WFP
World Food Programme

SAVING LIVES
CHANGING LIVES

Assessing the Potential for Anticipatory Action for Drought in Belize

July 2025

Contents

ABOUT THE WORLD FOOD PROGRAMME **4**

ACKNOWLEDGEMENTS **4**

1. INTRODUCTION **5**

2. AGRICULTURAL CONTEXT AND CLIMATE RISKS IN BELIZE **7**

2.1 Agriculture and Livelihoods in Belize 7
2.2 Climate Risks and Impacts 7
2.3 Observed Climate Trends 8
2.4 Area of Study 9
2.5 Climate in Belize 11
2.6. Expected climate change in Belize 14
2.7 Historical Climate Trends 15

3. AGRICULTURAL LIVELIHOODS AND CLIMATE-SENSITIVE PERIODS: INSIGHTS FROM FARMERS **17**

3.1. Community mapping and agroclimatic calendars 17

4. SEASONAL FORECASTING AND OPPORTUNITIES FOR ANTICIPATORY ACTION **25**

4.1 Forecasting Models and Methods 25
4.2 Methods for Assessing Forecast Predictive Skills 25
4.3 Which system to use in Belize for better predictive skill? 26
4.4 Recommended Operational Forecasts to link to Anticipatory Actions 32

5. DESIGNING AN ANTICIPATORY ACTION FRAMEWORK FOR DROUGHT **34**

5.1 Using Agroclimatic Calendars and Forecasts to Define Triggers 34
5.2 Prioritizing and Tailoring Anticipatory Actions 34
5.3 Conclusion and Looking Ahead 35

REFERENCES **36**

PHOTO CREDITS **37**

ANNEX I **38**

FIGURE 1. SUGAR CANE PLANTATION IN COROZAL 10
FIGURE 2. MONTHLY CLIMATOLOGICAL CHARTS FOR COROZAL, ORANGE WALK, AND CAYO 12
FIGURE 3. DEFICITARY YEARS...13
FIGURE 4. DEFICITARY YEARS...13
FIGURE 5. DEFICITARY YEARS...13
FIGURE 6. FUTURE EXPECTED PRECIPITATION CHANGES BY 2100...15
FIGURE 7. ACCUMULATED PRECIPITATION | JUNE-AUGUST | COROZAL...16
FIGURE 8. ACCUMULATED PRECIPITATION | AUGUST-OCTOBER | COROZAL 16
FIGURE 9. COMMUNITY MAPPING OF CROPS IN COROZAL 18
FIGURE 10. AGRICULTURALISTS PREPARING AGROCLIMATIC CALENDARS...19
FIGURE 11. AGROCLIMATIC CALENDARS OF CORN AND GRASS FOR FEED IN COROZAL (DIFFERENT FARMERS).............20
FIGURE 12. AGROCLIMATIC CALENDARS OF CORN IN ORANGE WALK (DIFFERENT FARMERS) 21
FIGURE 13. AGROCLIMATIC CALENDARS FOR GRASS FOR FEED IN ORANGE WALK (DIFFERENT FARMERS)....................22
FIGURE 14. AGROCLIMATIC CALENDARS FOR CORN IN CAYO (DIFFERENT FARMERS)...23
FIGURE 15. AGROCLIMATIC CALENDARS FOR BEANS IN CAYO (DIFFERENT FARMERS) 24
FIGURE 16. ASSESSMENT OF PREDICTIVE SKILL FOR JUNE-JULY-AUGUST SEASON (ONE-MONTH LEAD) 27
FIGURE 17. ASSESSMENT OF PREDICTIVE SKILL FOR JUNE-JULY-AUGUST SEASON (TWO-MONTH LEAD) 28
FIGURE 18. ASSESSMENT OF PREDICTIVE SKILL FOR JUNE-JULY-AUGUST SEASON (THREE-MONTH LEAD).....................29
FIGURE 19. ASSESSMENT OF PREDICTIVE SKILL FOR JUNE-JULY-AUGUST SEASON (FOUR-MONTH LEAD) 30
FIGURE 20. ASSESSMENT OF PREDICTIVE SKILL FOR JUNE-JULY-AUGUST SEASON (FIVE-MONTH LEAD) 31
FIGURE 21. PREDICTIVE SKILL OF SEASONAL PRECIPITATION FORECAST FOR THE JUNE-JULY-AUGUST (JJA) SEASON INITIALIZED IN MAY...32
FIGURE 22. PREDICTIVE SKILL OF SEASONAL PRECIPITATION FORECAST FOR THE JUNE-JULY-AUGUST (JJA) SEASON INITIALIZED IN APRIL 32
FIGURE 23. PREDICTIVE SKILL OF SEASONAL PRECIPITATION FORECAST FOR THE JUNE-JULY-AUGUST (JJA) SEASON INITIALIZED IN MARCH 32

About the World Food Programme

Reaching nearly 150 million people in over 120 countries each year, the World Food Programme is the world's largest humanitarian organization saving lives in emergencies and using food assistance to build a pathway to peace, stability and prosperity, for people recovering from conflict, disasters and the impact of climate change.

The WFP Caribbean Multi-Country Office works with national, regional and international partners to strengthen the region's resilience to the climate crisis, and other risks. WFP adopts a systems-focused approach as part of its capacity strengthening efforts through research and advocacy, digitalization, human resource development, south-south cooperation, and by investing in critical infrastructure and assets. WFP works with partners to provide direct assistance to populations impacted by shocks when events surpass national and regional capacities.

These investments place the most vulnerable people at the centre of efforts to minimize the combined impacts of climate, economic and other shocks on the Caribbean. WFP Caribbean's multi-country strategic plan supports 22 countries and territories across the English- and Dutch-speaking Caribbean through leveraging its expertise in vulnerability analysis and mapping; end-to-end supply chain management; shock-responsive social protection; food systems strengthening and climate risk financing.

Acknowledgements

The report was prepared by the WFP Caribbean Multi-Country Office. It was written by Diego Pons, Greta Aubke and Sarah Bailey.

Thanks to the Ministry of Agriculture, Food Security and Enterprise and the National Meteorological Service of the Government of Belize for the engagement and support during the consultations. Special recognition to the farmers and communities who participated in the workshops.

WFP expresses its gratitude to the Government of Ireland, Global Affairs Canada, and the European Civil Protection and Humanitarian Aid Operations for their generous support.

1. Introduction

Belize's agricultural sector is a critical pillar of livelihoods, food security and the economy at both local and national levels. Yet, increasing climate variability and the rising frequency of extreme weather events are placing mounting pressure on the farming communities that sustain the country's rural economy. In particular, smallholder farmers, who form the backbone of Belize's agriculture, are highly vulnerable to drought-related impacts such as reduced yields, crop failure and income loss. These risks are compounded by broader climate change trends that are expected to increase the severity and frequency of droughts and other climate extremes in the region.

Anticipatory action offers a way to manage these risks before they escalate. It is an emerging approach that uses seasonal forecasts and early warning information to trigger preventive measures ahead of a shock. For drought-affected farmers, this could mean securing water for irrigation and livestock, receiving cash or inputs to support dry-season planting, or taking steps to reduce land degradation and preserve soil moisture, among other potential measures.

Experiences from neighbouring countries such as Guatemala and Honduras show that anticipatory action can reduce the impacts of drought on rural livelihoods when early support is well-timed and appropriate. In these settings, smallholder farmers have received assistance to better manage dry spells by using forecasts to activate simple, practical interventions that are feasible and backed by clear implementation mechanisms. There is an opportunity to build on regional experiences by tailoring anticipatory action to the climate context and agricultural systems in Belize.

Importantly, there is already has a foundation of experience in delivering innovative support to farmers in Belize to buffer shocks. Following Hurricane Lisa, the Ministry of Agriculture, Food Security and Enterprise (MAFSE) and the World Food Programme (WFP) partnered to provide affected farmers with cash transfers and vouchers via a digital wallet. This demonstrated capacity for timely, tailored assistance provides a strong platform for anticipatory action. By using climate forecasts to shift the timing of such support earlier, Belize can explore new and expanded options for protecting smallholder livelihoods before drought impacts fully materialize.

Designing effective anticipatory actions requires understanding when farmers are most vulnerable during the agricultural calendar and how reliable seasonal forecasts are in predicting drought conditions in Belize. Analysis to inform the feasibility of anticipatory action and a potential framework for it was carried out by WFP in partnership with MAFSE and the Belize National Meteorological Service. It explores how anticipatory action for drought could be developed and applied in Belize, with a focus on protecting smallholder farmers' livelihoods. Specifically, the report aims to answer three interlinked questions:

1. When are critical agricultural periods that are most vulnerable to drought, and what crops and farming practices are involved?

2. What is the reliability (or predictive skill) of seasonal climate forecasts to anticipate drought during these critical periods?

3. How can these insights be used to design practical anticipatory actions, including triggers that can activate early responses?

To address these questions, this report combines local knowledge gathered from farmers – through community mapping and agroclimatic calendars – with scientific analysis of seasonal climate forecasts. By bringing these perspectives together, the report lays the groundwork for an anticipatory action framework that is both technically sound and grounded in the realities of farming communities in Belize.

This work also contributes to WFP's broader efforts in the Caribbean to strengthen food security and resilience to climate shocks, including through collaboration with national partners to explore risk-informed and proactive approaches to disaster risk management.

The following sections outline the agricultural context and climate risks in Belize, present findings from community-based assessments of farming livelihoods, analyze the skill of seasonal forecasts, and propose a framework for defining anticipatory actions that could protect farmers ahead of drought events.

2. Agricultural Context and Climate Risks in Belize

2.1 Agriculture and Livelihoods in Belize

Belize has a diverse agricultural sector that plays a vital role in its economy and sustenance of its population. Agriculture is a cornerstone of Belize's economy, contributing significantly to GDP and employment. Key crops include sugarcane, citrus fruits, bananas, corn, beans, and rice. Livestock farming and fisheries also hold substantial importance. Belize's agriculture is, however, predominantly rainfed making it highly dependent on weather patterns. In addition to the weather extremes, the agricultural sector faces challenges such as fluctuating market prices, labour shortages and climate change. Smallholder farmers, who constitute 75 percent of the farming population, are particularly vulnerable to these challenges.[1]

2.2 Climate Risks and Impacts

The economic impacts of climate change in Belize are projected to be substantial. Historical data and future projections indicate that extreme weather events, such as hurricanes, floods, and droughts, has caused and will probably continue to cause significant damage. For example, the combined economic impacts of hurricanes from 2000 to 2020 exceeded $1 billion USD. Wildfires have been unprecedented in recent years according to the Global Fire Monitoring Center (GFMC). Future projections suggest that, without significant mitigation and adaptation efforts, the economic costs associated with climate variability and change impacts could reach several billion dollars by 2070.[2]

To mitigate the adverse effects of climate variability and change, a diverse toolbox of disaster management, risk reduction and adaptation strategies are needed, including anticipatory actions. The World Food Programme (WFP) has developed a range of strategies to reduce climate vulnerability in other countries, such as supporting early warning systems, climate-resilient agricultural practices, financial mechanisms like weather-index insurance and anticipatory action mechanisms.[3] These have proved successful in mitigating the damage caused by different climate extremes globally, and in adjacent countries such as Guatemala.[4]

Implementing tailored anticipatory actions can significantly enhance the resilience of Belize's agricultural sector and more particularly, smallholder farmers. Techniques such as drought-resistant crop varieties, improved irrigation systems, and sustainable land management practices can help

---

[1] FAO, European Union and CIRAD. 2022. *Food Systems Profile - Belize. Catalysing the sustainable and inclusive transformation of food systems*. Rome, Brussels and Montpellier, France.
[2] World Bank. 2024. *Belize climate data*.
[3] See WFP's Anticipatory Actions.
[4] WFP. 2023. *Acciones anticipatorias ante la sequía en el corredor seco de Guatemala*. Noticia de prensa.

stabilize production and ensure food security. By investing in these measures, Belize can protect its agricultural livelihoods from the increasing unpredictability of climate patterns.

To begin to work on anticipatory actions, a better understanding of farmer's needs for climate information is crucial. This necessitates a basic knowledge of the location of crops and broad agricultural activities in order to identify adequate actions with the potential to mitigate or reduce potential drought impacts. In data-deprived rural areas of Latin America, community mapping and the creation of agroclimatic calendars offer practical solutions to gather and utilize local knowledge for improving agricultural livelihoods. These tools empower communities to take an active role in managing their agricultural resources, enhancing resilience to climatic variability, and supporting sustainable development. By combining participatory approaches with scientific knowledge, these methods can bridge data gaps and foster more effective agricultural planning and decision-making.

2.3 Observed Climate Trends

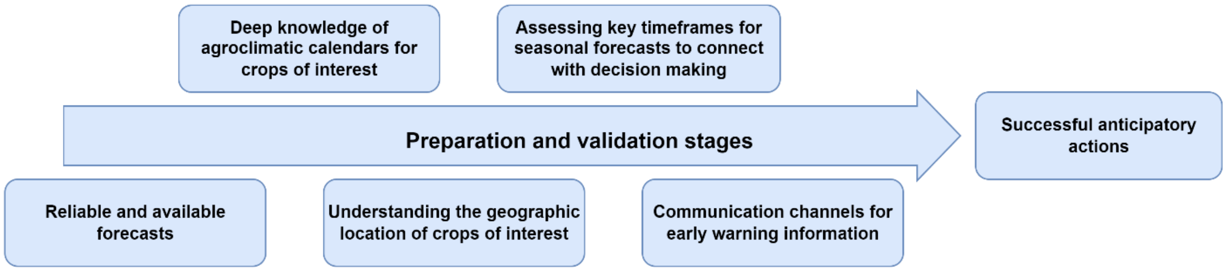
Once some of the hydrological demands of the crops prioritized for anticipatory action are understood, they can be connected with high-quality climate forecasts. In this project, seasonal climate forecasting is used, which is a process that can predict climate variables, such as temperature and precipitation, several months in advance. These forecasts are crucial for planning and decision-making in various sectors, particularly agriculture, water resource management, and disaster preparedness. In the context of precipitation, seasonal forecasts can indicate the likelihood of above-average, below-average, or near-average rainfall over a given period. These insights enable stakeholders to implement anticipatory actions to mitigate the impacts of climate variability and extreme weather events.

