Environmental Science and Technology

Project Report

Case Study

Desertification in the Sahel-Sahara region

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Figure 1 **- Different Landscapes**

The Sahel, a transitional region between southern woodlands and the northern Sahara Desert, features flat savannahs, plateaus, and sporadic mountains. This transition is primarily determined by rainfall, decreasing from 600-1000 mm in the south to 100 mm in the north. Southern areas have dense tree cover, gradually shifting to thorny Acacia dominance in the north. Further south, it transitions into Guinea moist savannah woodlands, while the central region exhibits parkland ecosystems with agriculture and valuable tree species. In the north, grasslands prevail with thorny shrubs due to grazing and land clearing. **Over 5000 years, human activities like bush burning, tree clearing, and grazing have transformed much of the original wooded savannah into agriculture** and extensive grasslands, expanding the typical savannah landscapes southwards.

The Sahel has weathered Pre-Cambrian bedrock (granite and sandstone) & nutrient-poor southern soils due to heavy rainfall. Sahara Desert storms in the dry season fertilize the Sahel and distant regions like the Amazon. West Africa is mostly flat, with elevations between 200 and 400 meters. Some rolling hills are remnants of ancient sand dunes from when the Sahara extended into the Sahel over 12,000 years ago.

❖ Geology and Topography:

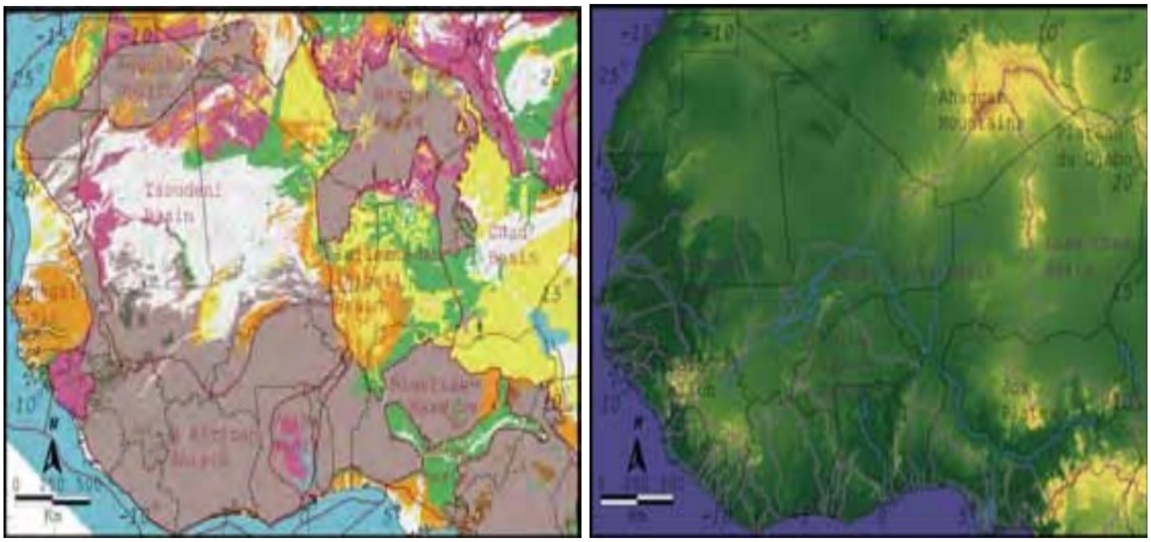


Figure 2 - **Geology and Topography of Sahelian region**

Africa, including West Africa, boasts ancient Pre-Cambrian geology. The West African Shield underlies the Sahel, revealing itself in the south but covered by younger rocks in the north. This shield was once part of Gondwanaland, connecting Africa with other landmasses 500 to 200 million years ago. Erosion shaped extensive plains, some now forming highlands. The breakup of Gondwanaland created large basins and troughs in West Africa, later filled with sediments, forming younger surface rocks. **The African shield's basement rock is mostly granite, with younger sediments primarily sandy.** Different sedimentary rocks occur in various regions, and volcanic rocks, mainly basalt, formed in some areas. **These sedimentary rocks have undergone multiple erosion cycles, depleting them of nutrients for plant growth.**

West Africa and the Sahel is a flat region, with elevations usually between 200 & 400 meters above sea level. The Niger and Senegal river basins are the major water sources in the region. The Niger River flows north from Fouta Djallon, where rainfall is very high, & then flows in a north-easterly direction on the West African Shield, until it reaches the Paleozoic Niger basin, where it makes a large bend south into the Benue Basin. **The Niger Inland Delta is an alluvial fan formed by sands carried by the Niger River.**

❖ Climate:

Figure 3 - **Monsoon patterns**

The last century has seen extended periods of both high and low rainfall over the Sahel. **Rainfall increased** quite strongly in the **early 20th century**, followed by a **wet period in the 1920s and 1930s**. The **1950s** and early 1960s **had very high rainfall, followed by a striking decline in the 1970s** and 1980s of about 40%. Such declines in rainfall have not been observed elsewhere on Earth during the last century.

The Sahel experienced droughts also in earlier centuries, with recordings for the coastal region from the 1640s–1780s. Famines also raged in the coastal regions during the first half of the 19th century. **Closer scrutiny of rainfall records in the Sahel, and elsewhere in Africa, reveal (quasi) cycles of 80 years**. **Recent droughts** were most likely **initiated by lower rates of overturning circulation in the Atlantic Ocean**. The slowdown of the Atlantic thermohaline circulation has, however, continued after the rains have recovered, while the currents in the mid-latitude **Atlantic Ocean (at latitudes outside West Africa) have remained relatively constant.** On this shorter time scale it is more probable that sea surface temperatures in the Indian Ocean have the major influence on rainfall in the Sahel.

❖ Precipitation in Sahel

The Sahel, a vast arid and semi-arid region stretching across Africa, is renowned for its distinctive climate and ecological challenges. Situated between the Sahara Desert to the north and the savannas to the south, the Sahel region is particularly susceptible to desertification with climate and precipitation playing a major role in this.

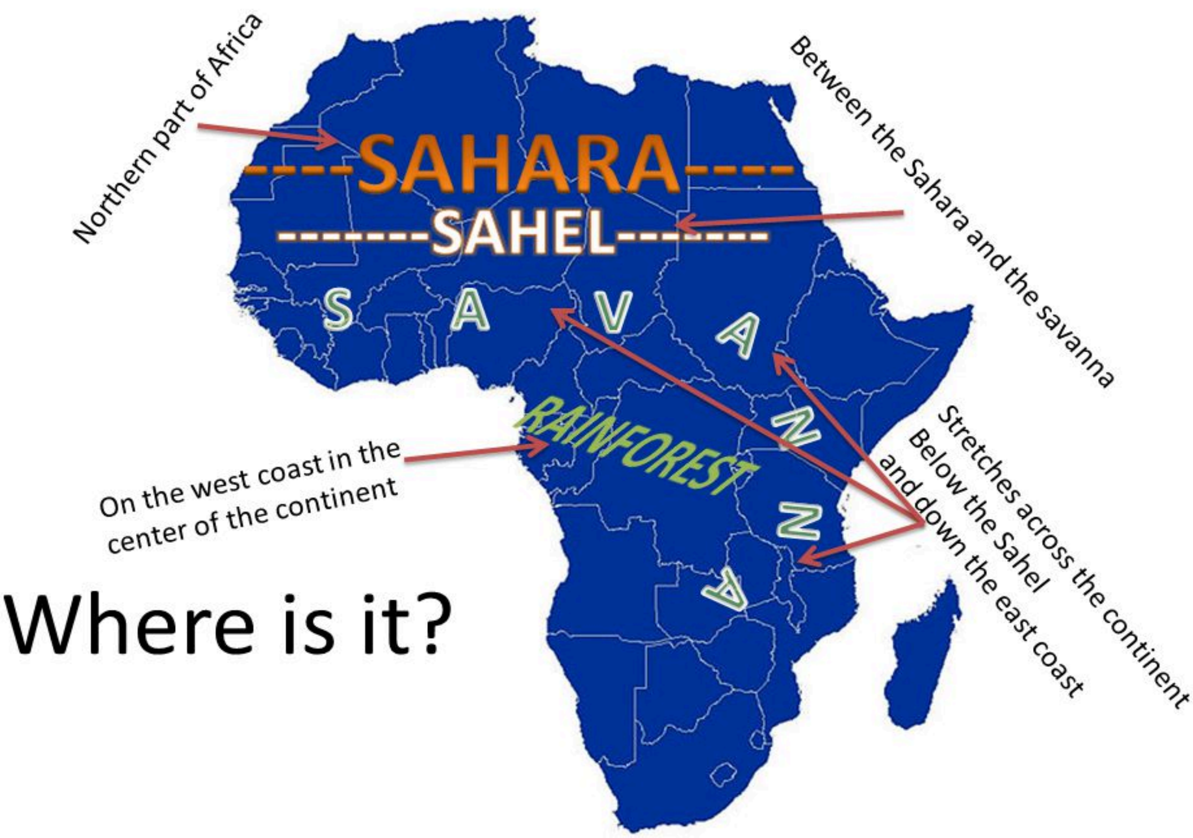


Figure 4 - **Location of Sahel in Africa**

The Sahel's vulnerability to desertification is intricately tied to these climatic fluctuations, which influence the availability of water resources, vegetation cover, and overall land health. In this section we delve into the role climate and precipitation factors play in the process of desertification in the Sahel.It seeks to examine the intricate web of interactions between these meteorological variables and the broader ecological and socio-economic implications for the region's inhabitants. By understanding the dynamics of climate and precipitation in relation to desertification, we aim to shed light on the complex challenges facing the Sahel and explore potential strategies to address this pressing issue.

