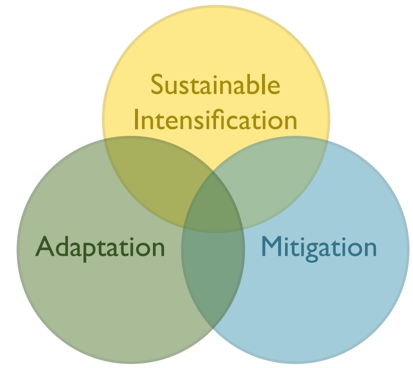
FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

Climate Change Impacts on Coffee Production in Mexico and Central America

Atlas

Climate-smart coffee 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 coffee 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.

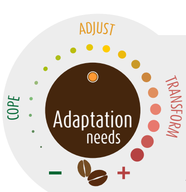


To support an efficient adaptation, CIAT developed a climate change impact gradient for coffee production. The gradient is a coffee-specific evaluation of the results of the projected climate impact for this crop, which shows the most likely degree of adaptation effort needed in possible future climate scenarios.

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 50 mm could be critical for coffee in areas with low water availability; however, it would be irrelevant in those areas where rainfall is heavy throughout the year.

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

This atlas for Central America provides general information on the different degrees of adaptation efforts needed to mitigate climate change impacts on coffee 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 coffee in the region and opens the debate on sustainable practices and necessary investments to face future risks. The map of coffee presences helps identify coffee production zones; maps of agroclimatic zones show future changes of agroclimatic zones suitable to grow coffee; 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.



Tres grados de esfuerzo de adaptación (gradiente de impacto)

Incremental Adaptation dwhere climate is most likely to remain suitable and adaption will be achieved through a change in 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 coffee production will remain feasible.

Sistemic Adaptation where climate is most likely to remain suitable, but with substantial stress in traditional production systems; adaptation will require a comprehensive change in 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 where climate is more likely to make coffee 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 coffee production under these conditions in the future.

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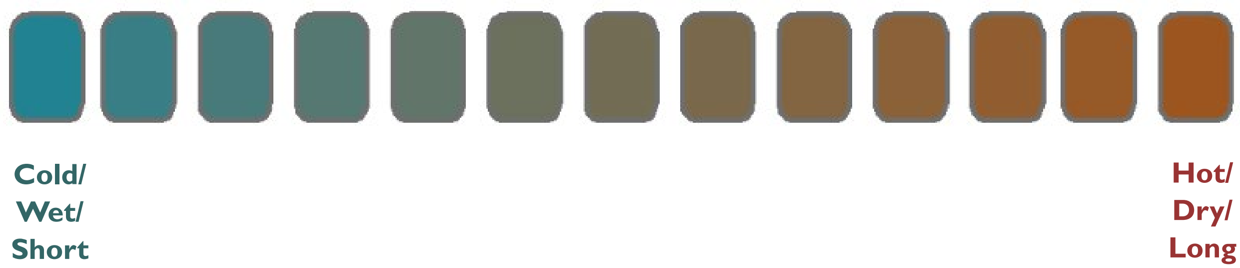
CCAFS
CIAT International Center for Tropical Agriculture
Since 1967 Science to cultivate change

The method used a comparison of the distribution of climatic zones in which Arabica coffee 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 farm level. The method considered the adaptation range using current production practices, and not a likely expansion of such range through novel technologies. The adoption of Climate-smart Agriculture (CSA) practices for coffee 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 coffee 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 coffee, those are the areas with the lowest or highest values, as the case may be.

Agroclimatic Zones Suitable for Coffee Production in Mexico and Central America

13 agroclimatic zones



With the purpose of reflecting the diversity of agroclimatic zones in Central America, we identified and describe 13 agroclimatic zones in the region. Since water stress is a limiting factor for coffee production in the region, we organized these zones according to their features in the dry season. By features we mean the length of the dry season, the average temperature, and rainfall.

The maps show that in the future, hot/dry/long zones become less suitable than cold/wet/short zones.

Mixed: These zones are suitable for coffee production, 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.

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

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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. Vistit: *https://doi.org/10.7910/DVN/9QUGUR*
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).

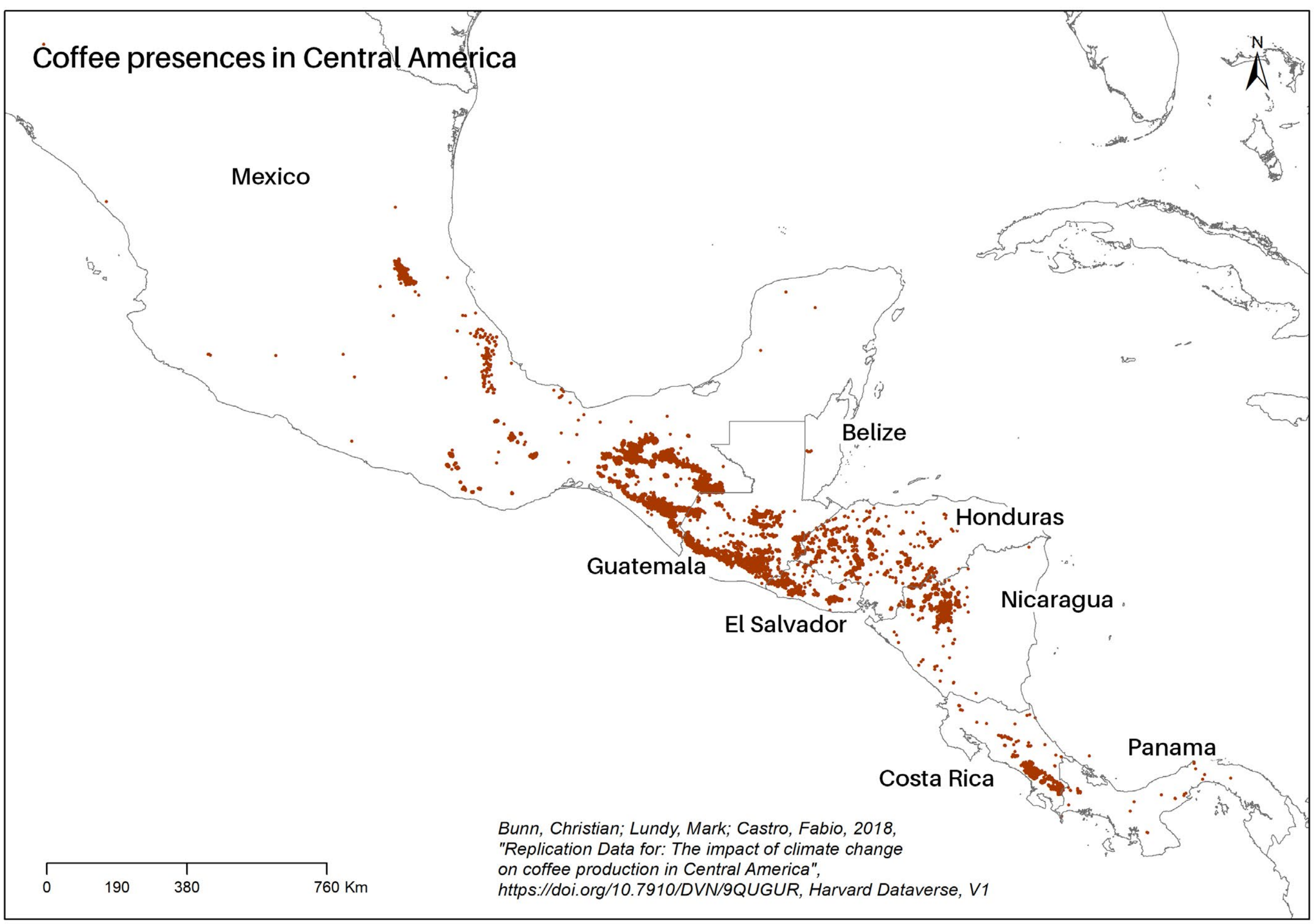
Central America

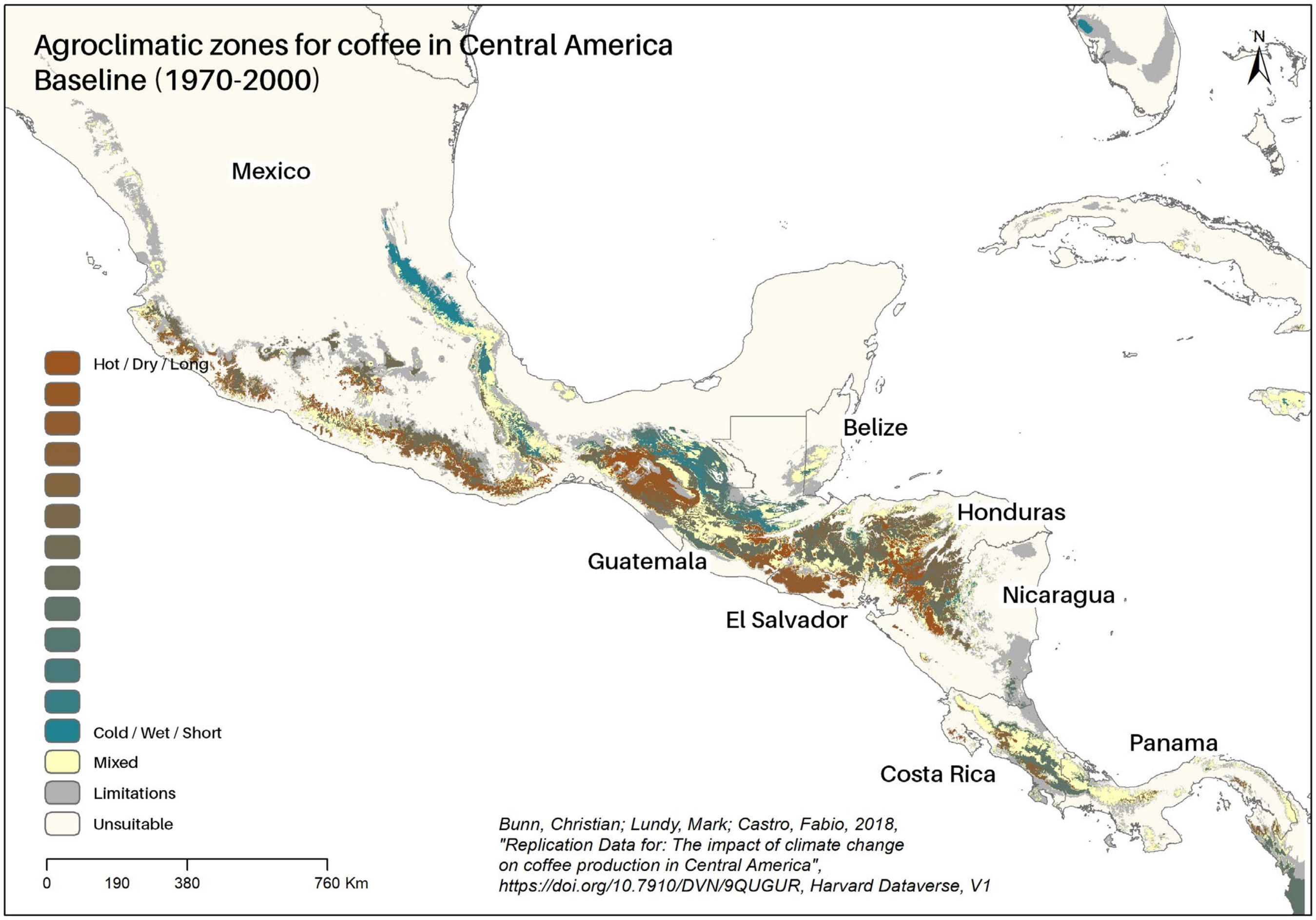
The following figure shows coffee presences in the region. Coffee is grown along Central America, in an area with the shape of a continuous corridor of farms in the south of Mexico, Guatemala, and El Salvador. In Honduras, there is a more scattered presence. In Nicaragua, coffee is found mainly in the north of the country, and the opposite is observed in Costa Rica, where coffee is found mostly in the south.

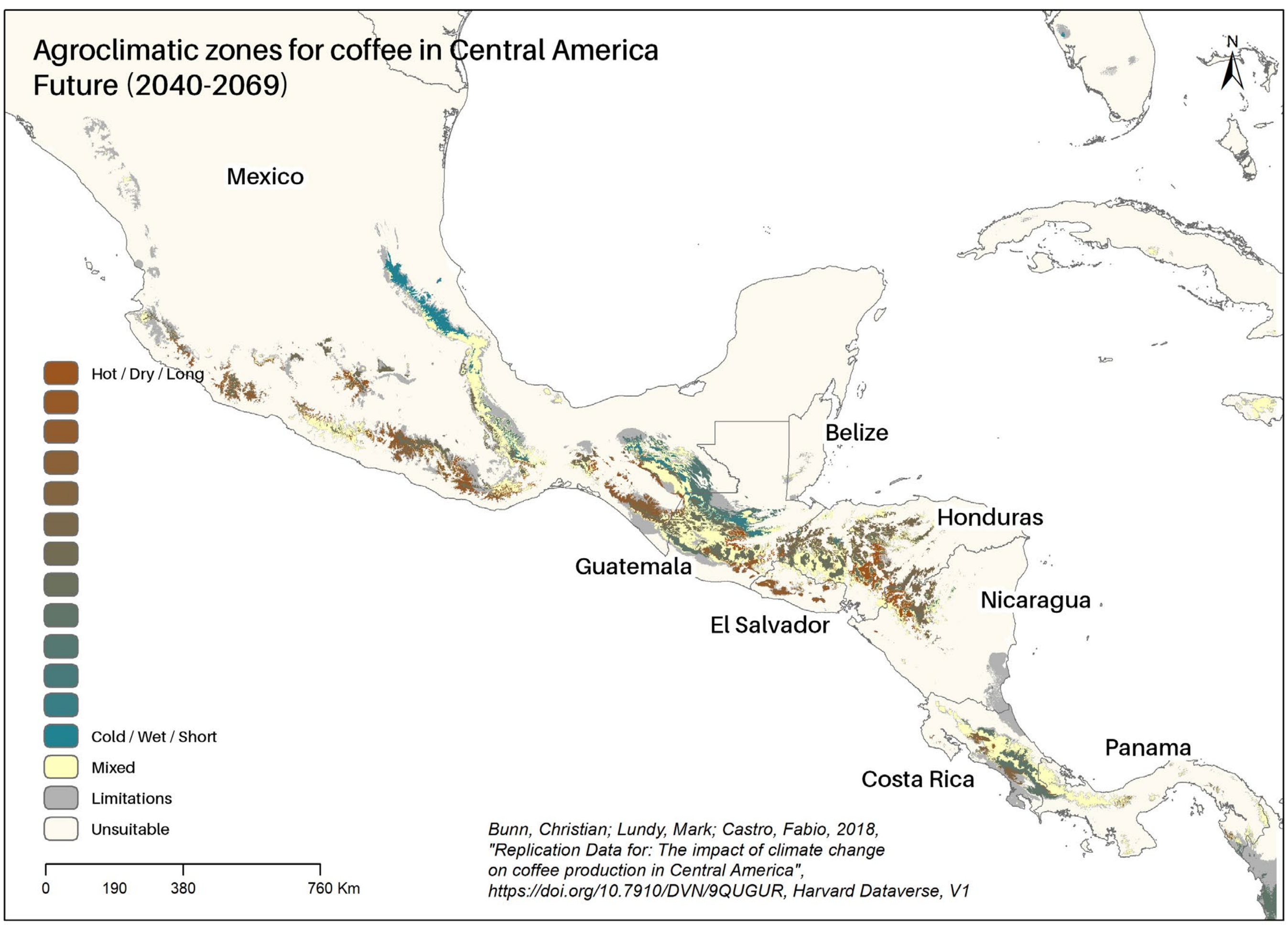
Agroclimatic zones in the baseline (or at present) are observed in zones ranging from dry / hot and long, to cold, wet, and short zones. Certain pattern may be noticed in suitable zones that are dry / hot and with a bit longer dry season, which are located close to the Pacific Ocean. On the other hand, zones which are cold / wet and with the shortest dry season are located mainly in the center of the country, such as in Guatemala and Mexico, where the mountain range has a higher altitudes than areas close to the sea. Mixed zones and zones with limitations are located next to agroclimatic zones.