WFP utilizes seasonal climate forecasts to plan and execute anticipatory actions aimed at reducing the adverse effects of climate anomalies. For instance, forecasts indicating a high probability of drought can prompt early interventions such as water conservation measures, distribution of drought-resistant seeds, pre-positioning of food supplies in vulnerable areas, and the distribution of cash or vouchers to at risk populations. Similarly, forecasts predicting excessive rainfall can lead to flood preparedness activities, including strengthening of infrastructure, evacuation planning, and community education programmes.[5]

Seasonal climate forecasting, particularly for precipitation, is a vital tool for anticipatory actions in data-deprived regions like rural areas in Latin America. Utilizing sources for modelling such as the North- American Multi-model Ensemble (NMME) and the European Copernicus (C3S), and employing rigorous methods to assess predictive skill, enhances the reliability of these forecasts. An assessment of seasonal forecast predictive skill for Belize undertaken in the context of the project underscores the potential of using advanced modelling approaches to improve seasonal rainfall predictions in Central America, offering valuable insights for enhancing resilience and adaptive capacity in Belize and beyond. This report presents the following stages from 1 to 3 as preparation and validation steps towards successful development of an anticipatory action mechanism for drought in Belize (Figure 1).

[5] WFP. 2019. *Anticipatory Actions in Response to Seasonal Climate Forecasts*.

FIGURE 1. ANTICIPATORY ACTION COMPONENTS FOR DROUGHT IN BELIZE



Source: authors.

Understanding seasonal patterns helps in planning agricultural activities and preparing for climatic variations in stage 1. Identifying which crops are vulnerable to climate extremes allows for targeted interventions in stage 2. Accurate and timely forecasts provide the necessary lead time for implementing preventive measures in stage 3. Finally, reliable communication channels ensure that the forecast information and corresponding actions reach the relevant stakeholders effectively in stage 4. These elements collectively provide the foundation for effective anticipatory actions, thereby mitigating the impacts of extreme climate events on food security and livelihoods.

2.4 Area of Study

Three districts have been prioritized for this study namely, Corozal, Orange Walk, and Cayo districts.

Corozal District

Located in the northern part of Belize, Corozal has a population of approximately 45,310 people. The demographic composition is diverse, comprising mainly Mestizo, with significant Maya, Creole, and other ethnic groups. The district's economy is heavily reliant on agriculture, with sugarcane being the predominant crop. Other significant agricultural activities include the cultivation of vegetables, fruits, and grains, alongside fishing, which also contributes to the local economy.[6] Despite its agricultural productivity, Corozal faces substantial economic challenges, reflected in its high poverty rates. Many residents live below the poverty line, hindered by limited economic opportunities. Access to the internet in Corozal is moderate, with recent improvements in infrastructure increasing connectivity, although rural areas still face significant challenges.[7] The Multidimensional Poverty Index (MPI) for Corozal is below the national average, but it is only situated behind Toledo, indicating lower levels of income, education, and healthcare access compared to more urbanized areas.[8]

Corozal is known for its fertile lands and favourable climate for agriculture with many smallholder farmers relying on the production of sugarcane (Figure 2). The district also produces a variety of fruits and vegetables, contributing to local markets and export.[9] Farmers in Corozal face challenges

---

[6] Government of Belize. Ministry of Agriculture, Food Security and Enterprise. 2024. *Production Statistics*.
[7] World Bank. 2024. Data. Indicator: Individuals using the Internet (% of population) – Belize.
[8] Government of Belize. Statistical Institute of Belize. 2024. *Poverty Statistics*.
[9] Government of Belize. Ministry of Agriculture, Food Security and Enterprise. 2024. *Production Statistics*.

such as soil degradation, pests, and the impacts of climate change. Anticipatory and adaptive actions, such as crop diversification and sustainable farming techniques, can help mitigate these risks.[10]

FIGURE 1. SUGAR CANE PLANTATION IN COROZAL

Source: authors | May 2024.

Orange Walk District

This district is also situated in northern part of Belize and has a population of around 54,152. The demographic profile is predominantly Mestizo, with smaller communities of Maya, Creole, and other ethnicities. Agriculture is a vital part of Orange Walk's economy, with sugarcane being the most important crop. The district also extensively cultivates corn, beans, and citrus fruits, and is known for its agro-industrial activities. Like Corozal, Orange Walk experiences high poverty rates, particularly in its rural areas where agriculture is the primary livelihood.[11] The (MPI) for Orange Walk is comparable to that of Corozal, highlighting similar challenges in terms of income, education, and healthcare access.[12] The district is a key agricultural district in northern Belize. Yet, the district's agriculture is highly susceptible to droughts and floods, affecting crop yields and farmers' incomes.

Cayo District

Located in western Belize, Cayo is one of the larger districts with a population of about 99,105. It is characterized by a diverse population, including Mestizo, Maya, Creole, and expatriate communities. Cayo's economy is diverse, with agriculture playing a significant role. The district produces vegetables, grains, and livestock, and also benefits from tourism and small-scale industries. The

[10] CIAT; World Bank. 2018. *Climate-Smart Agriculture in Belize*. CSA Country Profiles for Latin America and the Caribbean Series. International Center for Tropical Agriculture (CIAT); World Bank, Washington, D.C. 24 p.
[11] World Bank. 2024. *Poverty indicators.*
[12] Government of Belize. Statistical Institute of Belize. 2024. *Poverty Statistics*.

district's agriculture benefits from relatively favorable rainfall patterns but is not immune to climate risks.[13] While poverty remains a concern, Cayo has a lower poverty rate compared to Corozal and Orange Walk, partly due to its more diversified economy. Internet access in Cayo is relatively better, especially in urban areas like San Ignacio and Belmopan, although rural areas still face connectivity issues.[14] The MPI for Cayo is lower than that of Corozal and Orange Walk, reflecting better educational facilities, healthcare services, and economic opportunities.[15]

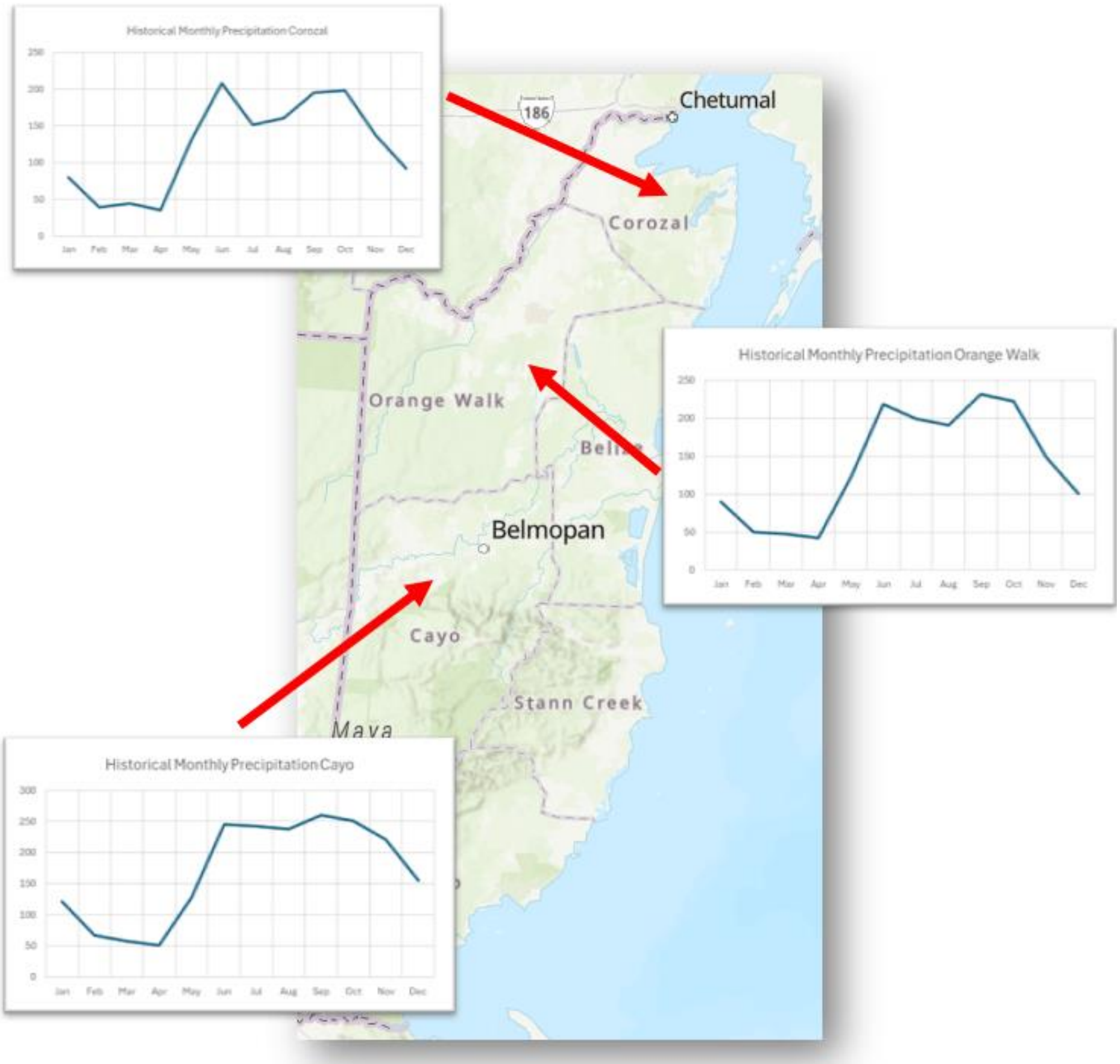
2.5 Climate in Belize

Belize experiences a tropical climate characterized by warm temperatures and high humidity year-round. Average annual temperatures typically range from 24°C (75°F) in January to around 27°C (81°F) in August, with the warmest months being May to September[16]. The country has a distinct rainy season, which lasts from June to November, contributing to an average annual rainfall that varies significantly by region (Figure 3). Coastal areas receive about 1,800 mm (71 inches) of rain annually, while the southern regions can get up to 4,000 mm (157 inches).[17] Even within the northern districts of Corozal, Orange Walk, and Cayo precipitation regimes at a monthly scale are diverse. Note in Figure 3 how the monthly climatological periods for precipitation in Corozal, in the northern-most area of the country, have a true mid-summer drought[18] in July and August while Cayo in the inland presents almost a continuous precipitation regime throughout the rainy season. Orange Walk sits somewhere in-between. Nevertheless, the June-July-August precipitation season is critical for crops in the three districts and recent droughts have affected the region when compared to the average conditions in each location.

---

[13] Government of Belize. Ministry of Agriculture, Food Security and Enterprise. 2024. *Production Statistics*.
[14] Government of Belize. Statistical Institute of Belize. 2024. *Poverty Statistics*.
[15] *Ibid.*
[16] World Bank. *Climate Change Knowledge Portal*. 2025.
[17] Government of Belize. National Meteorological Service of Belize. 2021. *Annual Weather Report*. Link.
[18] The mid-summer drought is a period of reduced precipitation in the middle of July-August associated with agroclimatic calendars in most of Central America and the Caribbean (Maurer et al., 2021).

FIGURE 2. MONTHLY CLIMATOLOGICAL CHARTS FOR COROZAL, ORANGE WALK, AND CAYO



Source: authors.

Notice the true mid-summer drought in Corozal to the north and the almost consistent precipitation from June to November in Cayo during the rainy season. Orange walk shows a mild mid-summer drought. Also notice that the annual accumulated precipitation increases from the northern districts towards the southern, in-land areas.

Droughts have been a recurring issue in Belize, particularly affecting the agricultural sector. Notable droughts occurred in 1983, 1994, 2001, and 2019. Farmers participating in workshops in the three districts in May 2024 have a clear recollection of the 2019 drought. These events have had significant economic impacts, primarily through reduced agricultural yields. The Belize Ministry of Agriculture estimates that that particular drought resulted in loss of $50 million USD in crop and livestock production.[19]

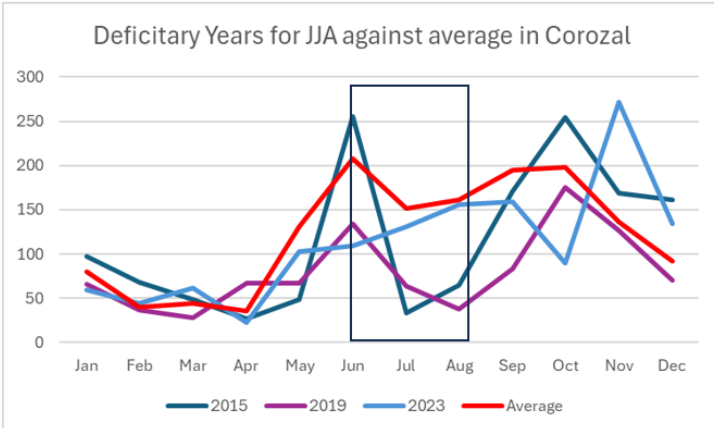


FIGURE 3. DEFICITARY YEARS

In the Corozal district, the 2019 drought was the most severe of the recent droughts as seen here. This was mostly due to low precipitation in June as well as very low precipitation in July and August compared to the average expected precipitation for those months. The drought in 2015 was also severe but precipitation in June probably helped farmers.