The Sahel has typically a semi arid climate i.e it is typically hot, sunny, dry and somewhat windy throughout the year. It is similar to that of the Sahara desert in the north, albeit a bit less extreme. The climate in Sahel can be divided into two seasons essentially, one wet and the other season dry, although the inhabitants have added two transitional seasons, both characterized by the humidity of air and by the rise in temperature. The duration of the seasons differs from south to north in this region. In the southern areas, the rainy season typically starts in late May or early June, whereas in the northern regions, it doesn't commence until July.

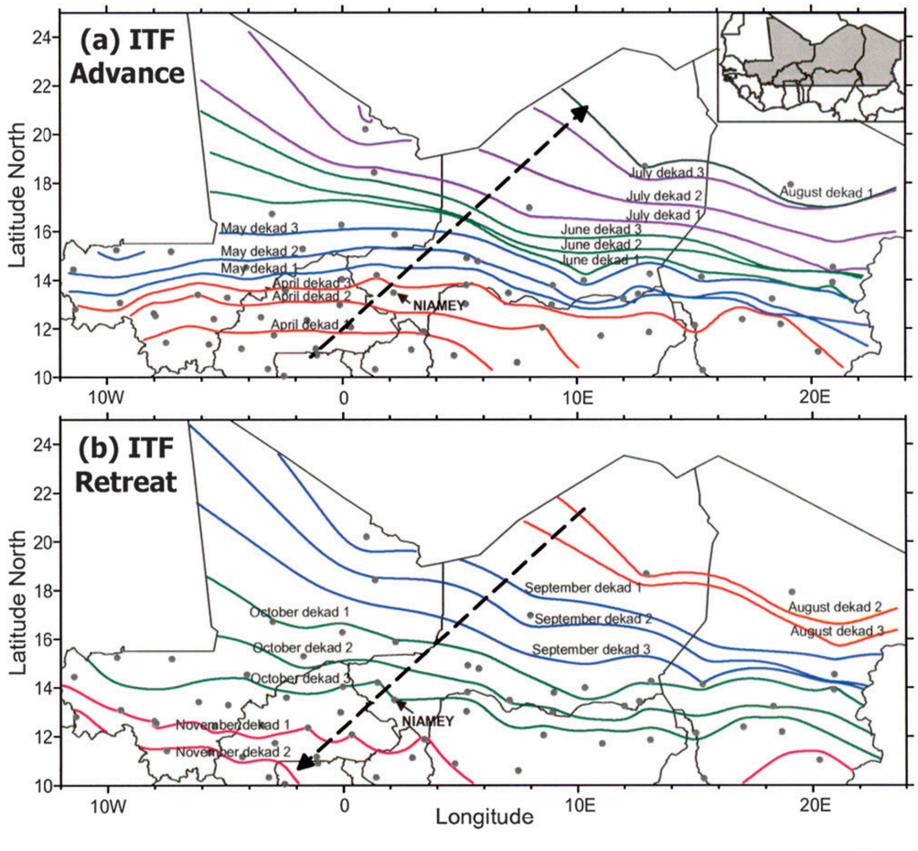


Figure 5 **- Figures related to Inter Tropical Front (ITF)**

The different seasons, well-known to the inhabitants, illustrate the underlying climatic process. The rainy season coincides with the arrival of the Intertropical Front (ITF), which is the boundary between dry continental air and moist sea air. This collision creates turbulence, leading to intense convective storms that often occur in the late afternoon. Prior to the rain, there are violent sandstorms, and sometimes the rain doesn't reach the ground.

As the ITF moves north, the 'monsoon' arrives, bringing humid winds from the southwest. Conversely, when the ITF retreats southward, it brings the dry harmattan, a northeast wind. Rainfall is closely linked to the unpredictable movement of the ITF. Early advances, temporary retreats, and late returns of the ITF can result in uneven rainfall distribution, negatively impacting vegetation.The transitional seasons, occurring in May and June as well as in late September and early October, mark the movement of the ITF as it travels northward

and then returns southward. During these periods, the two air masses are not yet firmly established in their typical patterns.
The pastoralist's way of life follows a different seasonal calendar compared to the farmer in the south, who relies on rain-fed agriculture. For pastoralists, the rainy season brings plenty: pastures flourish, animals produce milk, and herders no longer need to water them at wells. In the subsequent seasons, during autumn and the early cold season, surface-water pools and sufficient pastures are available. However, as the cold season ends and the hot period begins in March or April, the animals can only feed on dry straw and require watering at deep wells or boreholes. Food becomes scarce for people as milk production decreases, and the task of providing water and protection for the animals becomes more demanding. The food shortage occurs during the hot season before the rains return. In contrast, farmers experience abundance after the rainy season ends and harvesting begins. Their season of scarcity aligns with the rainy season when weeding often takes place while granaries are already empty.

ITF is a specific feature within the ITCZ. **ITCZ (Inter tropical convergence zone)** is a broad area near the equator where the north and south trade winds meet. It is characterized by ascending air, high humidity, & frequent rainfall. Sahel typically falls at the northernmost part of the ITCZ zones. During periods of desertification or drought in the Sahel region, there is often a weakening or southward shift of the Intertropical Convergence Zone (ITCZ). This shift means that the ITCZ may not reach its typical northernmost position during the Northern Hemisphere summer. As a result, Sahel experiences reduced rainfall during what is typically monsoon season.

Temperature:

The **mean and annual temperatures differ again between the north and south part of the Sahel** region as illustrated below. Note that Agadez is situated in the North region and Talhoua in the South region. It's evident that the **average annual temperature rises as you move from north to south, although the difference isn't substantial.** However, the annual temperature variation expands from south to north. In the northern regions, both the highest and lowest monthly temperatures become more extreme, with the minimum temperature changing more rapidly compared to the maximum temperature.

Month	Mean monthly and annual temperatures (°C)	
	Agadez, 1926–54	Tahoua, 1939–54
January	20·0	24·1
February	22·8	25·7
March	27·4	29·4
April	31·1	32·6
May	33·9	33·6
June	33·5	32·4
July	32·2	29·3
August	30·7	27·5
September	31·3	29·2
October	29·7	29·9
November	25·0	27·5
December	21·3	24·2
Annual mean	28·2	28·8
Maximum monthly temperature	48·5 (May 1940)	46·6 (May 1940)
Minimum monthly temperature	1·5 (January 1944)	4·2 (January 1941)

Table 1 - **Mean monthly and annual temperatures in Sahel**

Evaporation:

Evaporation is a crucial factor in the life of the North Sahel region as it leads to the drying of plants and pools. **The rates of evaporation reach their peak during the scorching dry months of March to May, decline in the subsequent months, and then rise again starting from November.** Evaporation levels are influenced by both wind and temperature, with temperature being the primary factor. The months with the highest temperatures, typically from March to June, experience the greatest evaporation rates. Additionally, the dry north-east harmattan wind contributes to increased evaporation. In general, as rainfall decreases, evaporation tends to increase. Moreover the presence of great heat and evaporation can be hard on people who often have heavy work to do at this time.

Precipitation:

Rainfall plays a central role in arid regions as it directly influences vegetation, surface water, and shallow groundwater. The duration of the rainy season decreases from south to north in the study area. Given below is a graph that illustrates the correlation between the temperatures and the rainfall per month in Sahel. As shown when the temperatures are high, there is less rain and vice versa.