In the future, the size of agroclimatic zones will be reduced. In southern Mexico, central Guatemala, and western Honduras, a major reduction of dry and hot zones can be observed close to the Pacific coast, as well as a reduction of area in cold and dry zones. Likewise, there is a significant reduction of agroclimatic zones for coffee in Nicaragua and Costa Rica.

Since suitable areas for coffee production in Central America will be considerably reduced in the future, the level of adaptation effort is mostly systemic. Systemic Adaptation suggests taking mitigation and adaptation measures to maintain coffee productivity.




Agroclimatic zones for coffee in Central America
Baseline (1970-2000)
N
Mexico
Belize
Honduras
Guatemala
Nicaragua
El Salvador
Panama
Costa Rica
Hot / Dry / Long
Cold / Wet / Short
Mixed
Limitations
Unsuitable
0
190
380
760 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
"Replication Data for: The impact of climate change
on coffee production in Central America",
https://doi.org/10.7910/DVN/9QUGUR, Harvard Dataverse, V1


Agroclimatic zones for coffee in Central America
Future (2040-2069)
N
Mexico
Belize
Honduras
Guatemala
Nicaragua
El Salvador
Panama
Costa Rica
Hot / Dry / Long
Cold / Wet / Short
Mixed
Limitations
Unsuitable
0
190
380
760 Km
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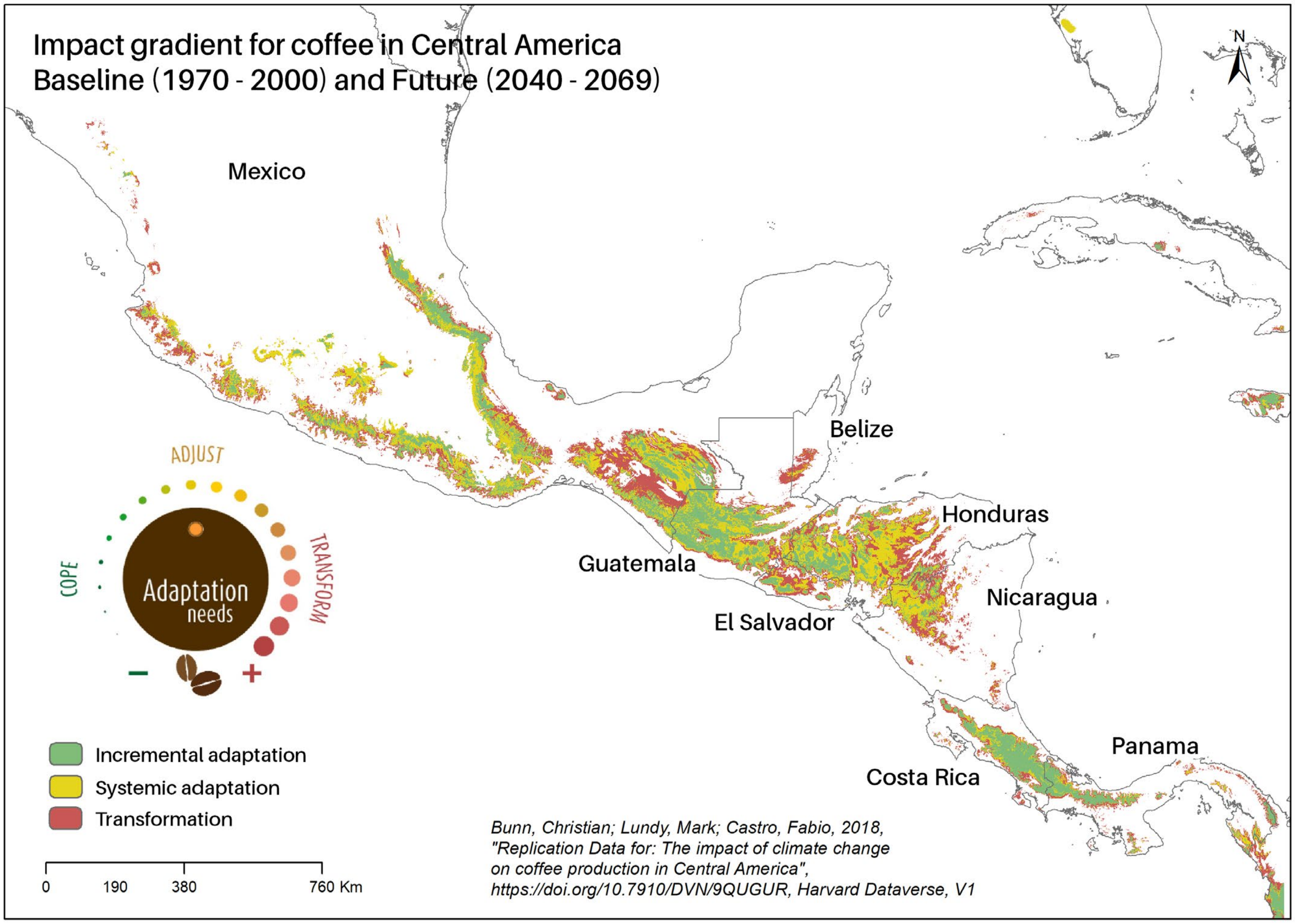

Impact gradient for coffee in Central America
Baseline (1970 - 2000) and Future (2040 - 2069)
Mexico
Belize
Honduras
Guatemala
Nicaragua
El Salvador
Costa Rica
Panama
N
ADJUST
COPE
TRANSFORM
Adaptation needs
−
+
Incremental adaptation
Systemic adaptation
Transformation
0
190
380
760 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
"Replication Data for: The impact of climate change
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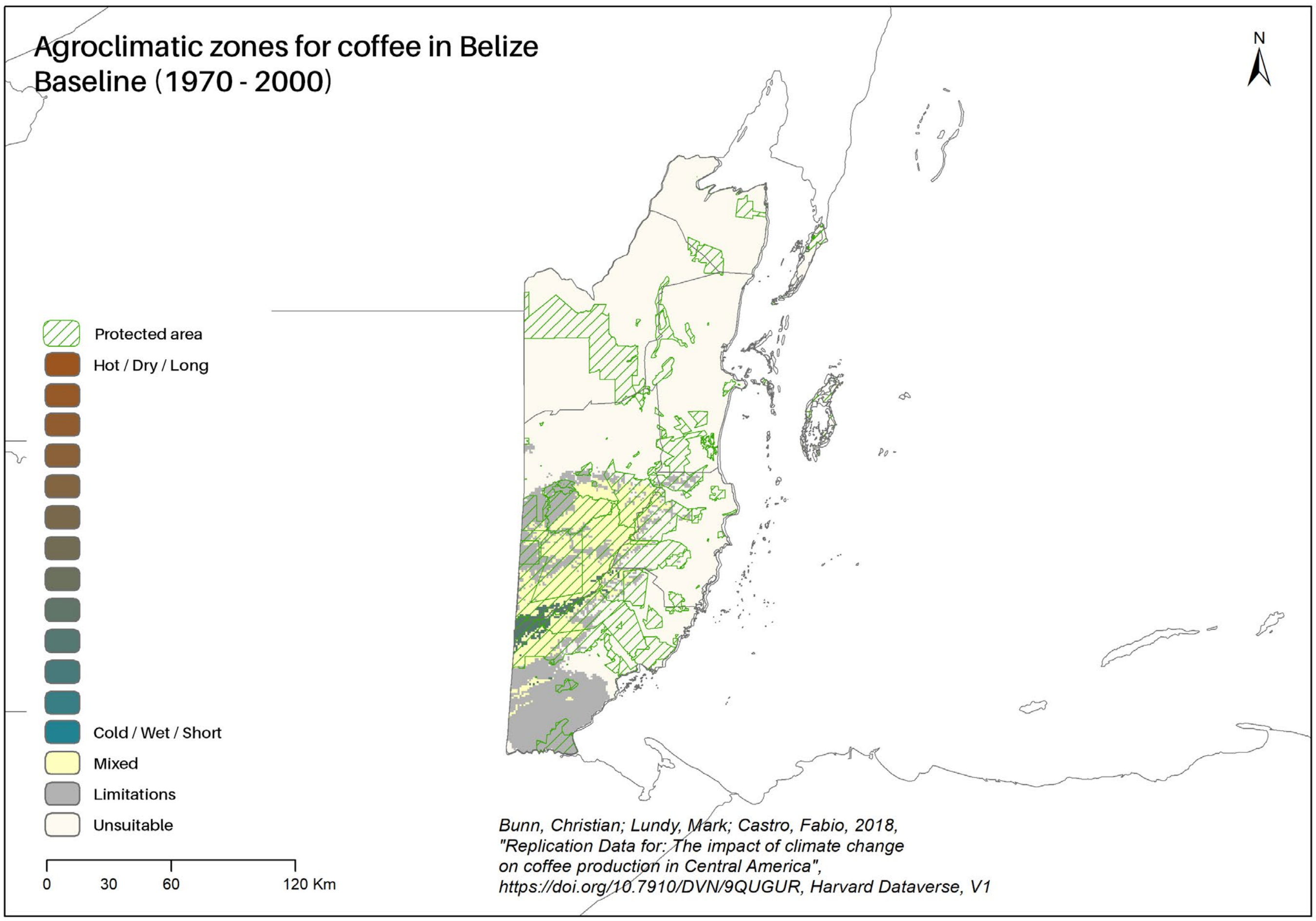
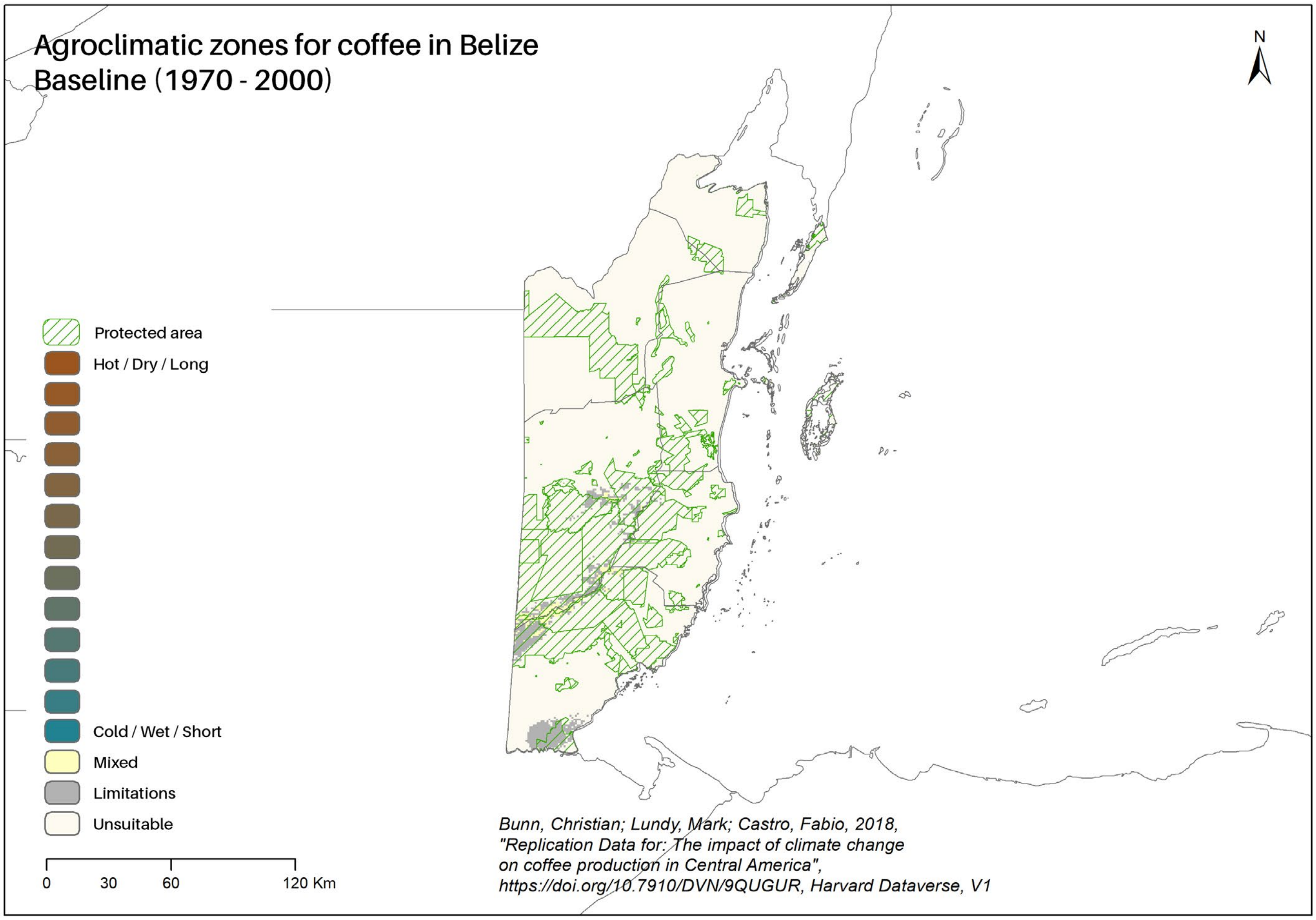
https://doi.org/10.7910/DVN/9QUGUR, Harvard Dataverse, V1

Belize

Agroclimatic zones in this country are very limited. Only wet/cold/long zones are observed in the south of the country, surrounded by areas with limitations or mixed. In the future, the overall picture is not positive, since well-defined agroclimatic zones disappear and the county is left with only zones with mixed conditions or with limitations. Regarding the impact gradient, a larger presence of transformation zones is observed, which suggest switching to other crop.