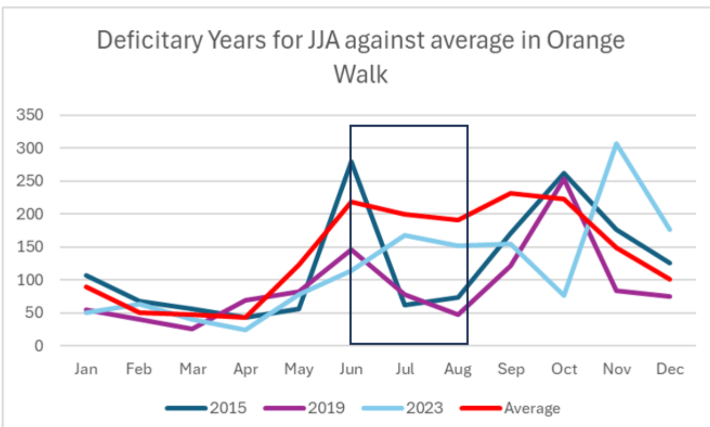


FIGURE 4. DEFICITARY YEARS

In the Orange Walk district, the 2019 drought was also the most severe of the recent droughts as seen here. As with Corozal, this was due to low precipitation in June as well as very low precipitation in July and August compared to the average expected precipitation for those months. The drought in 2015 was also more severe but precipitation in June probably helped farmers

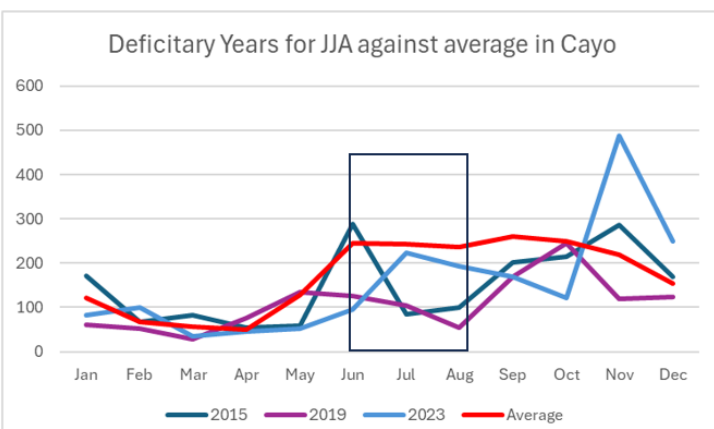


FIGURE 5. DEFICITARY YEARS

For the Cayo district, the 2019 drought was also the most severe of the recent droughts, but the precipitation deficit started earlier in the year, and the total accumulated precipitation was much less than expected for the JJA season. Note in the three figures that rainfall deficits rarely occur after October. Critical deficits occur mostly in JJA and ASO seasons.

[19] Government of Belize. Ministry of Agriculture, Food Security and Enterprise. 2019. *Production Statistics*.

Besides drought as the major hazard to focus on here, Belize is also vulnerable to hurricanes, which can cause extensive damage due to high winds, storm surges, and heavy rainfall. Some of the most impactful hurricanes include Hurricane Hattie (1961), Hurricane Mitch (1998), and Hurricane Richard (2010). Hurricane Hattie caused extensive damage with estimated costs of $60 million USD at the time, which would be significantly higher today when adjusted for inflation.[20] Flooding is another significant climate hazard in Belize, typically occurring during the wet season from June to November. Major floods have been recorded in 1931, 1961, 2000, and 2008. The 2000 flood, caused by Hurricane Keith, resulted in damages amounting to approximately $225 million USD, severely impacting infrastructure, housing, and agriculture.[21] More recently, unprecedented wildfires are occurring in areas of Belize where they did not use to occur.[22]

2.6. Expected climate change in Belize

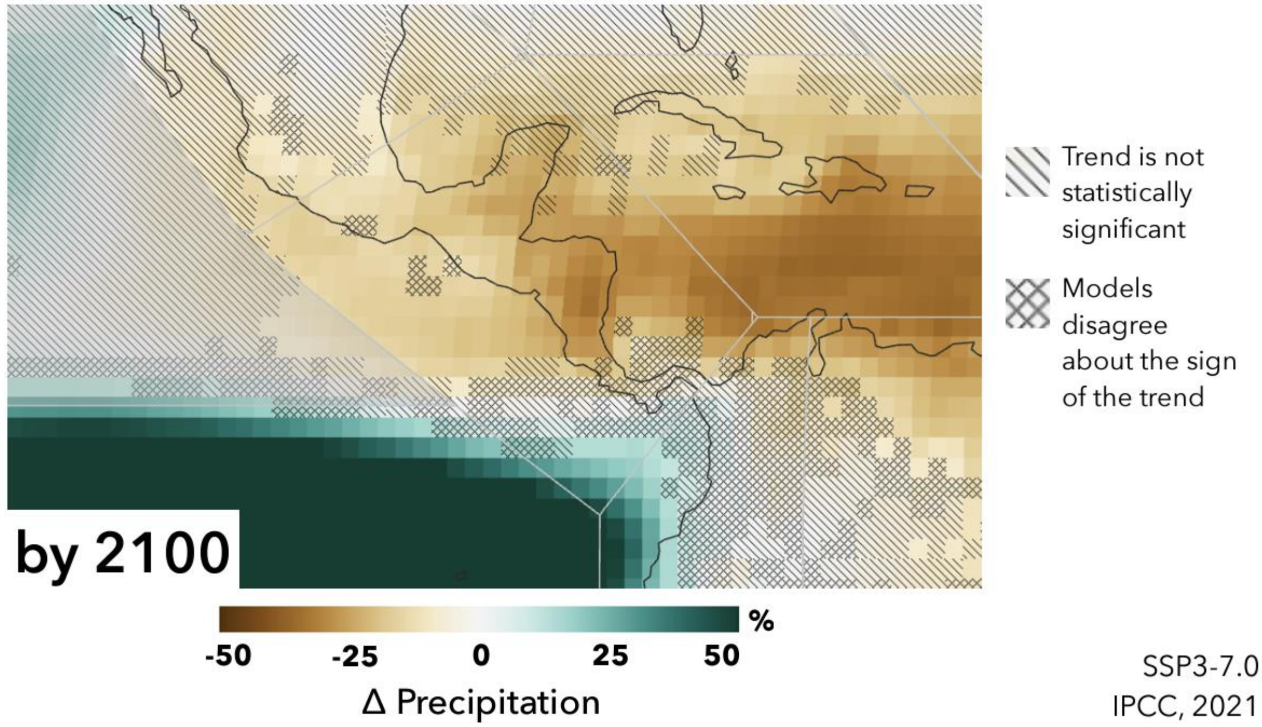
Climate change poses a significant threat to Belize, with projections indicating increased frequency and intensity of extreme weather events. The Intergovernmental Panel on Climate Change (IPCC) provides scenarios for future climate conditions based on different greenhouse gas concentration pathways, known as Shared Socioeconomic Pathways (SSPs). The two scenarios often considered are SSP24.5 and SSP58.5. Under the SSP24.5 scenario, Belize is expected to experience a moderate increase in average temperatures and slight changes in precipitation patterns by 2030. The frequency of droughts may increase, impacting water resources and agriculture. Conversely, under the SSP58.5 scenario, more severe temperature increases and significant reductions in rainfall during the dry season are anticipated, exacerbating drought conditions.[23]

By 2050, under the SSP24.5 scenario, Belize may face more pronounced changes in precipitation patterns, with an increase in rainfall intensity during the wet season leading to higher risks of flooding. The SSP58.5 scenario predicts even more extreme changes, with significant increases in both temperature and precipitation variability. This could result in more frequent and severe droughts and floods, with substantial economic impacts on agriculture, infrastructure, and human health.[24] Looking further to 2070, the impacts under SSP24.5 suggest a continued trend of increased temperatures and altered precipitation patterns, though potentially stabilized if global mitigation efforts succeed. Under SSP58.5, Belize could face severe climate disruptions, with extreme heat, prolonged droughts, and intense rainfall events becoming the norm. These changes would severely impact agricultural productivity, water resources, and coastal ecosystems, leading to significant economic losses and social challenges.[25]

---

[20] National Hurricane Center. 1961. *Monthly Weather Review*.
[21] National Hurricane Center. 2001. *Revised deaths and Damage*.
[22] Global Fire Monitoring Center (GFMC). 2024. *Bush fires persist throughout Belize; MDRM updates public*. Press release.
[23] Lee et al. 2021.
[24] *Ibid.*
[25] *Ibid.*

FIGURE 6. FUTURE EXPECTED PRECIPITATION CHANGES BY 2100

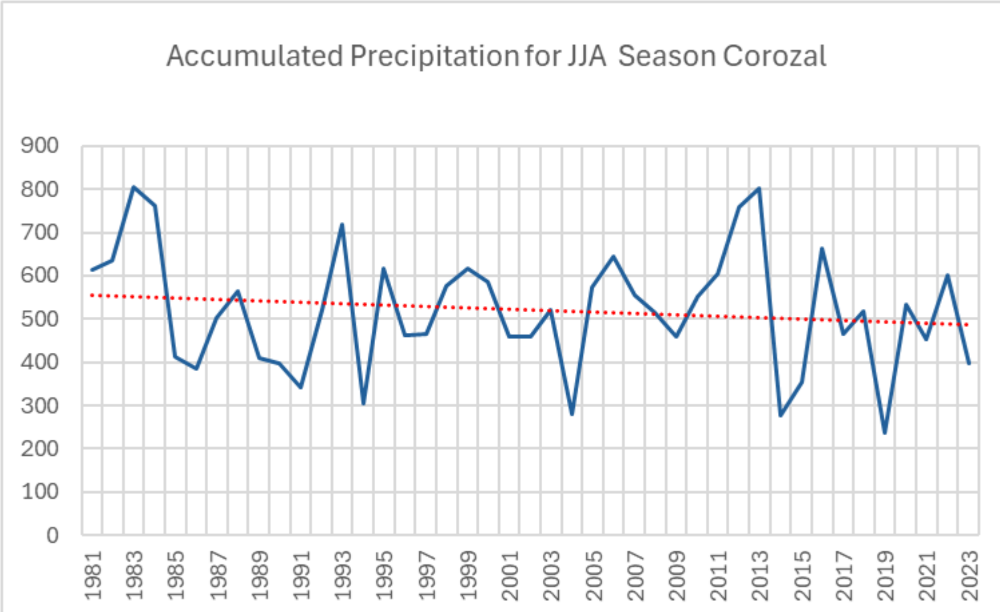


Source: Lee et al., 2021 in IPCC 2021.

2.7 Historical Climate Trends

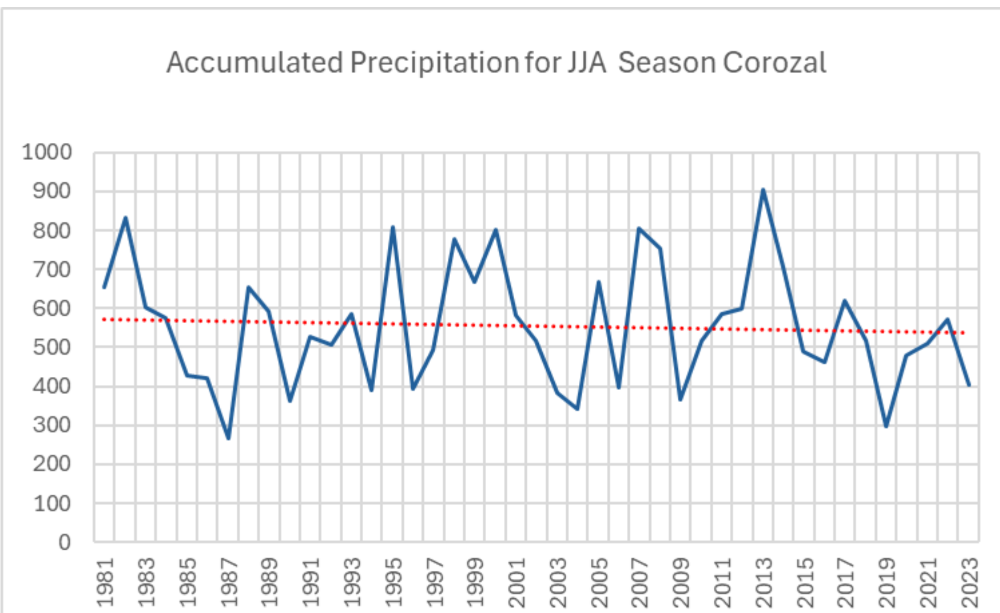
The graphs below illustrate historical trends for precipitation in Belize from 1981 to 2023 during critical agricultural periods of June-July-August and August-September-October. The data shows variability in precipitation patterns over the past decades with a trend towards less accumulated precipitation for both periods in the prioritized district of Corozal. Note the declining trends are consistent with the climate change scenarios by IPCC. For Orange Walk and Cayo please refer to Annex I.

FIGURE 7. ACCUMULATED PRECIPITATION | JUNE-AUGUST | COROZAL



Source: The author with data from CHIRPS[26].

FIGURE 8. ACCUMULATED PRECIPITATION | AUGUST-OCTOBER | COROZAL



Source: The author with data from CHIRPS[26].

[26] Funk, C., Peterson, P., Landsfeld, M., et al. 2015. The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. *Scientific Data, 2, 150066*.

3. Agricultural Livelihoods and Climate-Sensitive Periods: Insights from Farmers

Changing patterns of historical rainfall have been presented in the previous sections as well as future precipitation changes projected by the end of the Century. To determine potential implications of these changes to the livelihoods of agriculturalist in the prioritized districts, it is imperative to understand the critical phenological stage of their crops as well as the degree of exposure of these crops regarding their relative location. The next sections discuss the methods and results of community mapping and agroclimatic calendar exercises that were conducted in three workshops with farmers in Corozal, Orange Walk and Cayo in May 2024.