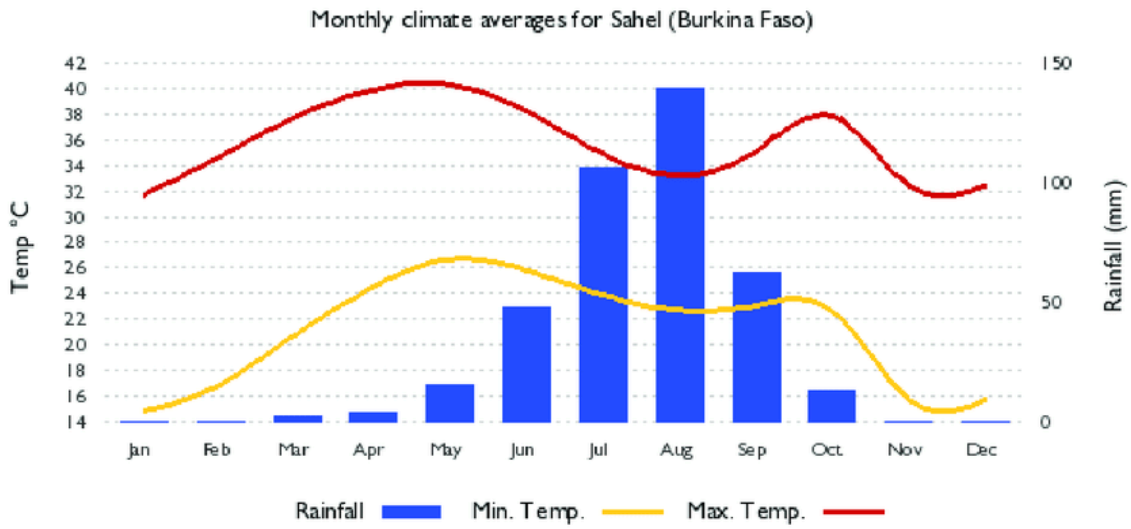


Figure 6 **- Monthly climate averages for Sahel (Burkina Faso)**

Rainfall in the Sahel zone is best described as highly irregular. This irregularity is primarily attributed to the variability in the northward progression of the Intertropical Front, accompanied by its diverse air masses, which follows a specific path relative to the sun's position around the equator.When the Intertropical Front extends far to the north, it results in abundant rainfall and a longer-than-average rainy season. Conversely, when its northward movement is constrained, rainfall becomes insufficient, leading to a shorter rainy season and increased evaporation. This, in turn, accelerates the drying of the soil, which is already inadequately moist.

Variation with time:

Rainfall irregularities with time occur **at 2 levels: one hand rainfall is unevenly distributed within 1 cycle** and on the **other hand rainfall totals vary considerably from one year to another uneven distribution in rainfall may not be useful to vegetation**. Here the notion of '**useful rain' comes, i.e the portion of rain that positively impacts the development of plant cover.** Early rainfall in the season can trigger vegetation to germinate and start growing, but its survival relies on subsequent rain. If rain returns a month later, the recovery of vegetation is limited to species with ample reserves and a second set of seeds that didn't germinate with the initial rain. Regardless, such irregular timing weakens, stunts, and thins out the vegetation. When abnormal rainfall timing occurs, especially after several years of regular patterns, it can eliminate many annual species, making perennial plants more dominant. However, if this irregularity persists, even perennial plants deplete their reserves and decline.

Stations	May	June	July	August	September	Total, 1973
P1	—	0·5	32·5	80·4	—	113·4
P2	—	4·2	31·2	45·8	0·2	81·4
P3	—	2·3	25·0	91·5	—	118·8
Agadez	—	10·8	39·4	17·9	0·1	76·1[1]

1. Including 8·1 mm in April.

Table 2 **- Variation of rainfall with location**

Useful rain can be defined as the rain that enables the soil to retain enough water to allow plants to develop to maturity without a break. The useful rainy season is usually short and can change from one year to the other.

The concept of "**useful rainfall**" is essential in understanding why droughts can have a severe impact on livestock, even when the total annual rainfall appears normal or above average. This phenomenon was evident in the years 1967 and 1968 across the study area, spanning from Tahoua to Agadez.In 1967, despite a total rainfall of 155.3 mm (close to the historical mean of 164.2 mm), it was considered a good year because the rainfall was distributed evenly at regular intervals. However, in 1968, although the total rainfall was higher at 165.1 mm, it was a drought year with significant livestock losses. The key difference was the distribution of rainfall: in April 1968, 50.2 mm of rain fell in just six days, initiating the vegetation's growth cycle prematurely. Unfortunately, there was very little rain in May, only 0.5 mm in one day. This disrupted the normal maturation of vegetation due to the lack of rain when it was needed . In summary, **droughts can result from a deficiency in "useful rainfall**," which is critical for the proper development of vegetation. Even if the total annual rainfall seems adequate, irregular distribution can have detrimental effects on the environment and agriculture.

Rainfall irregularity is emphasized to show that the annual averages poorly represent the complex situation of Sahel. The below graph is the Sahel rainfall with 0 corresponding to the mean rainfall over the course of the years, and the y axis denotes the standard deviation of the rain fall.The interannual irregularity can often produce rainfall shortages over a series of successive years as was the case from 1969 to 1972. The cumulative effect of these years cause droughts of catastrophic proportions.

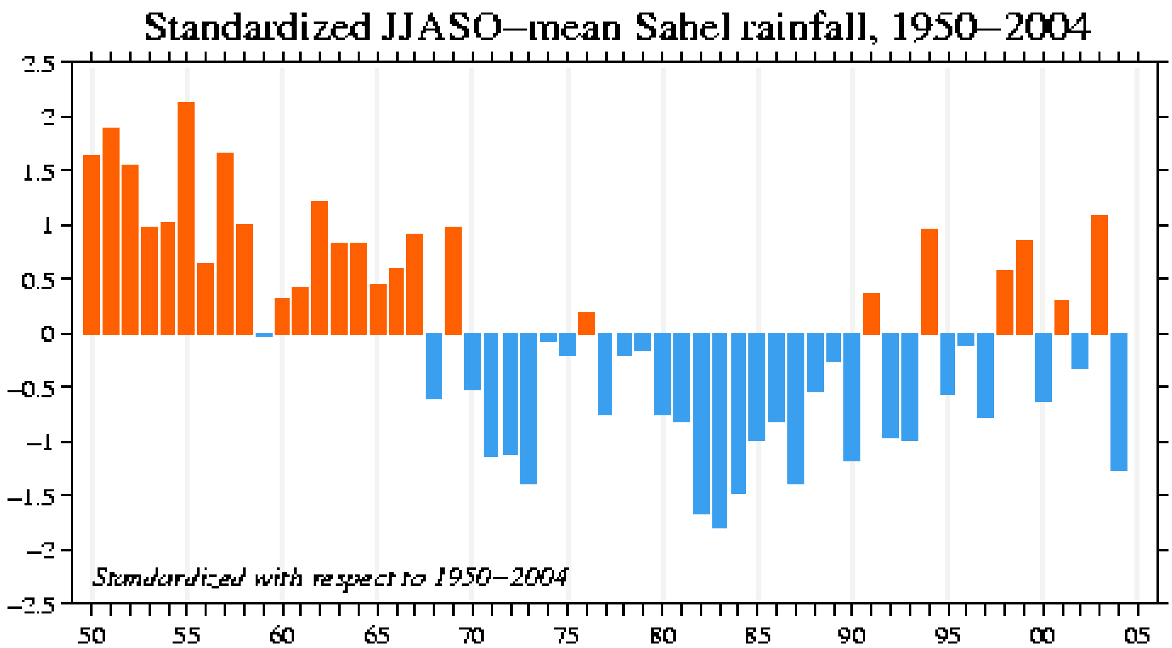


Figure 7 **- Standardized JJASO - mean Sahel rainfall, 1950-2004**

In conclusion, it's important to highlight that while there may be differing opinions regarding long-term climatic changes, there hasn't been conclusive evidence to demonstrate a significant decrease in total rainfall at the present moment.The only consistent aspect of the Sahel climate that remains undisputed is the irregularity of rainfall, characterized by the succession of dry years.

<u>Effect of El-Nino:</u>

El-Nino Southern Oscillation (ENSO) also affects the precipitation of rainfall. During an El Niño, the Warm Pool rainfall extends further into the warmer water, the entire tropical troposphere warms up, and the warm upper‑level anomalies increase the atmospheric stability over the Sahel region, thus dampening rain‑producing moist convection and causing drought.

❖ Population and Demographics

Population growth has been a significant driver of environmental change in the Sahel. The region has experienced rapid population growth rates, with many countries having some of the highest fertility rates in the world.

Population growth and demographic factors in the Sahel are intimately linked to desertification. The increasing population strains natural resources, promotes unsustainable land-use practices, and exacerbates water stress, all of which contribute to the degradation of the Sahel's fragile ecosystems. Understanding these demographic dynamics is crucial for developing effective strategies to combat desertification and promote sustainable development in the region.

The population of West Africa is growing very rapidly (2.1 percent per year for Economic Community of West African States (ECOWAS) countries and 3 percent for landlocked countries without a coastline for 2005–2025, i.e. the inner Sahel). Over the past 30 or so years, the Sahel countries, in particular, have had the highest population growth rates in the world. It is estimated that the rural areas of the Sahel will be four times more populated in 2025 than in 1968 at the onset of the drought. This **puts pressure on space, water resources, and plant resources, in connection with pastoral pressure, agribusiness, and land grabbing**.

