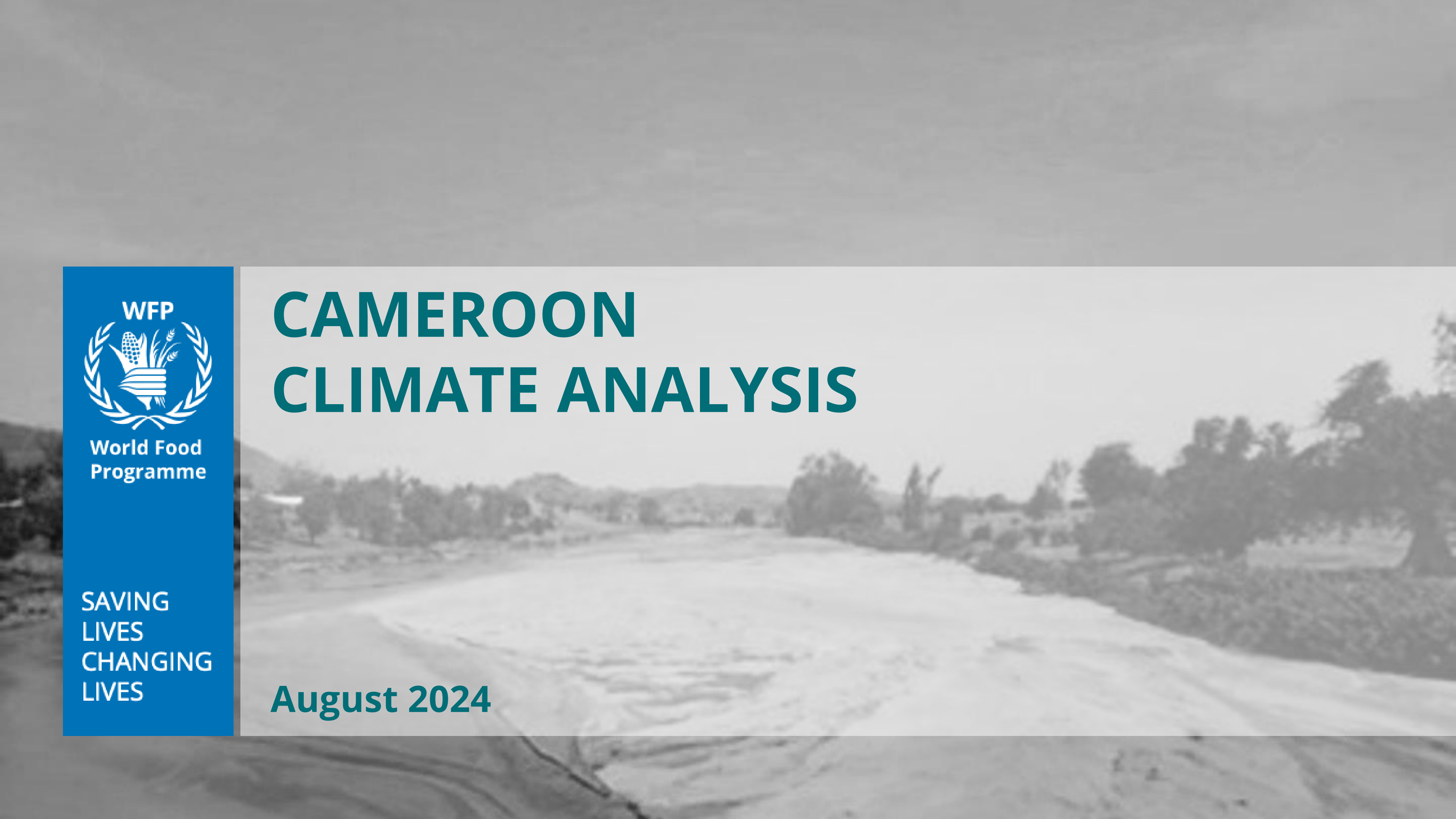

WFP
World Food Programme

CAMEROON CLIMATE ANALYSIS

August 2024

SAVING LIVES CHANGING LIVES

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Table of Content

BACKGROUND

Cameroon: Map of Regions

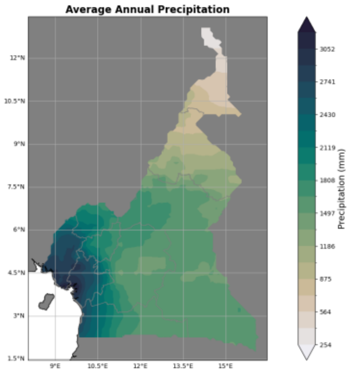
This document presents a comprehensive climate analysis for Cameroon, utilizing medium-term observational data over a period of 43 years, from 1979 to 2022, encompassing metrics on precipitation, temperature, and vegetation.

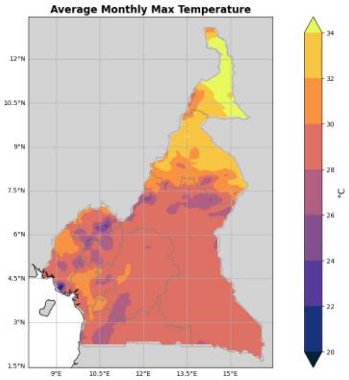
The framework of the study is centered around three pivotal themes: averages, variability, and trends. Within this context, 'averages' describe the broad climate attributes, 'variability' describes frequency, year-on-year changes, and 'trends' evaluate the direction and magnitude of long-term climatic shifts.

Disclaimer: The boundaries and names shown in this document do not imply official endorsement or acceptance by United Nations

BACKGROUND

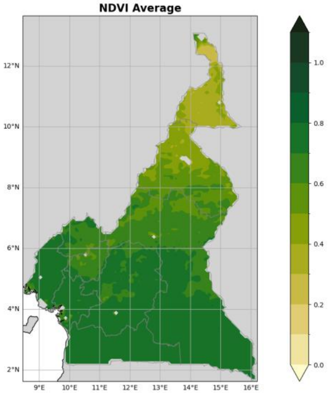
Rainfall: MSWEP
Global rainfall dataset.
Daily, 10km resolution
1979-2020





Temperature: MSWX
Global temperature dataset.
Daily, 10km resolution
1979-present

The research employed three sets of gridded data covering rainfall, temperature, and vegetation to conduct a comprehensive study across Cameroon. This involved identifying the average patterns for each variable throughout the country, examining how these patterns have shifted over time at both national and sub-national levels, and creating maps to visualize the trends for each variable throughout the study period. These trends were analyzed on a monthly basis to categorize regions by their seasonal trend profiles.



Vegetation: NDVI
Global GIMMS NDVI.
15days, 8km resolution
1982-2022

The findings sought to establish a correlation between the trends observed in rainfall (and to a lesser extent, temperature) data and the corresponding trends in vegetation, ensuring a coherent understanding of climate dynamics and its impact on natural landscapes in Cameroon.

EXECUTIVE SUMMARY

Agro-Ecological Zones and Rainfall Patterns:
Cameroon exhibits five distinct agro-ecological zones with diverse rainfall patterns:

- The semi-arid North and Far North regions experience one short rainy season.
- The Adamawa region has a prolonged rainy season.
- The western highland regions enjoy an even more extended rainy season.
- The southern and central regions have a bi-modal rainy season.
- The southwestern regions feature a mono-modal tropical rainforest climate.

Overall Rainfall Trends: Over the past four decades, there is an observed shift towards drier conditions across most of Cameroon. While most regions show a decrease in rainfall, the Littoral, Far North, and South regions maintain stable rainfall levels, and the South-West region shows a slight increasing trend.

Yearly Rainfall Variability: The Far North region faces significant variability (over 35%), leading to unpredictable rainfall patterns that push communities towards more conservative livelihood strategies, like pastoralism.

Decade-Scale Precipitation Changes: There is a general decreasing trend in annual precipitation, with the East region experiencing the most significant decrease (6-9% per decade). In contrast, the Far North and South regions show minimal declines, while the South-West region sees an increase in rainfall (3-6% per decade).

Monthly Rainfall Anomalies: Notable anomalies include:

- In the North, the dry season shows significant increases in rainfall in February (20% per decade), followed by a dramatic decrease in March (43%), misleading farmers into premature planting, risking crop failures and undermining food security and economic stability.
- During the traditional dry season, northern regions experience increased rainfall, while central and other northern areas see a significant decrease in December (42%) and January (60%) rainfall. These trends suggest more intense dry periods and heighten flood risks.

Rainy Days Trends: There is a steady decrease in the number of rainy days, with more intense rain events contributing to annual totals. This results in delayed onset of the rainy season and fewer but more intense rainfalls.

Heavy Rainfall Days: The frequency of heavy rainfall days corresponds to wet and dry seasons, with anomalies like decreased heavy rain at the start of the rainy season in northern regions, potentially reducing the risk of soil and crop damage; and increased heavy rains during the short dry season in southern tropical forests, leading to elevated risks of soil erosion and flash floods.

Dry Spells During Rainy Season: Significant regional variations exist, with Far North experiencing long dry spells in June, but showing a favorable trend of decreasing lengths. Despite this, the Far North experiences high year-to-year variability, with 8-10 day oscillations, impacting its short and intense rainy season. In contrast, the central and southern regions show moderate and low dry spell lengths, but face an increasing trend over longer periods.

Vegetation Health and Quantity (NDVI): Regional variations in vegetation closely align with rainfall patterns. The South, with abundant rainfall, shows thriving vegetation, while the north, with limited rainfall, exhibits sparse vegetation and water scarcity challenges. High inter-annual rainfall variability leads to corresponding NDVI variability, impacting agricultural stability. An anomalous decreasing trend in NDVI observed in the North region during rain season onset, in May, which suggests that the beginning of the rainy season may have been delayed, or the early rains were insufficient to stimulate immediate growth in vegetation.

Temperature Trends: Northern regions experience the highest increases in maximum temperatures, leading to more extreme daytime heat. Central and northern regions see rises in minimum temperatures, indicating warmer nights. These temperature increases could elevate evaporation rates, intensify water scarcity, and disrupt ecosystems.

Conclusion: Addressing national climate challenges requires region-specific adaptive strategies. In the North and Far North regions, developing infrastructure for rainwater harvesting, flood control measures and promoting drought-resistant crops, crop diversification, conservative livelihood strategies like pastoralism can mitigate the impacts of unpredictable rainfall and high variability. Implementing efficient irrigation systems and water management practices is crucial in the East and central regions to counter prolonged dry spells and decreasing rainfall trends. In the South-West and Littoral regions, maintaining sustainable agricultural practices and soil conservation techniques will manage the risks of soil erosion and flash floods due to heavy rains. Robust early warning systems and climate monitoring should be prioritized to provide timely and accurate information, enabling communities to prepare for extreme weather events.

OVERVIEW

In terms of **data** used, the analysis used a 41 year long gridded rainfall record of Multi-Source Weighted Ensemble Precipitation (MSWEP) from 1979 to 2020. MSWEP background field explains **3.86** times more rainfall variability than CHIRPS background field. CHIRPS data records starts from 1981. The analysis uses 43 year long temperature records of Multi-Source Weather (MSWX) from 1979 to 2022. MSWX leverages the strengths of various sources to develop a comprehensive global surface temperature dataset with improved spatial and temporal resolution, accuracy, and coverage, achieved through the unique merging of Climatologies at High resolution for the Earth's Land Surface Areas (CHELSA) climatology, Climatic Research Unit Time Series (CRU TS), and ERA5 Reanalysis data. The vegetation data set was somewhat shorter, from 1981 to 2022, and it used the Normalized Difference Vegetation Index (NDVI) as a metric that describes the quantity and health of vegetation.

Cameroon's **rainfall distribution** showcases a stark gradient, with the South-West region receiving the highest annual levels of up to 3207 mm, in stark contrast to the Far North's minimal 253 to 581 mm. Central Cameroon acts as a transitional zone with moderate rainfall ranging from 1556 to 2222 mm, represented by varying shades of green on climate maps. The rainy season begins with a gradual increase in precipitation in February and March, peeking from June to September, which is the only rainy season in the semi-arid Far North. Concurrently, the southern and central regions experiences its primary rainy season from mid-March to June, followed by a shorter secondary season from September to November. The southwestern regions characterized with tropical rainforest climate has intense mono-modal rainy season from March to November, while the western regions in the highlands experience low rainfall from January to March, with rainfall increase from April and peaks in July and August and August and September, respectively. The diverse rainfall patterns, from the pronounced dry season to the intense wet periods, mirror the country's shift from equatorial in the south to Sahelian climates in the north. These patterns, detailed through long-term regional data, indicate extended rainy seasons in the central and coastal regions, with significant rainfall in the Littoral region from June to October. Such climatic diversity requires tailored approaches to agricultural planning and water management across Cameroon's distinct agro-ecological zones.

The analysis of Cameroon's rainfall reveals a complex picture of fluctuating patterns and long-term trends. A significant finding is the overall decrease in rainfall, as indicated by a steady downward trend line, suggesting a broader climatic shift towards drier conditions over four decades.

This pattern of decline is particularly pronounced in areas like the East region, where the decrease in precipitation is starker, hinting at more acute challenges ahead in terms of water scarcity and agricultural impacts. However, this general trend of diminishing rainfall is not uniformly observed across all regions; the Far North and South regions exhibit relatively stable precipitation patterns with only minor reductions, indicating less pronounced long-term changes. Notably, the Littoral region maintains a striking level of precipitation consistency over the years, despite yearly fluctuations, pointing to a unique climatic stability. While South-West region experiences a slight increase in rainfall amounts. These findings highlight the nuanced nature of climatic changes from 1979 to 2020 within Cameroon, emphasizing the need for region-specific strategies in addressing the potential impacts of long-term drying trends on agriculture, ecosystems, and water management.

Inter-annual variability in rainfall, marked by season-to-season changes and quantified by the coefficient of variation, reveals that Far North region experiences significant variability, over 35%, leading to unpredictable rainfall patterns. This high variability is especially impactful in regions with lower average annual rainfall, such as the Far North and North, challenging the socio-economic resilience of these communities. The irregular precipitation forces a shift towards more conservative, risk-averse livelihood strategies, often pushing communities away from farming due to its unreliability and towards alternative means like pastoralism. Both short-term annual changes and long-term climatic trends contribute to this variability, affecting the regional precipitation patterns and socio-economic stability. To combat these challenges and support resilience, a comprehensive approach that includes informed policy-making, proactive community engagement, and innovative technology utilization is essential for managing the effects of climate variability.

The comprehensive analysis of rainfall in Cameroon from 1979 to 2020 reveals a broad trend of decreasing precipitation across many areas, with notable exceptions are the two coastal regions, South-West and Littoral, where rainfall has slightly increased and remained constant, respectively. This disparity underscores the climatic diversity of Cameroon and necessitates region-specific adaptation strategies. Detailed monthly trend analysis further clarifies the seasonal distribution of these changes, highlighting critical periods of decreased rainfall that can adversely affect agricultural planning and water management.

SUMMARY

In particular, the analysis identifies three distinct zones with unique challenges: the southern regions face early-season rainfall declines, threatening agriculture; the northern areas experience extreme variability, complicating resource planning; and the central zones deal with severe dry spells, demanding drought-resistant agricultural practices. These insights emphasize the urgent need for tailored strategies to mitigate the impacts of climate variability on Cameroon's environmental health, agriculture, and water security, showcasing the complex interplay between climate trends and socio-economic resilience.

