated monthly climate means of the 1970–2000 period onto a 0.5 arcminute grid, which were downloaded from the WordClim database (Hijmans et al., 2005), representing our current baseline climate. They were used to calculate 19 bioclimatic variables commonly used in modeling of crop suitability (Nix, 1986). Third, applying Random Forests in unsupervised variations to biologically significant bioclimatic variables, different clusters of cocoa suitability were detected within the occurrence data. These clusters can be interpreted as different climate zones that allow growing cocoa, but under different climate conditions. Fourth, using all bioclimatic variables, Random Forest clusters were trained to distinguish between suitable areas (falling into one of the suitable climatic zones) and unsuitable areas for cocoa. Clusters were applied to climate data from the 19 climate scenarios of the 2030 and 2050 periods on the basis of different climate models. This resulted in 19 distinct suitability maps that were averaged to obtain one single map for each period (2030 and 2050).

Finally, recommendation domains were defined according to the quality of change between climatic zones under current conditions and under future conditions in each of the 19 GCM projections. Incremental Adaptation is where climate conditions for cocoa production are projected to remain unchanged. Systemic Adaptation is where climate conditions for cocoa production are projected to change, although they continue to be suitable. Transformational Adaptation is where climate conditions are projected to change in such a way, that previously suitable zones are most likely to become unsuitable to grow cocoa in the future.

How certain is the projection?

As any future outlook, our model has a considerable degree of uncertainty and should be considered only as a projection, not a prediction. The uncertainty in our model comes from the emission scenarios, the climate models, and the crop model. We used 19 global climate models as equally valid projections of future climate. These models show a high level of agreement on the increase of temperature, but they disagree on the regional and seasonal distribution of rainfall. Therefore, the resulting impact gradient is largely influenced by the temperature increase, while the disagreement on rainfall is masked. However, an increase in temperature means a greater demand of water for agriculture. Lastly, our model is an “all other things equal” model that only considered a change in climate. Our statistical approach is designed to avoid overfitting and it also deliberately includes marginal locations for cocoa. This should be considered “friendly” uncertainty because it means that through guided adaptation, the worst impacts will be avoidable.

CIAT

The International Center for Tropical Agriculture (CIAT) – a member of the CGIAR Consortium – develops technologies, innovative methods, and new knowledge that better enable farmers, especially smallholders, to make agriculture eco-efficient – that is, competitive and profitable as well as sustainable and resilient. Headquartered near Cali, Colombia, CIAT conducts research for development in tropical regions of Latin America, Africa, and Asia.
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The Decision and Policy Analysis (DAPA) team at CIAT performed the analyses presented here, under the leadership of Christian Bunn, and with the support from Fabio Castro-Llanos. **Contact:** ***cbunn@cgiar.org***

This publication should be cited as: Bunn, C; Lundy, M; Wiegel, J; Castro-Llanos, F. 2019. Climate Change Impacts on Cocoa Production in Central America and the Caribbean. International Center for Tropical Agriculture (CIAT), Cali, Colombia. 35p.
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The authors acknowledge the financial support from the United States Agency for International Development (USAID), the Swiss Agency for Development and Cooperation (SDC) and the CGIAR Research Program on Policies, Institutions, and Markets (PIM). Key elements of this work were implemented as part of the Climate-smart Value Chains project of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and the Feed the Future Learning Community for Supply Chain Resilience consortium of USAID, with additional support from the Feed the Future Partnership for Climate-smart Cocoa project implemented by WCF, and the Cocoa Value Chain Knowledge Management in Central America Project, implemented by Rikolto. The authors thank the multiple partners in the region for providing location points of cocoa plantations, as well as for reviewing the outcomes of the study.

The icon on the maps is a "Setting" adaptation by Juan Pablo Bravo and "cocoa" by Amos Kofi Commey, The Noun Project.