Country	Pop. 2019 (millions)	Pop. 2050 (millions)	Pop. 2050 / pop. 2019	Fertility rate	Life expectancy	Infant mortality (‰)	Human Development Index (HDI) ranking	Rural pop. as a percentage	Percentage of population growth in years 2005–2025
Burkina Faso	20.3	43.4	2.1	5.23	60.9	84	183	60	2.84
Cabo Verde	0.55	0.68	1.2	2.29	72.7	20	125	34	1.98
The Gambia	2.35	4.88	2.1	5.25	61.5	68	174	35	2
Guinea-Bissau	1.92	3.56	1.9	4.51	57.8	82	177	56	3.02
Mali	19.7	43.6	2.2	5.92	58.7	105	182	52	2.92
Mauritania	4.53	9.03	2	4.59	64.6	79	159	25	2.44
Niger	23.3	65.6	2.8	6.95	61.8	102	189	75	3.23
Senegal	16.3	33.2	2	4.65	67.5	45	164	45	1.86

Table 3 **- Population statistics in Sahel countries**

Resource Demands

The Sahel region is experiencing a significant population boom, intensifying the demands for vital resources like food, water, and shelter. **To meet the growing needs of this expanding population, communities increasingly engage in agricultural activities**. However, the quest to produce more and secure livelihoods often leads to the adoption of unsustainable practices, further exacerbating the challenges of land degradation in the region.

One prominent **consequence of** this **population pressure is overgrazing**. With the rising demand for meat and dairy products, extensive livestock grazing becomes common. This practice not only depletes the vegetation but also tramples the soil, contributing to erosion and reducing its capacity to support healthy plant growth. The soil degradation, in turn, jeopardizes the viability of agriculture in the long run.

Another outcome is the expansion of agricultural lands to accommodate the growing food requirements. This expansion, while essential for providing sustenance, often involves excessive land cultivation. Repeated plowing and planting without implementing proper soil conservation measures can lead to soil erosion, the loss of topsoil, and diminished agricultural productivity. Consequently, this **overuse contributes to the degradation of arable land and negatively affects its fertility.**

Furthermore, as the **population seeks to secure water for agricultural purposes, inefficient irrigation methods come into play**. This puts added pressure on water resources and compromises their sustainability. Inefficient irrigation not only leads to water scarcity but also impacts the land when not applied effectively, further deteriorating the health of the soil and vegetation.

To address these interconnected challenges, it is essential to prioritize sustainable agricultural practices, responsible land management, and water conservation measures. **Striking a balance between the increasing resource demands of the growing population** and environmentally responsible resource utilization is imperative for the long-term well-being of both the people and the land in the Sahel region.

<u>**Limited Access to Family Planning and Land Fragmentation**</u>

Limited access to family planning and reproductive health services in some Sahelian countries has contributed to high fertility rates.

High fertility rates have led to larger family sizes in rural Sahelian communities. As land is passed down to multiple heirs, it becomes fragmented into smaller plots.

Land fragmentation hinders sustainable land management practices, and makes the land more susceptible to soil erosion and desertification.

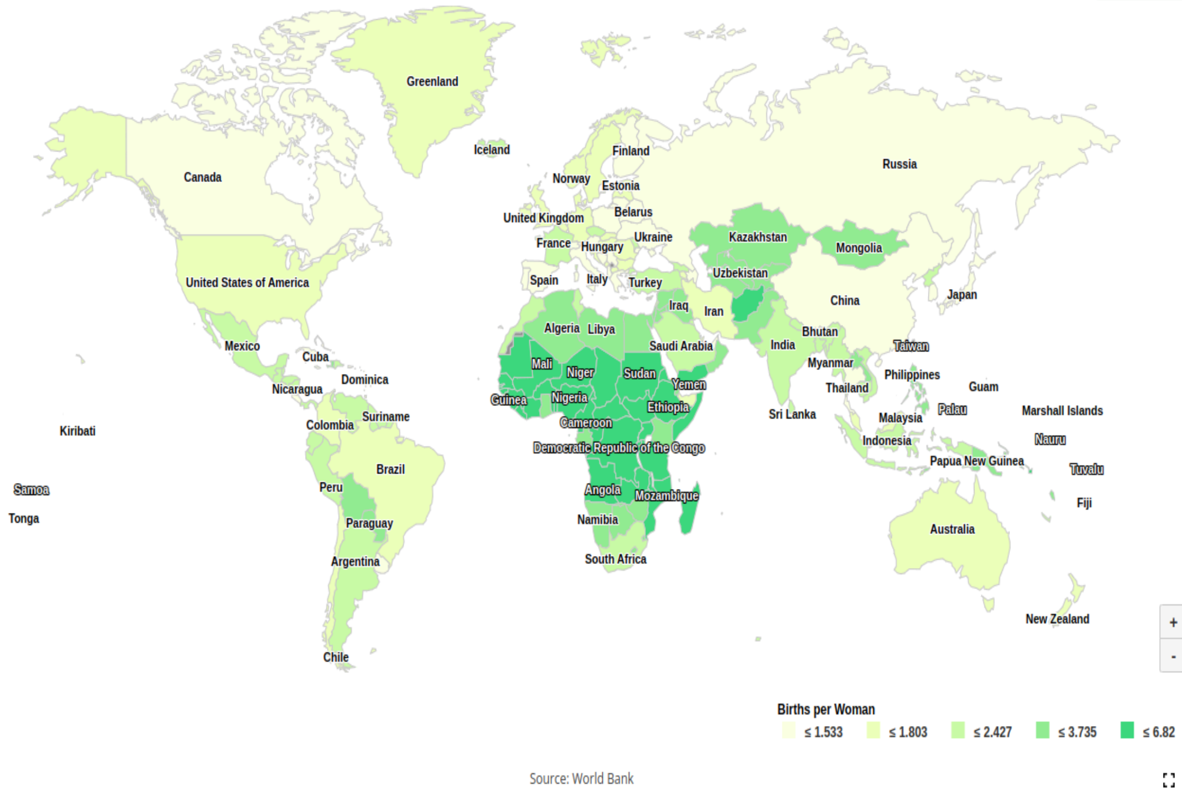


Figure 8 **- Fertility rates across the world**

As evident in the visual representation above, the fertility rate in Sahelian countries stands out as exceptionally high when compared to others. While there has been a decline in fertility rates compared to previous years, the current Total Fertility Rate (TFR) remains suboptimal for positively impacting land usage conditions.

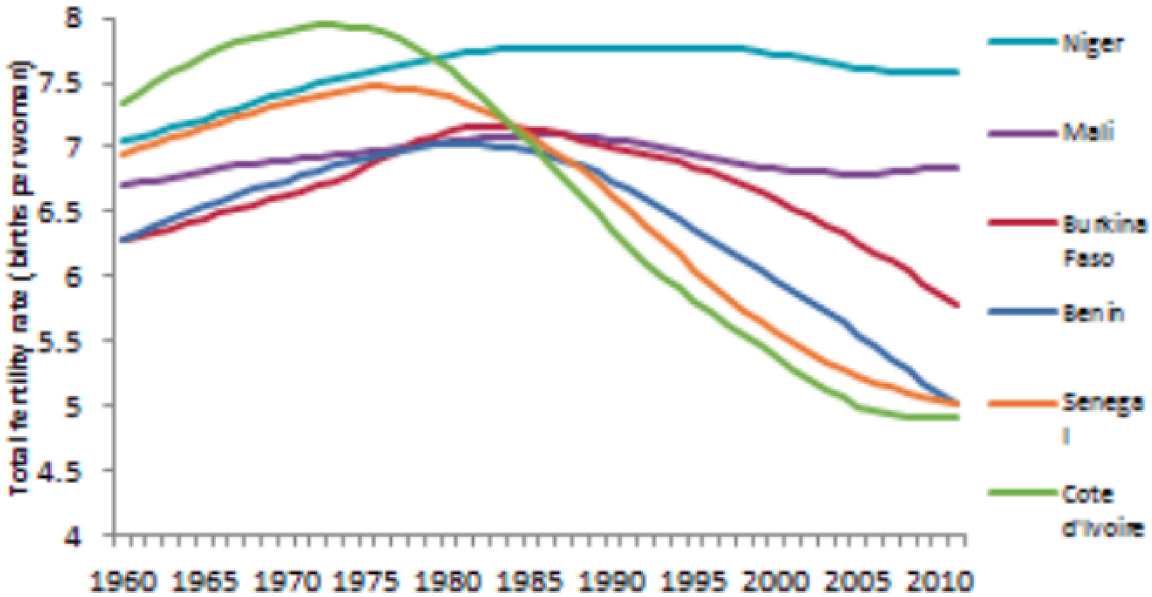


Figure 9 **- Graph depicting Fertility rates from the years 1960-2010 in Sahel**

Youth Population and Employment

The Sahel region is home to a predominantly youthful population, a demographic characteristic that has a significant impact on the challenges related to land degradation and desertification. The lack of employment opportunities in rural areas places immense pressure on land resources as young people, seeking to secure their livelihoods, may resort to unsustainable land-use practices out of necessity.

The **pressure exerted on land resources by young individuals engaging in unsustainable practices cannot be overstated**. Overgrazing, deforestation, and the utilization of poor agricultural methods are some of the repercussions of this dire need for survival. These practices not only accelerate the immediate degradation of the land but also hinder the region's capacity to regenerate and recover from the environmental damage incurred.

In light of these challenges, addressing the issue requires a multifaceted approach, as creating viable job opportunities for youth, particularly in non-agricultural sectors, becomes paramount. The efforts to alleviate the pressure on land resources should align with the demographic reality of the region. Recognizing that young people are not only the bearers of these challenges but also a significant part of the solution is essential to reversing the trends of desertification and land degradation in the Sahel.