The analysis of rain days in Cameroon reveals a nuanced pattern across its diverse climates, showing a consistent decrease in rain days, particularly in the southern regions, indicating a shift towards fewer but potentially more intense rainfall events. This change poses varying challenges across the country, from the south's reliable equatorial climate to the north's predictable semi-arid conditions. The trend analysis highlights significant shifts, such as delayed rainy seasons in the north and stronger dry periods in the south, necessitating adaptive agricultural and water resource management strategies. Four distinct climatic zones have been identified, each requiring tailored approaches to combat the impacts of these changes, including the implementation of efficient water management practices, adaptation of cropping calendars, and sustainable land management. These strategies are crucial for maintaining ecological integrity and ensuring the sustainability of agricultural activities in the face of decreasing rain days and increasing climatic variability across Cameroon.

The distribution of heavy rainfall days in Cameroon mirrors the pattern of average seasonal rainfall, with regions like the Littoral and South-West experiencing the most heavy rainfall events per season, consistent with their higher average seasonal rainfall. Conversely, the Far North and areas within the North, Adamawa, and East regions see the fewest heavy rainfall days, aligning with their lower seasonal rainfall averages. Notably, while the trend in heavy rain days shows an increase, especially in the central to eastern parts of Cameroon, the overall annual rainfall is decreasing, particularly from the northern to central regions. This divergence suggests a shift towards less frequent but more intense rainfall events, a pattern that aligns with certain climate change scenarios, indicating changes in climate behavior where periods of intense rainfall become more common, even as total rainfall volume may decline.

Optimal agricultural productivity in Cameroon hinges not only on cumulative rainfall but on the spread and timing of rain and dry spells that critically determine crop resilience and yield. The Far North's prolonged dry periods, stretching up to 38 days, threaten water availability and agricultural stability, demanding robust drought management strategies. While the Southern regions experience shorter dry spells conducive to traditional farming cycles, they must still navigate the variability with careful monitoring and proactive irrigation systems. However, the North's decreasing dry spell lengths highlight the more favorable agricultural conditions. In contrast, the Southern regions' increase in dry spell lengths suggests can hinder crop growth and development. To tackle the challenge of inter-annual variability, particularly in the Far North with oscillations of 8 to 10 days, a multi-pronged strategy is vital. It includes deploying advanced seasonal forecasts, promoting crop diversification to build resilience, and implementing robust water conservation techniques.

The Normalized Difference Vegetation Index (NDVI) illustrates a clear dichotomy in vegetation health across Cameroon, closely tied to regional rainfall patterns. In the moisture-abundant south, high NDVI values highlight dense, thriving vegetation, supported by stable, ample water availability conducive to lush forests and fertile agricultural lands. Conversely, the arid north exhibits lower NDVI averages, reflecting sparse vegetation due to limited rainfall, characteristic of the Sahelian climate, impacting ecosystems and agriculture. Variability in annual rainfall directly influences NDVI trends, with regions experiencing significant precipitation fluctuations showing corresponding variations in vegetation health. This suggests a direct link between rainfall patterns and vegetation vitality, impacting agricultural productivity and ecosystem stability. To address these disparities, tailored management strategies are essential, focusing on sustainable practices in the south and innovative water management and drought-resistant crops in the north. Longitudinal data from 1982 to 2022 reveals a positive national trend in vegetation health, suggesting improvements in environmental management or climatic conditions. However, localized negative trends, especially in the southwestern rainforest regions, indicate challenges like deforestation and climate change effects. Seasonal NDVI analysis between March and October showcases the dynamic interplay between climate, human activities, and vegetation health, with staggered rainy seasons affecting regional vegetation trends differently. Effective land management and conservation efforts, particularly in agricultural zones and semi-arid regions, are pivotal in sustaining and enhancing vegetation health and resilience in Cameroon.

SUMMARY

The distribution of maximum (Tmax) and minimum (Tmin) temperatures in Cameroon highlights pronounced regional variations. The north experiences the highest Tmax, indicating a warmer climate compared to the cooler south. Tmin trends reveal significant increases in central and northern regions, suggesting a notable rise in night-time temperatures. This temperature variability is influenced by both topography and regional climatic conditions. Seasonal patterns show Tmax and Tmin peaking in late spring before the onset of the wet season, reflecting the climatic rhythm tied to the dry and wet cycles. During the wet season, temperatures moderate due to increased cloud cover and precipitation. Over the past decade, trends indicate disproportionate warming across regions, with northern regions witnessing a more significant rise in Tmin. This suggests a stark increase in night-time temperatures, particularly affecting the Far-North, North, and Adamawa regions. The rising Tmax, especially in the northern regions, contributes to more extreme daytime heat, which can lead to increased evaporation rates, reduced soil moisture, and stress on water resources. These changes have profound implications for environmental and socio-economic systems, particularly agriculture and water management. Adaptive strategies are necessary to cope with the temperature swings and their impacts on ecosystems and human health. The analysis underscores the necessity for Cameroon to adapt its agricultural practices, water management, and public health initiatives to the evolving climate, especially in light of the increased minimum temperatures extending beyond traditional dry and rainy seasons. This warming trend could exacerbate water scarcity, impact agricultural cycles, and alter ecosystems, demanding a comprehensive approach to climate resilience. This approach should include water conservation, drought-resistant crops, and infrastructure planning. Continuous climate monitoring and integrated management strategies are crucial for mitigating the adverse effects of temperature changes on Cameroon's diverse landscapes and communities.

Cameroon’s climate varies from tropical in the south to semi-arid in the north, heavily influencing its rainfall patterns and seasons. Due to its diverse geography, bordering the coast in the west and extending into Central Africa, Cameroon experiences distinct climatic zones which affect the duration and intensity of its rainfall seasons.

Northern Cameroon experiences a more semi-arid climate, with single rainy season from June to September, while southern Cameroon experiences a tropical climate with two primary rain seasons with major rainfall season lasting from mid-March to June, and second, shorter rainy season from September to November.

Areas of lower rainfall include northern divisions of Far North and North with seasonal amounts of just over 500mm and 1,000mm respectively. While high rainfall areas include the south-western divisions of South West and Littoral with seasonal amounts over 2,500mm.

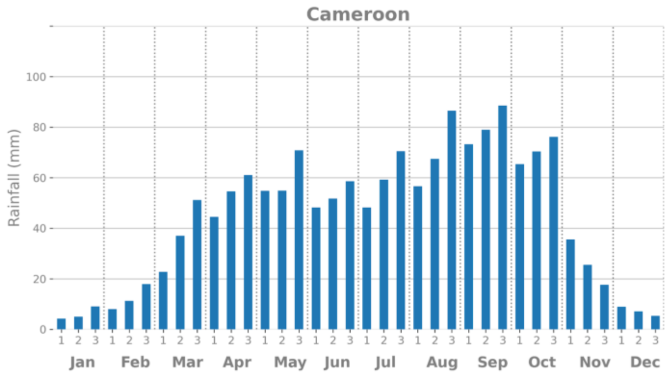


Chart 1 - National Average Annual Rainfall

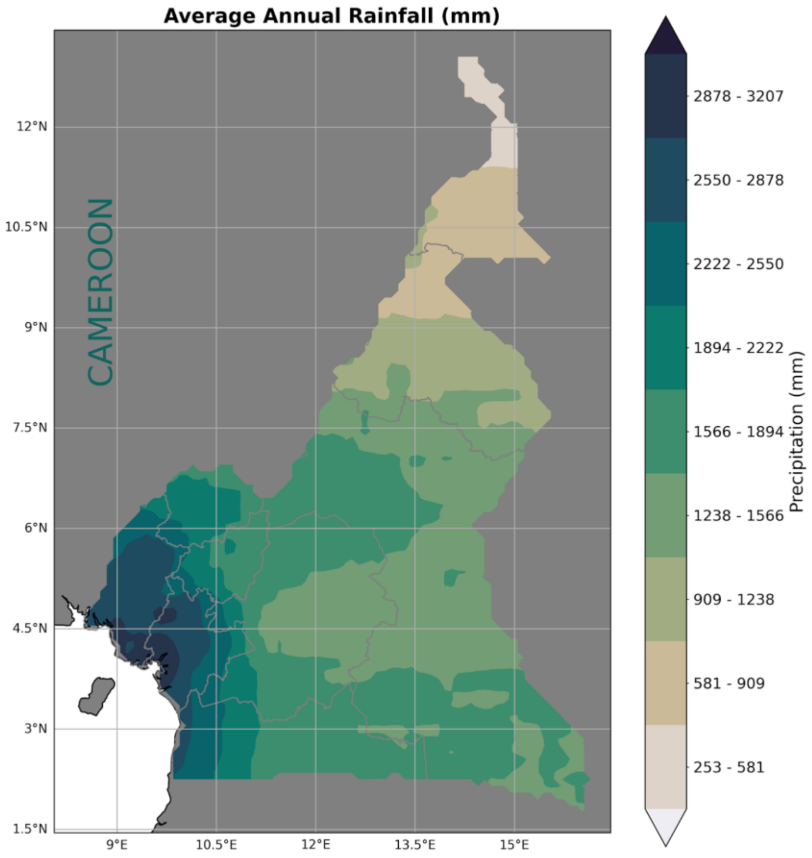
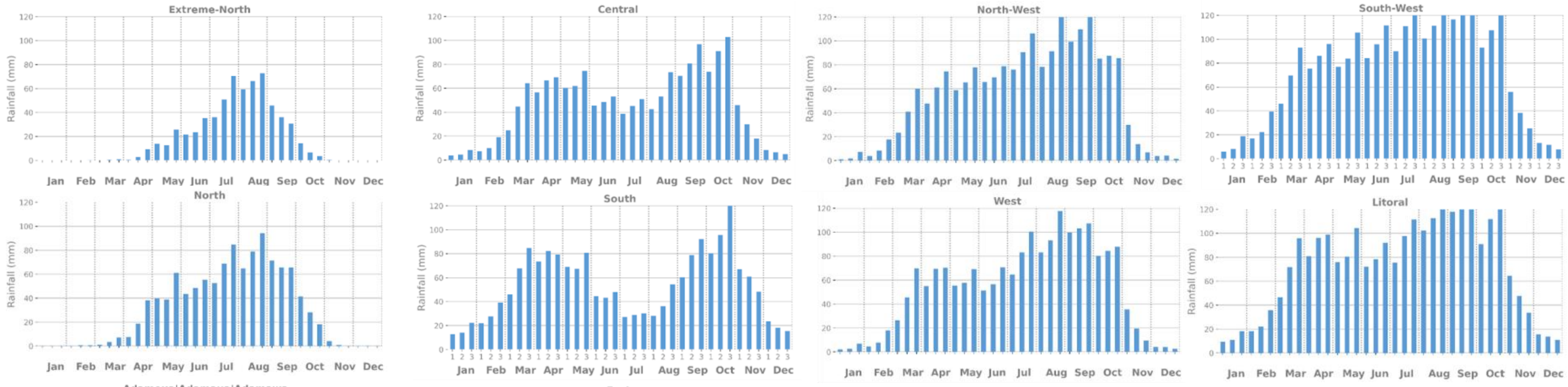


Figure 1 - National Average Annual Rainfall

RAINFALL — Region-level long-term average seasonal profiles



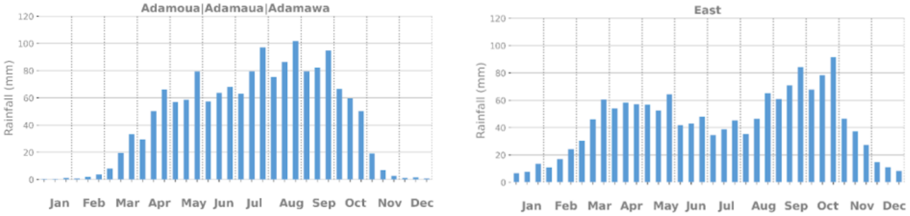


Chart 2 - Region-level Average Annual Rainfall

The graphs show the long-term (1979-2020) seasonal rainfall profile for each of the ten regions of Cameroon, with blue bars representing a long-term average of 10 day mean region rainfall.

This region-level data underscores Cameroon's climatic complexity, and reflects the climatic gradient from the semi-arid Sahelian north to the equatorial south, crossing through variable central terrains.

The rainfall patterns are geographically diverse. The northern regions, including Adamawa, North, and Extreme-North, experience a defined peak in rainfall around August, indicative of their shorter rainy seasons within a semi-arid climate. The Adamawa region experiences a slightly more extended rainy season compared to the North and Extreme-North regions, providing a longer growing season that allows for more diverse agricultural activities. Transitioning southward, the Central, East, and South regions experience two distinct rainy seasons. The first rainy season occurs from March to June, followed by a short dry spell in July and August, and then a second rainy season from September to November, with peaks in May and October. The North-West and West regions experience low rainfall from January to March, with rainfall increase from April and peaks in July and August and August and September, respectively. The rapid changes in dekadal rainfall suggest high variability in rainfall amounts which can disrupt agricultural schedules. In the coastal South-West and Littoral regions, which embrace a tropical rainforest climate, there is one of the longest and most intense rainy seasons from March to November, with significant peaks occurring from March to October and July to October, respectively. The consistent and substantial rainfall during the peak months supports a variety of crops but requires effective water management strategies to address the risks of flooding and landslides.

RAINFALL — All Cameroon Seasonal Long-Term Rainfall Amounts

The graph shows a plot of the all-Cameroon seasonal rainfall from 1979 until 2020. It ignores the within country variation in order to provide clear overview of the changes in rainfall along the available temporal record.

The time series graph reveals notable fluctuations in precipitation, with the blue line representing the year-to-year changes showing significant variability. Overlaying this is the red line, a five-year moving average that smooths out these annual variations to highlight medium-term trends, which appear to oscillate, suggesting alternating periods of relatively wet and dry conditions over the years. The most critical feature of this graph is the black trend line, indicating a gradual but steady decrease in rainfall over the more than four decade period. This declining trend suggests a long-term drying pattern that could be linked to broader climatic shifts, possibly influenced by global climate trends. While the moving average demonstrates the intermediate variability, the persistent downward trend line calls attention to the potential long-term challenges that Cameroon may face, such as shifts in agricultural viability, ecosystem changes, and water resource management.

The data thus underscores the importance of understanding both the short-term variability and long-term changes in rainfall patterns for informed agro-ecological planning and sustainable development in Cameroon.