3.1. Community mapping and agroclimatic calendars

Community mapping is a participatory approach that involves local communities in creating detailed maps of their own environments. This method leverages the knowledge and insights of community members to produce accurate and context-specific data about local resources, infrastructure, and socio-economic conditions. In data-deprived contexts such as rural areas in Latin America, community mapping can be a powerful tool for gathering information that is often overlooked or unavailable through conventional data collection methods.[27] By engaging residents in the mapping process, communities can document valuable information about their surroundings, including natural resources, land use, water sources, and transportation networks. This participatory process not only enhances the accuracy of the maps but also fosters a sense of ownership and empowerment among community members[28]. The resulting maps can be used for various purposes, such as planning and implementing development projects, improving disaster risk management, and advocating for resources and services from government authorities and non-governmental organizations (NGO).[29]

In rural Latin American areas where formal agricultural data is often lacking, community mapping of crops can provide critical insights into agricultural livelihoods. This involves working with farmers to map the locations and extents of different crops, identify soil types, document irrigation practices, and note pest and disease occurrences (Figure 10). The process can highlight the spatial distribution

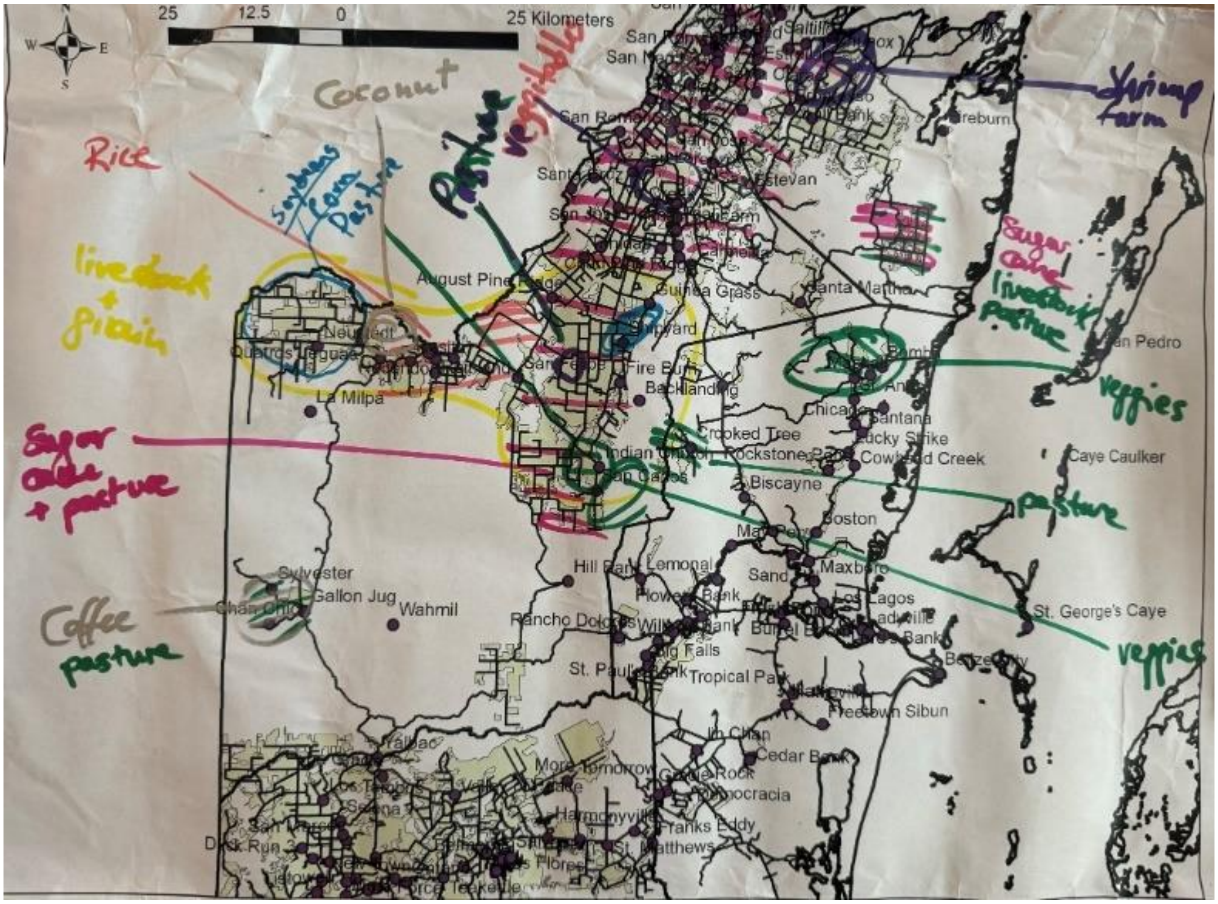
[27] McCall, M. K. 2014. Mapping territories, land resources and rights: Communities deploying participatory mapping/PGIS in Latin America. *Revista do Departamento de Geografia – USP*, *Volume Especial Cartogeo*, 94–122. Link

[28] Fals-Borda, O. (1987). The Application of Participatory Action-Research in Latin America. *International Sociology*, *2*(4), 329-347. Link

[29] *Ibid*.

of agricultural activities, reveal patterns of land use, and identify areas of high productivity or vulnerability.[30]

FIGURE 9. COMMUNITY MAPPING OF CROPS IN COROZAL



Source: authors.

3.2. Agroclimatic Calendars

Agroclimatic calendars are tools that combine agricultural and climatic data to provide a timeline of critical farming activities and weather patterns throughout the year. These calendars are particularly valuable in rural areas with limited access to formal meteorological data. By integrating local knowledge with available climatic information, agroclimatic calendars help farmers make informed decisions about planting, harvesting, and other agricultural practices.[31] Three workshops were conducted, one in each prioritized district, to assess the key crops and agricultural activities during the phenological cycles of the crops (Figure 11).

[30] IFAD. 2018. *Community Mapping for Climate Resilience*.
[31] Food and Agriculture Organization. 2016. *Agroclimatic Calendar Guide*.

FIGURE 10. AGRICULTURALISTS PREPARING AGROCLIMATIC CALENDARS

Source: authors

An example of the use of agroclimatic calendars to help farmers make use of climate information is that used by the PICSA method. The Participatory Integrated Climate Services for Agriculture (PICSA) method, developed by the International Center for Tropical Agriculture (CIAT) and the University of Reading, leverages agroclimatic calendars to empower farmers with seasonal climate information. By integrating local knowledge with scientific climate data, PICSA enables farmers to make informed decisions about planting, harvesting, and other critical agricultural activities. In Guatemala, this approach has been particularly effective. For instance, farmers in the Guatemalan highlands used agroclimatic calendars to anticipate and prepare for irregular rainfall patterns, which led to improved crop yields and enhanced food security.[32]

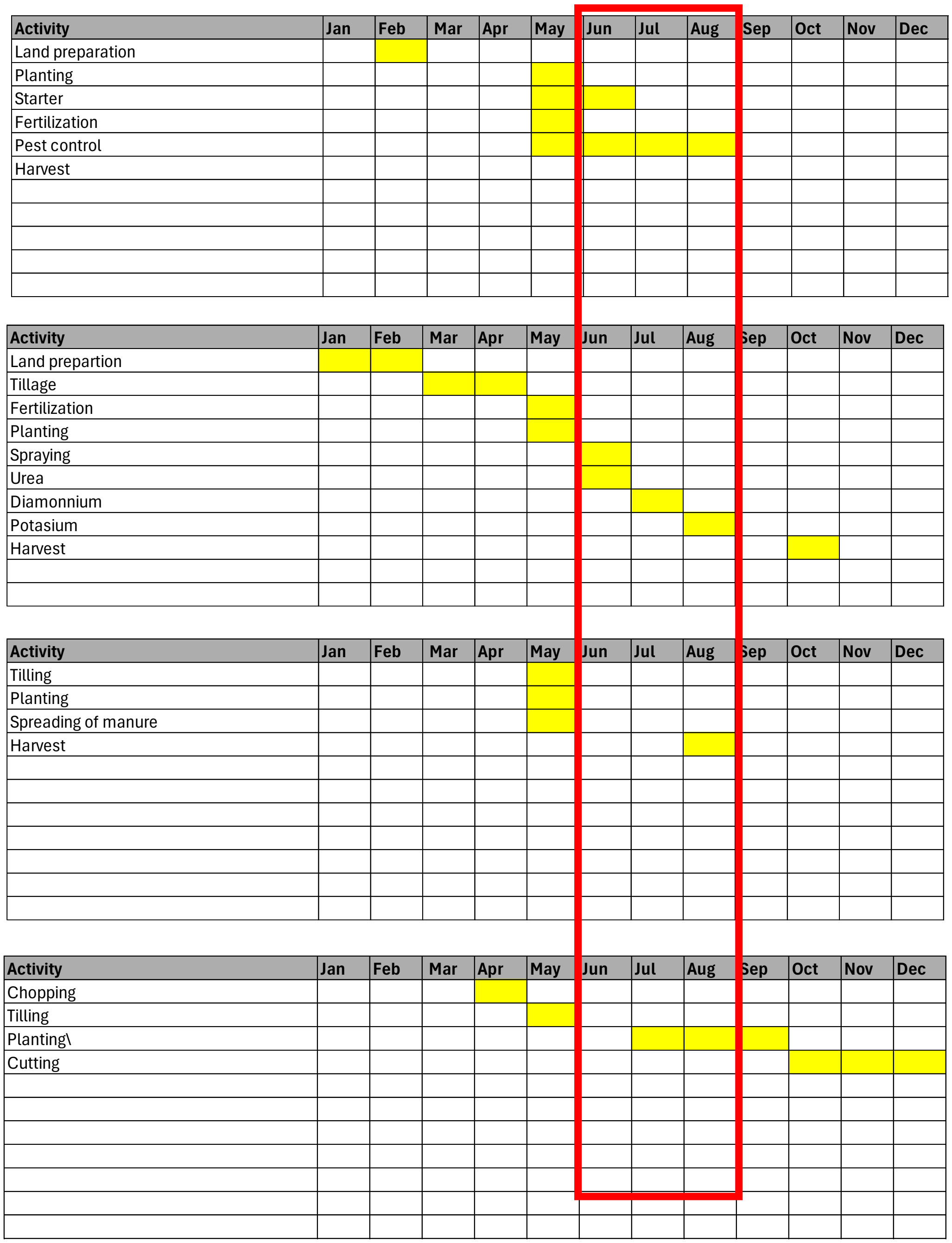
3.3. Seasonal Agricultural Activities by District

This section shows some of the agroclimatic calendars for relevant crops prepared by farmers in the three districts during the field visits.

---

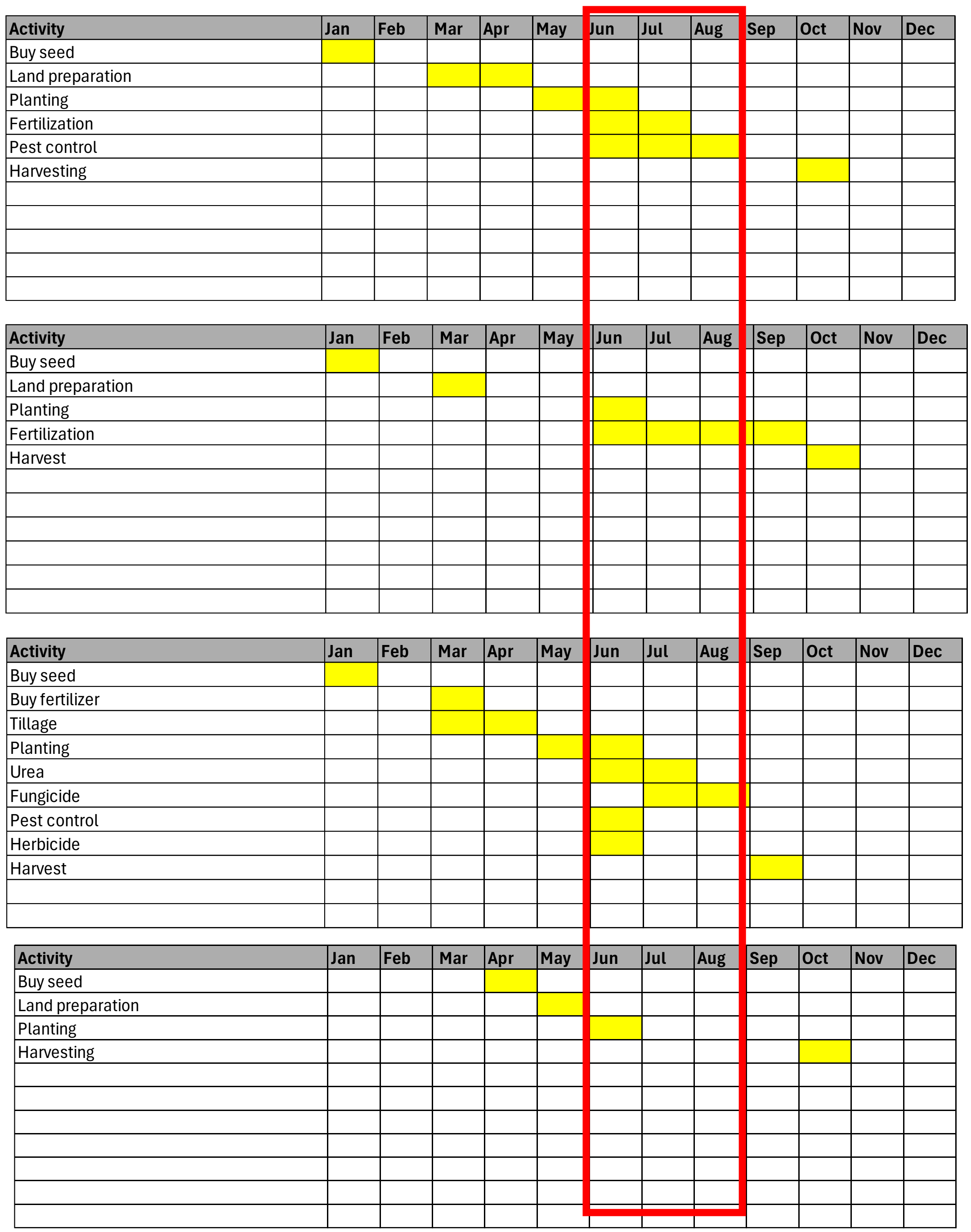
[32] Dorward et al. 2015. *Participatory Integrated Climate Services for Agriculture (PICSA): Field Manual.*

FIGURE 11. AGROCLIMATIC CALENDARS OF CORN AND GRASS FOR FEED IN COROZAL (DIFFERENT FARMERS)



Source: authors.

FIGURE 12. AGROCLIMATIC CALENDARS OF CORN IN ORANGE WALK (DIFFERENT FARMERS)



Source: authors.

Note that many of the activities, including planting, occur during the June-July-August season.