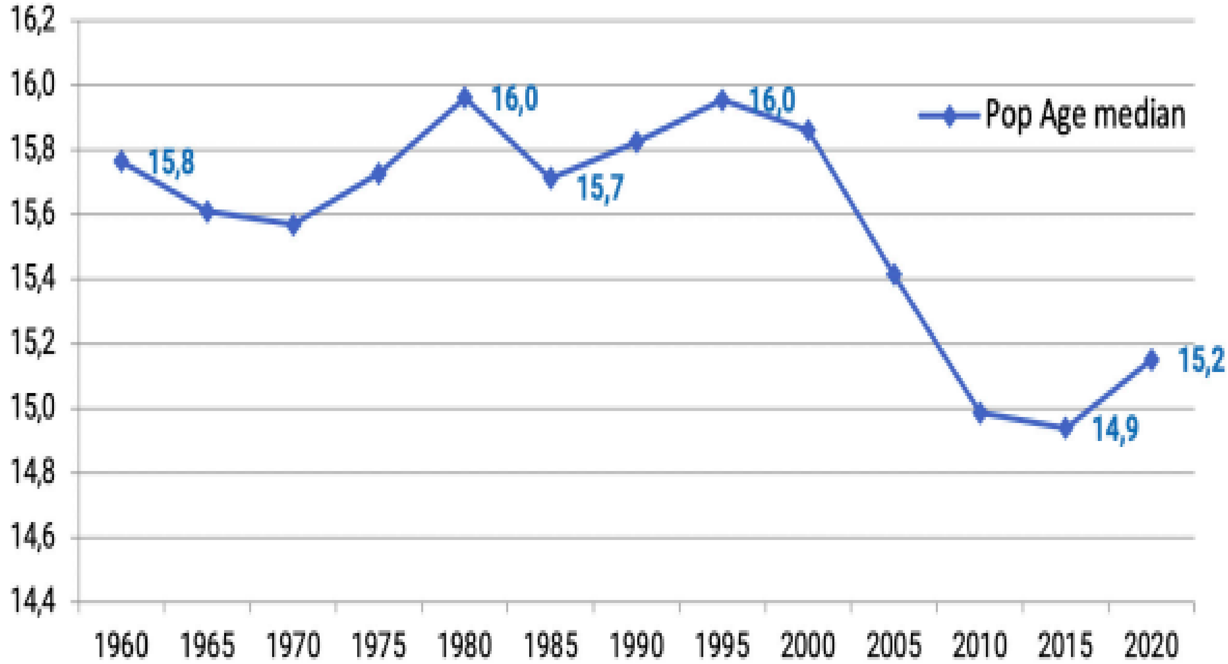


Figure 10 **- Population Age Median in Sahel**

<u>Water Stress</u>

Water stress, aggravated by a growing population, is a key factor driving desertification in the Sahel. With an increasing number of people, the demand for water resources has surged, placing additional strain on already limited sources. This overuse and exploitation of finite water resources deplete aquifers and surface water bodies, further degrading the region's ecosystem and accelerating desertification. This crisis not only threatens the sustainability of water supplies but also puts pressure on local communities, who rely on these resources for agriculture, livestock, and daily necessities. Additionally, the degradation of these ecosystems worsens desertification, endangering local biodiversity and agricultural productivity. The situation also prompts migration in search of water and arable land, potentially leading to conflicts over resources and regional instability. Tackling water stress is crucial for mitigating desertification in the Sahel and ensuring a sustainable future for its inhabitants.

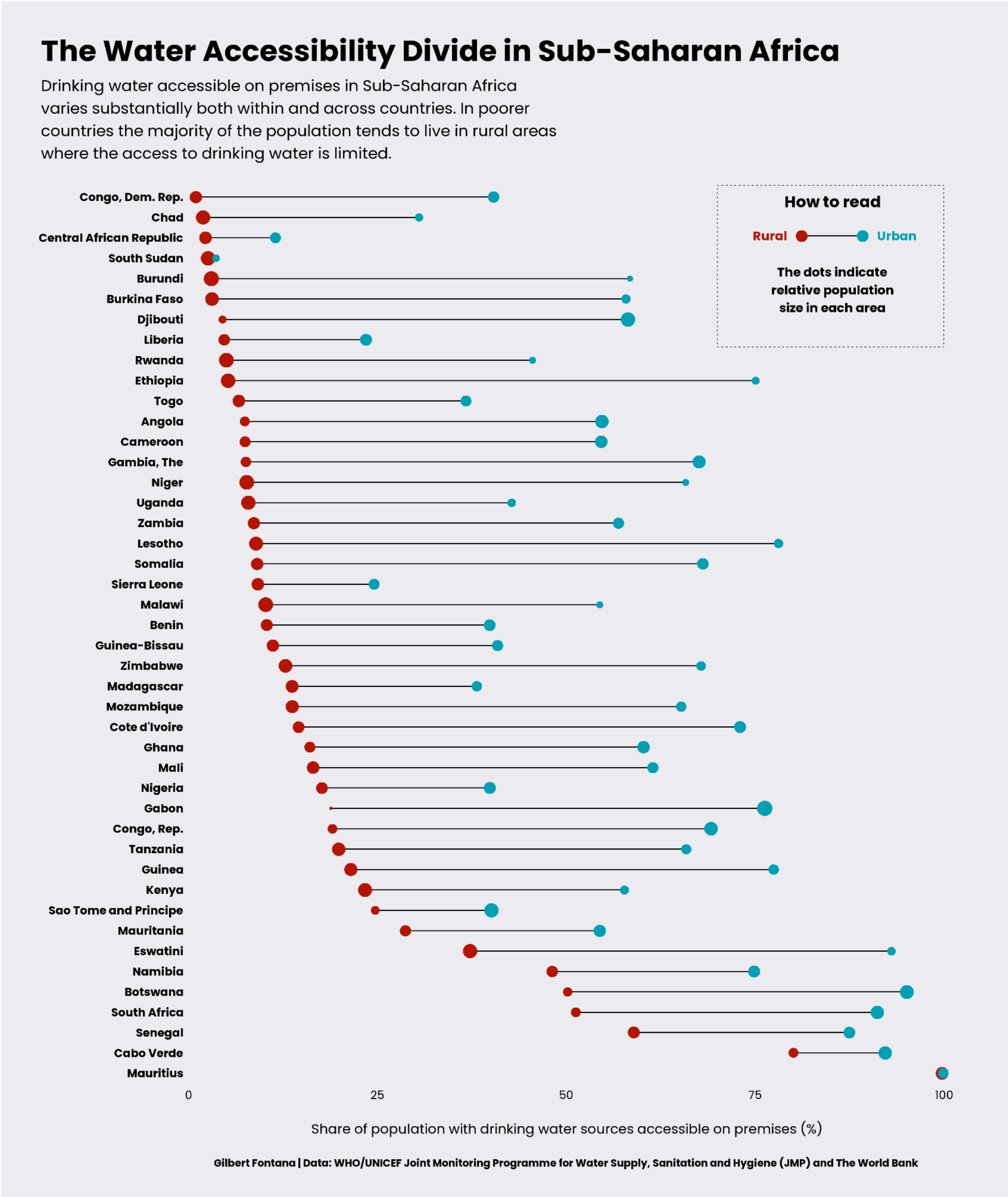


Figure 11 - **The Water Accessibility Divide in Sub-Saharan Africa**

Climate-Induced Migration

Climate-Induced Migration **in the Sahel is a direct result of climate change and environmental degradation**. The relentless challenges in the region, including **land degradation, water scarcity, and food insecurity**, force communities to make the difficult decision to leave their homes in search of more sustainable living conditions. Unfortunately, this migration has profound implications, extending well beyond the displaced communities.

Forced migration resulting from these environmental challenges places **immense pressure on the areas that receive the migrants**. When these communities seek refuge in new regions, they often compete with the local populations for limited resources. This heightened competition intensifies the demand on the land and its ecosystems, potentially exacerbating land degradation, water scarcity, and resource competition.

The consequences of climate-induced migration are far-reaching. In host areas, the influx of migrants can strain the capacity of the environment to support the needs of both established and incoming populations. Land, water, and food resources become scarcer, and the intensified competition can lead to overuse and depletion of already vulnerable ecosystems. This, in turn, may result in **localized desertification, a process that further deteriorates the land and leads to the loss of fertile soil.**

Additionally, climate-induced migrants often face significant challenges in accessing essential resources, **leaving them vulnerable to poverty and social conflict.** The strain on social services and economic opportunities in host communities can potentially give rise to tensions and conflicts over limited resources.

Mitigating the impact of climate-induced migration on land degradation in the Sahel necessitates a **multifaceted approach.** This includes bolstering the resilience of vulnerable communities, promoting sustainable land management practices, and ensuring responsible resource allocation. Moreover, international cooperation is essential to addressing the root causes of climate change. By embracing these measures, the Sahel can take significant strides toward mitigating the consequences of climate-induced migration and working toward a more sustainable, stable, and equitable future for all its residents.