Agroclimatic zones for coffee in Belize
Baseline (1970 - 2000)
N
Protected area
Hot / Dry / Long
Cold / Wet / Short
Mixed
Limitations
Unsuitable
0
30
60
120 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
"Replication Data for: The impact of climate change
on coffee production in Central America",
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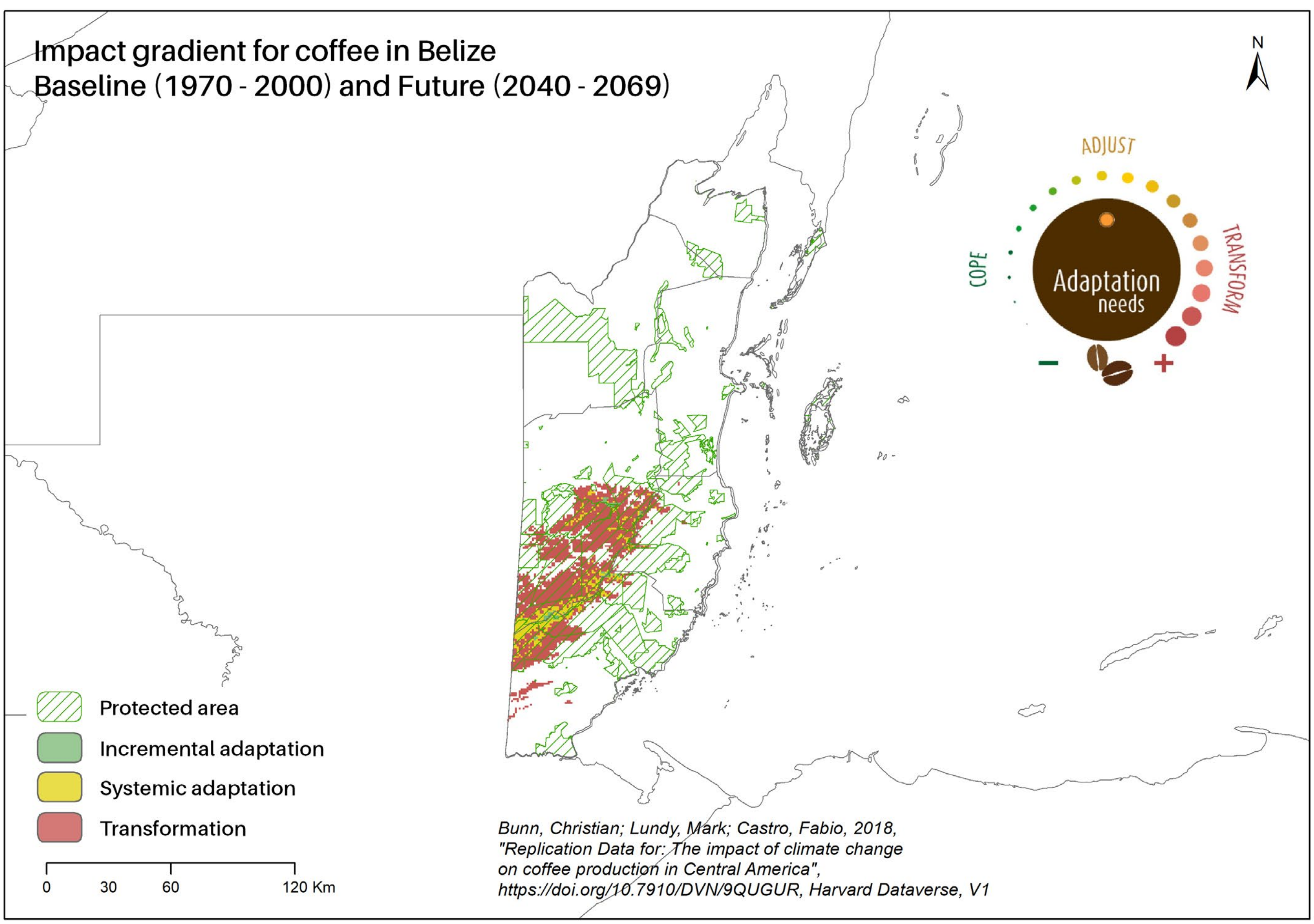
Impact gradient for coffee in Belize
Baseline (1970 - 2000) and Future (2040 - 2069)
N
ADJUST
COPE
TRANSFORM
Adaptation
needs
–
+
Protected area
Incremental adaptation
Systemic adaptation
Transformation
0
30
60
120 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
"Replication Data for: The impact of climate change
on coffee production in Central America",
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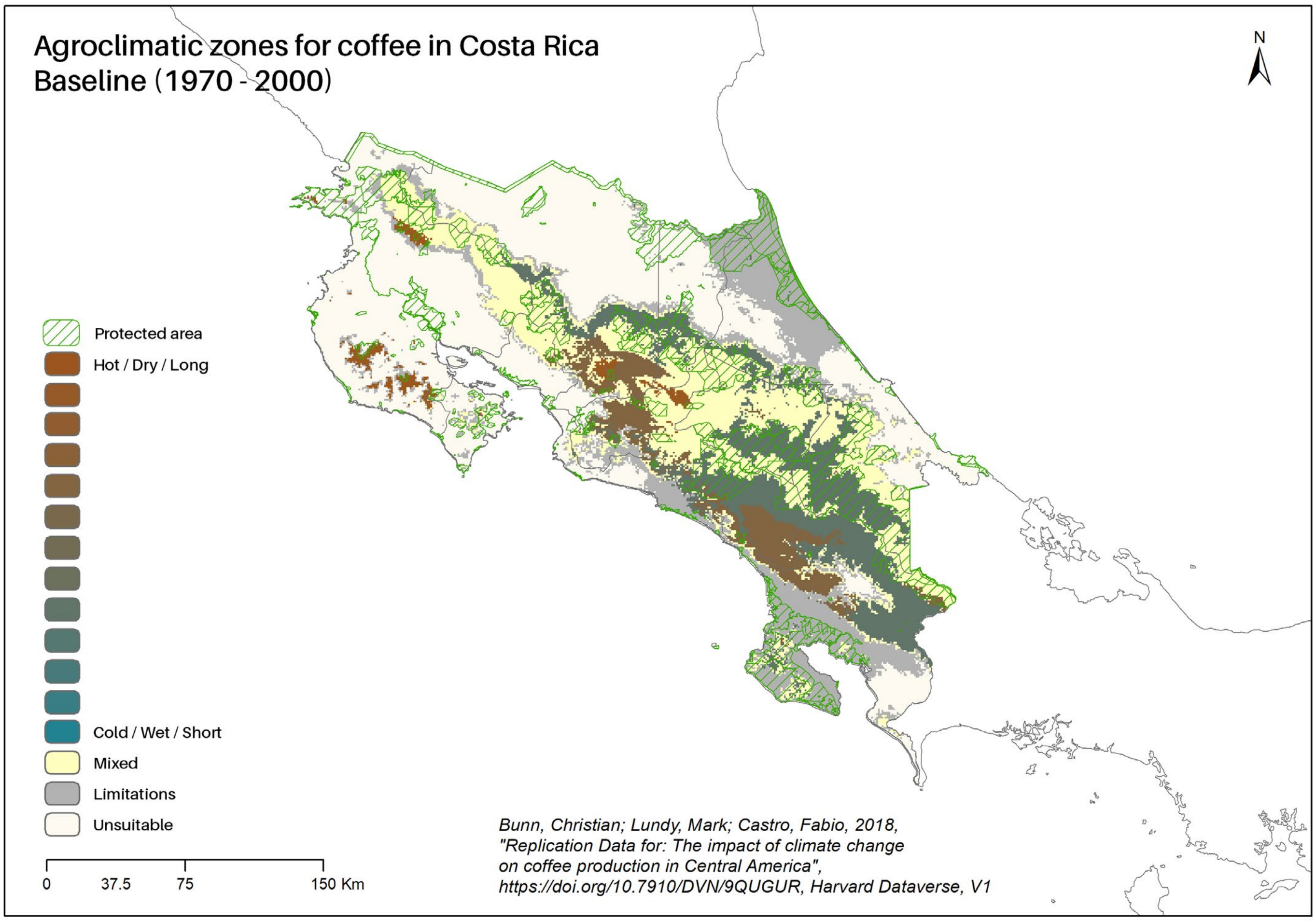
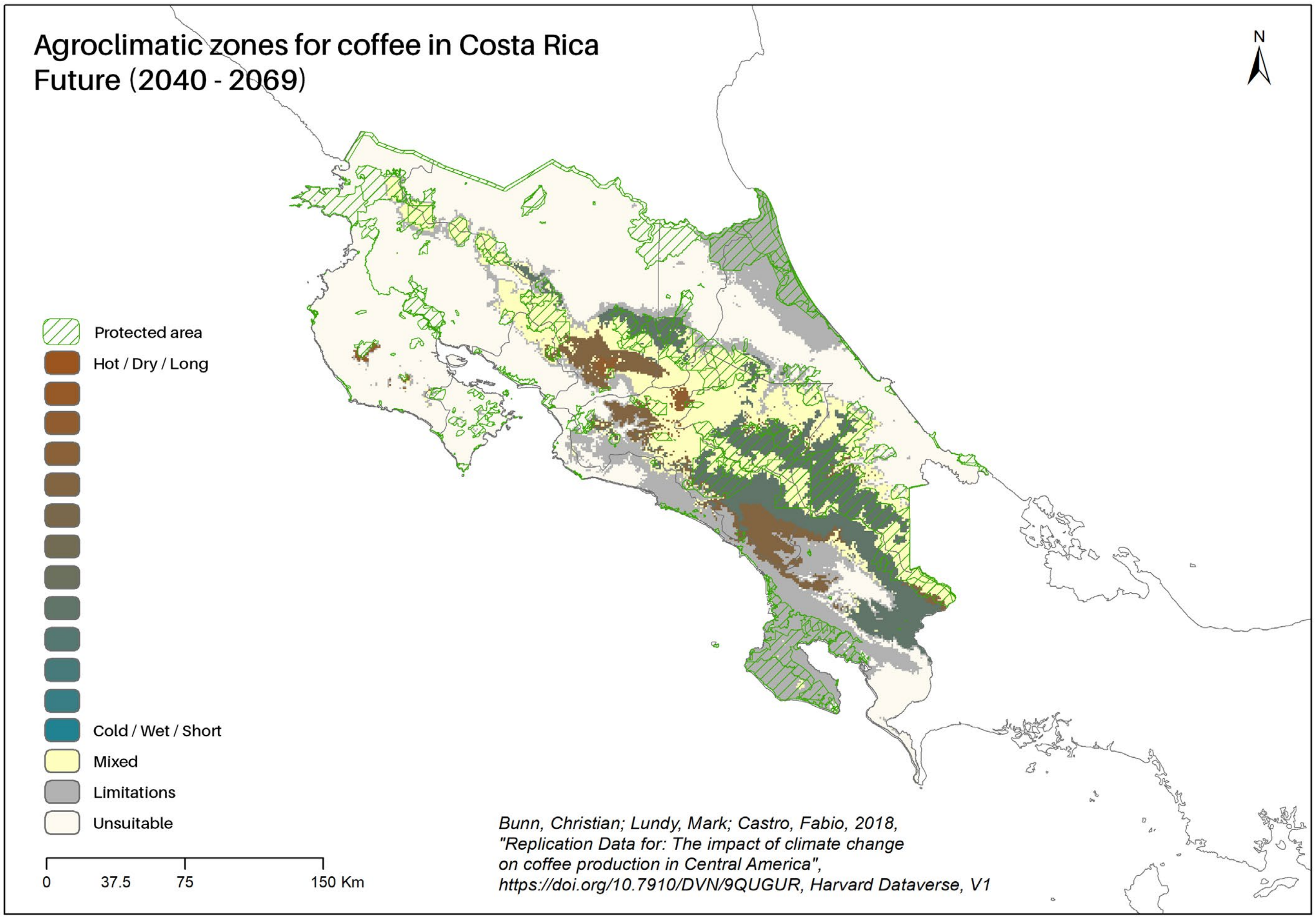
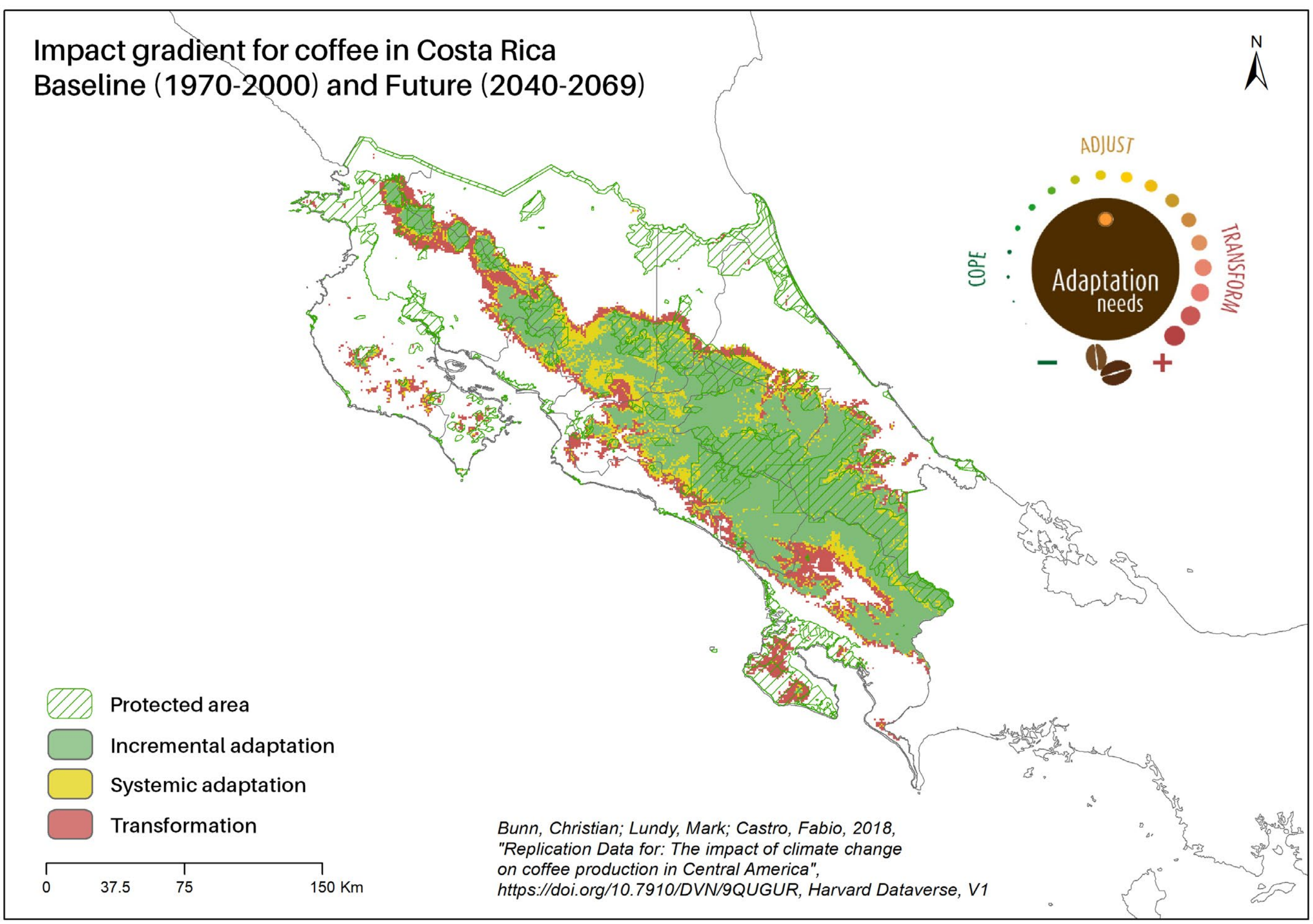
Costa Rica

The baseline or current conditions in the country, indicates large areas of suitable zones. Mixed and hot zones surround cold zones. Regarding climate, in the future, there is a reduction in suitability, but it is not alarming, since the reduction is observed only in the border of suitable zones. Adaptation efforts should be incremental.