FIGURE 13. AGROCLIMATIC CALENDARS FOR GRASS FOR FEED IN ORANGE WALK (DIFFERENT FARMERS)

Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Land preparation												
Planting												

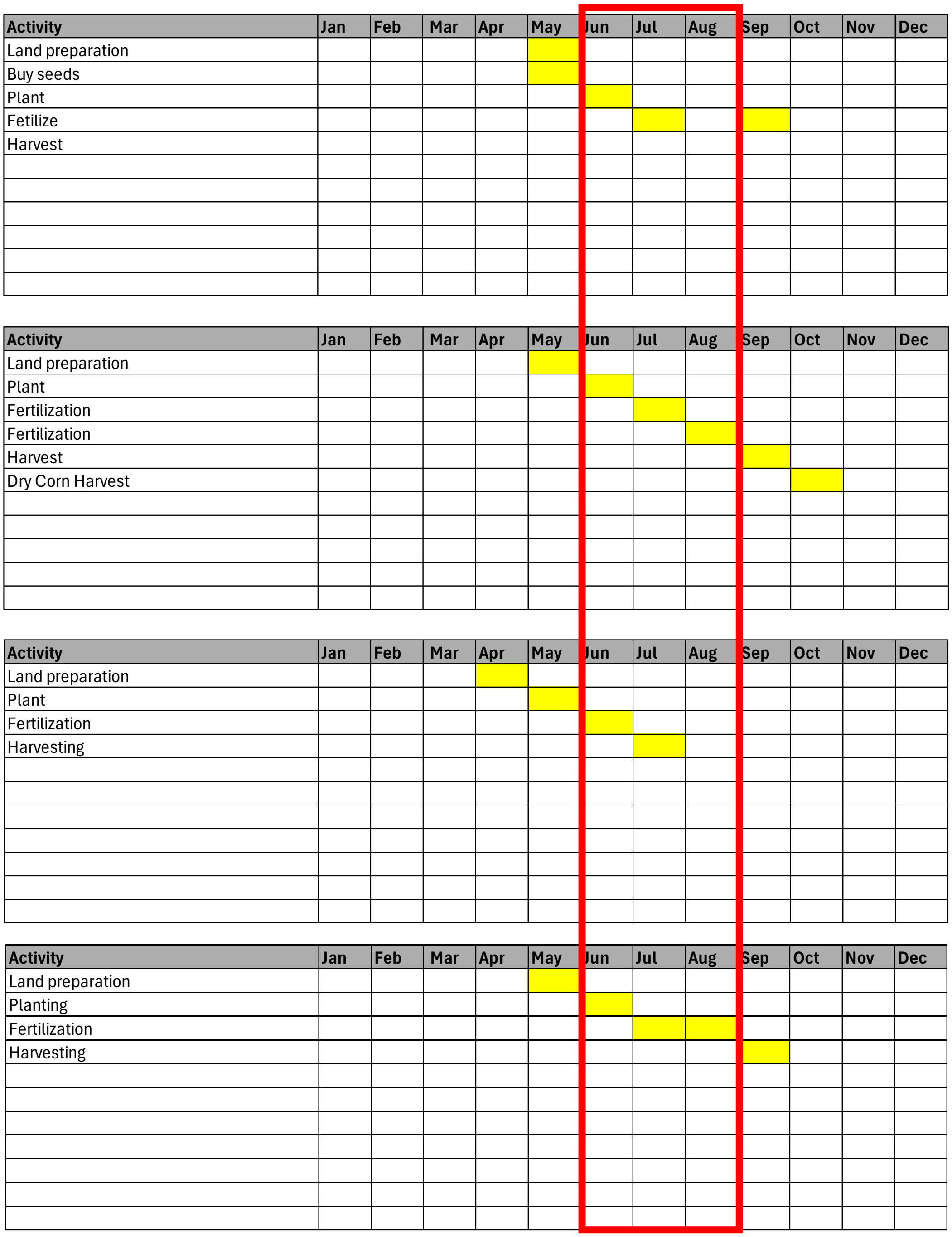
Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Land preparation												
Buying seed												
Planting												

Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Land preparation												
Planting												
Weed control												
Fertilization												

Source: authors.

Note that many of the activities, including planting, occur during the June-July-August season.

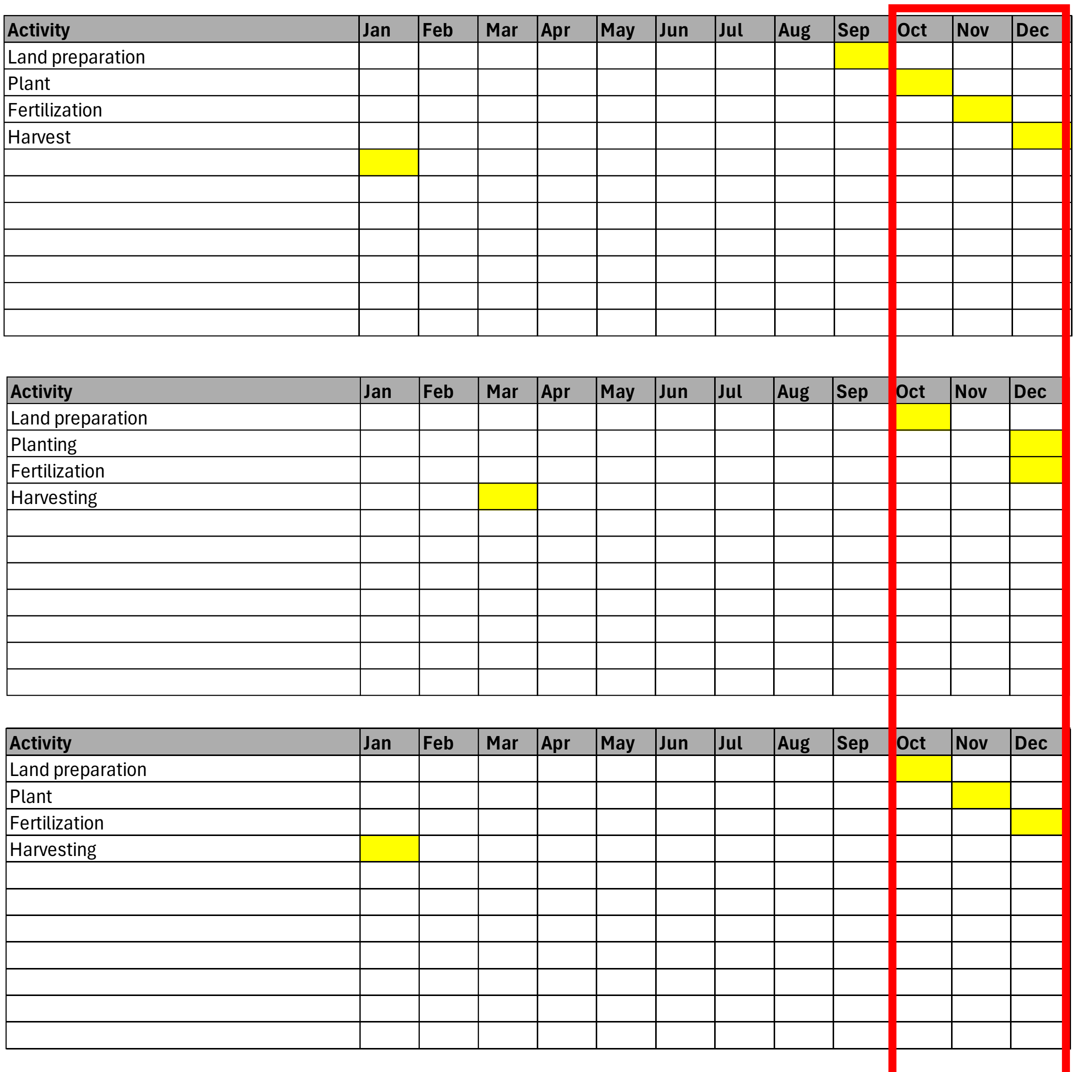
FIGURE 14. AGROCLIMATIC CALENDARS FOR CORN IN CAYO (DIFFERENT FARMERS)



Source: authors.

Note that many of the activities, including planting, occur during the June-July-August season.

FIGURE 15. AGROCLIMATIC CALENDARS FOR BEANS IN CAYO (DIFFERENT FARMERS)



Source: authors.

In the corn and grass for feed calendars, many of the activities, including planting, occur during the June-July-August season, whereas for the beans calendar they occur during the October-November-December season. This season is not particularly variable when it comes to precipitation. These crops are clearly exposed to different climatic conditions and hence deserve their own assessment which goes beyond the scope of this report.

4. Seasonal Forecasting and Opportunities for Anticipatory Action

4.1 Forecasting Models and Methods

Seasonal climate forecasts are generated using a variety of models and data sources. Two prominent sources are the North American Multimodel Ensemble (NMME) and the Copernicus Climate Change Service (C3S). The NMME is a collaborative effort among several climate modelling centres in North America. It combines forecasts from multiple models to improve the reliability and accuracy of seasonal climate predictions. The ensemble approach helps to account for uncertainties and biases present in individual models, leading to more robust forecasts.[33] The Copernicus Climate Change Service, part of the European Union's Copernicus Programme, provides comprehensive climate information and services. C3S utilizes both dynamic and hybrid modelling approaches to produce seasonal forecasts. Dynamic models are based on physical principles governing the atmosphere, while hybrid models integrate statistical techniques with dynamic models to enhance predictive skill.[34]

4.2 Methods for Assessing Forecast Predictive Skills

To establish the predictive skill of seasonal climate forecasts, various statistical tests and metrics are employed. Commonly used methods include:

- *2AFC (Two-Alternative Forced Choice)*:: The 2AFC method assesses the ability of a forecast system to distinguish between two different states, such as above-average and below-average rainfall. It measures the proportion of correct discriminations made by the forecast system.[35]

- *Spearman and Pearson Correlations*: Spearman's rank correlation and Pearson's correlation coefficient are used to measure the strength and direction of the relationship between observed and predicted values. Spearman's correlation is non-parametric and assesses

[33] Kirtman et al. 2014. *The North American Multimodel Ensemble: Phase-1 seasonal-to-interannual prediction; Phase-2 toward developing intraseasonal prediction.*
[34] Copernicus Climate Change Service. 2021. [Seasonal Forecasting](#).
[35] Mason & Weigel. 2009. *A generic forecast verification framework for administrative purposes.*

monotonic relationships, while Pearson's correlation is parametric and evaluates linear relationships.[36]

- *ROC (Receiver Operating Characteristic)* Curve: The ROC curve evaluates the performance of a binary classifier system as its discrimination threshold is varied. It plots the true positive rate against the false positive rate, providing insights into the trade-offs between sensitivity and specificity in the forecast system.[37]

4.3 Which system to use in Belize for better predictive skill?

A recent study by Kowal et al. (2022) provides a comprehensive analysis of the predictive skill of seasonal rainfall forecasts in the region. The researchers compared forecasts from the C3S and NMME, focusing on their ability to predict seasonal rainfall anomalies over Central America, including Belize. The study utilized various metrics, including the 2AFC score, Spearman's rank correlation, and ROC curves, to evaluate the predictive skill of the models. Results indicated that both dynamic and hybrid approaches have significant skill in predicting seasonal rainfall anomalies, although the hybrid models generally showed slightly better performance.[38]

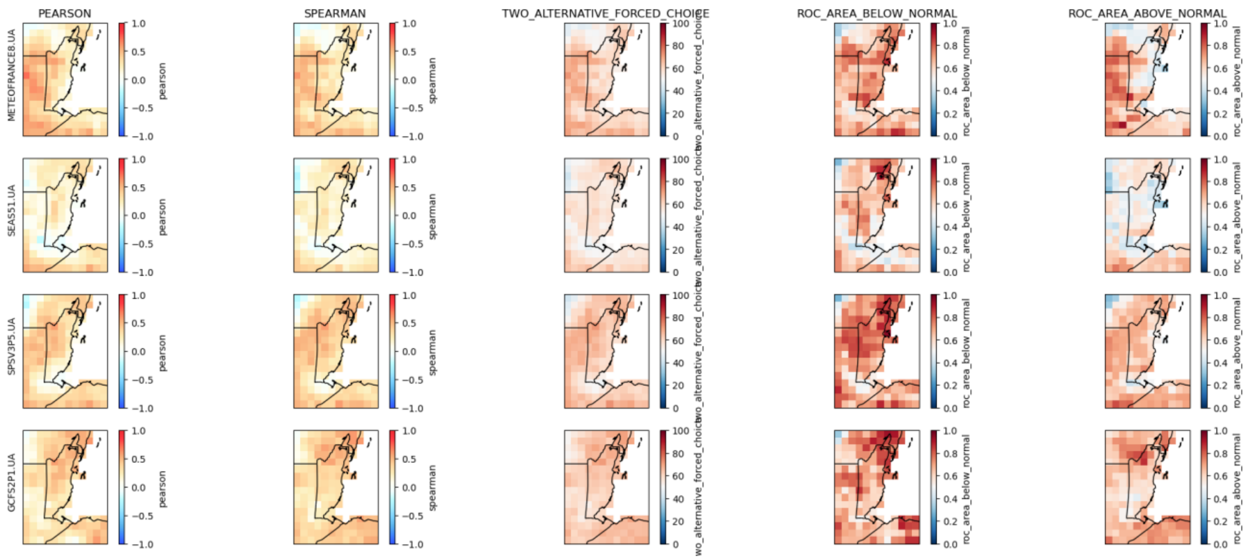
The predictive skill varied across different regions within Central America. Areas with complex topography, such as mountainous regions, posed greater challenges for accurate predictions. In contrast, more homogenous regions, including parts of Belize, demonstrated higher predictive skill.[39] The NMME and C3S models both performed well, but the hybrid models from C3S exhibited higher accuracy in capturing the timing and magnitude of rainfall anomalies. This highlights the value of integrating statistical techniques with dynamic models to enhance forecast reliability.[40]

Below are the results of assessing the predictive skill of several models from the C3S ensemble to evaluate direct (precipitation from model output against gridded precipitation at the same spatial domain) and indirect (model output of a different variable against precipitation at a different spatial domain). Note that for some periods and lead times the U component of wind in hPa (East to West in m/s) in the Caribbean, is a better predictor of precipitation in Belize. Other times, the precipitation outcome from model ensembles seems to outrun the indirect estimates.