Urbanization and Peri-Urban Expansion

Urbanization and Peri-Urban Expansion have become **prominent trends** in the Sahel as rural populations continue to grow. Many individuals are drawn to urban areas in **search of improved economic opportunities and better living conditions**. This migration to urban centers has led to a substantial increase in urbanization, with cities and towns expanding into areas that were once predominantly rural. The **expansion of urban areas into peri-urban regions**, where urban and rural spaces intersect, presents a set of distinct challenges. These areas often lack adequate urban planning and infrastructure, leading to rapid, uncontrolled urban expansion. This **unregulated growth** is a significant contributor to **land degradation**, as it encroaches upon valuable arable land and natural ecosystems, disrupting the ecological balance.

The **demand for housing and infrastructure in peri-urban areas frequently results in the clearance of vegetation and topsoil**, often for construction purposes. This process leaves the land more vulnerable to the forces of desertification. The **removal of vegetation eliminates vital soil stabilization, exacerbates soil erosion, and weakens the land's capacity to resist degradation.** Additionally, the **loss of topsoil diminishes the fertility of the land**, further reducing its ability to support agriculture and vegetation growth. To combat the challenges posed by urbanization and peri-urban expansion in the Sahel, it is crucial to implement sustainable urban planning practices that prioritize responsible land use, reforestation efforts, and the preservation of natural ecosystems. By doing so, the Sahel can balance the demand for economic opportunities with the need to protect its land and resources from further degradation, ultimately promoting a more sustainable and resilient future for both urban and rural communities.

The below graph depicts change in Niger's urbanization rate between 1955 and 2012:

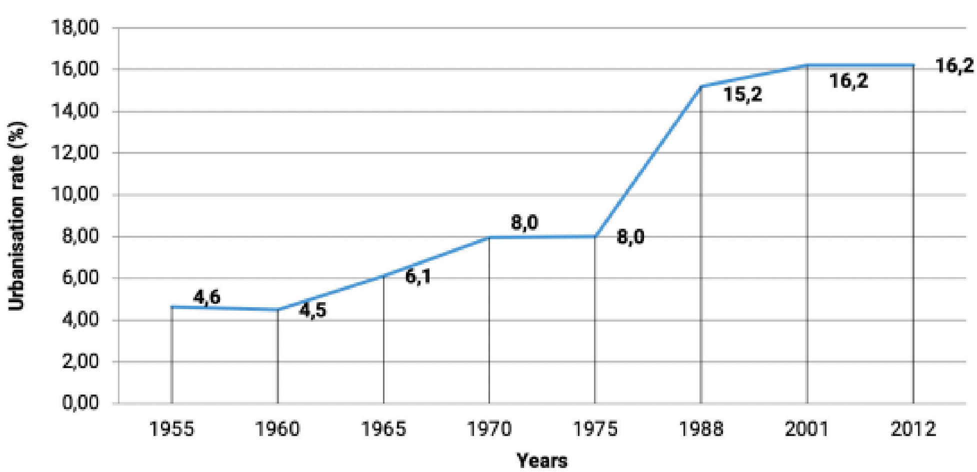


Figure 12- Niger's urbanization rate between 1955 and 2012

Rural Population Growth

Rural populations in the Sahel heavily rely on subsistence agriculture for their livelihoods. As families expand, there is an increased need to cultivate more land to meet growing food demands. In many cases, this results in the clearance of forests and grasslands, leading to deforestation and soil degradation, both of which contribute to desertification.

Nomadic pastoralism is a traditional way of life in many Sahelian communities. The population growth in these areas has led to an increase in livestock herds, often exceeding the carrying capacity of the land. **Overgrazing depletes vegetation cover**, leaving the soil exposed to erosion and desertification processes.
High birth rates in rural areas can strain access to resources such as water and arable land. Competition for these resources can lead to conflicts and disputes among communities, which can disrupt sustainable land-use practices and hinder efforts to combat desertification.

The rural population in the Sahel is particularly vulnerable to climate change, which has led to erratic rainfall patterns and increased temperatures. A growing rural population, reliant on rain-fed agriculture, faces heightened risks due to climate variability, exacerbating desertification as **crops fail and soil becomes more susceptible to erosion**.
Many rural communities in the Sahel lack access to modern agricultural practices, technology, and education. This perpetuates traditional farming methods, some of which are unsustainable and contribute to land degradation.

Year	Total pop.	Rural pop.	Rural pop. as a percentage
1968	16.9	15	88.8
1980	29.1	24	82.5
2000	55	35.9	65.3
2010	72.5	44	60.7
2019	89	50.5	56.7
2050*	204	76.1	37.3

Table 4 - Population statistics in Sahel countries

The above table shows that the rural population is growing strongly in the Sahel, even if at a slower rate than the urban population. The rural population is more than three times higher than in 1968, the beginning of the drought.

Government Policies to tackle Population Growth and Resource Degradation

- **Family Planning in Mali:**
  Policy: Mali has adopted policies to address high fertility rates.
  Initiative: Government-sponsored family planning clinics provide access to contraceptives and reproductive health services. These efforts have contributed to a decrease in fertility rates and slower population growth.

- **Rural Development in Chad:**
  Policy: Chad's National Rural Development Strategy focuses on improving rural livelihoods.
  Initiative: Investments in rural infrastructure, such as roads, markets, and water sources, have been made to reduce dependency on agriculture and create alternative income sources.

- **Natural Resource Governance in Sudan:**
  Policy: Sudan has introduced policies to regulate natural resource management.
  Initiative: Legislation and enforcement mechanisms have been put in place to combat illegal logging and land grabbing, ensuring that resources are managed sustainably.

- **International Collaboration in Mali and Niger:**
  Policy: Mali and Niger are signatories to the United Nations Convention to Combat Desertification (UNCCD).
  Initiative: Through their involvement with UNCCD, these countries receive funding, technical support, and participate in knowledge-sharing networks to enhance desertification control efforts.

- **Afforestation Programs in Senegal:**
  Policy: Senegal aims to combat desertification and resource degradation through afforestation and reforestation.
  Initiative: The government is launching large-scale afforestation programs, encouraging the planting of trees to combat soil erosion, increase soil fertility, and mitigate the effects of desertification. These initiatives also provide job opportunities for local communities, reducing their dependence on depleting natural resources.

- ❖ **<u>Sustainable Agriculture in Burkina Faso:</u>**
  Policy: Burkina Faso is committed to sustainable agriculture practices.
  Initiative: The government promotes sustainable farming techniques such as agroforestry, crop rotation, and conservation farming. These methods help conserve soil, reduce land degradation, and improve crop yields, ensuring food security and protecting vital natural resources.

- ❖ **<u>Land Tenure Reform in Mauritania:</u>**
  Policy: Mauritania recognizes the importance of land tenure reform.
  Initiative: The government is working to clarify land ownership and land use rights, ensuring secure land tenure for local communities. This reduces conflicts over land and resources, promotes responsible land management, and contributes to combatting desertification and resource degradation.

- ❖ **<u>Livestock Management and Grazing Policies in Nigeria:</u>**
  Policy: Nigeria recognizes the importance of sustainable livestock management.
  Initiative: The government is implementing policies to regulate grazing and ensure sustainable livestock practices. Proper grazing management prevents overgrazing, land degradation, and conflicts between farmers and herders.

These examples illustrate how governments in the Sahel region are taking diverse approaches to address desertification while considering the role of population growth and demographic factors. These policies and initiatives not only aim to combat land degradation but also contribute to the broader goal of sustainable development in the Sahel.

❖ Composite Drought Index

Drought is one of the most complex and costliest natural hazards. It is difficult to accurately identify its onset and end, as it **generally starts slowly and gradually**. The impacts of drought are context-dependent, they are mostly diffused, both direct and indirect, short-term and long-term.

According to the International Disaster Database, over **1.1 billion people were affected by droughts, globally, between 1994 & 2013**. In this period, the **African continent registered about 131 droughts**, being the most affected continent. In the **Sahel region, drought remains a key driver of food insecurity**. The Sahelian droughts of the 1970s and 1980s is clear evidence of how droughts could affect livestock and crop productivity, causing **food insecurity and mass migration**. These unprecedented droughts also contributed to **land degradation and increasing desertification**. Due to its socioeconomic context, the Sahel region is considered one of the most vulnerable regions to climate change.

In the Sahel region, **drought is often combined with locust infestation, conflicts & political instability,** causing emergency situations. For example, in 2009, drought in Niger was combined with locust infestation, leading to approximately 805 million USD of losses, which corresponds to 30% of the GDP of the country. Moreover, the 2010 drought in the country affected the food security of about 40% of the population.