Agroclimatic zones for coffee in Costa Rica
Future (2040 - 2069)
N
Protected area
Hot / Dry / Long
Cold / Wet / Short
Mixed
Limitations
Unsuitable
0
37.5
75
150 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
"Replication Data for: The impact of climate change
on coffee production in Central America",
https://doi.org/10.7910/DVN/9QUGUR, Harvard Dataverse, V1


Impact gradient for coffee in Costa Rica
Baseline (1970-2000) and Future (2040-2069)
N
ADJUST
COPE
TRANSFORM
Adaptation
needs
–
+
Protected area
Incremental adaptation
Systemic adaptation
Transformation
0
37.5
75
150 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
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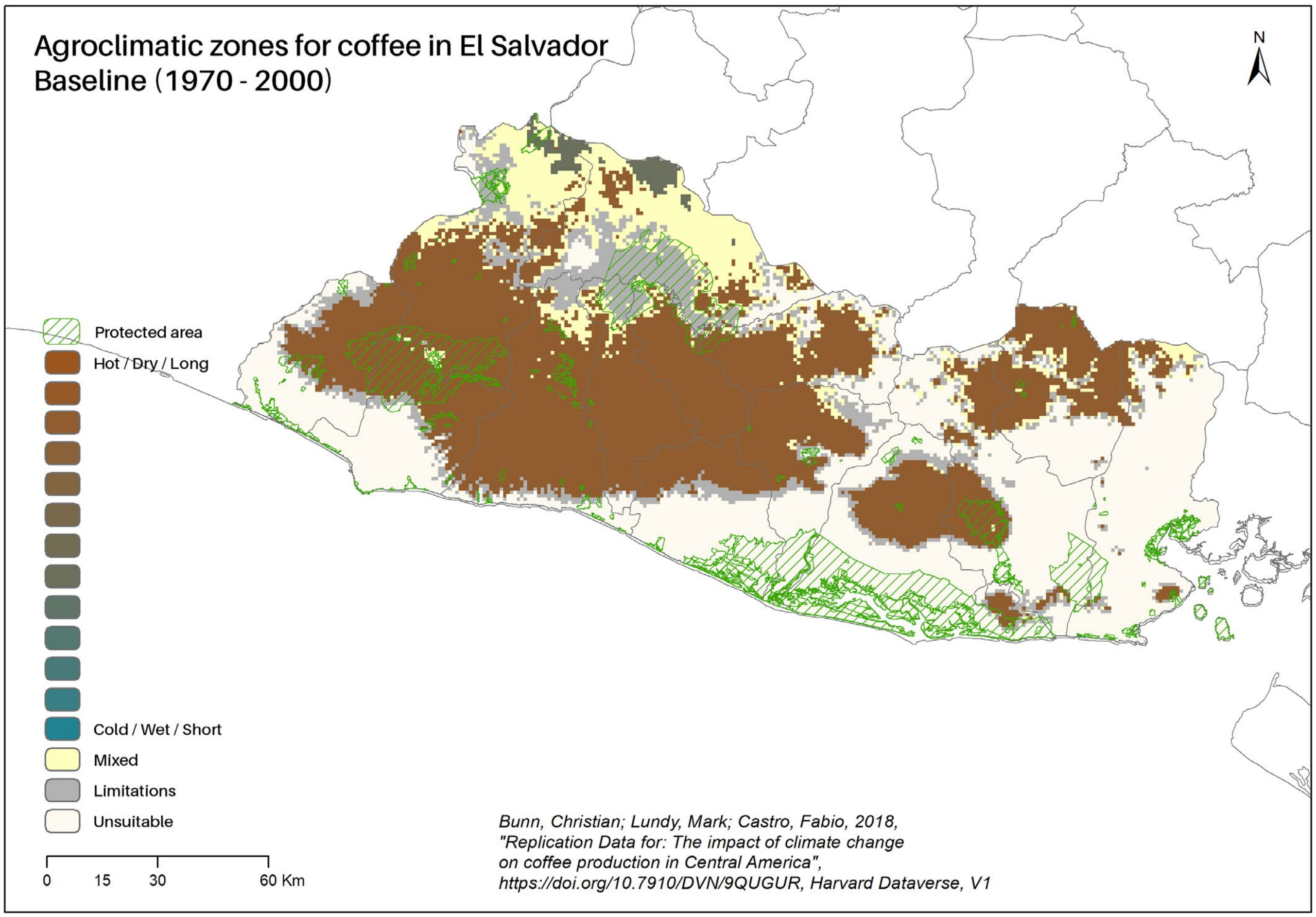
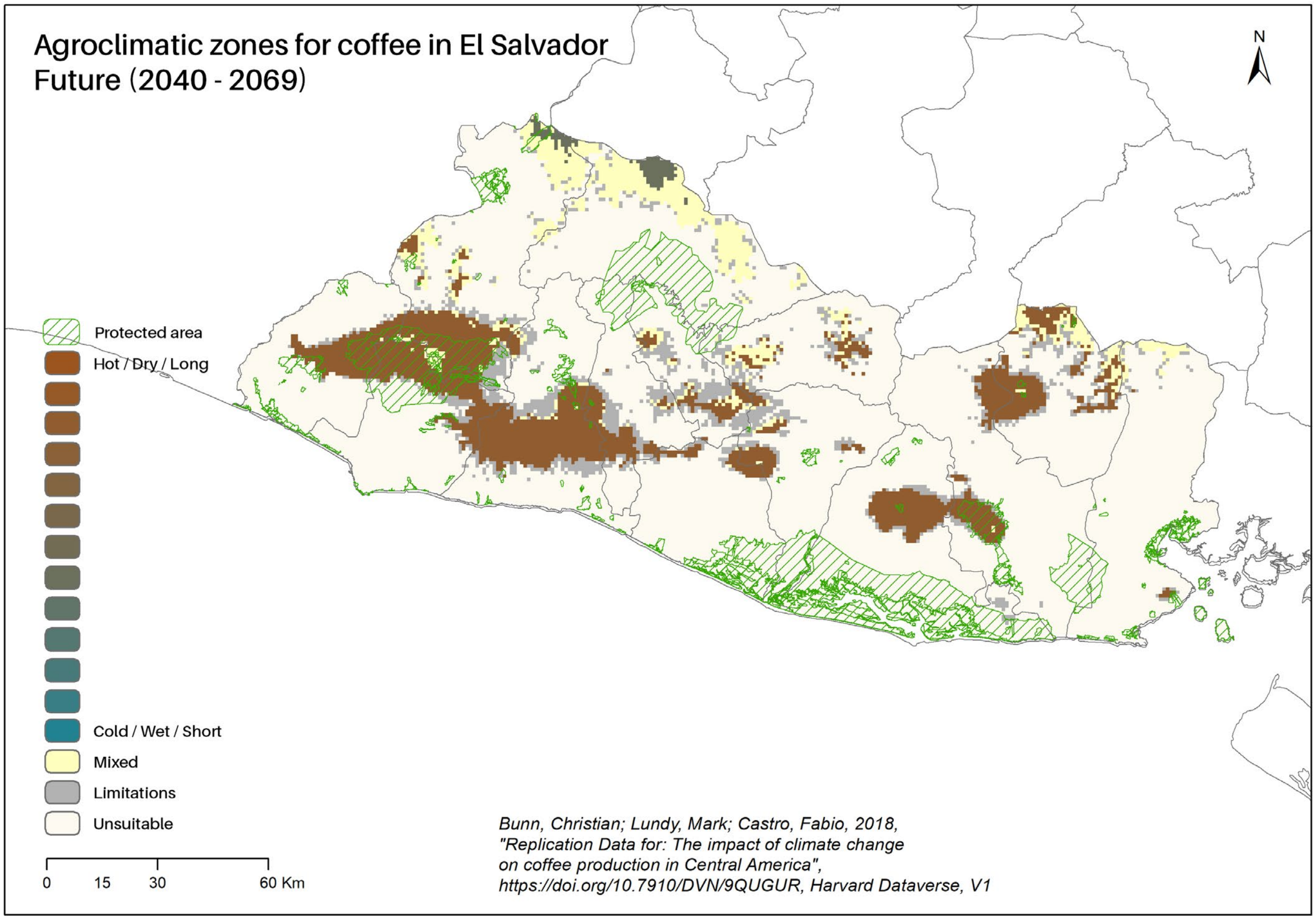
on coffee production in Central America",
https://doi.org/10.7910/DVN/9QUGUR, Harvard Dataverse, V1

El Salvador

El Salvador is perhaps the country with the largest percent of suitable area, relative to its size. For coffee production, the baseline shows hot suitable areas on the western part of the country. In the future, however, the zones show a considerable reduction of area and only a few points with suitability will be left, as seen towards the southwestern and central part of the country.




Agroclimatic zones for coffee in El Salvador
Future (2040 - 2069)
N
Protected area
Hot / Dry / Long
Cold / Wet / Short
Mixed
Limitations
Unsuitable
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15
30
60 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
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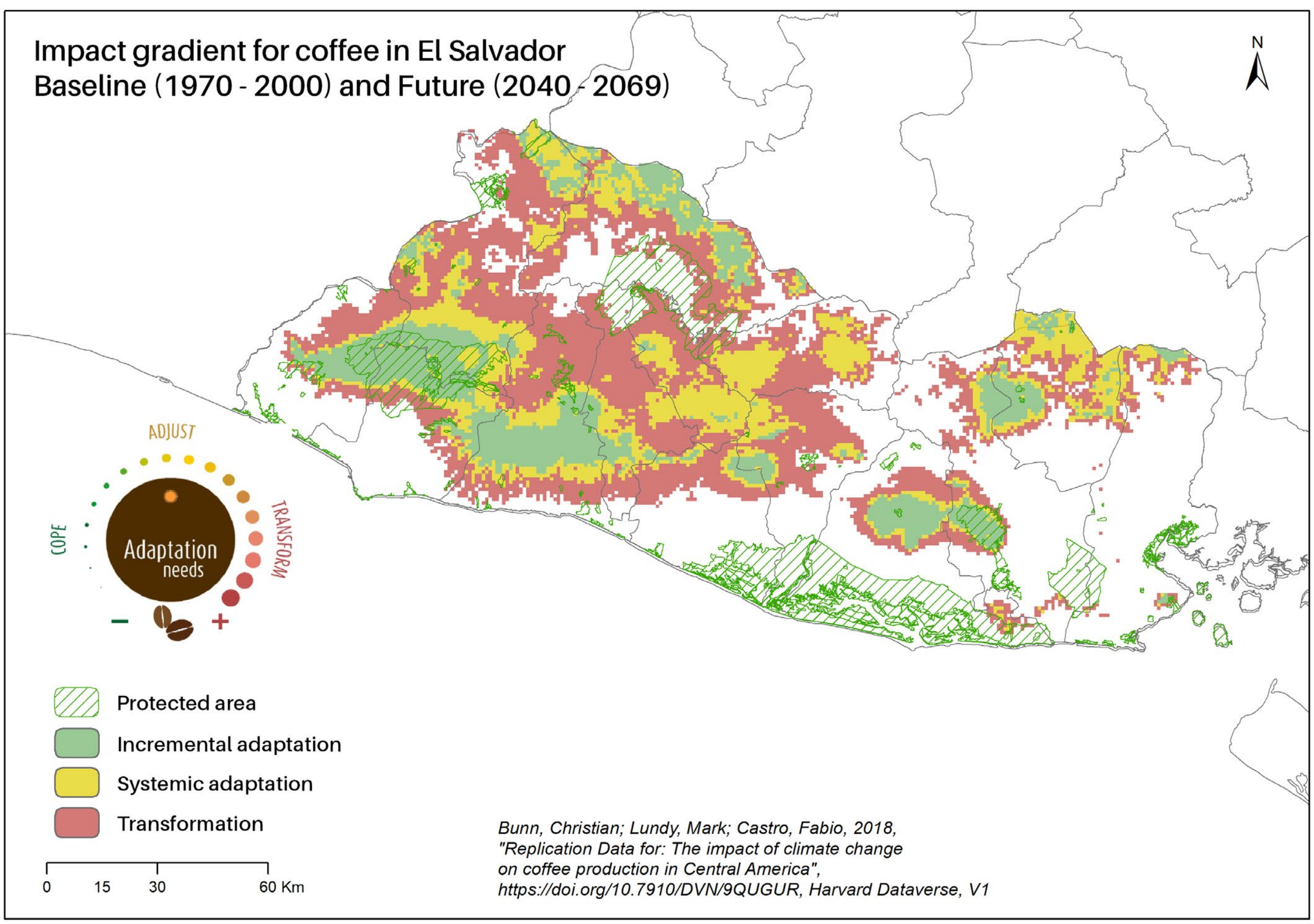
Impact gradient for coffee in El Salvador
Baseline (1970 - 2000) and Future (2040 - 2069)
N
ADJUST
COPE
TRANSFORM
Adaptation
needs
–
+
Protected area
Incremental adaptation
Systemic adaptation
Transformation
0
15
30
60 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
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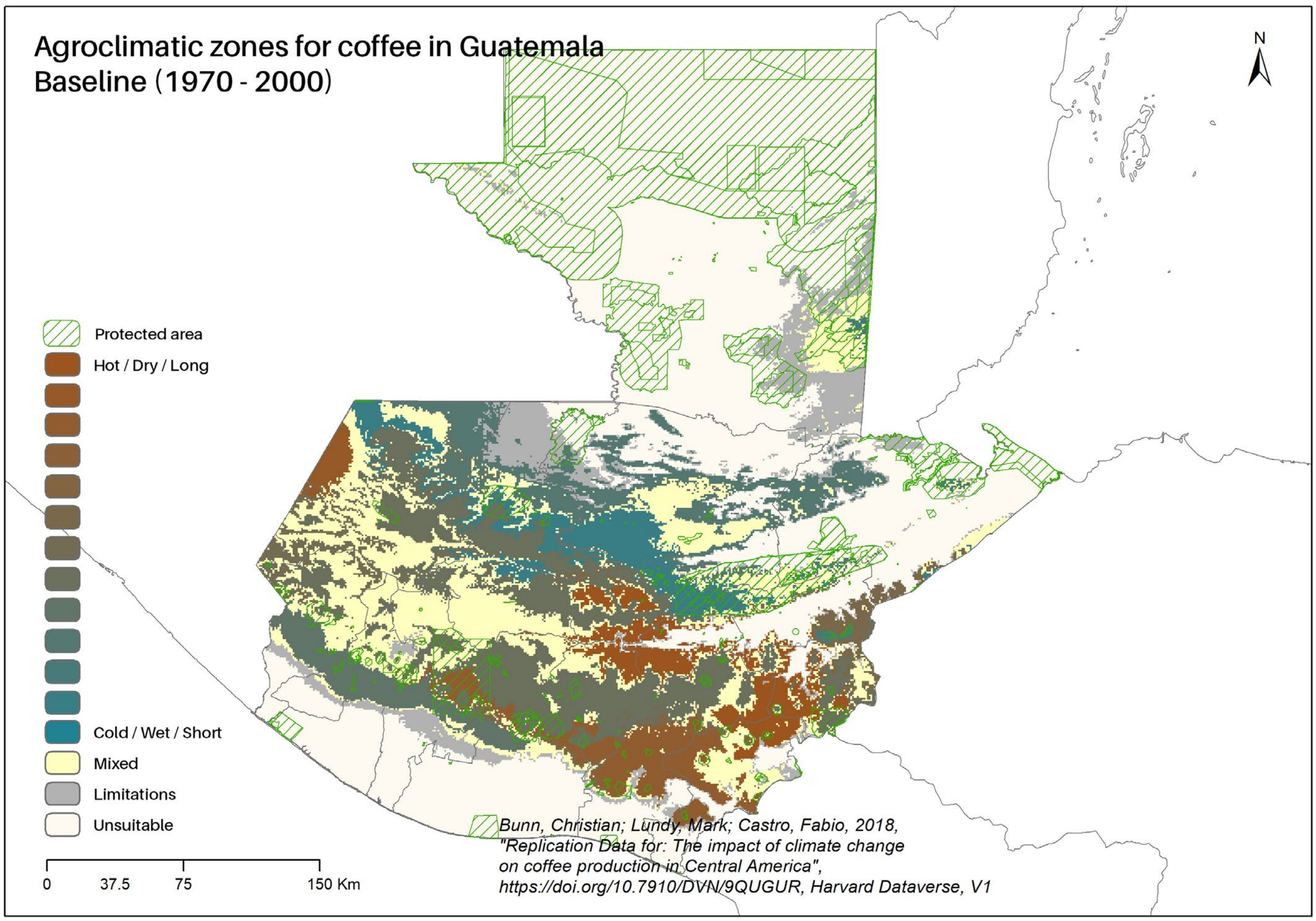
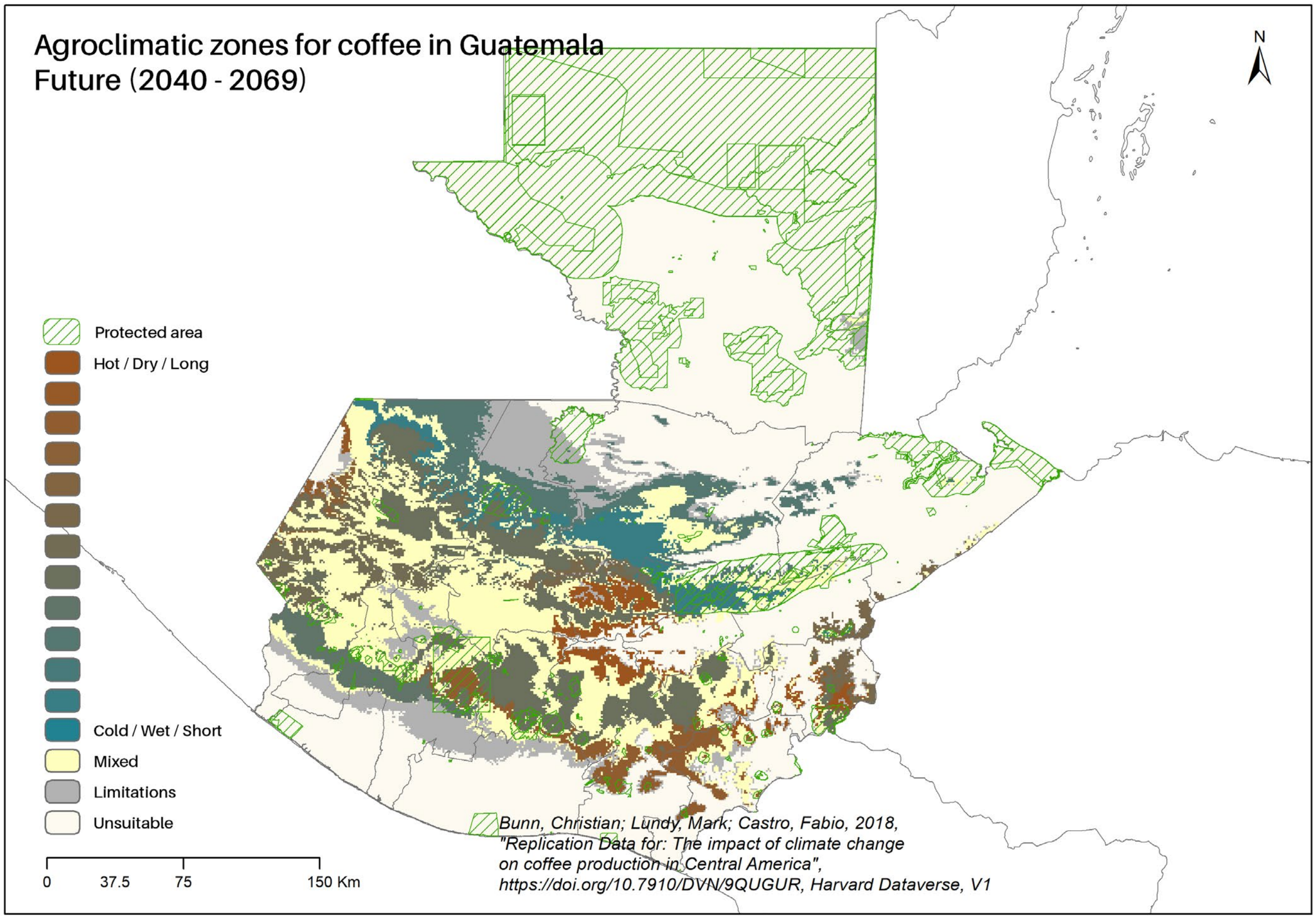
Guatemala