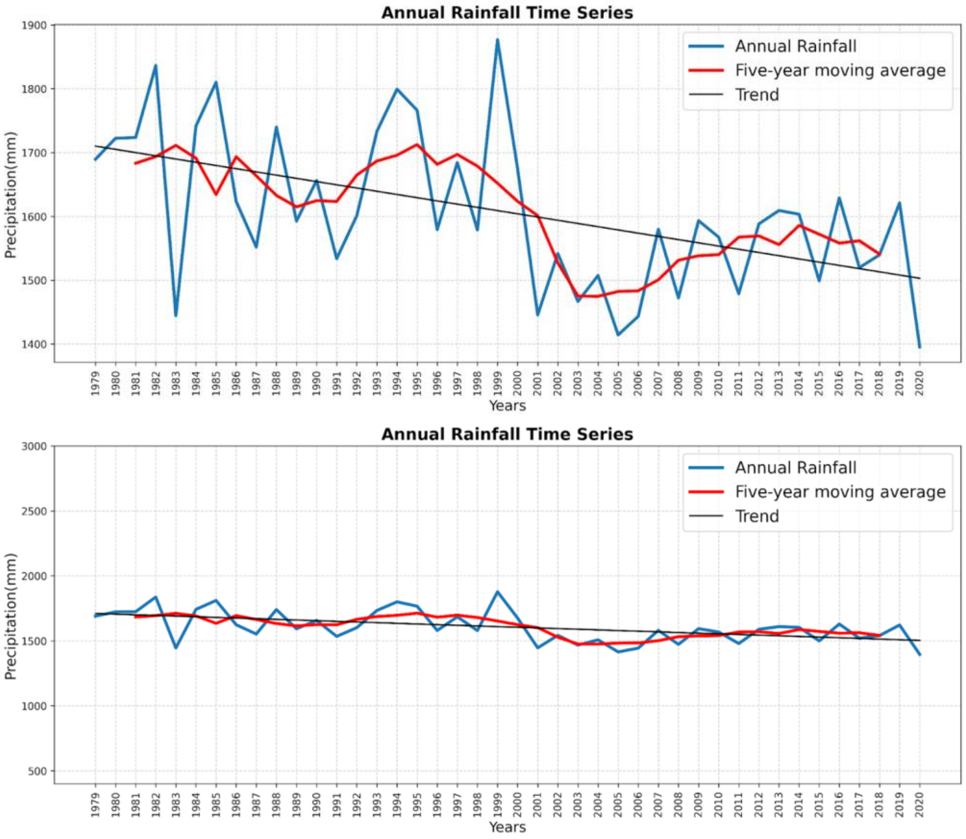
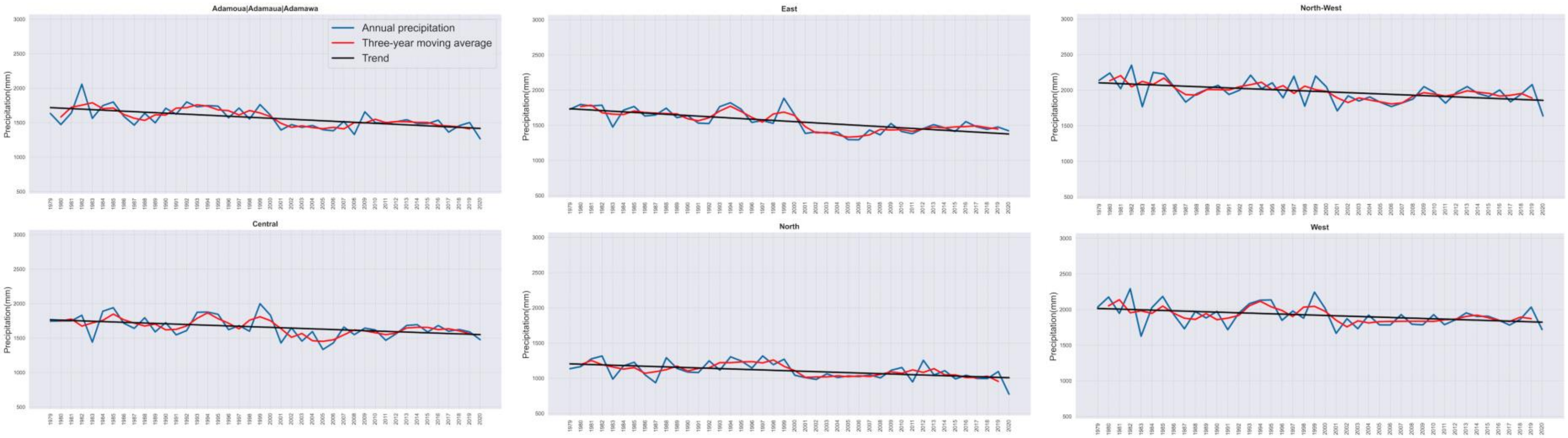


Chart 3 - All Cameroon Seasonal Rainfall Amounts

RAINFALL — Region-Level Seasonal Long-Term Rainfall Amounts



The rainfall trends across the regions of Cameroon from 1979 to 2020 there is a general pattern of decreasing precipitation over time, though the degree of this decrease varies from region to region. Across a collection of regions including Adamawa, Central, East, North, North-West, and West a consistent trend of declining precipitation has been observed, with variability in the extent of this reduction. The East region, in particular, demonstrates a more acute decline, suggesting a steeper trend towards drier conditions. Despite this overarching trend, all regions experience significant variability from one year to the next, indicating that high rainfall years are still interspersed among generally drier conditions. The three-year moving average supports the presence of a gradual decline in precipitation, smoothing out the more immediate fluctuations, yet suggesting a longer-term trend of decrease. The root causes behind these declining trends remain to be fully determined, warranting further exploration. Climate change, deforestation, and alterations in land use are potential contributors that need to be examined more closely.

Chart 4 - Region-level Long-Term Rainfall

RAINFALL — Region-Level Seasonal Long-Term Rainfall Amounts

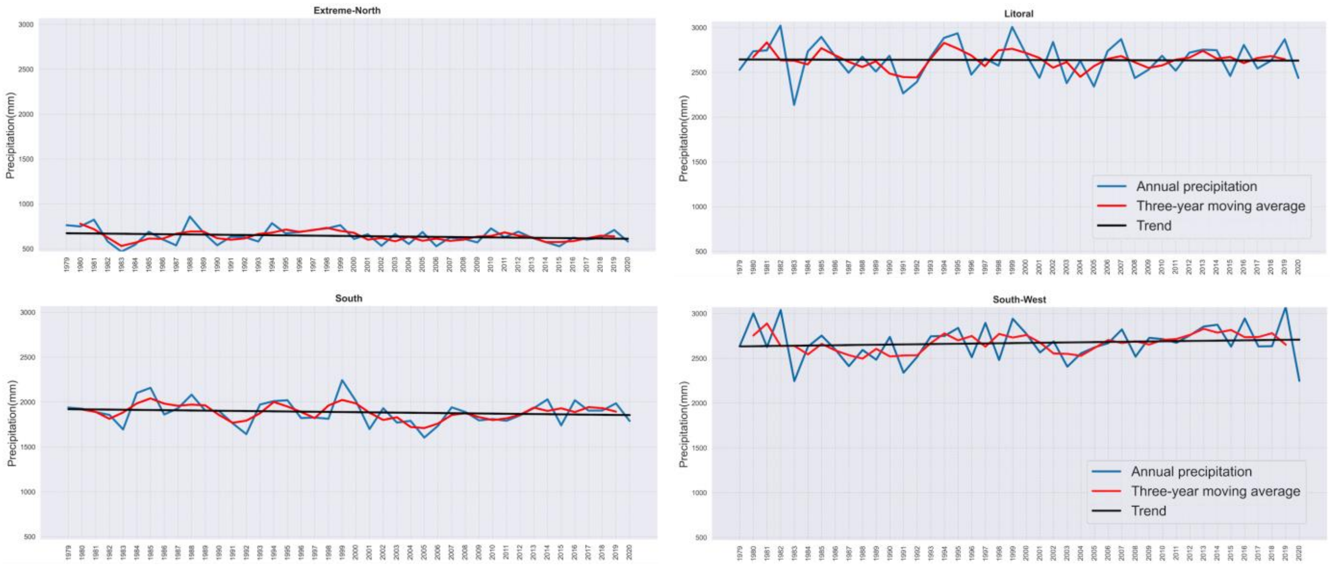


Chart 4 - Region-level Long-Term Rainfall

In contrast, the Extreme North (Far North) and South regions exhibit relatively stable precipitation trends with only minor decreases, highlighting less dramatic long-term changes compared to the aforementioned regions. The Far North region, in particular, presents an almost level trend, signifying a consistency in precipitation patterns with slight reductions. Similarly, the South region maintains a general stability, although a minor downtrend can be discerned. Despite this, year-to-year variability remains evident, suggesting that annual precipitation can still vary widely within these regions.

Standing apart are the two coastal regions, South-West and Littoral. While South-West region shows a slight increase in rainfall, Littoral region maintains a striking consistency in precipitation levels over time. The flat trend line points to an absence of a significant long-term increase or decrease in average annual precipitation, although variability is high on an annual basis. This implies that while individual years may present a range of wet to dry conditions, the overarching climate of the Littoral region has not shifted markedly over the years under consideration. This consistency in precipitation levels, despite yearly fluctuations, indicates a relative climatic equilibrium throughout the period studied.

The Coefficient of Variation (CV) is a statistical measure that standardizes the level of variability within a dataset relative to its mean, enabling comparisons across datasets with differing average values (e.g. wetter vs drier zones). By expressing the standard deviation as a proportion of the mean, the CV provides a dimensionless ratio that highlights the extent of variability in relation to the average value.

Inter-annual variability of rainfall refers to the fluctuations in precipitation from season to season. It is quantified by the coefficient of variation, which measures the extent of variability in annual rainfall relative to the mean over 1979 - 2020 period.

Figures 1 and 2 demonstrate that regions with lower average annual rainfall, specifically the Far North and North of Cameroon, exhibit more pronounced variability. The Far North, in particular, experiences variability above 35%, indicating highly unpredictable rainfall patterns that can drastically differ from year to year. This variability significantly impacts socio-economic resilience, compelling communities to adapt by adopting conservative, risk-averse livelihood strategies. The pronounced fluctuations in precipitation make agricultural livelihoods less reliable, pushing communities towards alternative livelihoods such as pastoralism. In cases of extreme variability, there may be a need to reevaluate the sustainability of farming altogether.

Inter-annual variability includes two components: short-term annual fluctuations and long-term trends. In Cameroon, both short-term fluctuations and long-term trends are important components of inter-annual variability, with their relative impacts varying across different regions of the country. These variations affect precipitation patterns and, consequently, socio-economic strategies and resilience. A multifaceted approach that encompasses informed policy-making, proactive community action, and the leveraging of technological innovations can enhance resilience to the impacts of climate variability and change.

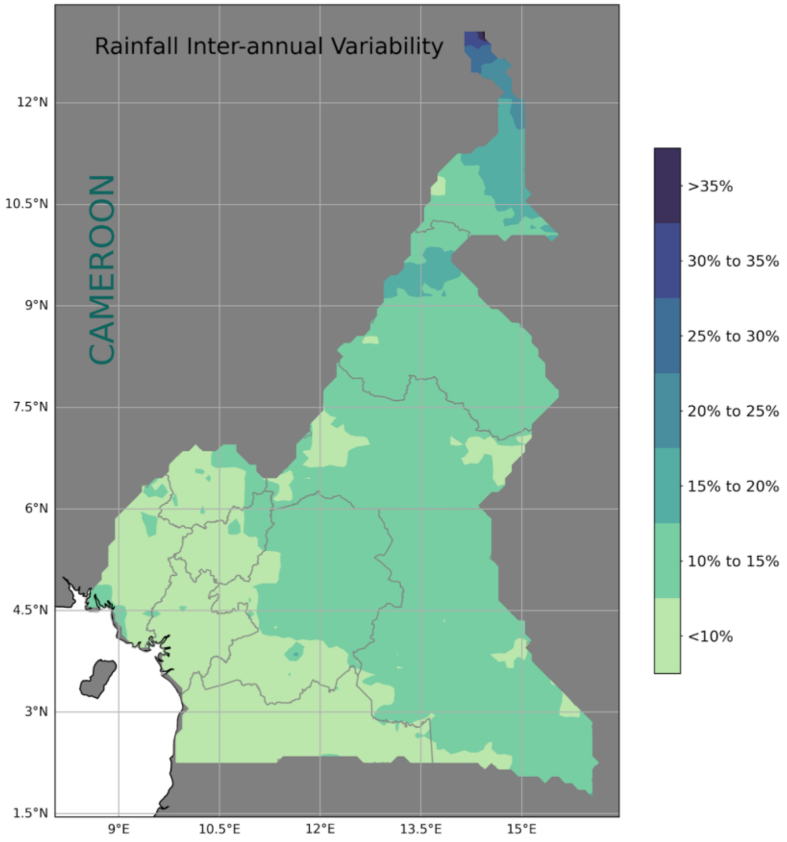


Figure 2 - Inter-annual Rainfall Variability (CV) 1979-2020

RAINFALL — Annual Rainfall Trends

The analysis of annual average rainfall time series has highlighted the diverse precipitation dynamics within Cameroon from 1979 to 2020. Building upon these initial findings, the forthcoming Figure 3. Annual Rainfall Trend (%/10yrs) assessment is examining the decadal-scale changes in precipitation. This quantitative evaluation is imperative for a comprehensive understanding of long-term climatic trends across the country's diverse regions. The focus on a ten-year trend percentage seeks to mitigate the short-term annual variations, thus offering a more granular view of the longer-term climatic changes.

Most regions are experiencing a reduction in rainfall, notably in the Adamawa, Central, East, North, North-West, and West regions, affirming trends noted in the annual rainfall time series. The East region exhibits the most significant decrease, at times 6-9% per decade, resulting in a cumulative change of 24-36% over four decades. The Extreme North and South regions, however, show minimal declines, indicating relative stability.

In contrast, the South-West and Littoral regions display a slight increase, which is more pronounced in the coastal area of South-West region of up to 6%/10yrs. These findings highlight the climatic diversity of Cameroon's regions and underscore the importance of region-specific approaches in climate trend analysis and adaptation strategies.

To refine the understanding of these trends, further analysis can disaggregate the data by mapping rainfall trends for each month separately. This nuanced approach allows can reveal how long-term changes in rainfall are distributed throughout the season. For instance, a long-term decrease in rainfall during the early months of the season may be offset by an increase in later months, resulting in no significant trend over the entire season. Such detailed analysis is invaluable for devising targeted climate adaptation measures that are attuned to the specific temporal patterns of change within each climatic zone.

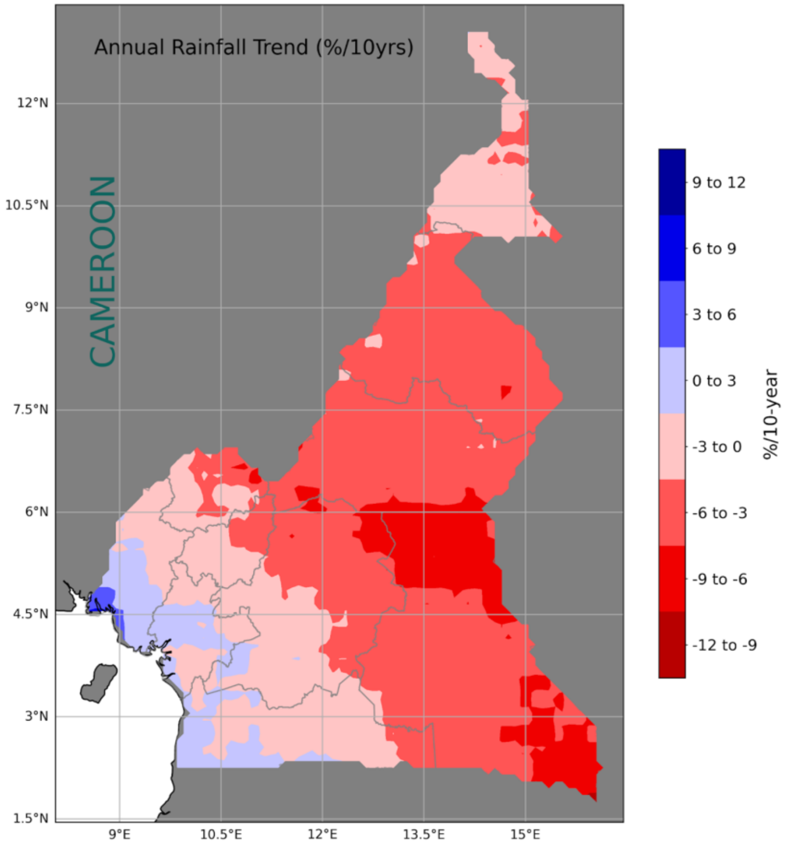


Figure 3 - Annual Rainfall Trend (%/10yrs)

RAINFALL — Monthly Rainfall Trends

In climatological studies, understanding **trends** in variables like rainfall is key to grasping long-term changes. These trends show whether there's a general increase or decrease in precipitation over time. By examining rainfall trends over decades and normalizing them as percentage changes relative to average rainfall, it becomes easier to compare different areas, irrespective of their baseline climatic conditions. This approach highlights how similar changes in rainfall can have different relative impacts depending on a region's typical rainfall levels. For example, a consistent decrease of -2.4 mm/year could represent a -2% change per decade in one area with higher average rainfall but a more substantial -4% change per decade in another area with less rainfall. This method reveals the relative significance of rainfall trends, offering a nuanced view of how climate change affects regions differently.