Figure 13 - **Major causes of Sahelian droughts**

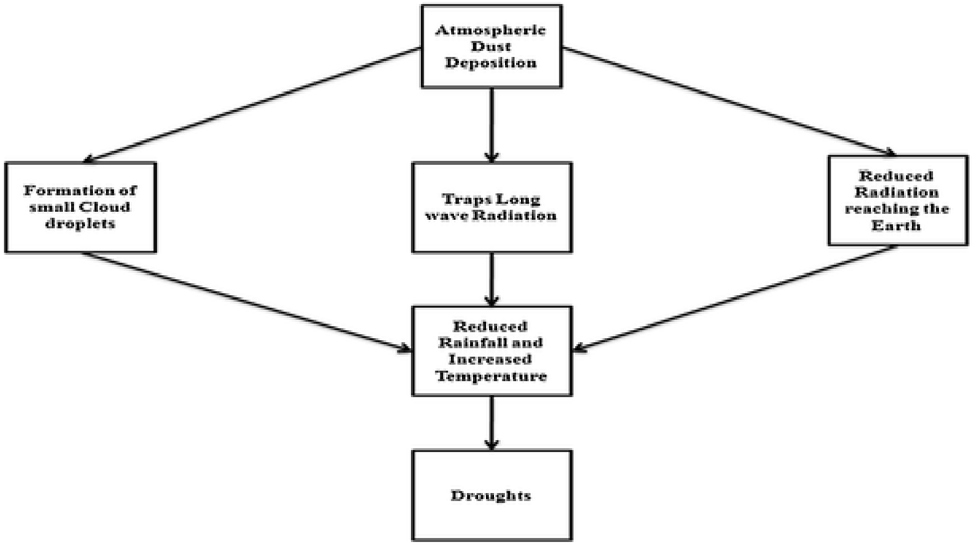
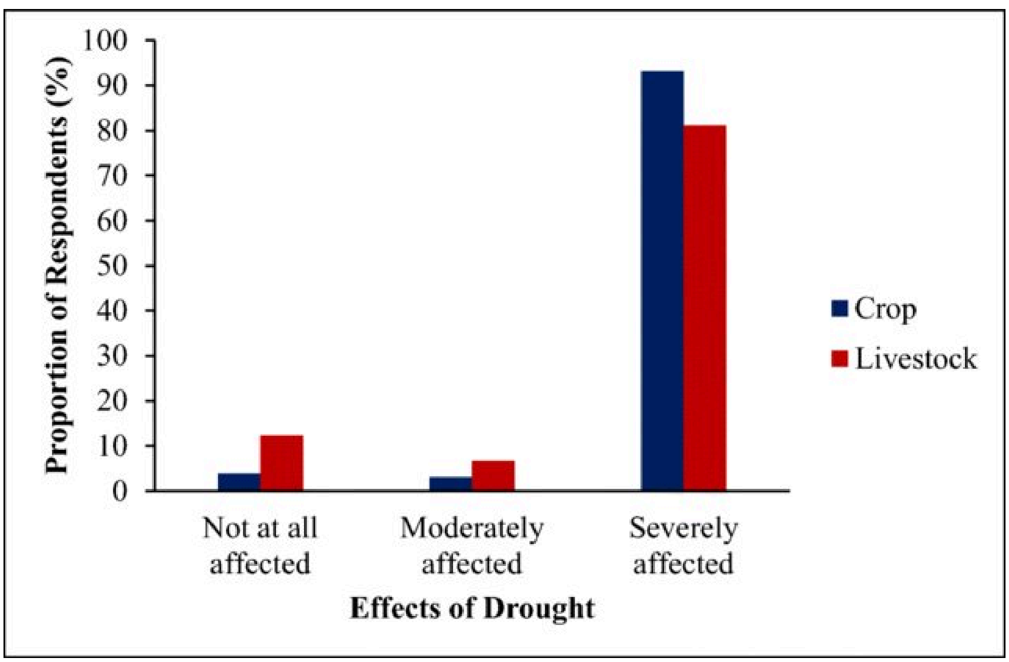


Figure 14 - **Extent of impacts of droughts on sources of livelihood**



Proposed approach for drought detection:

To effectively respond to drought, a comprehensive assessment of its socio-economic and environmental impacts is required. However, to understand drought impacts its spatiotemporal characterization is necessary. This is achieved by using drought indicators or indices, which are being calculated in recent years using earth observation data. One index which is very effective in drought prediction is the Composite Drought Index (**CDI**), which is derived from three important factors measured through remote sensing data, namely, Precipitation (obtained from the CHIRPS dataset), Temperature (measured as Land Surface Temperature - **LST**, obtained from the MODIS measurements), and Vegetation (measured as Normalized Difference Vegetation Index - **NDVI**, also obtained from the MODIS measurements). This computation of CDI using various factors enables the characterization of the combined effects of various factors in causing droughts.