In the baseline, suitable zones are located mainly to the west of the country. Agroclimatic zones vary from hot-dry to cold-wet areas. Areas in the north of the country are not suitable for coffee production. In the future, suitability will be reduced and mixed areas and areas with limitations will increase in size. Therefore, adaptation efforts or the impact gradient are mostly systemic and incremental. On the borders, adaptation efforts are transformational.




Agroclimatic zones for coffee in Guatemala
Future (2040 - 2069)
N
Protected area
Hot / Dry / Long
Cold / Wet / Short
Mixed
Limitations
Unsuitable
0
37.5
75
150 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
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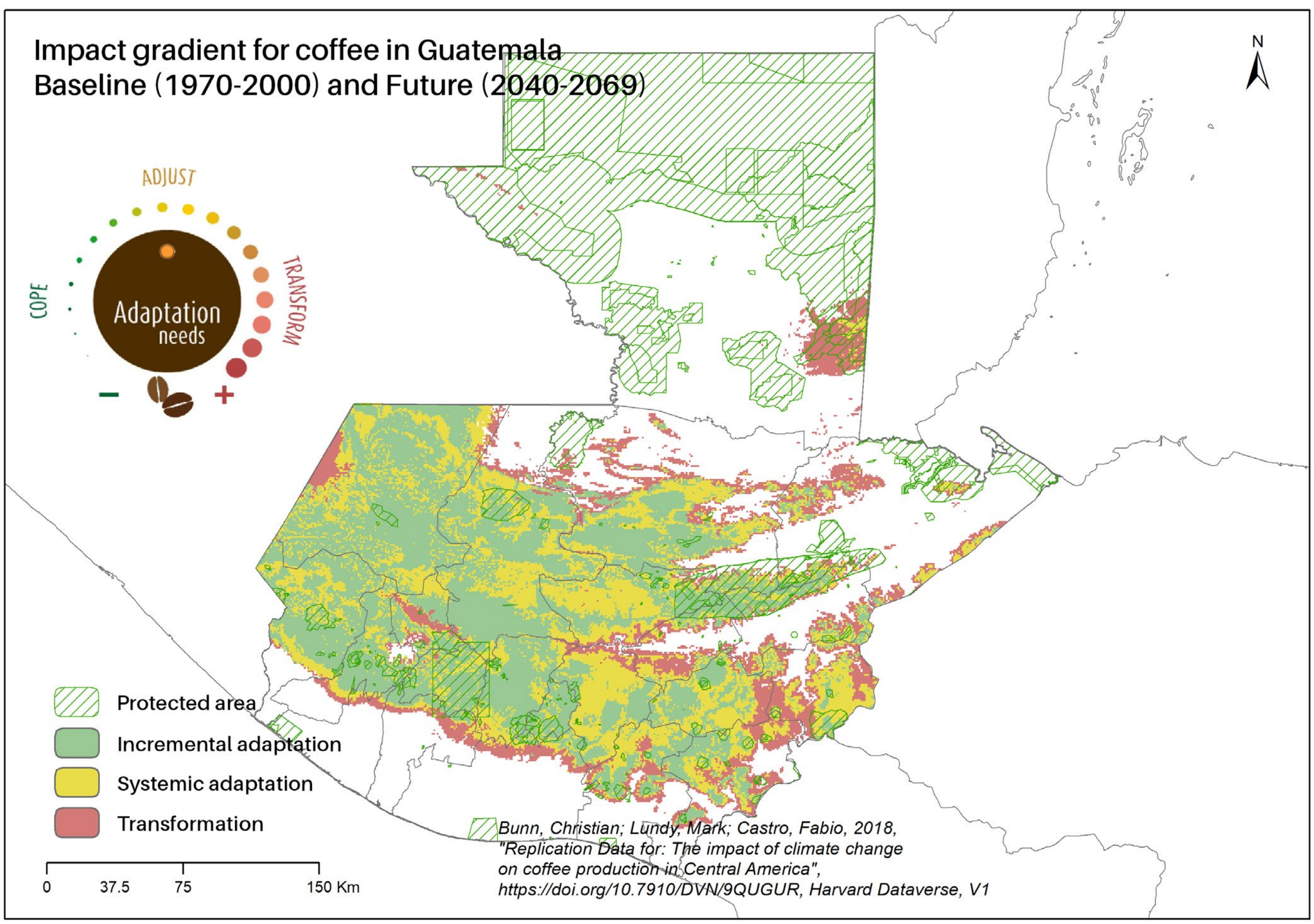
Impact gradient for coffee in Guatemala
Baseline (1970-2000) and Future (2040-2069)
N
ADJUST
COPE
TRANSFORM
Adaptation
needs
−
+
Protected area
Incremental adaptation
Systemic adaptation
Transformation
0
37.5
75
150 Km
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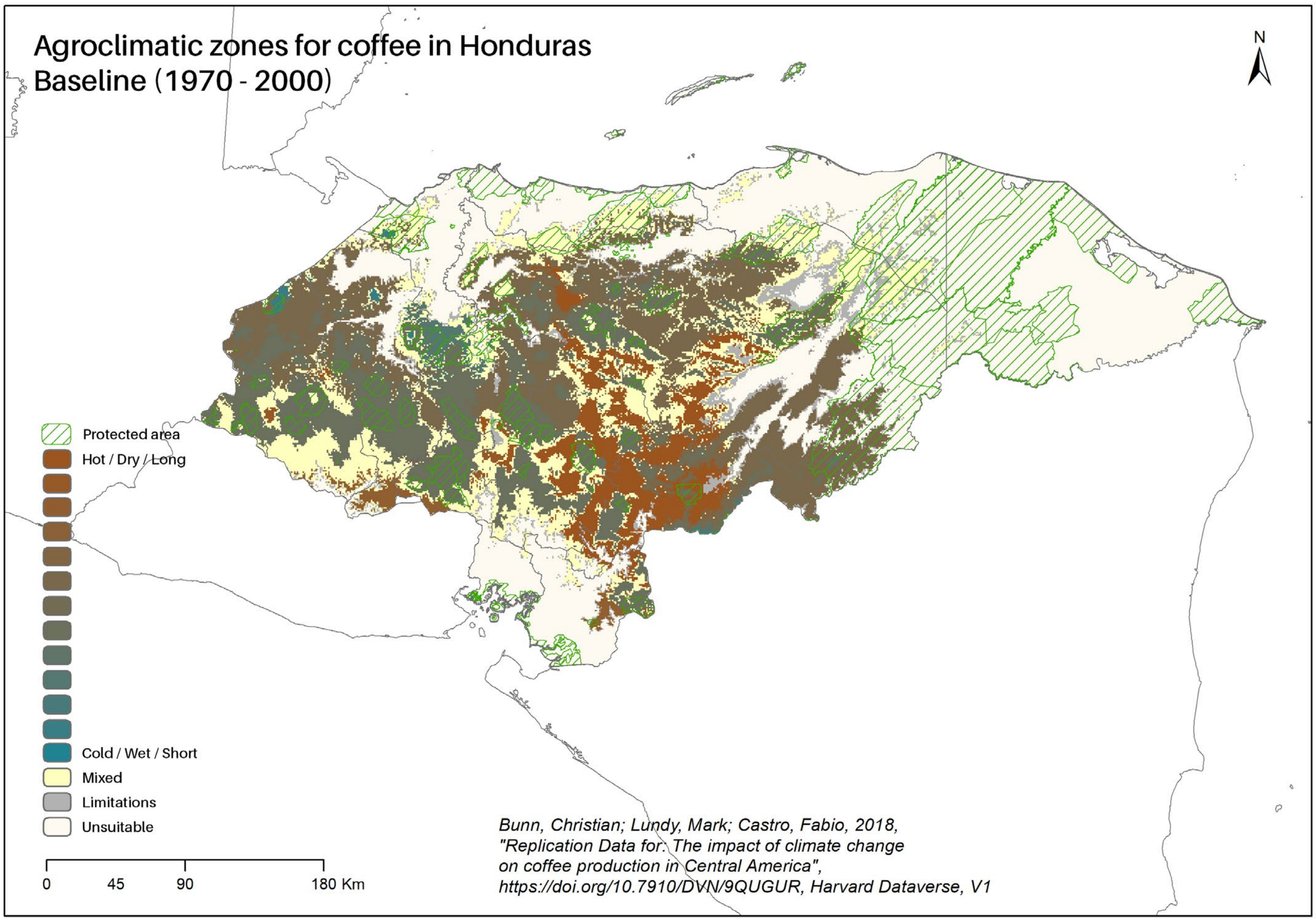
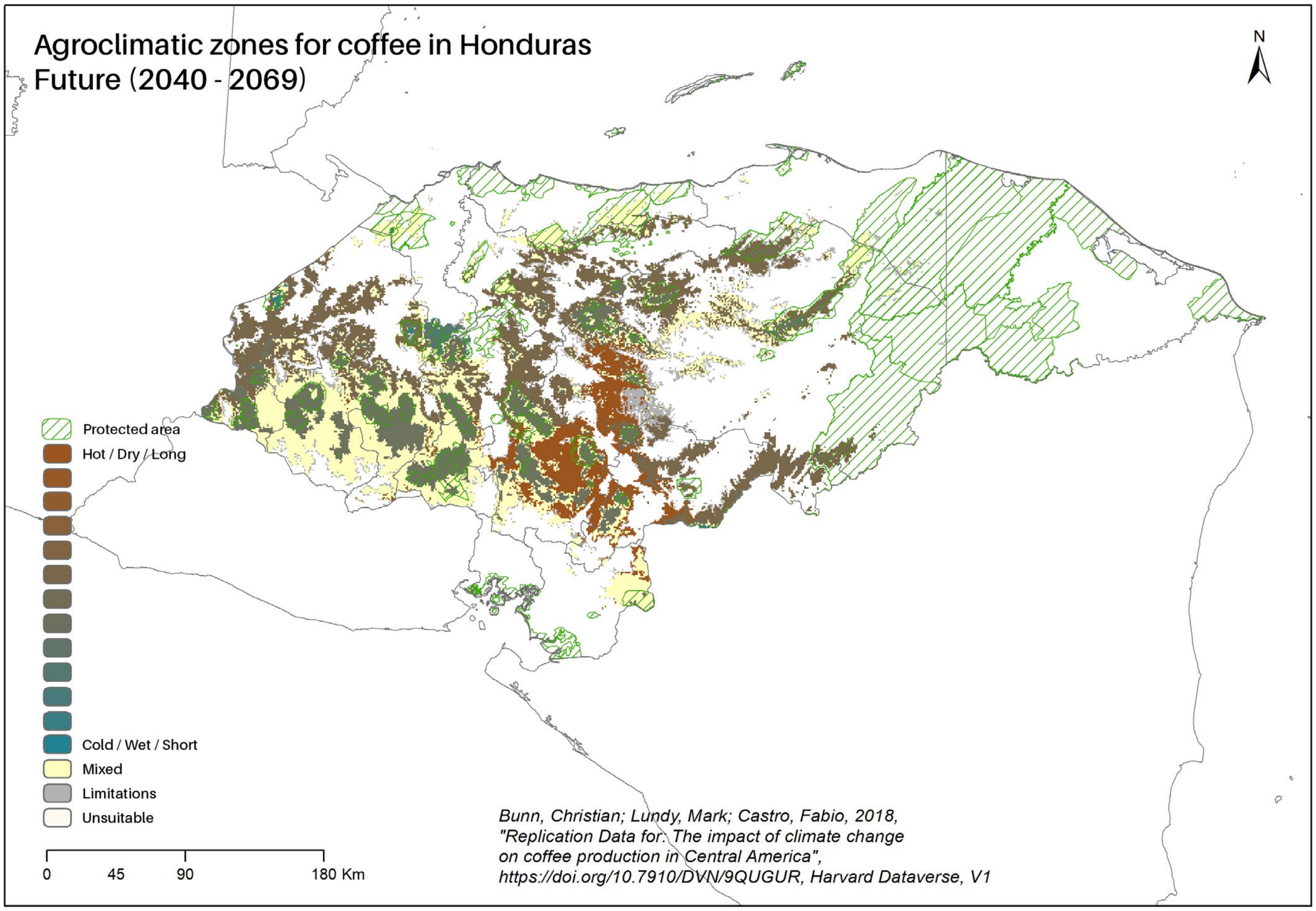
Honduras