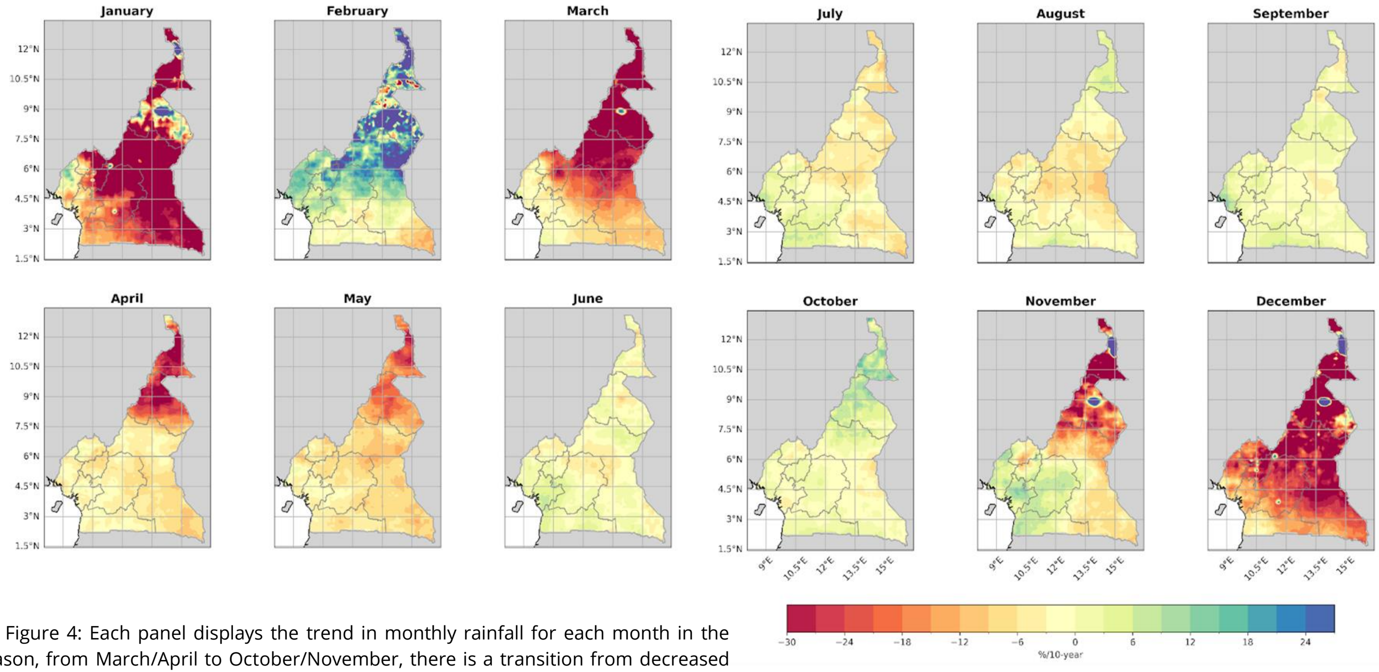


Figure 4 - Rainfall Monthly Trend (%/10yrs)

The monthly trend analysis is presented in Figure 4: Each panel displays the trend in monthly rainfall for each month in the calendar year. During the southern rain season, from March/April to October/November, there is a transition from decreased rainfall in the north and central regions in the early months (March to May) to a period of stability and minor increases across the country (June to August), aligning with the onset of the rain season in the north, which spans from May to September.

In the southern regions, where the rainy season is more prolonged, there is a gradual increase in rainfall as the season advances, culminating in more substantial increases from September to November. Conversely, the northern regions, after their rainy season ends in September, enter a pronounced dry season with notable declines in rainfall extending into December. However, there are anomalies, such as a significant trend in increase in rainfall observed in February in most of the northern regions, which could mislead farmers into prematurely initiating agricultural activities, anticipating the continuation of wet conditions. Should the expected rains not materialize, as suggested by the downward trend in March, such early planting efforts could result in crop failures, undermining food security and economic stability in these regions. Moreover, the trend analysis reveals that during the initial months of the traditional dry season (November, December, January), some northern regions experience significant trend in increased rainfall. This anomaly not only disrupts the anticipated agricultural calendar but also heightens the risk of flooding.

RAINFALL — Monthly Rainfall Trend Zoning

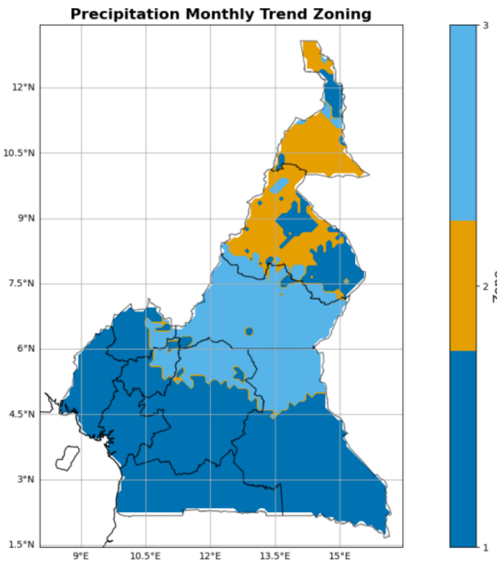


Figure 5 - Rainfall Monthly Trend Zoning

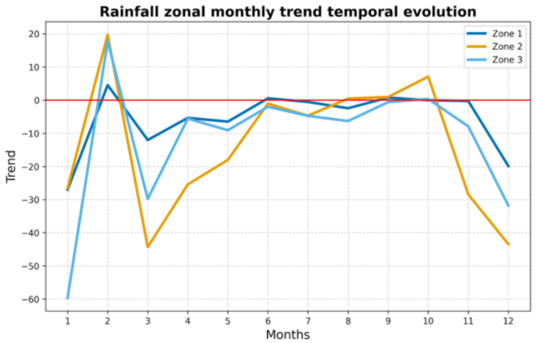


Chart 5 - Rainfall Zonal Monthly Trend Temporal Evolution

Figures 5 and Chart 5 identify regions where the monthly trends behave in similar way. The spatial distribution and temporal trends of rainfall vary markedly between three distinct zones, with each exhibiting unique seasonal dynamics that have profound implications for the region's ecological and socioeconomic fabric.

Zone 1, covering the southern regions, faces a precarious decline in rainfall at the critical onset of its rainy season in March, with a -11% trend over a decade, which threatens to delay crucial agricultural activities. This is followed by a consistent, though less severe, reduction in rainfall through to November, except for a marginal increase in June. The dry season from November to March sees an even more pronounced dry trend, with January's -29% and December's -20%, exacerbating water scarcity, hindering agriculture, and potentially reducing hydroelectric power output, upon which the region heavily relies.

Zone 2, predominantly in the northern regions, undergoes dramatic fluctuations. The dry season (September to May) sees a staggering rainfall trend rise in February (+20%/10yrs) followed by an alarming rainfall trend fall in March (-43%/10yrs), indicating extreme variability that can mislead agricultural scheduling and water resource planning. October to January is marked by a distinguished trend in decrease in precipitation, with December marking a negative of -42%, signaling a prolonged dry spell and harsher transition to drier conditions and underscoring the need for resilient agricultural strategies tailored to rapidly changing climate patterns.

Zone 3, in the central part of Cameroon, confronts a deeply negative trend during the peak of the dry season in December (-31%) and January (-60%), suggesting a more intense dry period. Such prolonged dry spells can deplete soil moisture, hinder planting schedules, and prompt the need for drought-resistant crop varieties. The persistent negative trends throughout the year, except for a slight uptick in February (+19%), heighten concerns over water management and the potential for adverse environmental effects such as increased wildfire risk and biodiversity loss.

Together, these trends across the three zones not only reflect the immediate challenges posed by climate variability but also underscore the urgent need for adaptive management strategies to safeguard Cameroon's agriculture, water security, and overall environmental health in the face of these ongoing climatic shifts.

RAIN DAYS — Average and Variability

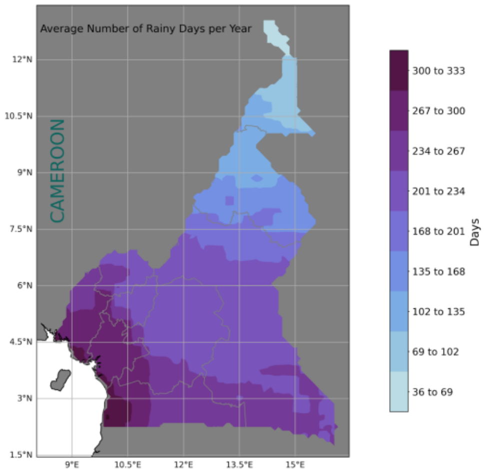


Figure 6 - Average Number of Rain Days per Year

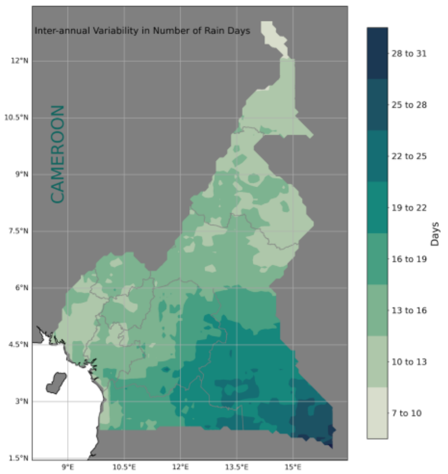


Figure 7 - Inter-annual Variability in Number of Rain Days

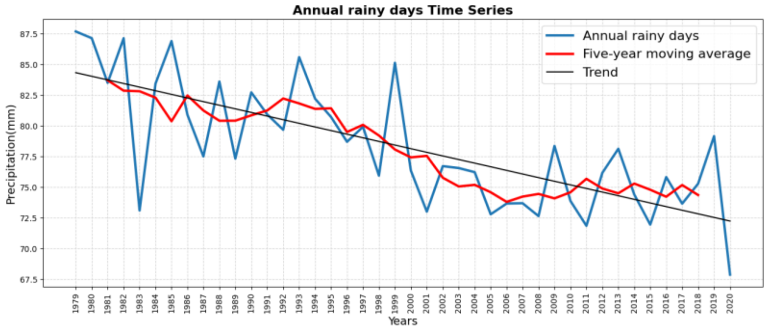


Chart 6 - All-Cameroon Seasonal Number of Rain Days

The average number of rain days (above 1mm) has spatial pattern similar but not identical to the seasonal rainfall (Figure 1). In the southern regions, the high number of rainy days combined with the lowest inter-annual variability points to a consistently wet, equatorial climate. Agriculture and water resource management can rely on this predictability, with over 250 days of rainfall annually ensuring ample water for year-round ecosystem support. In the southeastern region, the climate exhibits an intriguing complexity with the highest inter-annual variability in rain days. Despite the significant number of rainy days, ranging from 168 to over 200 annually, this variability introduces a level of unpredictability that demands careful consideration in both agricultural and water resource planning. As the transition to central regions occurs, the number of rainy days decreases to a range of 168 to 234 days, and the variability increases slightly. This moderate variability aligns with the transitional nature of the climate, which is less consistent than in the south but still offers a substantial number of rainy days for agricultural planning, albeit with increased risk due to variability. In the northern regions, the juxtaposition of a lower number of rainy days (38 to 102) with the lowest inter-annual variability (7 to 13 days) highlights a semi-arid climate with least fluctuations and hence a more predictable pattern.

The time series for annual rainy days displays variability similar to the annual rainfall time series, yet the downward trend is more pronounced and consistent. Both the five-year moving average and the trend line clearly illustrate a steady decrease in the number of rainy days over the years. This could imply that although there are fewer rainy days annually, the days that do have rainfall may be experiencing more intense precipitation events to contribute to the total annual rainfall.

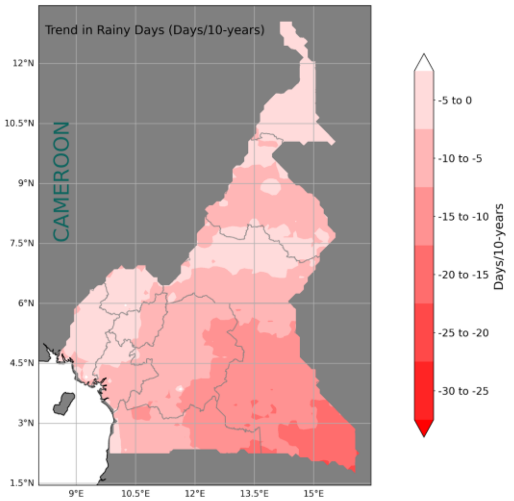


Figure 8 - Trend in Seasonal Rain Days (days/10yrs)

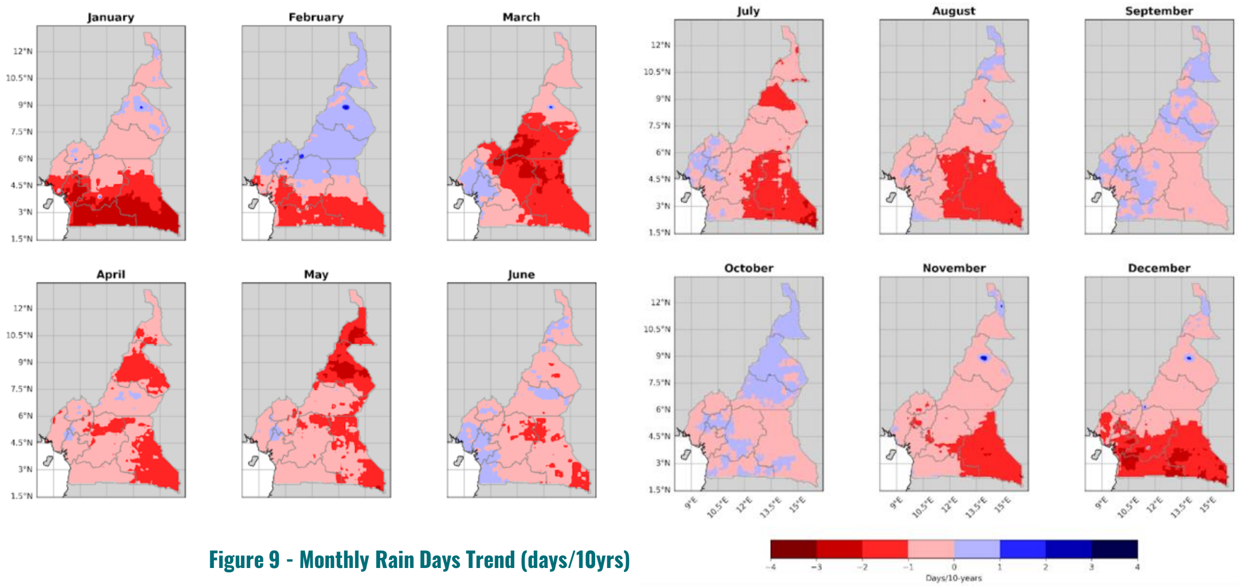


Figure 9 - Monthly Rain Days Trend (days/10yrs)

Figure 8 depicts trend with a clear decrease in the number of rain days over a 10-year period across Cameroon. The color gradient suggests that the decline is more severe in the southern regions, with the darkest shades indicating a reduction of 20 to 25 days per decade. As one moves northward, the decline appears slightly less pronounced, with areas showing a decrease of 0 to 10 days per decade.