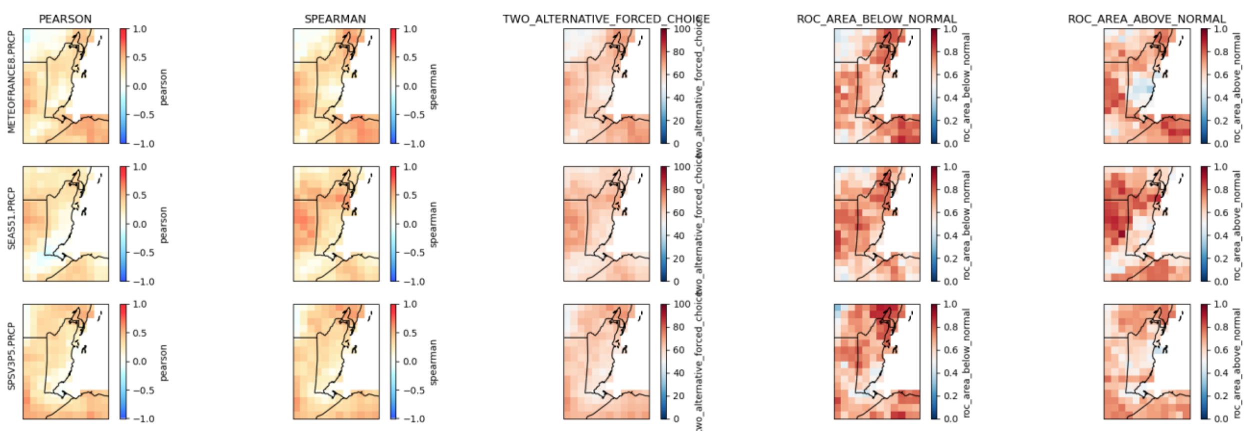
[36] Wilks, D. S. 2011. *Statistical Methods in the Atmospheric Sciences.*
[37] Jolliffe, I. T., & Stephenson, D. B. 2012. *Forecast Verification: A Practitioner's Guide in Atmospheric Science.*
[38] Kowal et al. 2022. *A comparison of seasonal rainfall forecasts over Central America using dynamic and hybrid approaches from Copernicus Climate Change Service seasonal forecasting system and the North American Multimodel Ensemble.*
[39] *Ibid.*
[40] *Ibid.*

FIGURE 16. ASSESSMENT OF PREDICTIVE SKILL FOR JUNE-JULY-AUGUST SEASON (ONE-MONTH LEAD)

U comp 925 Initialized in **May** for JJA:



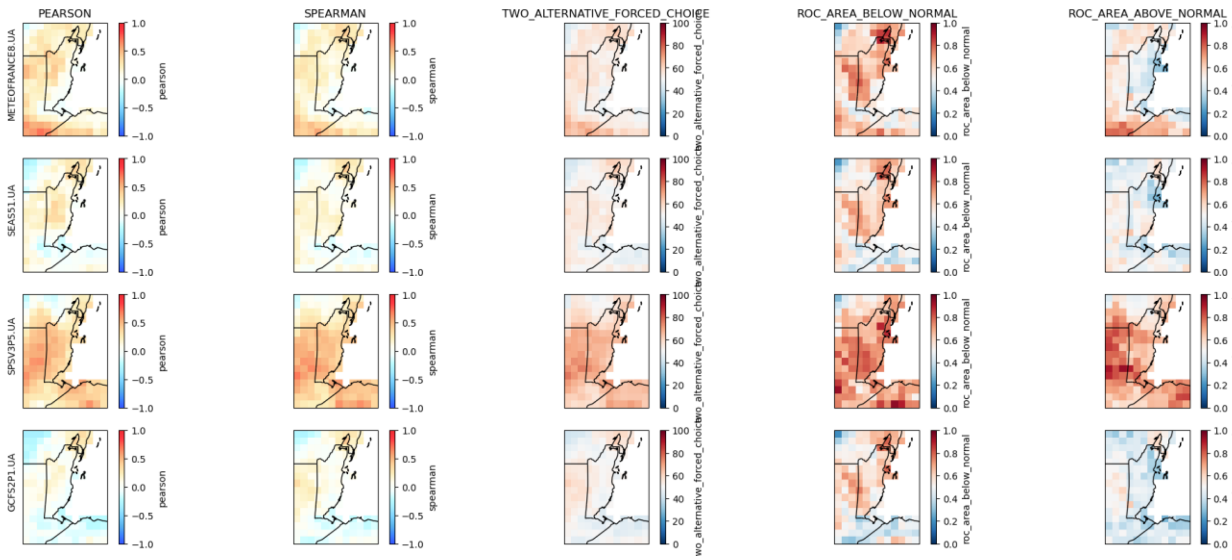
Model outcome (Direct):



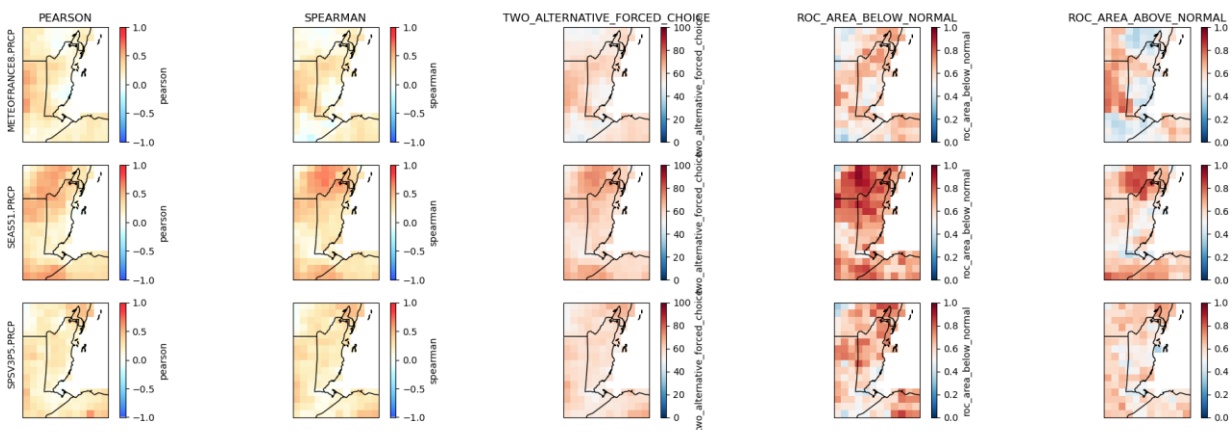
Source: authors. Metrics comparing wind (indirect) vs model output (direct) predictors for precipitation in Belize. From left to right: Pearson correlation, Spearman correlation, 2AFC, Roc Below and Roc Above.

FIGURE 17. ASSESSMENT OF PREDICTIVE SKILL FOR JUNE-JULY-AUGUST SEASON (TWO-MONTH LEAD)

U comp 925 Initialized in **April** for JJA:



Model outcome (Direct):

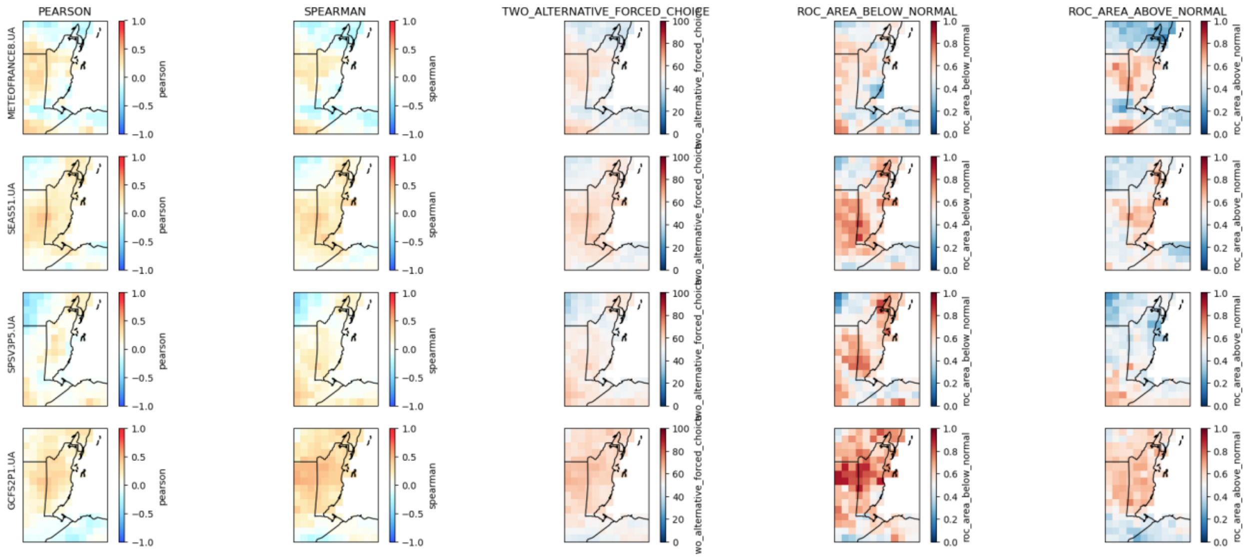


Source: authors. Metrics comparing wind (indirect) vs model output (direct) predictors for precipitation in Belize. From left to right: Pearson correlation, Spearman correlation, 2AFC, Roc Below and Roc Above.

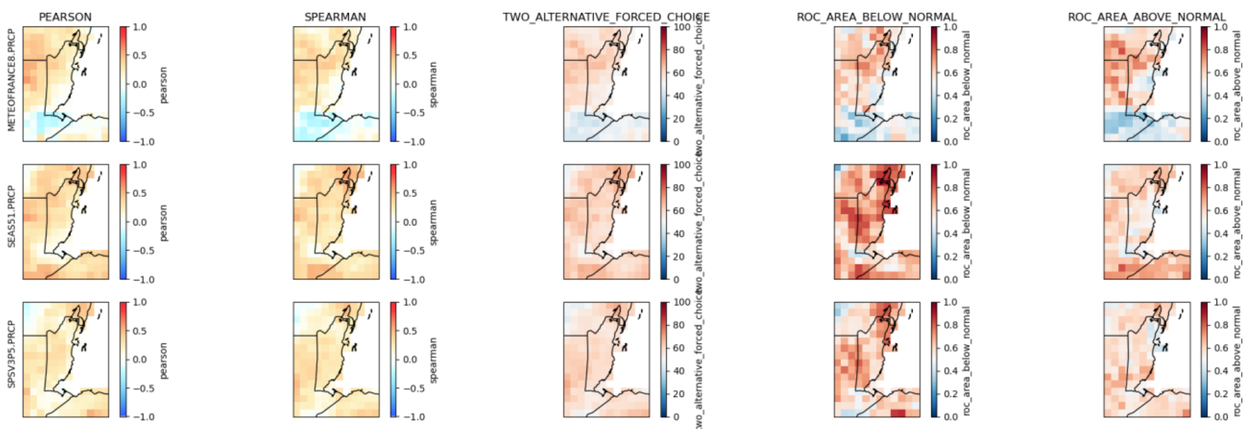
Up to this point, the U component of wind at 925 hPa seems to be a better predictor for precipitation in JJA over Belize. However, note in the following tests that this is no longer the case for the JJA season initialized with more than two-month lead.

FIGURE 18. ASSESSMENT OF PREDICTIVE SKILL FOR JUNE-JULY-AUGUST SEASON (THREE-MONTH LEAD)

U comp 925 Initialized in **March** for JJA:



Model outcome (Direct):

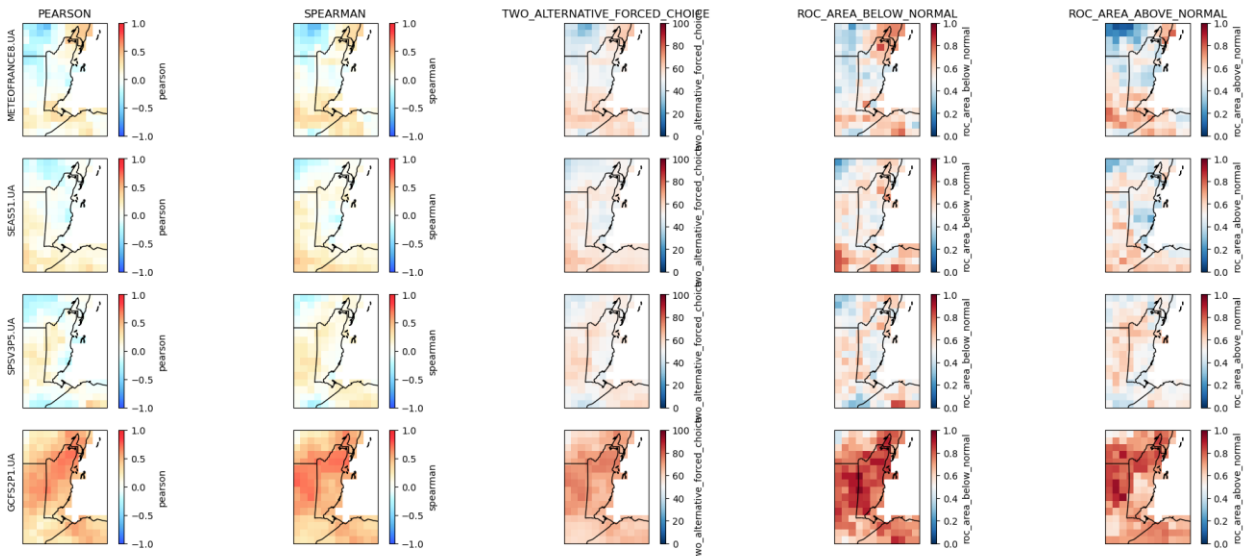


Source: authors. Metrics comparing wind (indirect) vs model output (direct) predictors for precipitation in Belize. From left to right: Pearson correlation, Spearman correlation, 2AFC, Roc Below and Roc Above.