Honduras presents hot suitable zones to a larger extent, particularly in the central and western part of the country. In the future, a substantial reduction of suitable areas is expected, with a high presence of mixed zones. The impact gradient shows mostly systemic adaptation efforts around incremental and transformational zones.





Agroclimatic zones for coffee in Honduras
Future (2040 - 2069)
N
Protected area
Hot / Dry / Long
Cold / Wet / Short
Mixed
Limitations
Unsuitable
0
45
90
180 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
"Replication Data for: The impact of climate change
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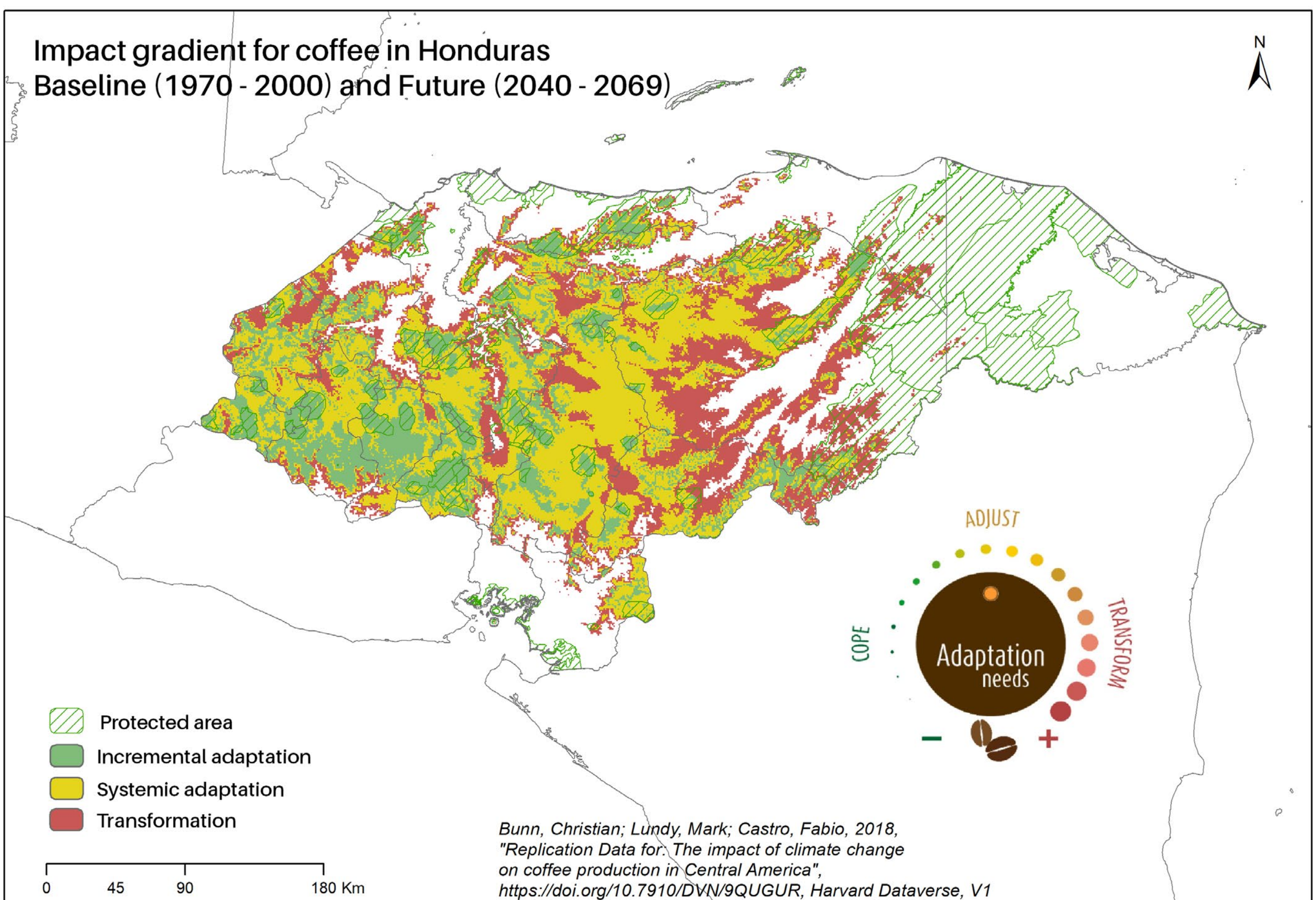
https://doi.org/10.7910/DVN/9QUGUR, Harvard Dataverse, V1



Impact gradient for coffee in Honduras
Baseline (1970 - 2000) and Future (2040 - 2069)
N
ADJUST
COPE
TRANSFORM
Adaptation
needs
−
+
Protected area
Incremental adaptation
Systemic adaptation
Transformation
0
45
90
180 Km
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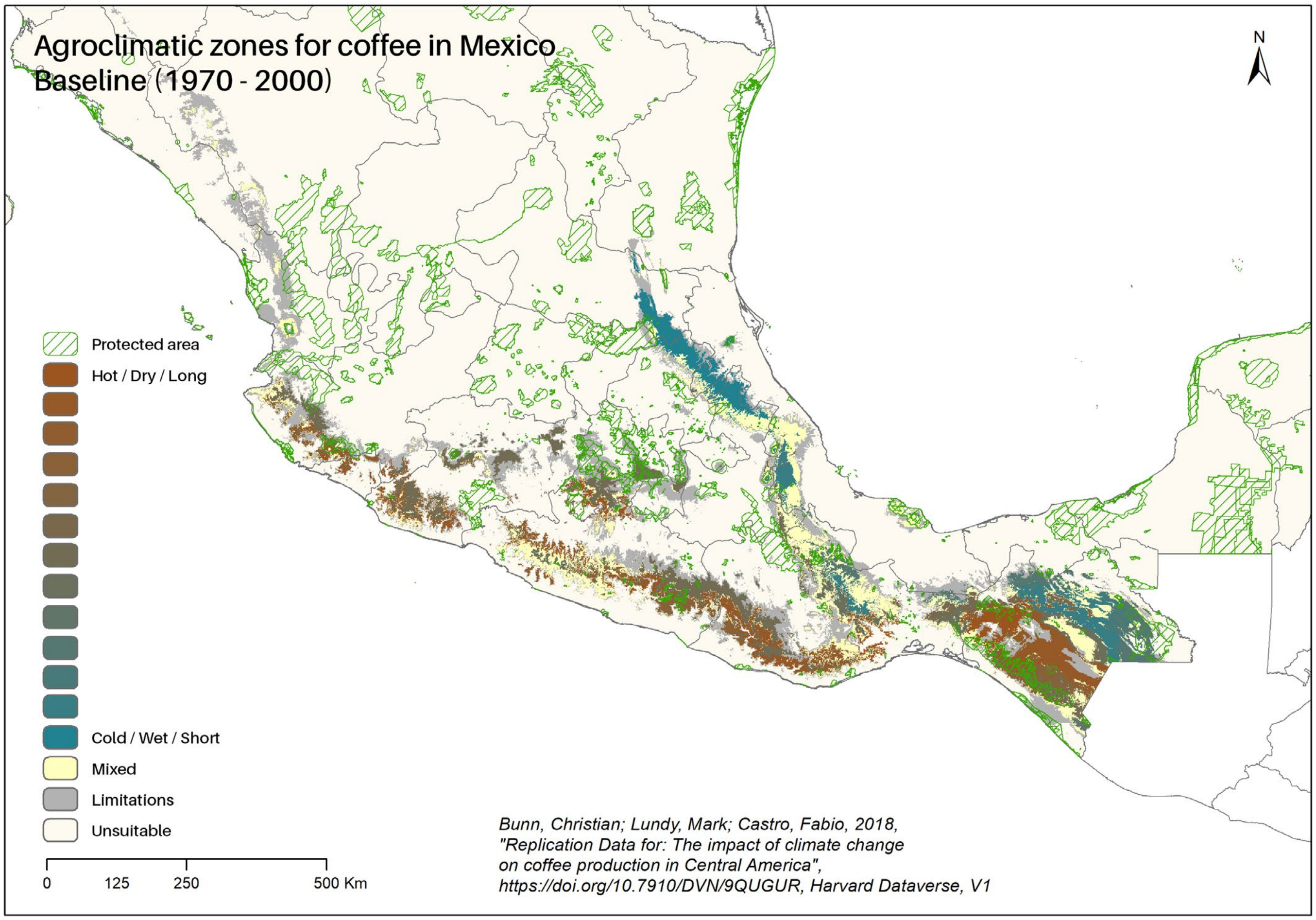
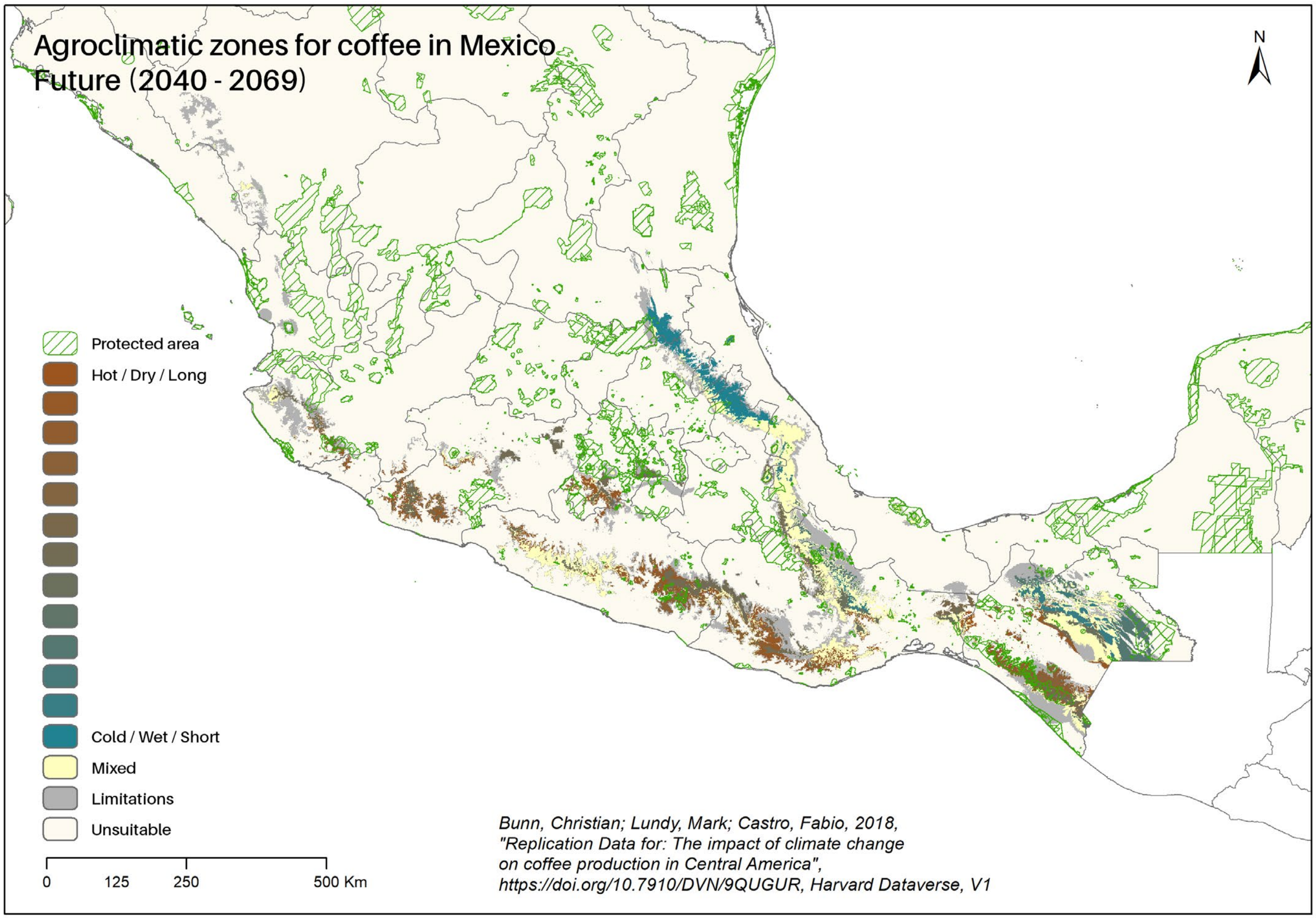
https://doi.org/10.7910/DVN/9QUGUR, Harvard Dataverse, V1

Mexico

In Mexico, suitable zones show small areas in the baseline. Currently, there is a corridor in the southwest of the country, close to the Pacific Ocean, as well as a suitability core on the border with Guatemala. A certain degree of reduction is observed in these zones in the future.