Analysis of monthly rain day trends reveals a nuanced view of changing climate. The onset of the rainy season in the northern areas appears delayed or less intense, with a significant trend in rain days decrease observed in May, followed by medium to slight decreases through to September. This suggests a potential shortening or weakening of the rainy season, with implications for agriculture and water availability. In contrast, the southern regions exhibits mixed patterns of slight increases and decreases in rain days at the season's onset, with a trend towards a possible earlier conclusion or decreased intensity by its end. The dry season, spanning October to April in the North and December to February in the South, also presents intriguing trends. The Northern region shows signs of an irregular onset, with slight to medium increases in rain days in October, moving to no significant change or partial increases through to December. This pattern could indicate less pronounced dry conditions or an extended rainy season. Meanwhile, the Southern region faces a potentially stronger dry season, especially from December to February, marked by significant decreases in rain days, suggesting more pronounced dry conditions. From January to April, during the North's dry season, a complex interplay of decreasing rain days with localized increases suggests variability and potential shifts in traditional patterns.

RAIN DAYS — Monthly Trend Zoning

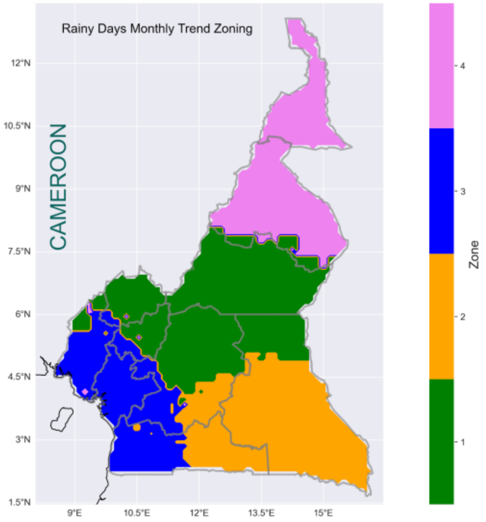


Figure 10 - Rain Days Monthly Trend Zoning

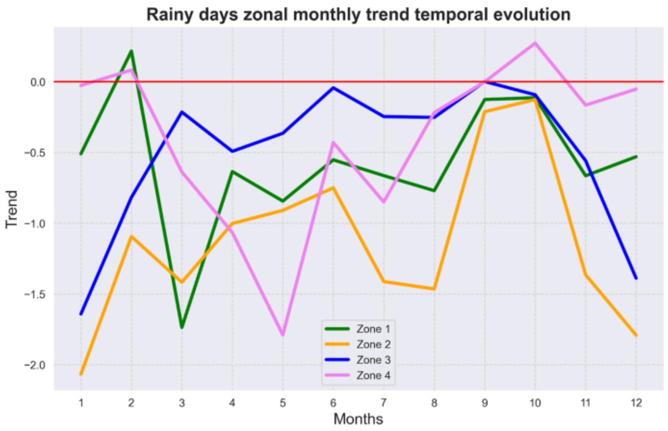


Chart 7 - Rain Days Zonal Monthly Trend Seasonal Evolution

The rain days monthly trend analysis can be summarized into a joint figure and chart. The analysis identifies regions where the monthly trends behave in a similar way.

Four main zones were identified. All zones display a general trend of decreasing rainy days, with Zone 2 experiencing the most consistent and severe drying pattern, and Zone 4 displaying the most variability with both increases and decreases throughout the year.

Such dynamics pose a challenge for Cameroon, requiring adaptive strategies tailored to each zone's unique climate dynamics. The need for efficient water management is emphasized, including the potential for rainwater harvesting, changes in cropping calendars, drought-resistant crops, and sustainable land management practices to maintain the balance between human needs and ecological integrity.

Zone 1 (Green) is zone is characterized by a slight overall drying trend throughout the year. Notably, the significant decrease in March could represent a challenge for water availability at the onset of the traditional rainy season, which starts around March and extends to November. The slight reductions in rainy days observed in other months, including the dry season from December to February, may not severely disrupt the established agricultural activities but could necessitate water conservation measures. Zone 2 (Orange) exhibits a more severe drying trend across all months. The reduction in rainy days is consistent, with notable decreases during the peak rainy season months and the onset of the dry season. This could result in increased stress on ecosystems and agricultural systems that rely on regular precipitation patterns, with potential implications for food security and biodiversity. Zone 3 (Blue) experiences moderate decreases in rainy days, particularly at the beginning and end of the year. This region's drying trend could affect both the high-biodiversity rainforests and the agricultural productivity of the area. The stability around September, which lies within the rainy season, may provide some relief and help sustain agricultural yields and ecosystem functions. Zone 4 (Pink) has the most variability in rainy day trends, with some months seeing increases and others decreases. The significant decrease of 2 days per decade in May, within the rainy season from May to September, could lead to challenges in water availability at the onset of the rainy season, which lasts from May to September. The increases in February and October, just at the transitions of the seasons, suggest a shifting pattern that could have complex impacts on pastoral and agro-pastoral systems prevalent in this zone.

HEAVY RAINFALL — Heavy Rain Days Average and Annual Trend

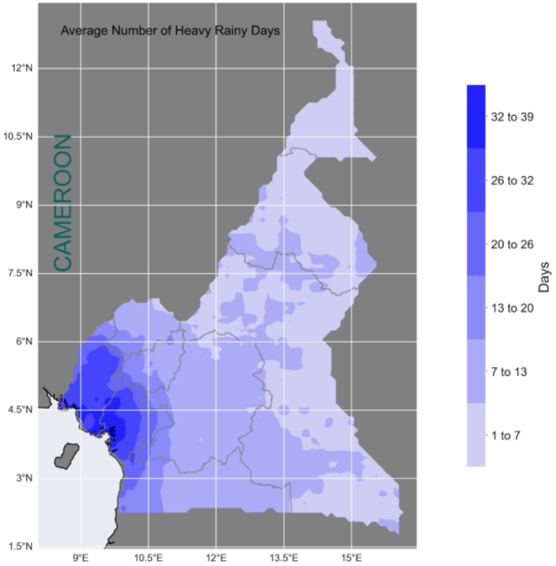


Figure 11 - Annual Heavy Rain Days Mean

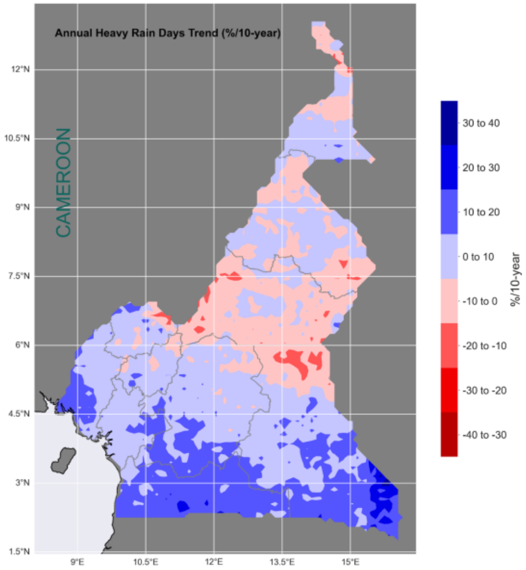


Figure 12 - Annual Heavy Rain Days Trend (%/10yrs)

Very heavy rains are defined as days with more than 20mm of rainfall. [Ref. ETCCDI Climate Extreme Indices] For each season on record, the total number of heavy rain events are produced and analysed. The analysis does not look into continuous sequences of these types of events.

The frequency of heavy rainfall days across Cameroon, Figure 11, exhibits a similar distribution to that of average seasonal rainfall from Figure 1, with regions experiencing a higher average seasonal rainfall generally coinciding with a greater number of heavy rainfall events. Specifically, the Littoral and parts of the South-West regions experience the highest frequency of heavy rainfall days, with 32 to 39 events per season, which aligns with the areas of highest average seasonal rainfall. In contrast, the Far North and selected areas of the North, Adamawa, and East regions register the lowest frequency of heavy rainfall events, between 1 and 7 per season, corresponding to the lower average seasonal rainfall observed in these areas.

Figure 12 displays annual heavy rain trend that is different from the seasonal rainfall trend from Figure 2. The heavy rain days trend figure shows an increase in heavy rain days in many parts of Cameroon, particularly in the central to eastern regions, while the figure of annual rainfall trends shows a decrease in total annual rainfall, especially in the northern to central regions. This difference could suggest that while heavy rain days are becoming more frequent in some areas, the overall volume of rainfall throughout the year might still be decreasing. This could be indicative of climate patterns where rain is less frequent but more intense on the days it occurs, which is a recognized pattern in some climate change scenarios.

In the semi-arid northern regions of Cameroon, where annual rainfall is relatively low, the trend of decreased heavy rain days during the critical early rainy season, particularly noticeable in May, might reduce the risk of soil and crop damage associated with intense rainfall events.

As the season progresses into June with a modest increase in heavy rain days, the challenge remains to balance the benefits of increased water availability against the potential damage from intense rain events. This balance is crucial to avoid the adverse effects of heavy rainfall, such as waterlogging and erosion, which could negate the gains from the increased water supply.

Conversely, during the dry season, which lasts from October to April, these regions generally experience a decrease in heavy rain days, aligning with the expected seasonal dryness.

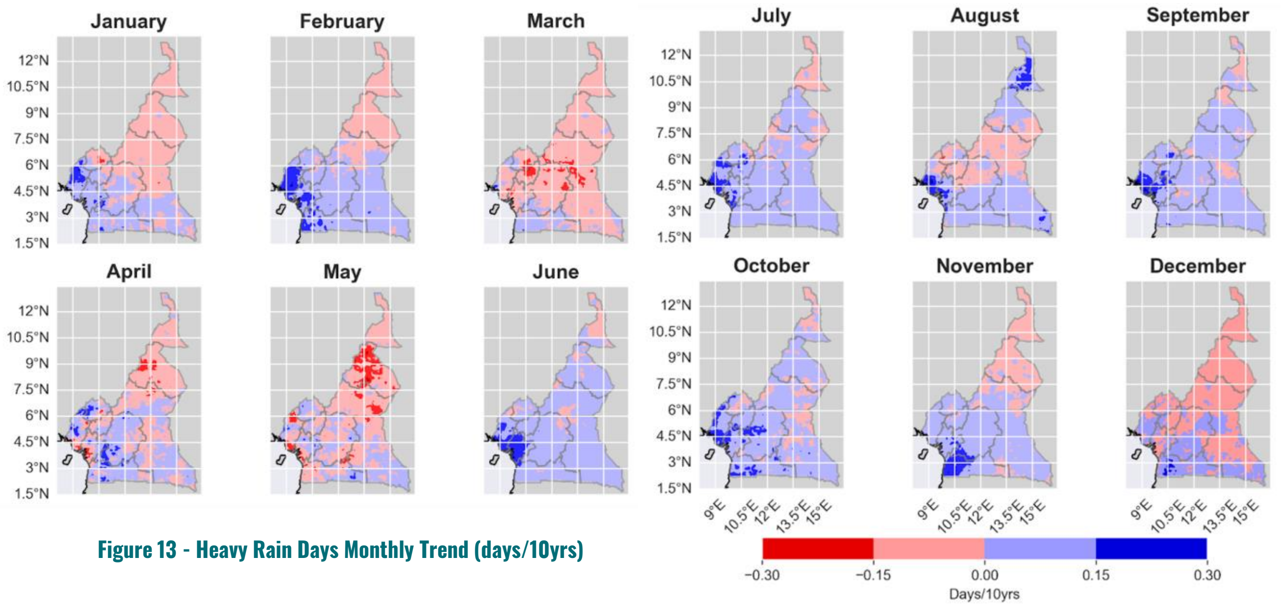


Figure 13 - Heavy Rain Days Monthly Trend (days/10yrs)

In the southern regions, where the rainy season extends from March or April to October or November, there's a notable increase in heavy rain days, particularly as the season peaks. This suggests an intensification of the rainy season. However, during the dry season, spanning December to February, the variability in heavy rain days introduces additional complexities. For regions witnessing an unexpected rise in heavy rain events, the risks of soil erosion, flash flooding, and the negative impact on off-season agricultural activities are juxtaposed with the need to capture and store this water for use during drier periods. These events, deviating from the norm, can cause significant disruptions.

On the other hand, areas experiencing a decrease in rainfall during this period may see little change in their agricultural and social practices, as this aligns with the expected dry season conditions. However, the overall inconsistency in rainfall patterns, marked by periods of unexpected heavy rain amidst generally dry conditions, necessitates adaptable water management strategies. These strategies must be flexible enough to manage the dual challenges of ensuring water availability during dry spells and mitigating the risks associated with sporadic heavy rainfall, thereby safeguarding agriculture and livelihoods in these regions.

DRY SPELLS — Average and Annual Trend

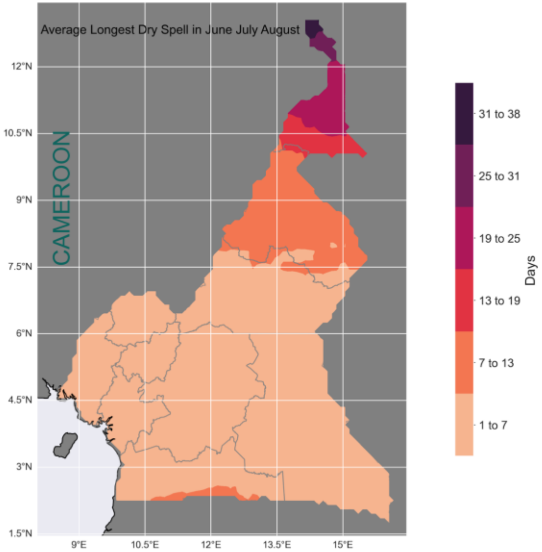


Figure 14 - Average Longest Dry Spell JJA

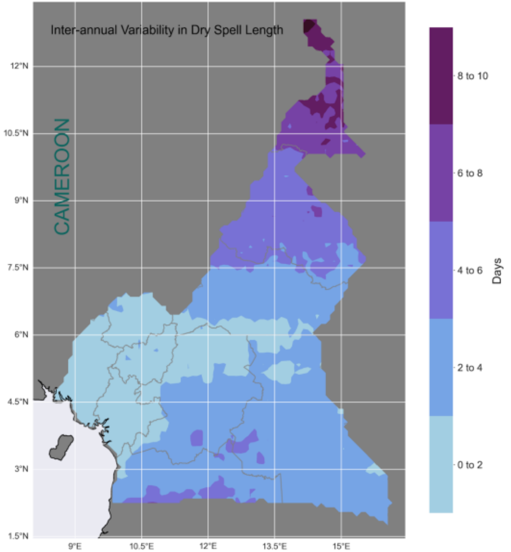


Figure 15 - Inter-annual Variability in Dry Spell Length JJA

Dry spells are defined as continuous periods during which rainfall is less than 2mm. Amounts smaller than 2mm are considered not to provide benefits to vegetation or crops. [Ref: De Groen and Savenije (2006)]

In the analysis, the focus was on the longest dry spell within the core seasonal period of June to August. Hence, one value is obtained per season, which is then analyzed in the conventional manner.