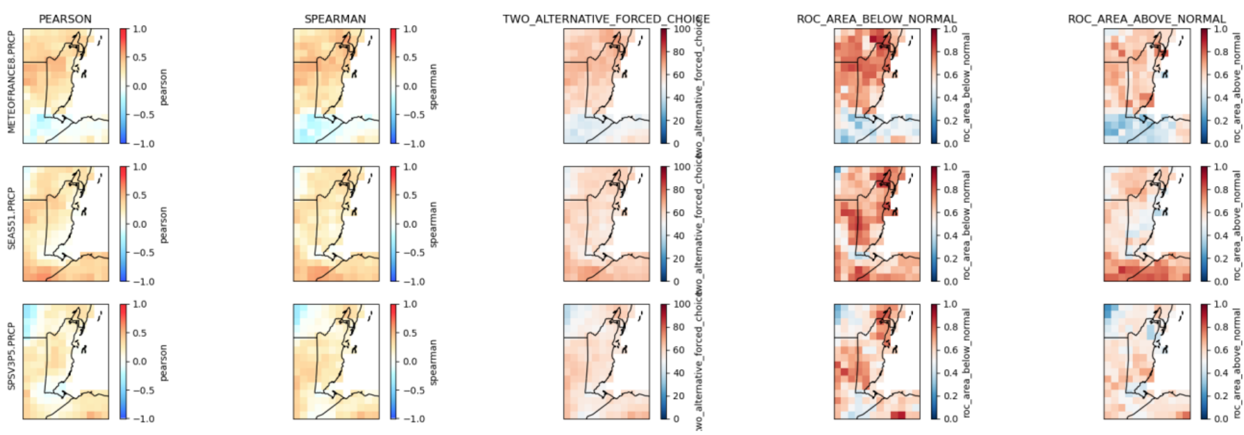
For the JJA season initialized in March, although some of the models using wind do show some skill for discriminating below-average precipitation on most of Belize, the direct models outperform most of the metrics, including the ability to discriminate above-average precipitation on two of the three models.

FIGURE 19. ASSESSMENT OF PREDICTIVE SKILL FOR JUNE-JULY-AUGUST SEASON (FOUR-MONTH LEAD)

U comp 925 Initialized in **February** for JJA (Four-month lead)



Model outcome (Direct):

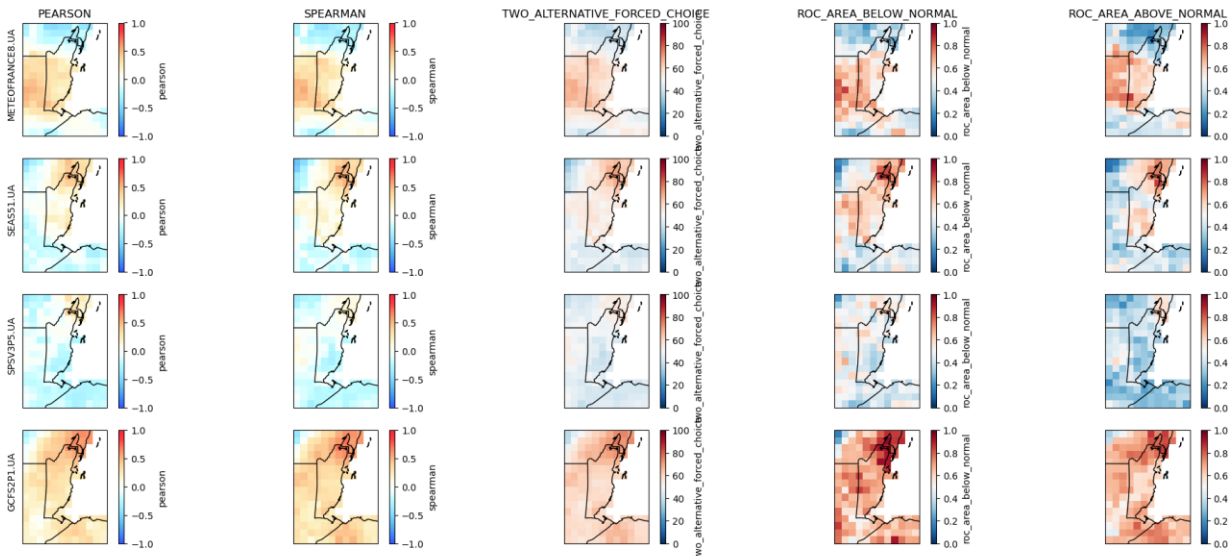


Source: authors. Metrics comparing wind (indirect) vs model output (direct) predictors for precipitation in Belize. From left to right: Pearson correlation, Spearman correlation, 2AFC, Roc Below and Roc Above.

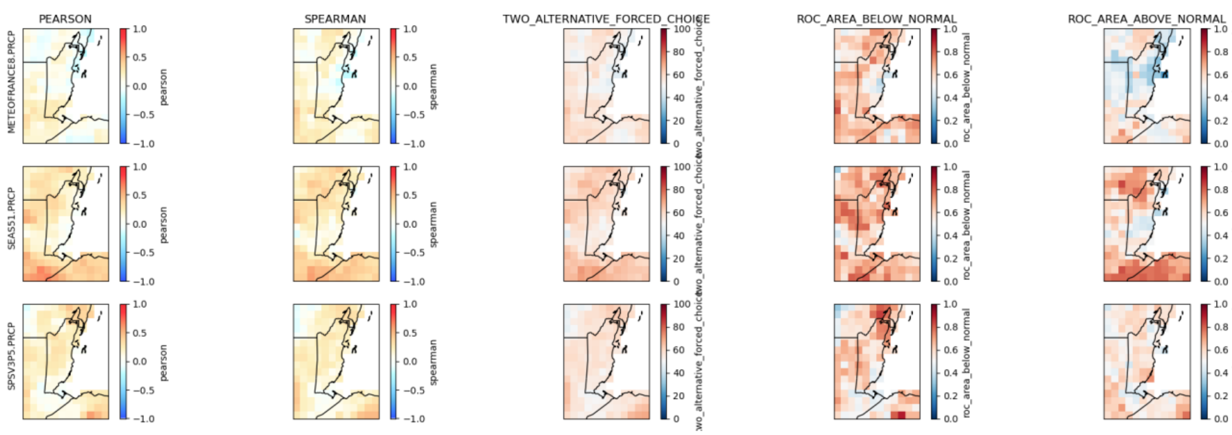
In the case of the JJA season initialized in February, only one of the models using wind do show some skill for discriminating below and above average precipitation for most of Belize. The direct models outperform most of the metrics, including the ability to discriminate above-average precipitation on two of the three models.

FIGURE 20. ASSESSMENT OF PREDICTIVE SKILL FOR JUNE-JULY-AUGUST SEASON (FIVE-MONTH LEAD)

U comp 925 Initialized in **January** for JJA:



Model outcome (Direct):



Source: authors. Metrics comparing wind (indirect) vs model output (direct) predictors for precipitation in Belize. From left to right: Pearson correlation, Spearman correlation, 2AFC, Roc Below and Roc Above.

Finally, in the case of the JJA season initialized in January and similarly to the previous assessment, only one of the models using wind shows some skill for discriminating below and above average precipitation for most of Belize. The direct models outperform most of the metrics but at this lead time of 5 months, the ability to discriminate above-average precipitation is lost for all the direct models for Belize.

4.4 Recommended Operational Forecasts to link to Anticipatory Actions

In the following series of figures (Figure 22-24), the predictive ability of the model ensembles is compared for the zonal wind estimation as a gridded precipitation predictor for the territory of Belize. It can be observed that, naturally, the forecast initialized in May for the period June-July-August (JJA) consists of higher predictive skill and discrimination in all the metrics used (Spearman correlation, 2AFC, ROC, Skill Score). As the initialization month (forecast lead time) moves away from the period of interest (JJA), the predictive ability of the model ensemble deteriorates. The territory with the highest predictive skill is northern Belize, including Corozal and Orange Walk. Some areas of Cayo show some predictive skill as well.

FIGURE 21. PREDICTIVE SKILL OF SEASONAL PRECIPITATION FORECAST FOR THE JUNE-JULY-AUGUST (JJA) SEASON INITIALIZED IN MAY

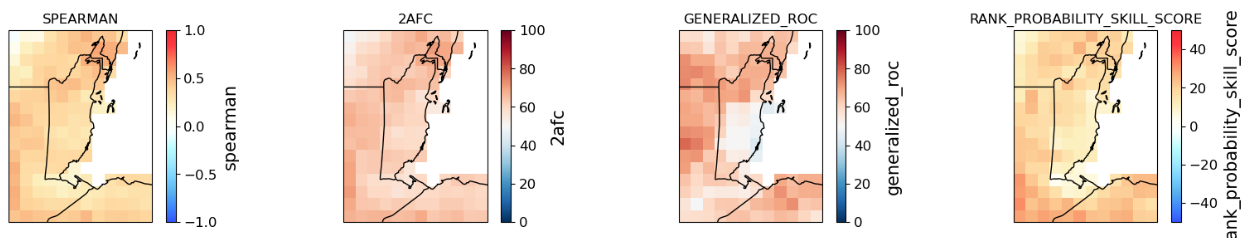


FIGURE 22. PREDICTIVE SKILL OF SEASONAL PRECIPITATION FORECAST FOR THE JUNE-JULY-AUGUST (JJA) SEASON INITIALIZED IN APRIL

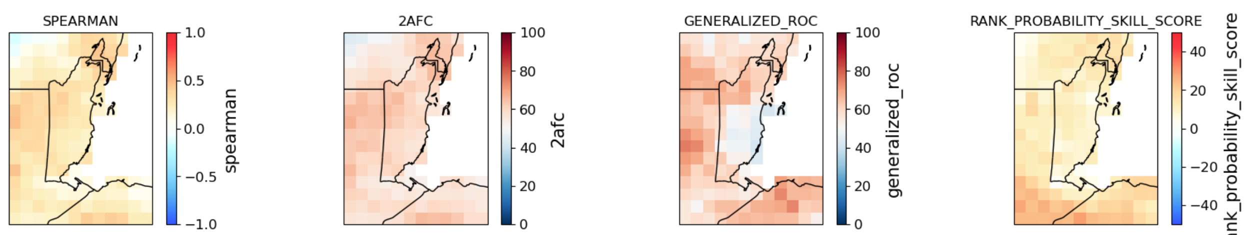
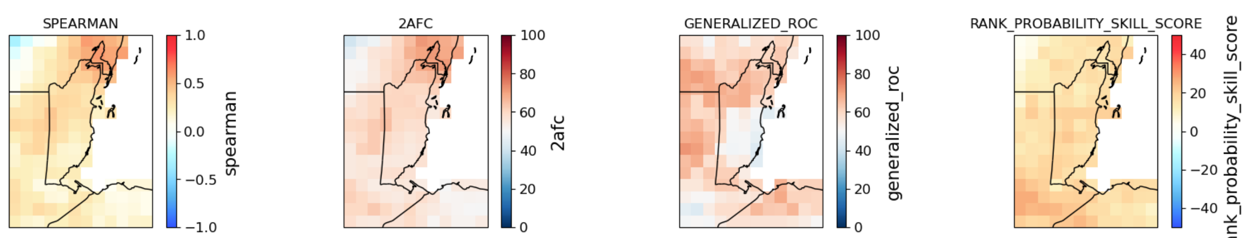


FIGURE 23. PREDICTIVE SKILL OF SEASONAL PRECIPITATION FORECAST FOR THE JUNE-JULY-AUGUST (JJA) SEASON INITIALIZED IN MARCH



Source: authors.

In the context of anticipatory actions for agriculture, communicating the uncertainty of seasonal precipitation forecasts is critical for effective decision-making. Farmers can use the seasonal forecast to inform their planting, irrigation and harvesting strategies. However, precipitation predictions, especially at a seasonal scale, carry inherent uncertainties due to the complexity of the climate system and model limitations. Properly communicating these uncertainties allows farmers and agricultural planners to make informed decisions that protect against potential risks by minimizing the impacts of adverse weather conditions such as drought or excessive rainfall.

With anticipatory actions, the goal is to take proactive measures before adverse climate impacts occur, reducing the vulnerability of crops and livelihoods. Providing farmers with forecasts that explicitly acknowledge and include uncertainty allows them to adjust their farming practices with greater flexibility. For example, in a seasonal forecast that indicates a 70% chance of below-average rainfall, it also presents the possibility of normal or even above-average rainfall. In this case farmers can implement strategies that balance both risks, such as selecting drought-tolerant crops or adjusting irrigation schedules. Clearly communicating this uncertainty can prevent over-reliance on forecast results without associated uncertainty, which can lead to economic losses if forecast conditions do not materialize.

5. Designing an Anticipatory Action Framework for Drought

5.1 Using Agroclimatic Calendars and Forecasts to Define Triggers

As discussed in section 2.2, a detailed understanding of agroclimatic calendars is fundamental for the successful implementation of anticipatory actions, as it allows us to identify critical periods for crop development and the optimal climatic conditions that favor their growth. In section 2.2, some of the agroclimatic activities identified by farmers for some of the most relevant crops in each region (Corozal, Orange Walk, and Cayo) have been highlighted. This knowledge is essential to anticipate the moments in which climatic variations, such as precipitation, can have a direct impact on agricultural productivity and to decide on the course of action at the farm level before the event happens. Many of the agricultural activities could be informed by the forecasts with a lead time of 3 months (e.g., forecast in March for June-July-August precipitation) with the highest confidence given to the forecast in May for June-July-August as discussed in the previous section. This means that under a risk-management framework, the most expensive anticipatory actions (e.g., cash transfers, input distribution, etc.) should be informed by the forecast with the least uncertainty (lead time of one month) for the JJA period.