Agroclimatic zones for coffee in Mexico
Future (2040 - 2069)
N
Protected area
Hot / Dry / Long
Cold / Wet / Short
Mixed
Limitations
Unsuitable
0
125
250
500 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
"Replication Data for: The impact of climate change
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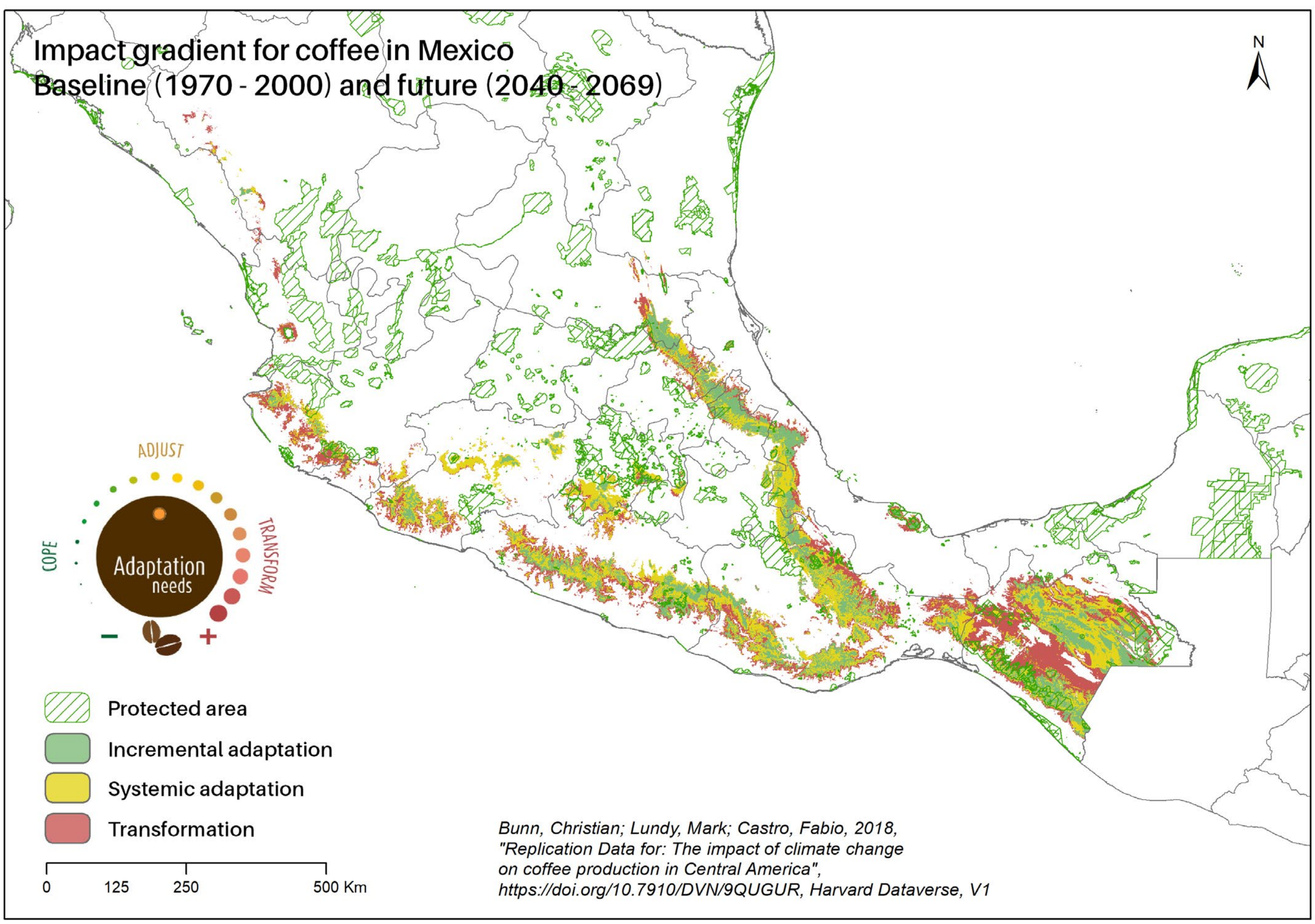

Impact gradient for coffee in Mexico
Baseline (1970 - 2000) and future (2040 - 2069)
N
ADJUST
COPE
TRANSFORM
Adaptation
needs
–
+
Protected area
Incremental adaptation
Systemic adaptation
Transformation
0
125
250
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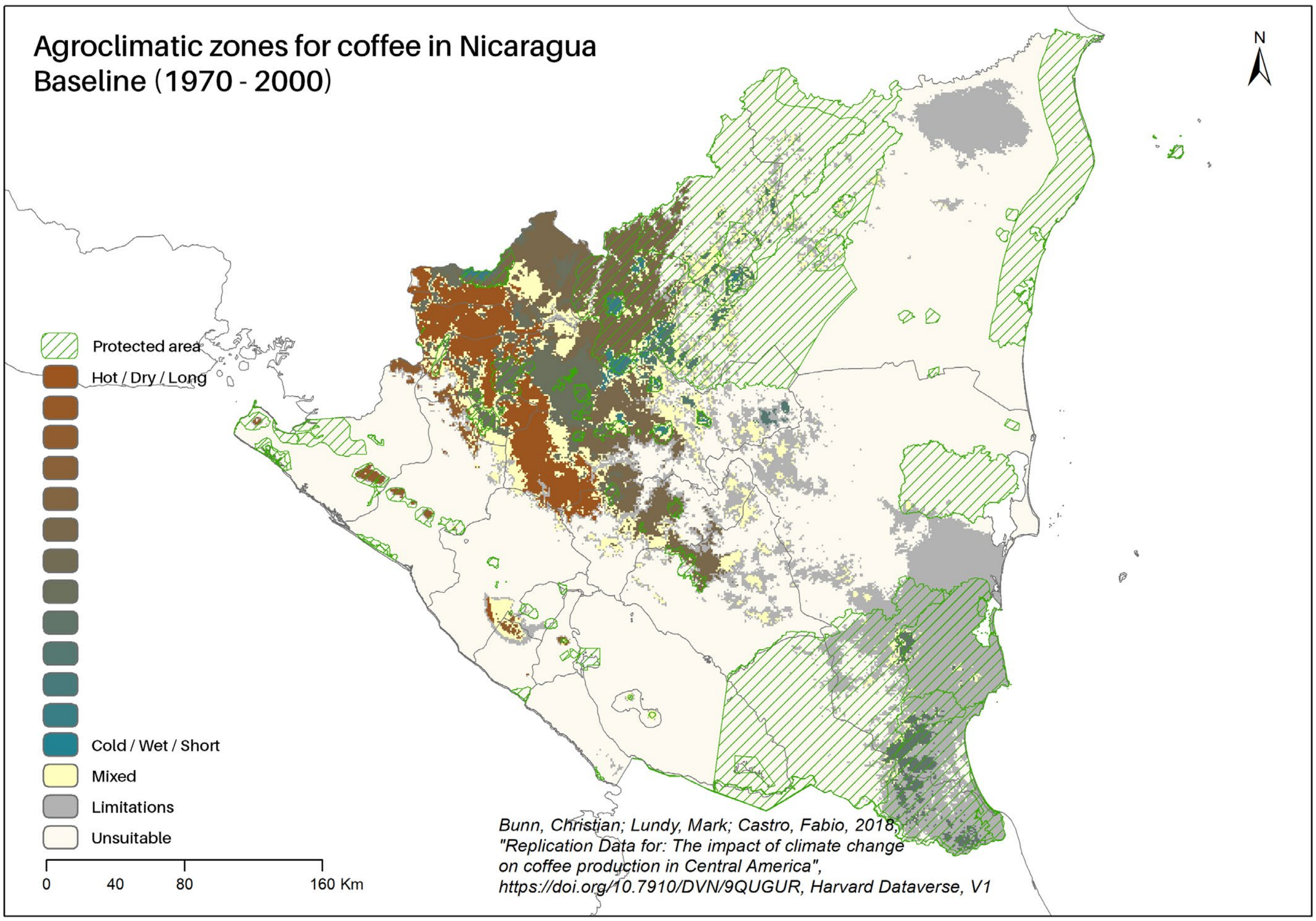
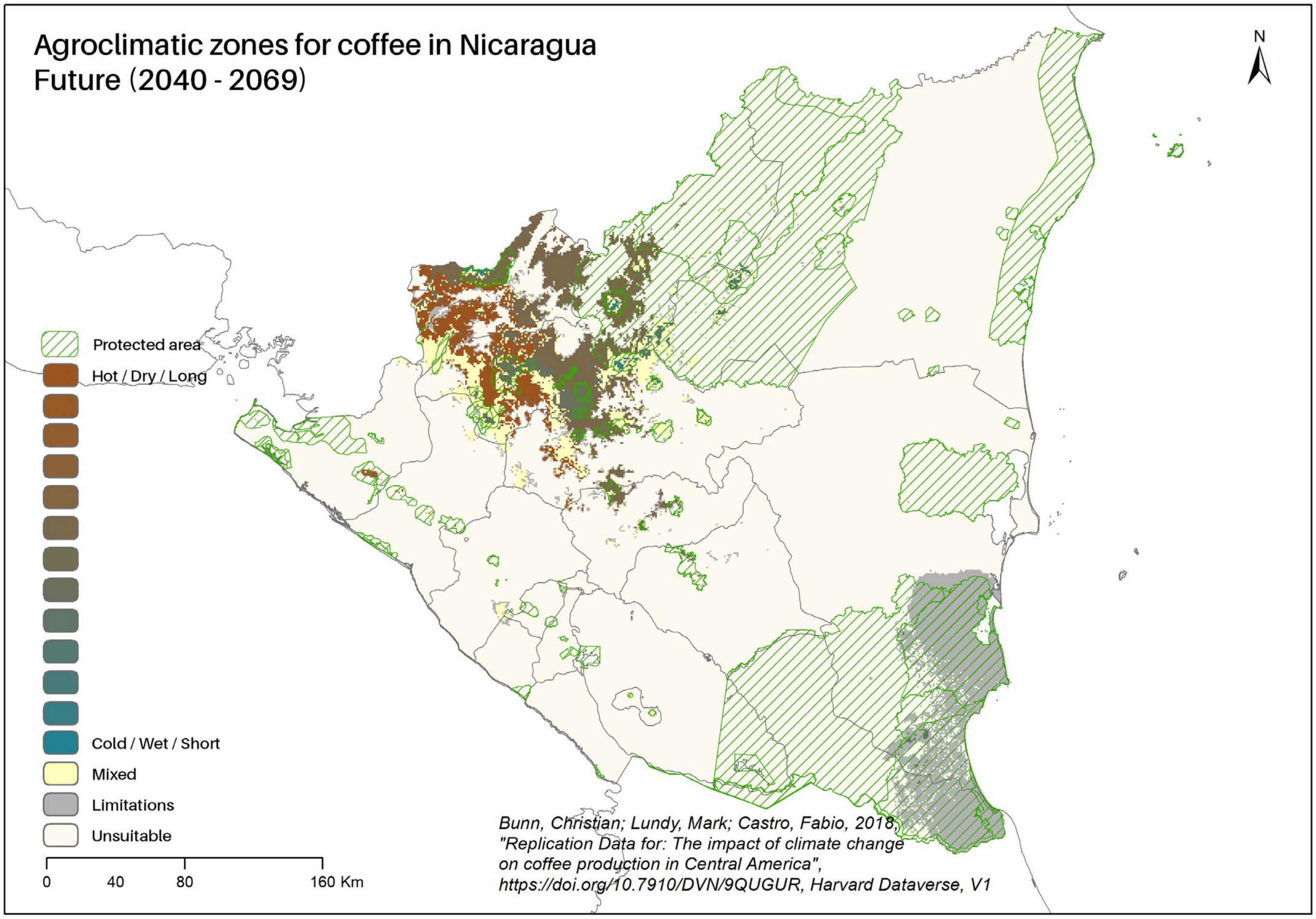
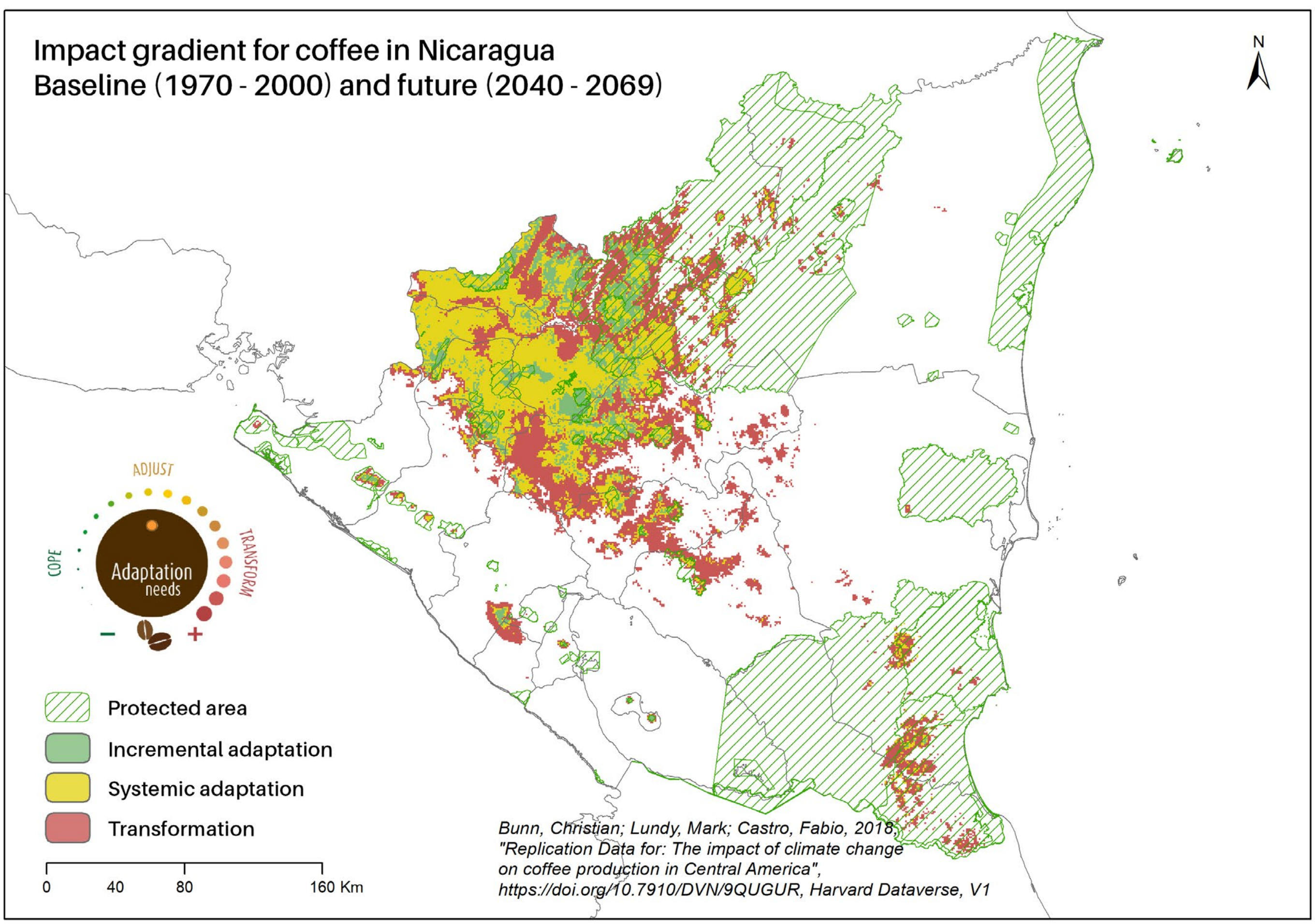
Nicaragua

Suitable zones for coffee production in the country are divided into sectors. Mostly hot and dry suitable areas are observed in the north. In the future, a considerable reduction of such areas is observed; therefore transformational or systemic adaptation is recommended to mitigate the effects of climate change.