Seasonal rainfall totals alone do not adequately assess the quality of the growing season; the distribution of rainfall is equally critical, especially the occurrence of dry periods that may exceed the natural resilience of crops.

This section examines the occurrence of dry spells within the core seasonal period of May to September. A dry spell is characterized as a succession of days receiving less than 2mm of rainfall—a quantity deemed insufficient for agricultural benefit.

Figure 14 reveals a notable gradient in the length of the longest dry spells during June, July, August period, with the Far North experiencing the most prolonged periods of up to 38 days, indicating potential water scarcity challenges for agriculture. The North region, while experiencing shorter dry spells, still faces interruptions that could disrupt sensitive stages of crop growth. In contrast, the southern regions experience the briefest dry spells, which may align with agricultural practices but still require careful monitoring due to the potential impact on crop development during longer rainy seasons. Figure 15 illustrates the inter-annual variability of dry spells during Cameroon's JJA period underscores a pronounced difference across regions. The Far North faces the greatest variability with oscillation of 8 to 10 days, presenting a significant challenge for managing agricultural cycles. The North region experiences moderate variations up to 6 days, potentially impacting crop yields. Conversely, the southern divisions have the least variability, suggesting more predictable rainfall patterns, though even minor deviations can affect crop growth.

To address these variabilities, particularly in the Far North, a suite of adaptive strategies is essential. Enhanced seasonal forecasts and crop diversification can provide a buffer against unexpected dry conditions. Water conservation methods and responsive irrigation systems are critical to manage the variability. Additionally, supportive agricultural policies, including insurance and subsidies for irrigation, can help farmers manage the risks associated with rainfall unpredictability. This comprehensive approach aims to maintain productivity and sustainability in Cameroon's agriculture despite climatic challenges.

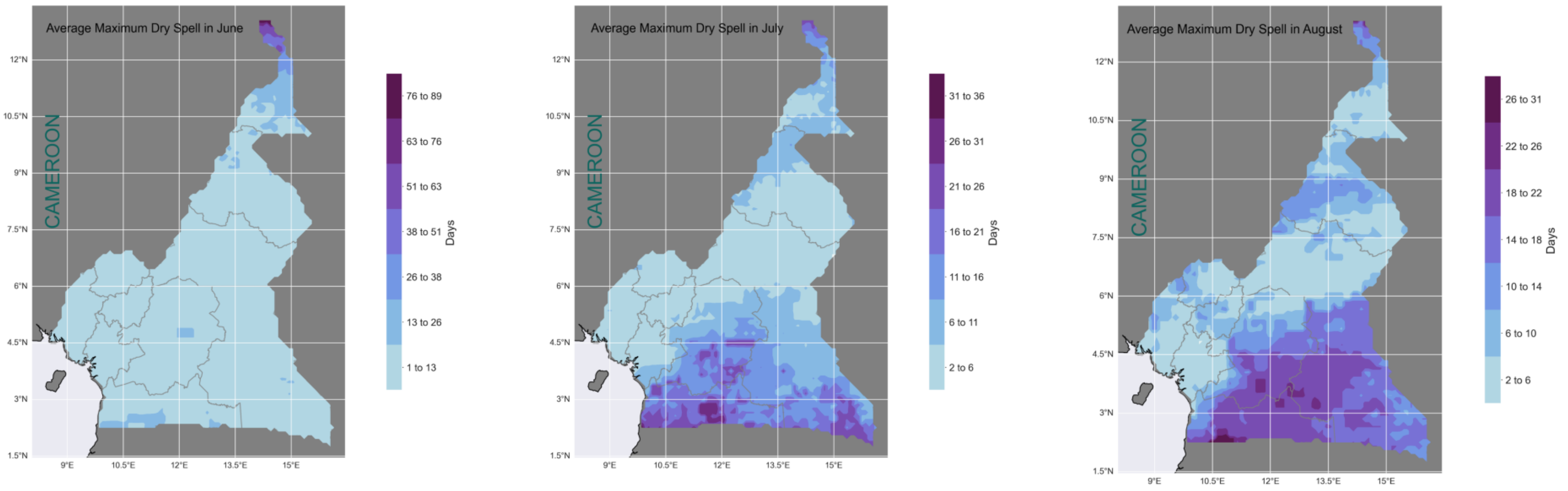


Figure 16 - Average Maximum Dry Spell in June, July, and August

The analysis was conducted on a monthly basis to account for the potential influence of early season termination or late onset on the longest dry spell during the June, July, and August (JJA) period, as illustrated in Figure 16. The figure indicates the average maximum dry spell in critical period of Cameroon's rainy season (JJA) reveals critical regional differences. The Far North is most affected, with dry spells in June sometimes exceeding 30 days, posing a severe risk to crop germination and necessitating strategic water management and planting adaptations. July sees shorter dry spells, yet in the South, spells up to 16 days may still impact vegetative crop growth, calling for diligent irrigation measures. By August, the duration of dry spells decreases further; however, even brief dry periods can affect crops during key development stages, reinforcing the importance of precise irrigation and soil moisture retention. Across all regions, proactive weather forecasting and tailored agricultural responses are vital to accommodate these climatic variations, ensuring sustainable crop production.

DRY SPELLS — Monthly Trend

In the northern regions of Cameroon, during the critical rainy season months of June, July, and August, there is an observed trend of decreasing maximum dry spell lengths. This emerging pattern can be favorable for agricultural sustainability as shorter periods without rainfall can support better crop germination and development, particularly during stages that are sensitive to water availability. Consequently, there is an opportunity to optimize agricultural practices, such as the introduction of crops that benefit from the increased moisture availability and the potential reduction in the need for extensive irrigation systems.

Conversely, in the southern regions where the rainy season extends over a longer period, the trend shows an increase in the length of maximum dry spells. This could pose challenges for agricultural activities, as extended dry periods can hinder crop growth and development. There is a pressing need for the implementation of adaptive agricultural practices, such as the introduction of drought-tolerant crop varieties and the development of more efficient irrigation systems to compensate for water deficits during these crucial growth periods.

The overall trend in Cameroon indicates a clear need for strategic water management, including enhanced water harvesting and storage capabilities, to provide a buffer against the variability in dry spell durations. Moreover, enhancing monitoring and forecasting efforts is imperative to provide farmers with timely information, enabling them to make informed decisions about crop management and water usage.

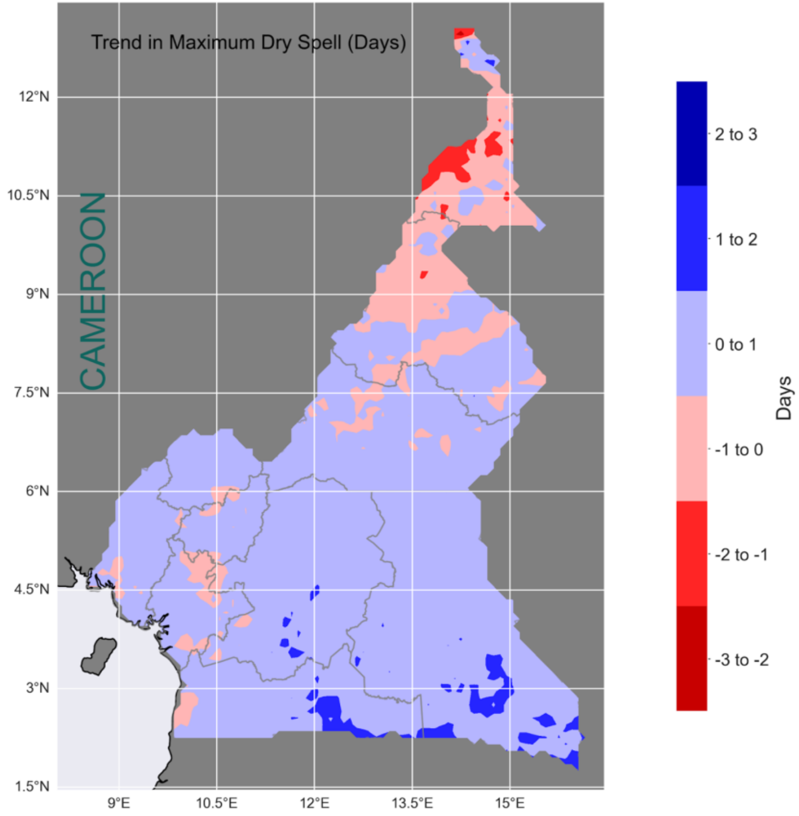


Figure 17 - Trend in Maximum Dry Spell in JJA

NDVI (Vegetation Vigour) — Average, Variability, and Long-term Trend

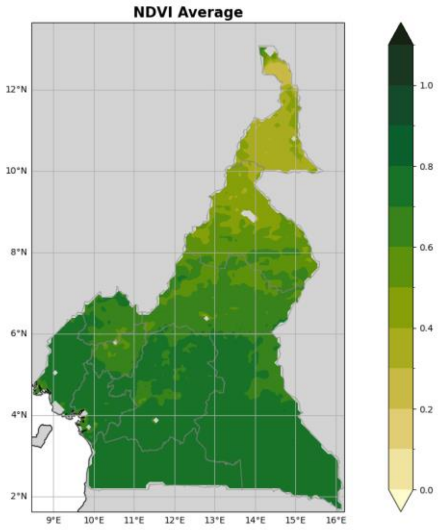


Figure 18 - NDVI Average

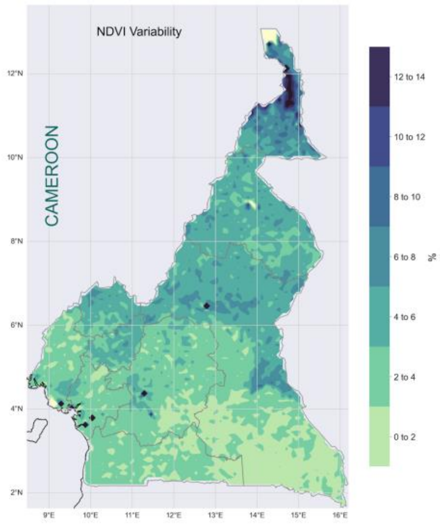


Figure 19 - NDVI Variability

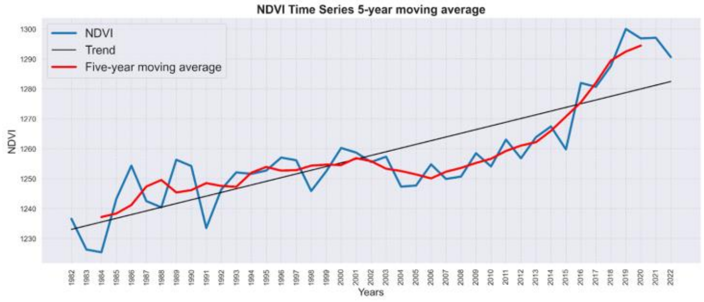


Chart 8 - All-Cameroon Seasonal NDVI

The Normalized Difference Vegetation Index (NDVI) is a metric that describes the quantity and health of vegetation. The NDVI values across Cameroon display a distinct relationship with rainfall patterns. In regions with abundant annual rainfall, primarily in the south, NDVI averages are high, denoting thriving vegetation. This suggests that areas with greater water availability support dense forests and productive agricultural land, providing stable conditions for consistent vegetative growth. Similarly, in the north, the NDVI averages are lower, indicative of less dense vegetation, which is likely due to the limited rainfall characteristic of the Sahelian climate.

This sparse vegetation reflects the region's struggle with water scarcity, affecting both natural ecosystems and agricultural viability. Adding the dimension of inter-annual rainfall variability, the regions with high variability have correspondingly high NDVI variability. This suggests that in areas where rainfall amounts fluctuate significantly from year to year, vegetation health is directly impacted, leading to inconsistent agricultural outputs and potential stress on ecosystems. To manage the variability in vegetation health as shown by NDVI, actions must be tailored to regional conditions. In the southern regions with stable NDVI values, maintaining the integrity of the ecosystems through sustainable practices is essential. Conversely, in the northern regions, strategies to combat the effects of NDVI variability necessitates a proactive approach to agriculture and land management. Diversifying water sources, such as through rainwater harvesting and water storage infrastructure, becomes essential to mitigate the unpredictability of water supply. Additionally, the implementation of drought-resistant or early-maturing crops can help secure agricultural yields against the backdrop of varying rainfall.

Chart 8 displays long-term positive trend in vegetation health and cover across the nation from 1982 until 2022. It ignores the within country variation in order to provide clear overview of the changes in rainfall along the available temporal record. Despite yearly variations, the overall trajectory, as indicated by the trend line, shows a sustained increase in NDVI values. This ascending trend, smoothed by the 5-year moving average, suggests an improvement in vegetative robustness over the years, hinting at potentially effective environmental management strategies, favorable climatic conditions, or both in Cameroon.

NDVI — Annual Trend

The annual vegetation trend in Cameroon, Figure 20, measured as a percentage change per decade, reveals predominantly positive NDVI trends throughout the country, with the most significant increases observed in the central and northern regions. Such trends indicate an improvement in vegetation robustness, likely a result of improved environmental conditions or effective land management practices that have fostered vegetative growth and vitality. The positive NDVI trends hold promising implications for carbon storage, biodiversity, and agricultural output. However, there are localized areas, particularly in the southwestern rainforest climate region, suggesting potential challenges like deforestation or adverse effects from shifts in climate patterns. These negative trends may pose risks such as soil erosion and loss of biodiversity.

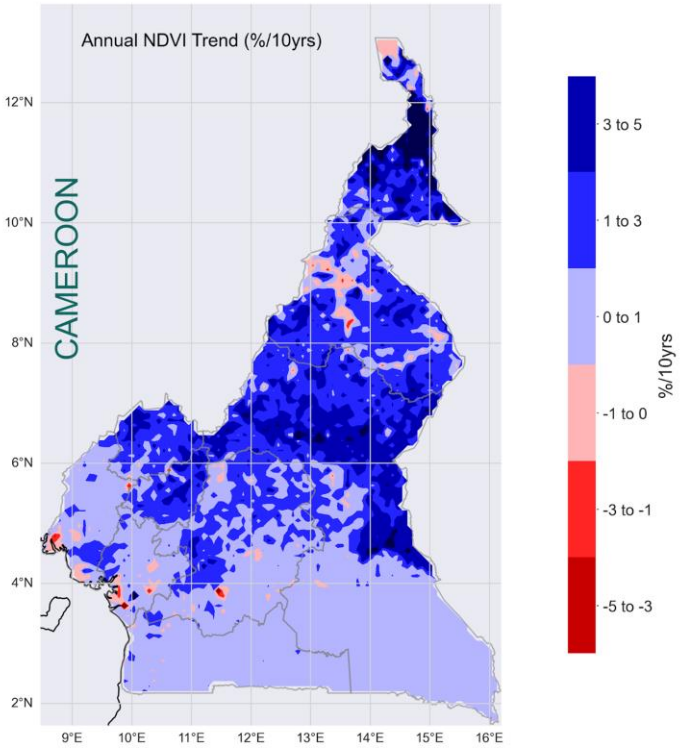


Figure 20 - Annual NDVI Trend (%/10yrs)

NDVI — Monthly Trend

The NDVI trends in Cameroon between March and October showcase the dynamic interplay between climate, vegetation health, and human activities across its diverse divisions. During this period, the NDVI trends vary significantly due to the staggered rainy seasons: in the north, the rainy season spans from May to September, while in the south, it extends from March/April to October/November. Initially, as the rainy seasons commence, there's an observed improvement in vegetation health, particularly notable in the northern regions like the Adamawa, and parts of Far North and North divisions, where NDVI trends indicate significant increases by April. This improvement aligns with the start of the southern rainy season and preludes the northern one.