5.2 Prioritizing and Tailoring Anticipatory Actions

Assuming that farmers will be the end-users as opposed to WFP or Cooperatives/Associations, an evaluation of possible anticipatory actions at the farm/household level needs to be undertaken. A prioritization and validation system for the actions needs to be established, in which the costs of the actions and their potential impact are being evaluated (high cost, high impact vs. low cost, low impact). High-cost actions should be carried out when the forecast suggests high confidence in the assigned probabilities (below normal, normal or above normal), and for this it is critical that the forecast be accompanied by predictive ability measures such as reliability and sensitivity. In the same way and based on these, the temporal and spatial consistency of the forecasts should be observed given their initializations. For example, for a seasonal precipitation forecast for the critical period of June-July-August, the predictive ability of the ensemble of models from February to May should be observed. In the same way, the probabilistic and deterministic forecast and its spatial consistency should be evaluated by the Meteorological Service of Belize. It allows field actions to be derived and key parameters of triggers and thresholds to be established for the activation of the corresponding actions for each region.

Additionally, understanding the geographic distribution of crops of interest is essential to contextualize climate forecasts within an appropriate spatial framework. Different crops have different sensitivities depending on the region and altitude, which implies that anticipatory actions must be localized and specific. With maps and geospatial analysis, it is possible to prioritize the areas that require greater attention and adapt interventions according to geographic vulnerability. This step allows resources and efforts to be focused on the most vulnerable areas, optimizing the effectiveness of actions.

It is clear that seasonal climate forecasting, particularly for precipitation, is a vital tool for anticipatory actions in data-deprived regions like rural areas in Latin and Central America. Utilizing sources such as the NMME and C3S, and employing rigorous methods to assess predictive skill, enhances the reliability of these forecasts. This underscores the potential of using advanced modeling approaches to improve seasonal rainfall predictions in Central America, offering valuable insights for enhancing resilience and adaptive capacity in Belize and beyond. The next steps include identifying the delivery mechanisms for climate information to ensure they are clear, trusted and relevant to farmers at the appropriate lead time for their decision-making.

5.3 Conclusion and Looking Ahead

This report marks an important first step towards developing an anticipatory action mechanism for drought in Belize, focused on protecting farmers' livelihoods and food security. By combining local knowledge through community mapping and agroclimatic calendars with scientific assessments of seasonal forecast skill, it highlights practical ways to identify when and where actions can be taken before drought impacts fully materialize.

Key findings emphasize the critical role of understanding crop cycles and agricultural decision points, the spatial distribution of vulnerable livelihoods, and the lead times at which reliable seasonal forecasts can support forward-looking and anticipatory decision-making. The report also underscores that defining drought triggers will require close collaboration between technical partners, including MAFSE and the National Meteorological Service, to ensure that forecasts are translated into actionable information that reaches farmers in time to inform critical choices.

Looking ahead, strengthening these capacities and systems will be essential to act ahead of drought, reduce the risks faced by smallholder farmers, and protect local and national food security in the face of increasing climate variability. Many of these farmers operate with limited reserves and high exposure to climatic shocks, which makes them particularly in need of timely measures to get ahead of negative impacts. They also hold detailed knowledge of local conditions and agricultural timing, which must be incorporated into any effective anticipatory system. Ensuring that early actions are locally relevant and clearly communicated will be key. By putting farmers at the center of anticipatory action design, Belize can build a more inclusive and resilient response system to climate risk.

References

Copernicus Climate Change Service. (2021). Seasonal Forecasting. Retrieved from https://climate.copernicus.eu/seasonal-forecasting

Dorward, P., Clarkson, G., & Stern, R. (2015). Participatory Integrated Climate Services for Agriculture (PICSA): Field Manual. CIAT and University of Reading. https://www.reading.ac.uk/picsa/tools/field-manual

Food and Agriculture Organization. (2016). Agroclimatic Calendar Guide. Available at https://www.fao.org/home/en/

Global Fire Monitoring Center (GFMC)- Bush fires persist throughout Belize; MDRM updates public. June 10th, 2024. Access via: https://gfmc.online/2024/06-2024/bush-fires-persist-throughout-belize-mdrm-updates-public.html

IFAD. (2018). *Community Mapping for Climate Resilience*. https://www.ifad.org/en/web/latest/-/story/community-mapping

Jolliffe, I. T., & Stephenson, D. B. (2012). Forecast Verification: A Practitioner's Guide in Atmospheric Science. John Wiley & Sons.

Kirtman, B. P., Min, D., Infanti, J. M., Kinter III, J. L., Paolino, D. A., Zhang, Q., ... & Becker, E. (2014). The North American Multimodel Ensemble: Phase-1 seasonal-to-interannual prediction; Phase-2 toward developing intraseasonal prediction. Bulletin of the American Meteorological Society, 95(4), 585-601.

Kowal, K., Barraza, V., & Mariotti, A. (2022). A comparison of seasonal rainfall forecasts over Central America using dynamic and hybrid approaches from Copernicus Climate Change Service seasonal forecasting system and the North American Multimodel Ensemble. Climate Dynamics, 59(9-10), 2347-2362.

Lee, J.-Y., J. Marotzke, G. Bala, L. Cao, S. Corti, J.P. Dunne, F. Engelbrecht, E. Fischer, J.C. Fyfe, C. Jones, A. Maycock, J. Mutemi, O. Ndiaye, S. Panickal, and T. Zhou, 2021: Future Global Climate: Scenario-Based Projections and NearTerm Information. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 553–672, https://doi.org/10.1017/9781009157896.006.

Mason, S. J., & Weigel, A. P. (2009). A generic forecast verification framework for administrative purposes. Monthly Weather Review, 137(10), 3311-3320.

Maurer, E. P., Stewart, I. T., Joseph, K., and Hidalgo, H. G.: The Mesoamerican mid-summer drought: the impact of its definition on occurrences and recent changes, Hydrol. Earth Syst. Sci., 26, 1425–1437, https://doi.org/10.5194/hess-26-1425-2022, 2022.

McCall, M. K. (2014). Mapping territories, land resources and rights: Communities deploying participatory mapping/PGIS in Latin America. Revista do Departamento de Geografia – USP, Volume Especial Cartogeo, 94–122.

National Meteorological Service of Belize. (2021). Annual Weather Report. Available at: https://www.hydromet.gov.bz/

Fals-Borda, O. (1987). The Application of Participatory Action-Research in Latin America. *International Sociology*, *2*(4), 329-347

Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., ... & Michaelsen, J. (2015). The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. Scientific Data, 2, 150066. https://doi.org/10.1038/sdata.2015.66
World Food Programme. (2019). Anticipatory Actions in Response to Seasonal Climate Forecasts. Retrieved from https://www.wfp.org/publications/anticipatory-actions-response-seasonal-climate-forecasts

World Bank. (2020). Belize Climate Data. Available at: https://climateknowledgeportal.worldbank.org/country/belize

World Bank. (2020). Participatory Mapping and Planning. https://www.worldbank.org/en/home

Wilks, D. S. (2011). Statistical Methods in the Atmospheric Sciences. Academic Press. Available at:

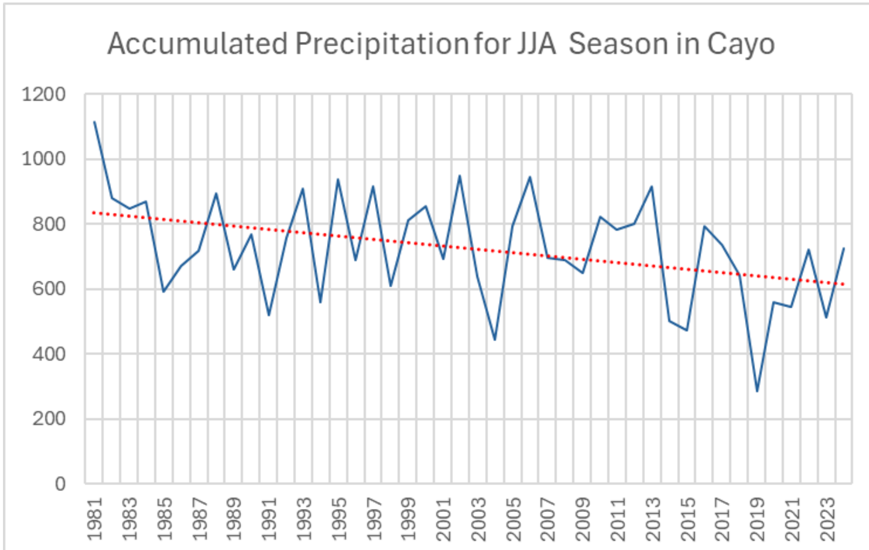
https://shop.elsevier.com/books/statistical-methods-in-the-atmospheric-sciences/wilks/978-0-12-385022-5

Photo credits

Cover page: WFP/Greta Aubke

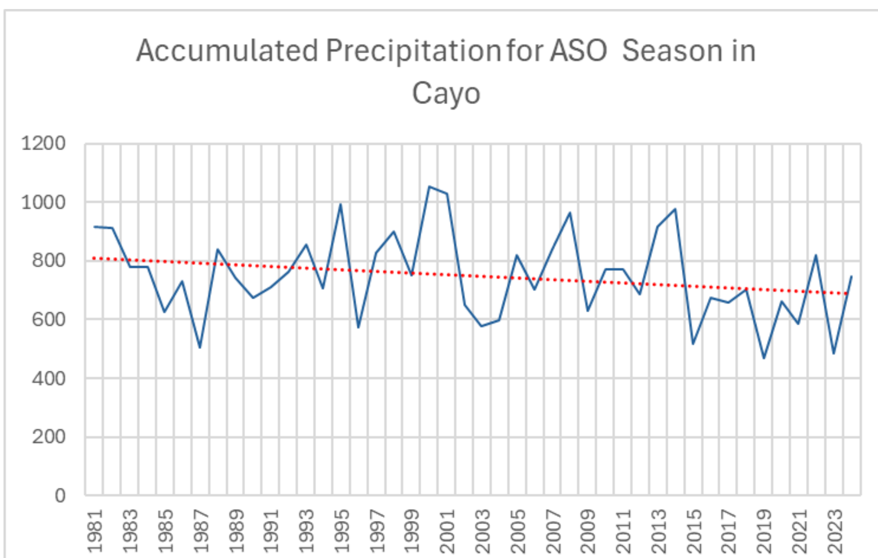
Annex I

ACCUMULATED PRECIPITATION | JUNE-AUGUST | CAYO



Source: The author with data from CHIRPS[41]

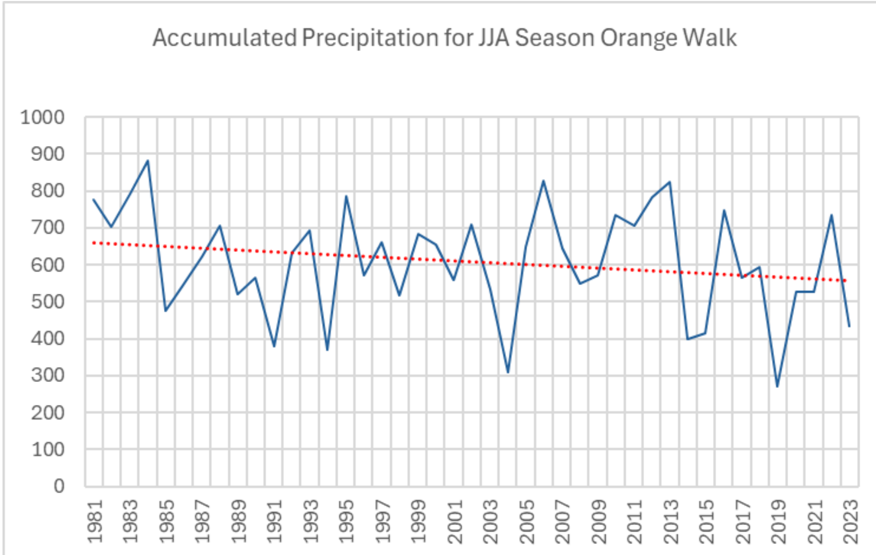
ACCUMULATED PRECIPITATION | AUGUST-OCTOBER | CAYO



Source: The author with data from CHIRPS[26]

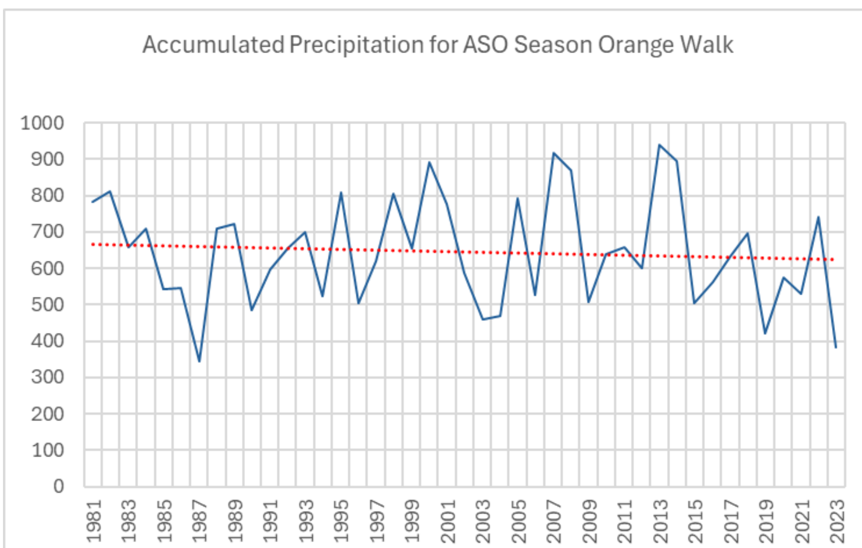
[41] Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., ... & Michaelsen, J. (2015). The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. *Scientific Data, 2*, 150066. https://doi.org/10.1038/sdata.2015.66

ACCUMULATED PRECIPITATION | JUNE-AUGUST | ORANGE WALK



Source: The author with data from CHIRPS[42]

ACCUMULATED PRECIPITATION | AUGUST-OCTOBER | ORANGE WALK



Source: The author with data from CHIRPS[26]

[42] Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., ... & Michaelsen, J. (2015). The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. *Scientific Data, 2*, 150066. https://doi.org/10.1038/sdata.2015.66

World Food Programme

Caribbean Multi-Country Office

UN House, Marine Gardens, Christ Church Barbados – T +1 246 467 6000

wfp.org/countries/caribbean