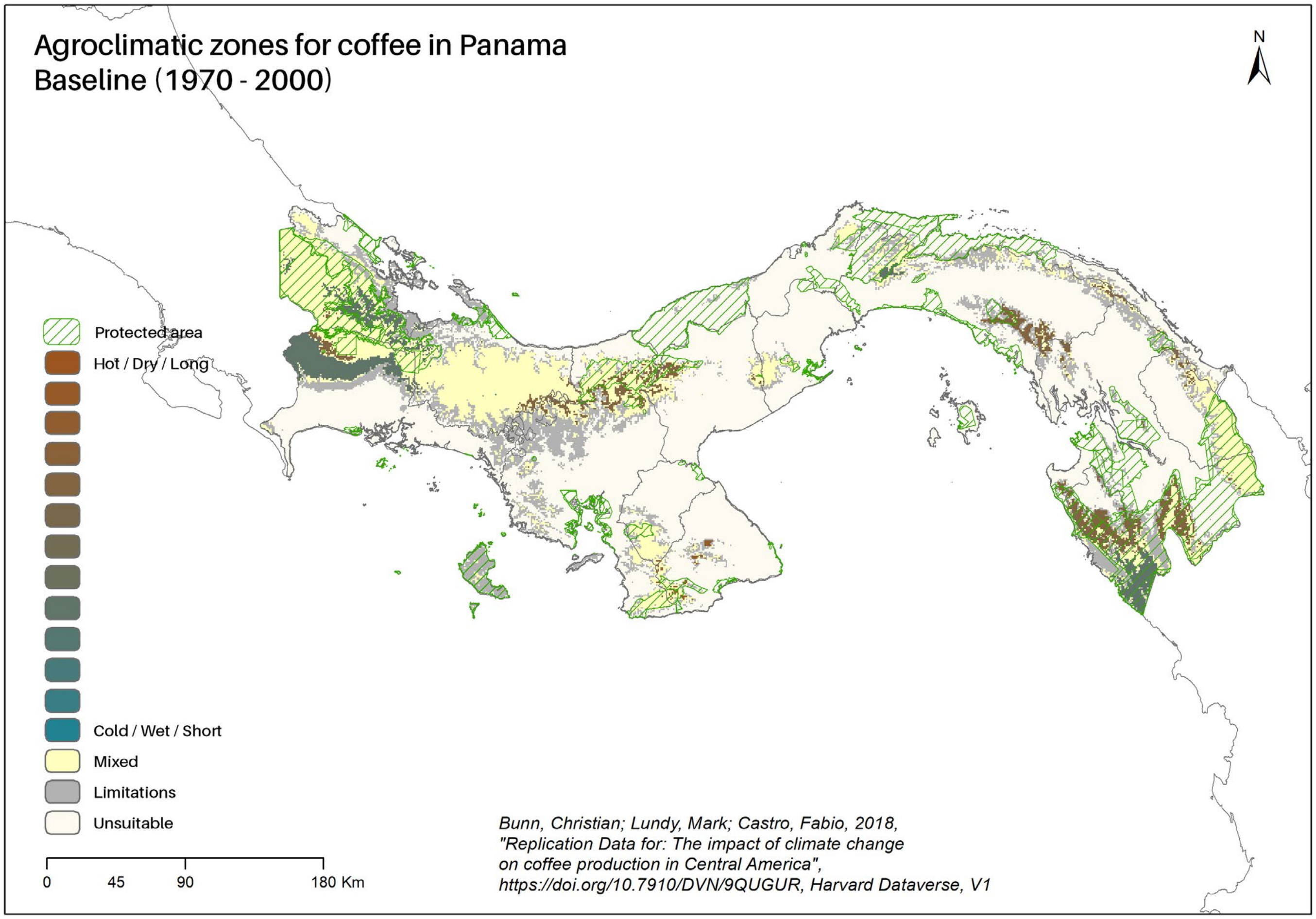


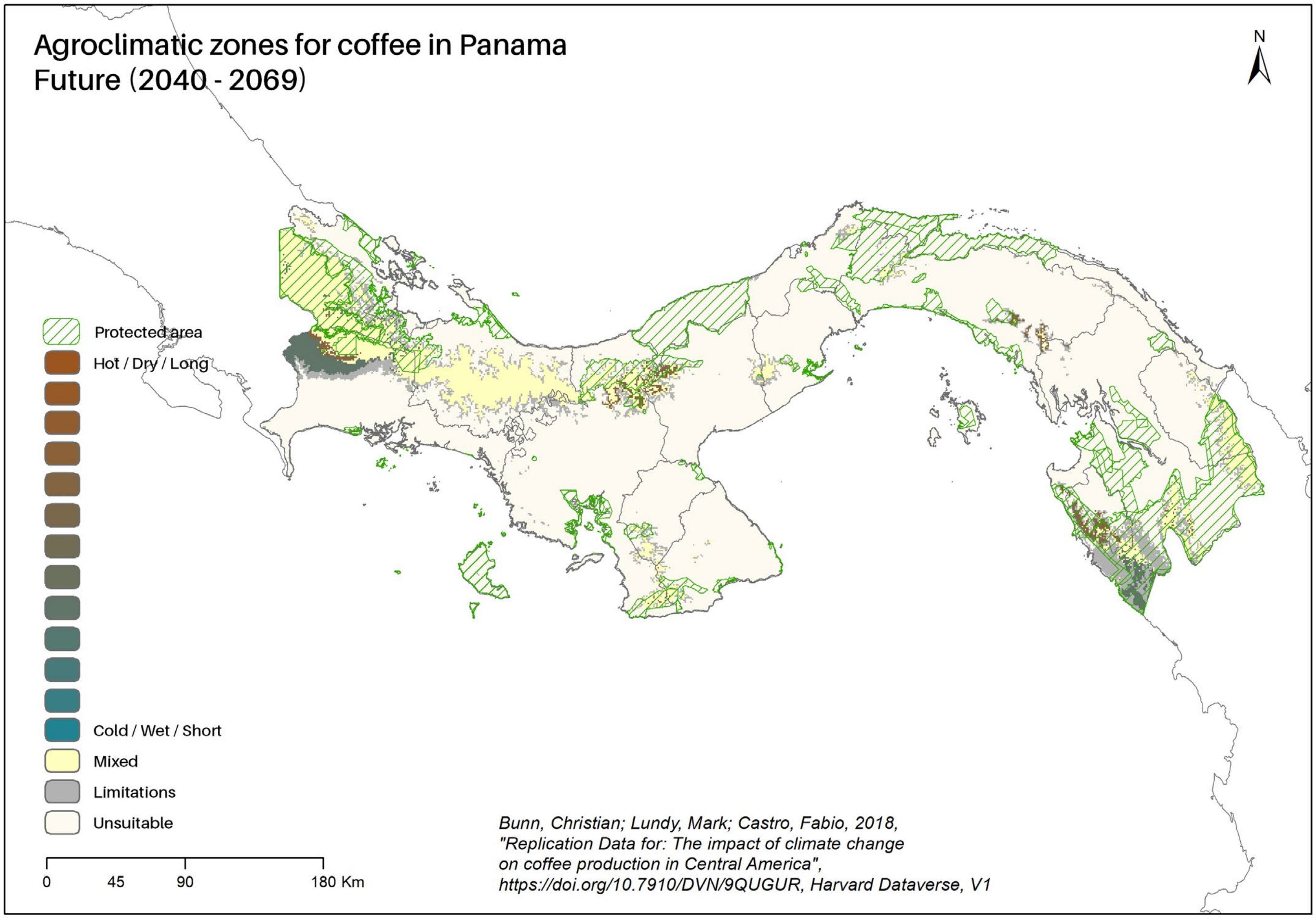

Agroclimatic zones for coffee in Nicaragua
Future (2040 - 2069)
N
Protected area
Hot / Dry / Long
Cold / Wet / Short
Mixed
Limitations
Unsuitable
0
40
80
160 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
"Replication Data for: The impact of climate change
on coffee production in Central America",
https://doi.org/10.7910/DVN/9QUGUR, Harvard Dataverse, V1

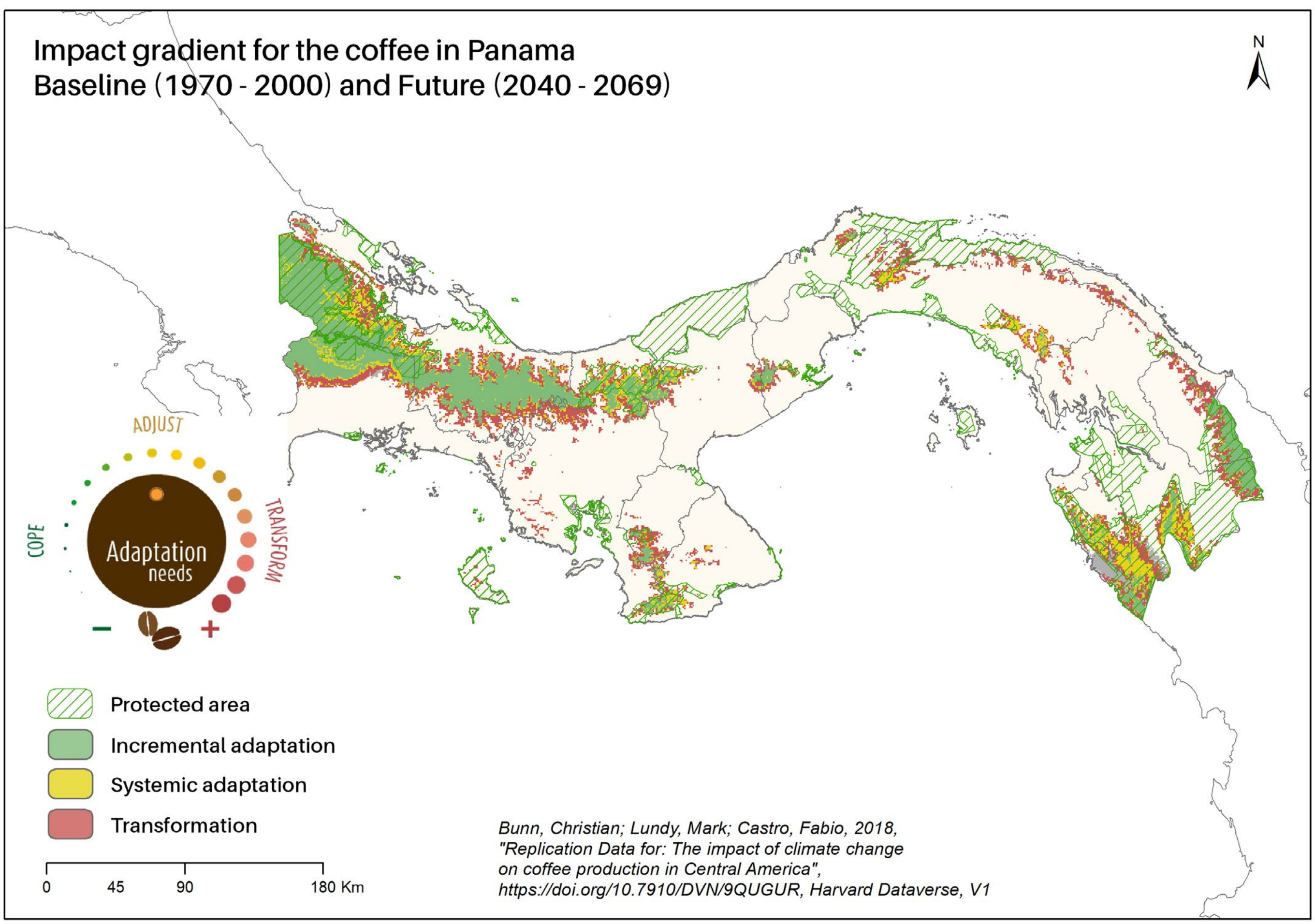

Impact gradient for coffee in Nicaragua
Baseline (1970 - 2000) and future (2040 - 2069)
N
ADJUST
COPE
TRANSFORM
Adaptation
needs
–
+
Protected area
Incremental adaptation
Systemic adaptation
Transformation
0
40
80
160 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
"Replication Data for: The impact of climate change
on coffee production in Central America",
https://doi.org/10.7910/DVN/9QUGUR, Harvard Dataverse, V1

Panamá

In the baseline, the country shows mainly suitable zones with cold / wet climate on the border with Colombia and Costa Rica. Zones are mostly mixed and with limitations. In the future, agroclimatic zones are mainly mixed and with limitations. It is thus recommended to conduct an incremental and transformational adaptation.




Agroclimatic zones for coffee in Panama
Future (2040 - 2069)
N
Protected area
Hot / Dry / Long
Cold / Wet / Short
Mixed
Limitations
Unsuitable
0
45
90
180 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
"Replication Data for: The impact of climate change
on coffee production in Central America",
https://doi.org/10.7910/DVN/9QUGUR, Harvard Dataverse, V1


Impact gradient for the coffee in Panama
Baseline (1970 - 2000) and Future (2040 - 2069)
N
ADJUST
COPE
TRANSFORM
Adaptation
needs
–
+
Protected area
Incremental adaptation
Systemic adaptation
Transformation
0
45
90
180 Km
Bunn, Christian; Lundy, Mark; Castro, Fabio, 2018,
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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 gases (GHGs), 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 coffee 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 coffee under present conditions 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 coffee is currently grown. Second, we interpolated monthly climate means of the 1950–2000 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 coffee suitability were detected within the occurrence data. These clusters can be interpreted as different climate zones that allow growing coffee, 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 coffee. 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 coffee production are projected to remain unchanged. **Systemic Adaptation** is where climate conditions for coffee 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 coffee 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 coffee. 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 support from Fabio Castro-Llanos. **Contact:** cbunn@cgiar.org

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The icon on the maps is a "Setting" adaptation by Juan Pablo Bravo, The Noun Project.