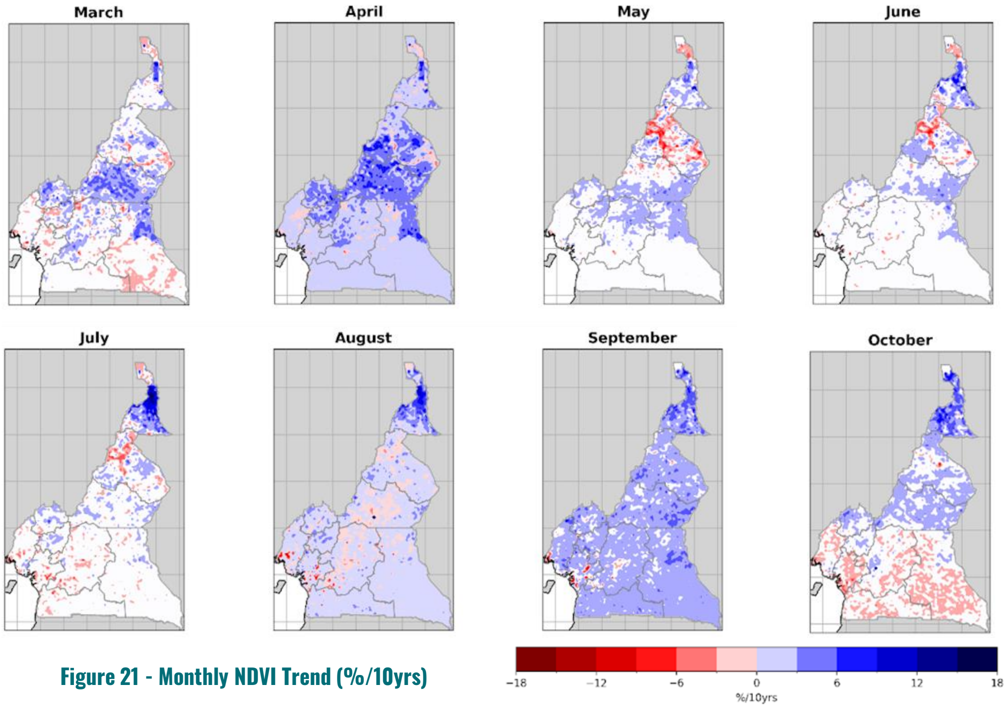


Figure 21 - Monthly NDVI Trend (%/10yrs)

As the seasons progress into May to July, the effects of the rainy season become more nuanced. The Far North experiences significant increases in NDVI, highlighting a robust response to the rainy season. However, the significant decrease in NDVI observed in the North region during May is a significant point of interest, particularly because this period marks the onset of the rainy season in northern Cameroon. Typically, the expectation is for vegetation health to begin improving with the commencement of rains. However, the decrease suggests that the onset of the rainy season may have been delayed or that the early rains were insufficient to stimulate immediate growth in vegetation. This anomaly could also be indicative of other stress factors on vegetation, such as higher temperatures or increased evapotranspiration rates, which could negate the benefits of early rainfall. As for the other regions, they exhibit more stabilized trends, with minor fluctuations reflecting the complex balance between rainfall adequacy and other influencing factors.

From August to October in the North region of Cameroon, NDVI trends reflect a nuanced progression of vegetation health, aligned with the rainy season's peak and subsequent transition towards drier conditions. August marks a period of slight vegetation growth, evidencing the beneficial impacts of the rainy season's moisture availability. This slight increase, however, is coupled with localized decreases in some areas, hinting at the presence of environmental or anthropogenic stresses that might offset the positive trends in specific locales. As the season advances into September, the trend of slight increases in NDVI persists, suggesting that the accumulated moisture and conducive growing conditions continue to support vegetation health. This period signifies the tail end of the rainy season, with vegetation capitalizing on the remaining moisture to sustain growth. By October, the NDVI trend stabilizes, shifting to mostly no change, with scattered areas still showing slight improvements. This stabilization marks the onset of drier conditions, where vegetation growth plateaus, reflecting the transition out of the rainy season. The sustained, albeit reduced, growth in some areas by October suggests that residual moisture or localized favorable conditions may continue to bolster vegetation health momentarily.

NDVI — Monthly Trend Zoning

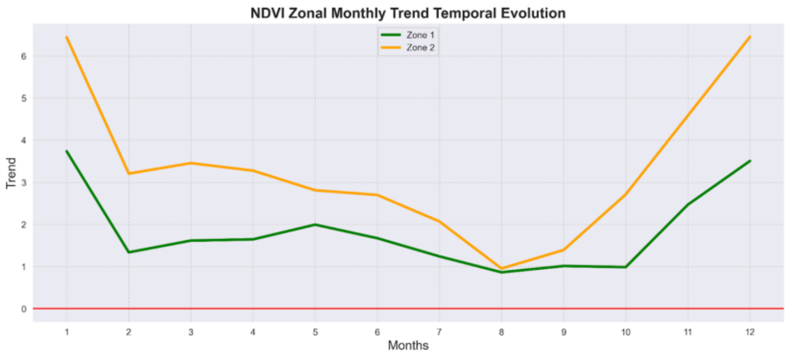


Chart 9 - NDVI Monthly Trend Seasonal Evolution

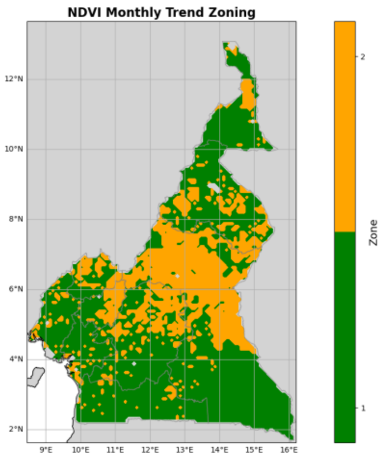


Figure 22 - NDVI Monthly Trend Zoning

The NDVI trends in Zone 1 (Green) reveal a dynamic and potentially well-managed landscape where agricultural activities complement the natural vegetation patterns, leading to higher NDVI increases even during the dry season. The consistency of the NDVI increase throughout the year could also suggest effective land management practices that support vegetation health.

Located in the central part of Cameroon, Zone 1 encompasses diverse ecosystems, including Mosaic Forest / Savannah, Croplands, and parts of Closed Evergreen Lowland Forest. The NDVI data indicate that this zone experiences significant vegetative growth during the dry season, particularly in January and December, with NDVI trend increases of 6.4% and 6.3%, respectively. These increases are likely reflective of agricultural practices that take advantage of the dry season for certain crops, perhaps using irrigation or other methods to sustain growth. Moreover, the consistent increases in NDVI throughout the wet season, though somewhat lower (ranging from 2.0% to 2.8%), suggest that the vegetation in this area is well-adapted to the seasonal rainfall patterns.

The high increase in November might correspond with the late-season growth of vegetation that has benefited from the cumulative rainfall during the wet season. The moisture retained in the soil and the still-abundant water bodies would allow for continued vegetative growth, even as the rains taper off. Conversely, the lower but steady increase in NDVI during the wet season months could be due to the already dense vegetation not showing drastic changes on a year-to-year basis, or due to cloud cover that can affect NDVI readings during these months.

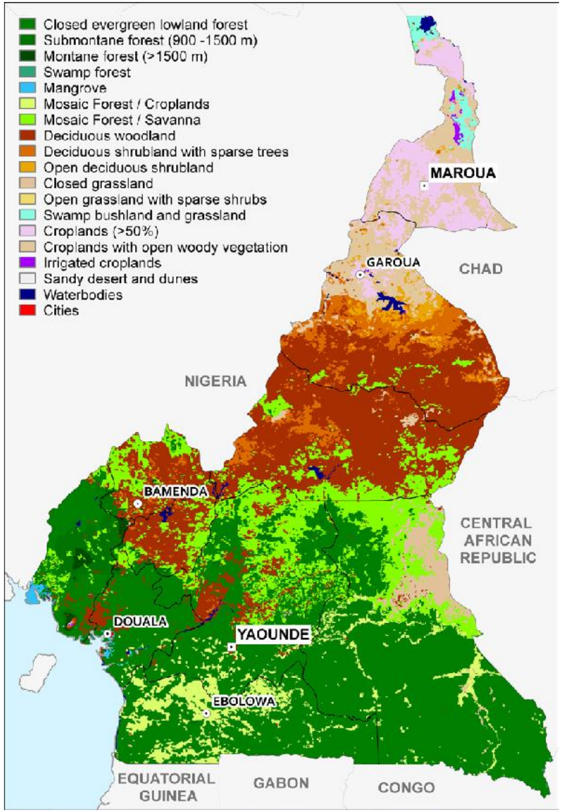


Figure 22 - Vegetation Cover in Cameroon

Interactive Atlas of forestry resources of Cameroon, version 2.0. Cameroon Ministry of Forestry and Fauna/ World Resources Institute 2007

NDVI — Monthly Trend Zoning

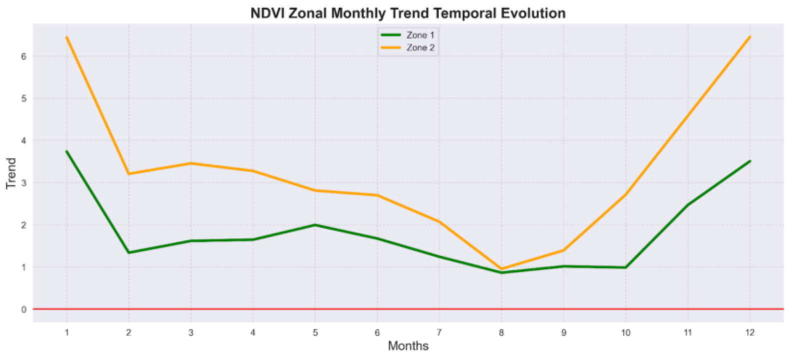


Chart 9 - NDVI Monthly Trend Seasonal Evolution

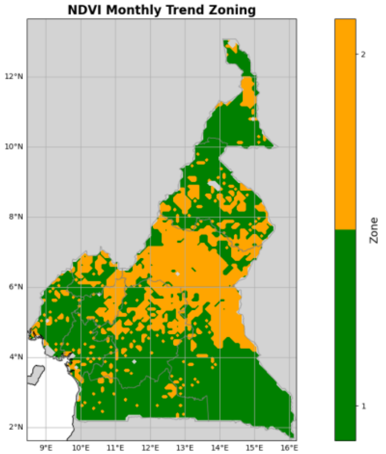


Figure 22 - NDVI Monthly Trend Zoning

In Zone 2 (Orange), the trends show a vegetation cycle closely tied to the rainfall patterns typical of semi-arid regions, with conservation efforts playing a crucial role in maintaining ecosystem health. The low but positive NDVI increases during the wet season indicate the vegetation's reliance on this period for annual growth, and the modest increases during the dry season suggest some degree of resilience to the harsher climatic conditions, perhaps supported by residual moisture and the conservation of natural habitats.

Zone 2 covers the northernmost regions of Cameroon, which are more arid and include the semi-arid areas around Waza National Park and parts extending towards Chad. This area experiences lower NDVI increases year-round, with the lowest during the wet season (May to September for the north) with values ranging from 0.8% to 2.0%. This could reflect the limited natural growth potential in semi-arid regions, where vegetation is heavily reliant on seasonal rainfall. The increases are modest, but they do show a positive trend, suggesting that the conservation efforts in places like Waza National Park and the presence of water bodies are beneficial to the region's vegetation.

The slightly higher NDVI increases during the dry season, particularly in January and December (3.9% and 3.5%, respectively), may be due to the vegetation's recovery post-rainy season or the effects of the harmattan winds that bring dryness but also clear skies, which could improve satellite NDVI readings. The dry season NDVI increases could also be reflective of the vegetation's reliance on the moisture reserves built up during the wet season.

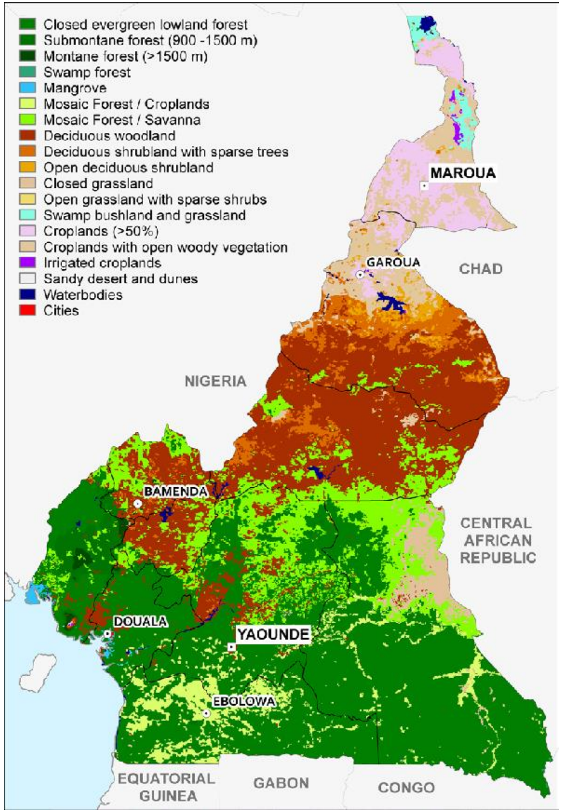


Figure 22 - Vegetation Cover in Cameroon

Interactive Atlas of forestry resources of Cameroon, version 2.0. Cameroon Ministry of Forestry and Fauna/ World Resources Institute 2007

TEMPERATURE — Long-term Average

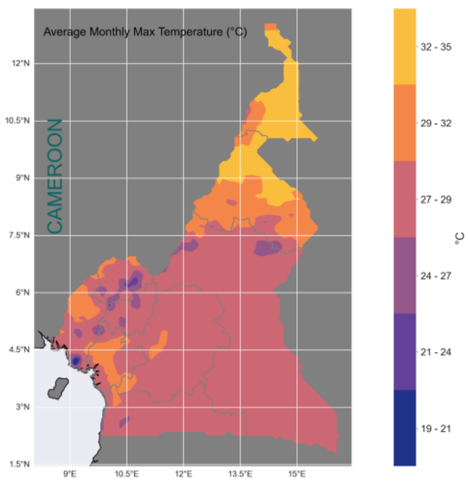


Figure 23 - Average Monthly Max Temperature

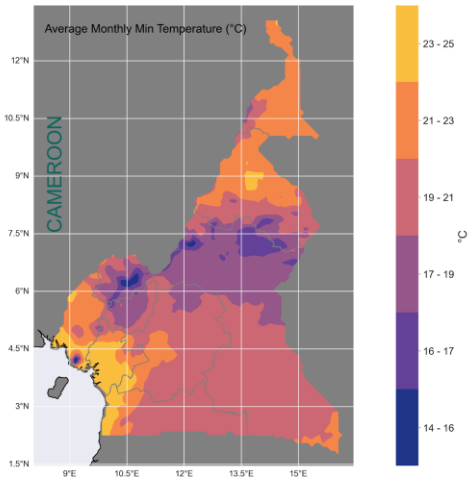


Figure 24 - Average Monthly Min Temperature

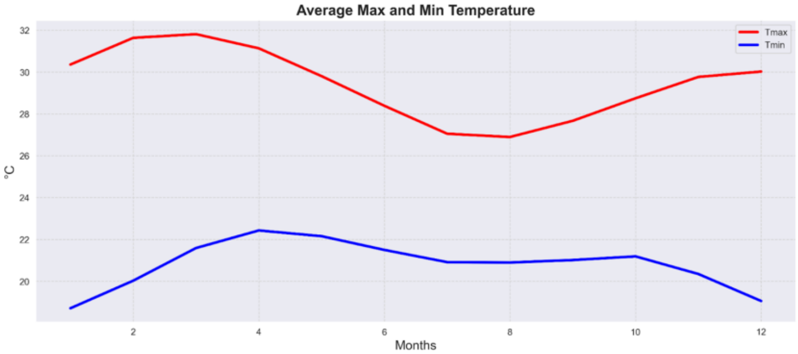


Chart 10 - Average Max and Min Temperature

The long-term average temperatures in Cameroon exhibit significant regional variation. Tmax is highest in the northern areas, reaching 32°C to 35°C, while the central region has moderate Tmax values between 27°C and 29°C. The south, which includes varied terrain like highlands and coastal zones, experiences cooler Tmax averages of 24°C to 27°C. For Tmin, the coldest readings are in the highlands with temperatures falling to 14°C to 16°C. The central part of the country has slightly warmer Tmin values around 17°C to 19°C. The north consistently shows the warmest Tmin, with temperatures between 23°C and 25°C. Both Tmax and Tmin demonstrate a warmer north and cooler south, indicating a temperature gradient that aligns geographically. Tmin, however, shows a more distinct variation, influenced by topography which affects night and early morning temperatures more than Tmax. The overall geographic temperature distribution is parallel for both Tmax and Tmin, but Tmin varies more significantly with the daily temperature range across different regions.

The monthly evolution of average Tmax and Tmin in Cameroon demonstrates a distinct seasonal pattern over the course of a year. Tmax begins the year on the higher side, dips slightly as the year progresses, peaks in the late spring, remains elevated during the middle of the year, and then declines towards the year's end. Tmin shows a sharp rise in the early months, peaks concurrently with Tmax in late spring, then levels off more than Tmax during the mid-year, and finally falls towards the end of the year. Both temperatures reach their minimum in December and their maximum in the late spring, with April and May being the warmest months. This seasonal behavior in temperature corresponds to the transitional periods between the dry and wet seasons in Cameroon, with the highest temperatures occurring just before the onset of the wet season. The temperature remains relatively more constant during the wet season, which could suggest a moderating effect of increased cloud cover and precipitation on daily temperature variations.

TEMPERATURE — Trends

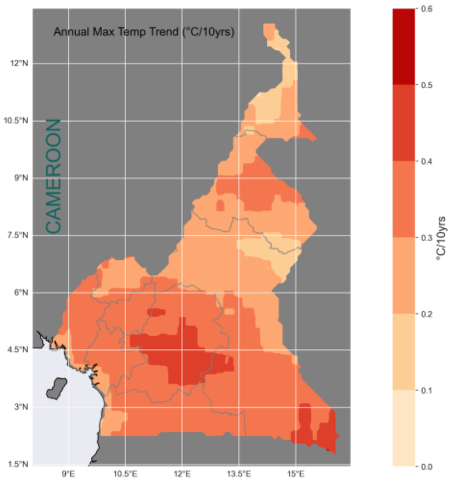


Figure 25 - Annual Maximum Temperature Trend

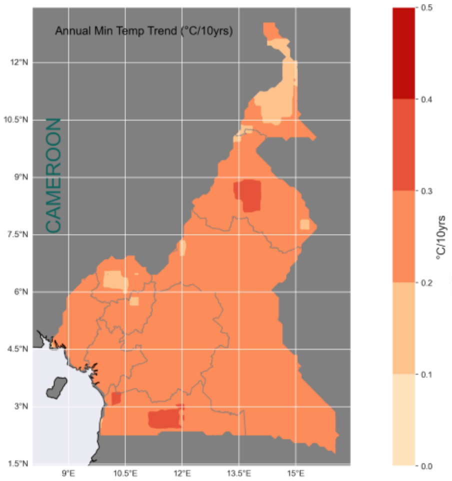


Figure 26 - Annual Minimum Temperature Trend

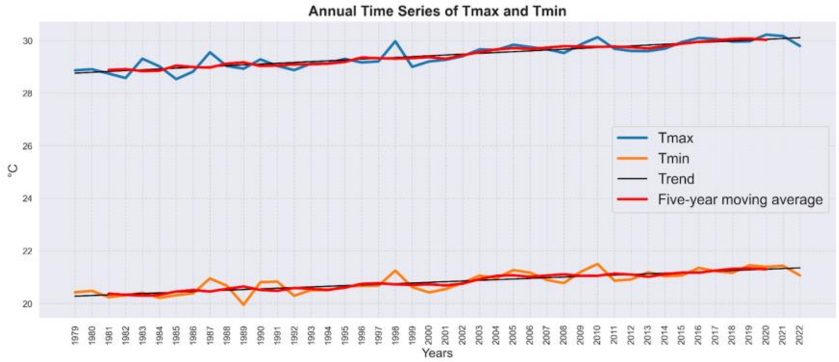


Chart 10 - All-Cameroon Seasonal Tmax and Tmin

The trends in temperature changes in Cameroon are not distributed evenly across the country's provinces. In the graphs representing the trends over a decade, both for annual minimum and maximum temperatures, it's evident that some provinces are experiencing greater changes than others.

For instance, the increase of Tmax varies by province. The central provinces, such as Centre and West, along with the northern regions like Extreme North and North, may be seeing a more pronounced rise in maximum temperatures. The varied rate of Tmax increase across provinces like Northwest, Southwest, and Littoral reflects the influence of regional factors, possibly including altitude and proximity to coastal areas.

As for Tmin, it is also rising across the country, but the graphs suggest that the Extreme North, North, and Adamawa provinces may be experiencing more significant increases in minimum temperatures compared to the southern provinces like South, East, and Littoral. This might indicate that nighttime temperatures in the northern provinces are becoming considerably warmer over time.

The long-term data further underlines that while all provinces are subject to warming, the Tmax and Tmin shows a pronounced rise over the years, particularly in the northern provinces. This information can be crucial for regional planning, as it highlights the need for tailored strategies to combat the effects of rising temperatures, which may differ in severity from province to province.

TEMPERATURE — Maximum Temperature Monthly Trends

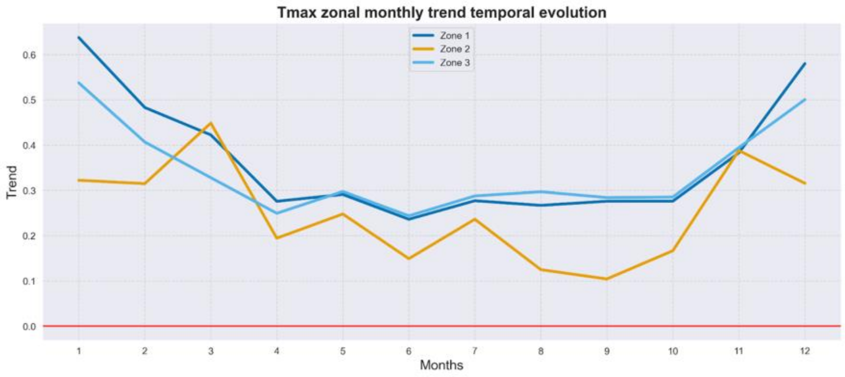


Chart 11 - Tmax Zonal Monthly Trend Seasonal Evolution

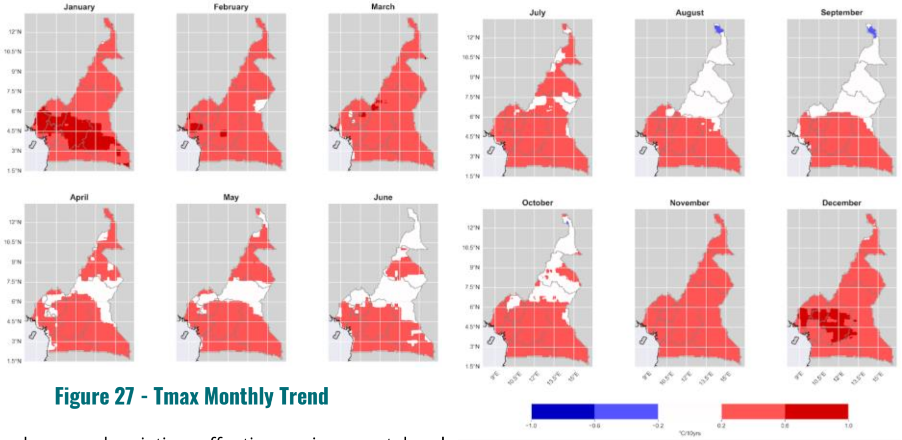


Figure 27 - Tmax Monthly Trend

Cameroon's monthly maximum temperature trends exhibit significant regional diversity and pronounced seasonal variation, affecting environmental and socio-economic systems. In the northern regions like the Extreme North, North, and Adamawa, the early part of the year sees substantial temperature increases, potentially intensifying water scarcity ahead of the critical agricultural season. This trend reverses with the onset of the rainy season, providing a cooling effect that might offer temporary relief. However, such abrupt shifts can disrupt agricultural cycles, affecting yields and pest dynamics. The southern regions experience more gradual temperature increases throughout the year, which may complicate water and crop management despite the longer rainy season.

In Cameroon, Tmax zones display temperature trends intricately tied to seasonal patterns. Zone 1, with its early and late-year temperature surges, sees stability during the rainy season from May to October. Zone 2's temperature rise softens notably during its rain season, then picks up as the dry season returns. Zone 3 maintains a moderate increase through its rainy season, spiking as it transitions to dry conditions. These trends underscore the need for Cameroon to seasonally adapt, balancing water management and agricultural strategies with infrastructural and health responses to the thermal shifts accompanying the rain and dry seasons.

The implications of these patterns are multifaceted. Agriculture in Cameroon needs to adopt climate-resilient practices to cope with these temperature changes. Effective water resource management is paramount, especially to adapt to the pronounced dry season in the north and to maximize the benefits of the southern rainy season. Public health measures must be intensified to address the risks of heat-related illnesses, and biodiversity conservation efforts are essential to safeguard ecosystems. Infrastructure planning must account for these temperature extremes, and continuous climate research and monitoring will play a crucial role in adapting to these changing conditions. An integrated approach encompassing these strategies will be critical for Cameroon to fortify its resilience against the varied impacts of its evolving climate.

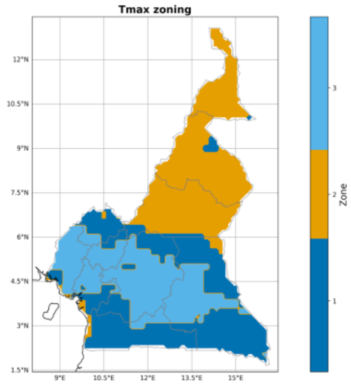


Figure 28 - Tmax Monthly Trend Zoning

TEMPERATURE — Minimum Temperature Monthly Trends

Chart 12 - Tmin Zonal Monthly Trend Seasonal Evolution

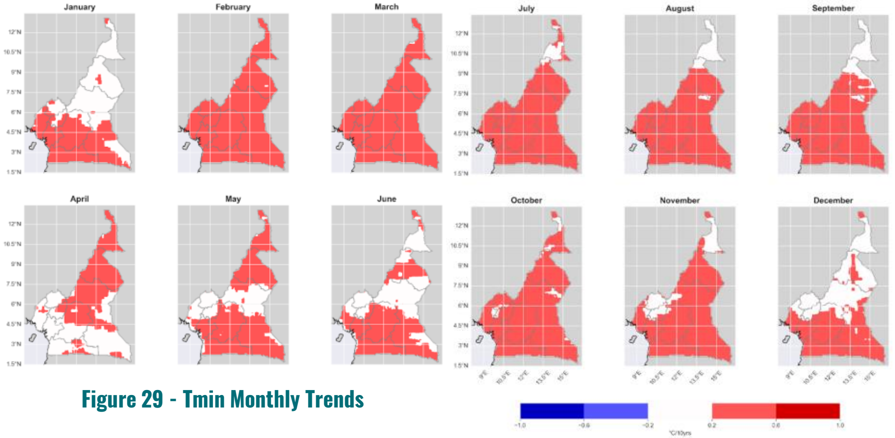


Figure 29 - Tmin Monthly Trends

In Cameroon, the substantial increase in minimum temperatures throughout the year, particularly from February to November, coincides with and extends beyond traditional dry and rainy seasons, leading to several environmental and socio-economic consequences. The warming trend is poised to elevate evaporation rates, intensifying water scarcity during the already dry seasons, and could potentially disrupt the balance of ecosystems during the wet seasons by affecting water availability, soil moisture, and the patterns of plant growth and wildlife.

For instance, in Zone 1, where the rainy season runs from May to September, the heightened minimum temperatures during these months might lead to increased evaporation, potentially diminishing water resources critical for agriculture and natural habitats. The warming trend continues into the dry season, which could exacerbate dry conditions and potentially extend the duration of heat stress on the environment. In Zone 2, the increase in temperatures just before the rainy season could alter the onset of agricultural cycles, potentially impacting planting and harvesting periods. Conversely, a cooler trend at the beginning of the dry season in December offers a brief respite, indicating a complex and variable impact of temperature trends on agricultural and natural systems. Zone 3's long rainy season, from March/April to October/November, is met with the highest temperature increases in March, suggesting that the rainy season may start warmer and more humid than usual, which could have significant effects on the intensity and distribution of rainfall, affecting agriculture and biodiversity.

The increasing trends in minimum temperatures across different seasons and zones in Cameroon necessitate a multifaceted approach to mitigate impacts and adapt to the changing climate. Strategies must include improving water conservation, adopting drought-resistant crops, enhancing meteorological forecasting, and implementing health awareness campaigns to manage heat-related risks. Urban planning must also adapt to manage the urban heat island effect, and ecological strategies such as reforestation can moderate local climates.

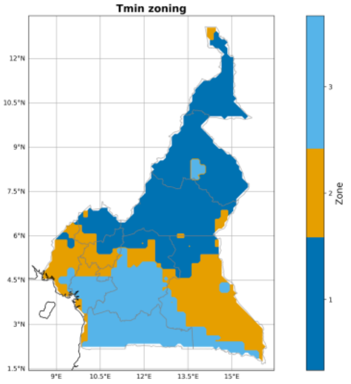


Figure 30 - Tmin Monthly Trend Zoning

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