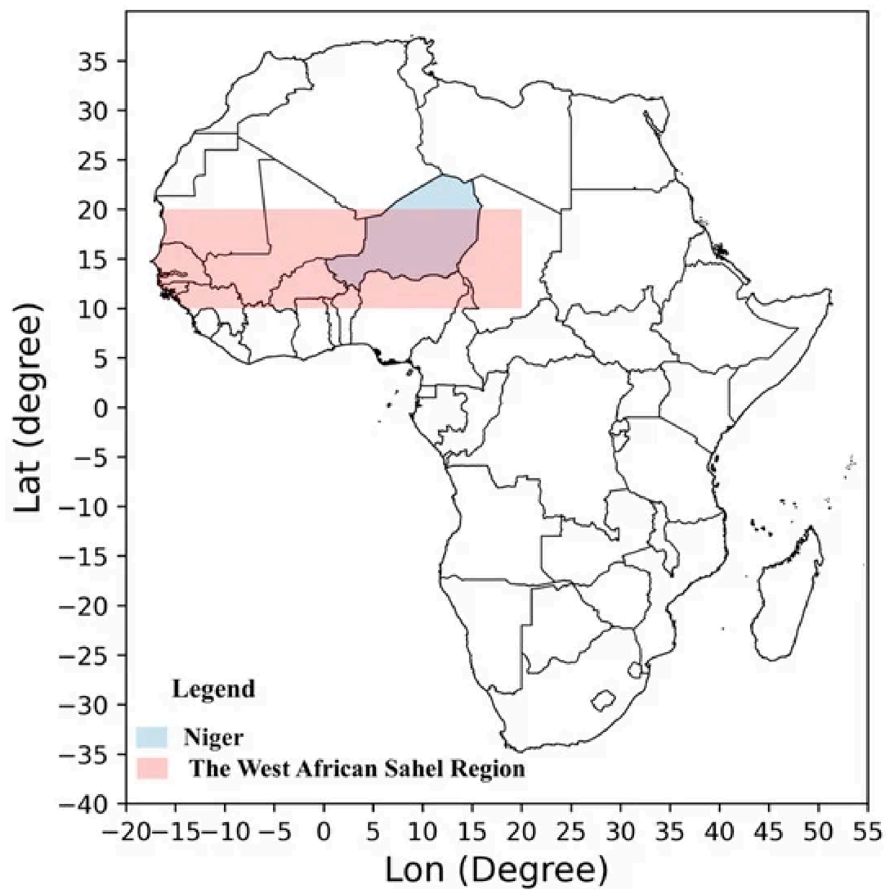


Figure 15 - Latitude and Longitude of Sahel

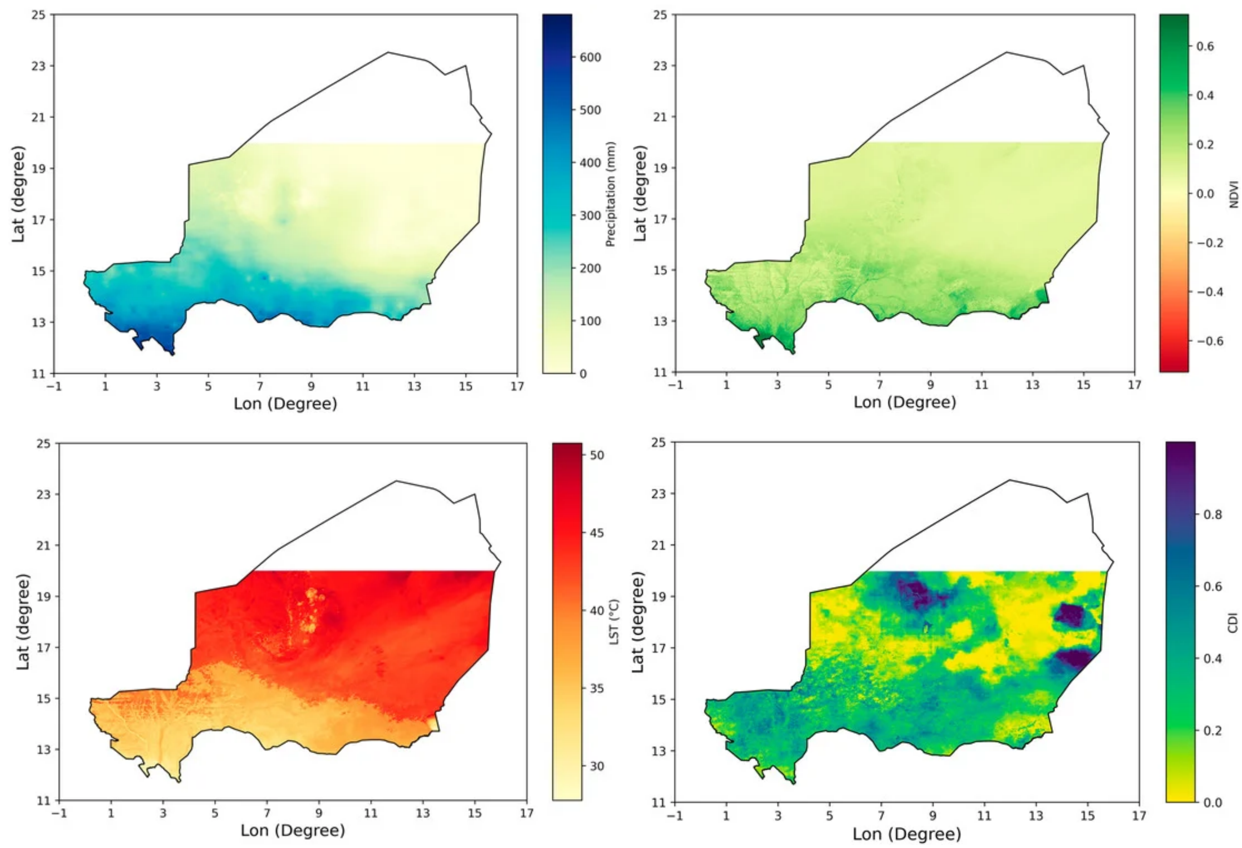


Figure 16 - CDI Analysis

Interpretation of CDI values:

The following table provides information regarding the classification of various levels of drought intensity based on CDI values:

CDI Interval	Classification
< 0.1	Extreme Drought
0.1 - 0.2	Severe Drought
0.2 - 0.3	Moderate Drought
0.3 - 0.4	Mild Drought
0.4 - 0.5	Near Normal
> 0.5	Above Normal

Table 5 - Interpretation of CDI values

Conclusions:

- As can be observed from the above table, we can confirm the presence of drought if the CDI value falls below **0.4**.
- This calculation is coordinate specific and hence drought intensities, characteristics, such as, onset, end, duration, spatial spread and frequency, can be computed for a given location or an area of interest.
- CDI enables us to clearly observe the correlation of various factors in influencing droughts and to better predict drought intensities due to its higher number of drought prediction classes.
- The above calculations generate a dataset purely using remote sensing data, and hence serves as an alternative for ground-observation-based measurements, which might not be viable or feasible for all locations at all times.
- The inclusion of precipitation, vegetation and temperature data guarantees higher accuracy while assessing the combined impacts of meteorological (precipitation and LST) and agricultural (vegetation) factors on droughts.
- This methodology also provides scope for drought analysis under the context of climate change as it also includes temperature data.
- Overall, CDI serves as a versatile measure in prediction and intensity estimation of droughts, ranging from a specific location to a wide stretch of land, with high accuracy.

❖ Niger Agriculture and Rural Development

Agriculture and rural development in Niger play a central role in sustaining the livelihoods of its population, with the majority relying on these sectors for their well-being. This brief introduction delves into the key aspects of Niger's agricultural landscape, the challenges it faces, and the innovative approaches taken to address these issues.

Agricultural Diversity and Significance: Niger's agricultural and livestock sectors are the lifeblood of nearly 82% of its population. Livestock production, including camels, goats, sheep, and cattle, contributes significantly to the nation's GDP, accounting for 14% and supporting approximately 29% of the population. Crop production, on the other hand, actively engages 53% of the population. These sectors are vital for food security, income generation, and employment opportunities in Niger.

Main Crops and Arable Land: Pearl millet, sorghum, and cassava are the primary rain-fed subsistence crops in Niger. These resilient crops form the basis of the country's food security, with farmers relying on rainwater for their cultivation. Additionally, Niger has ventured into irrigated rice production to meet internal consumption demands, despite the challenges associated with the cost of production. Cowpeas and onions are grown for commercial export, along with smaller quantities of garlic, peppers, potatoes, and wheat.

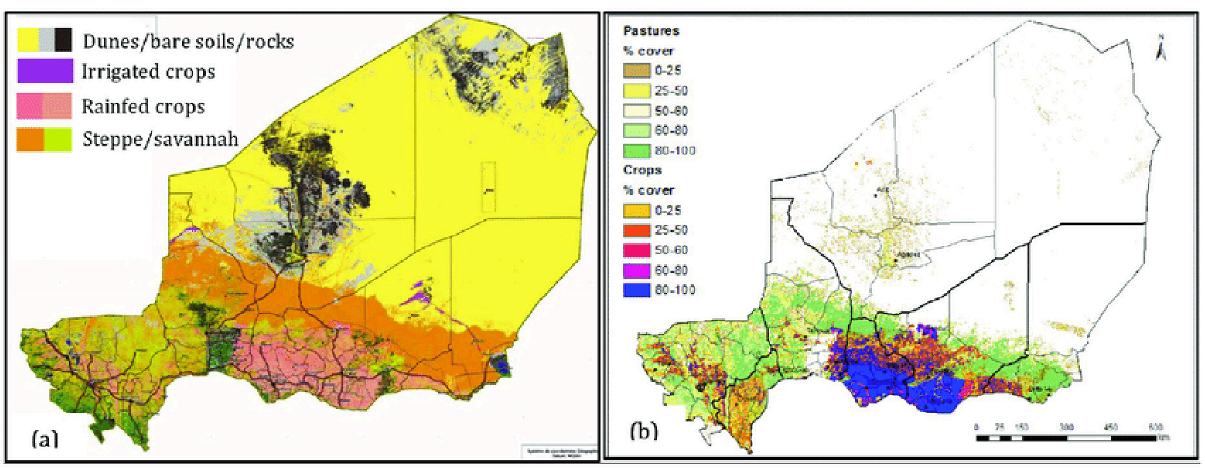


Figure 17 - Land Distribution in Sahel

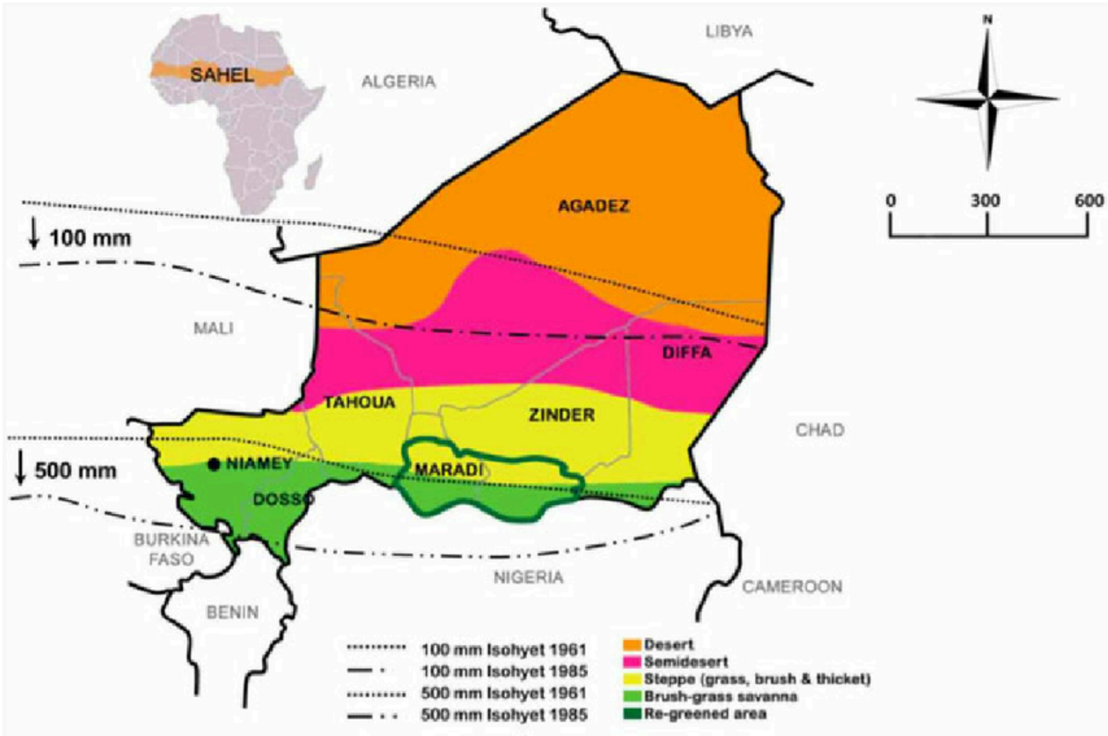


Figure 18 - Vegetation in Sahel

Vegetation and Wildlife in Niger: Niger's diverse climate zones shape its unique plant and animal life. In the desert regions, such as the Saharan area, vegetation primarily clusters around oases, with date palms and cultivated corn (maize) being notable. Animal life here must endure harsh conditions, and the dromedary is well-suited to this arid environment.

Challenges Faced:

Niger's agricultural sector grapples with several challenges, prominently among them being the erratic nature of rainfall. Rainfall in the region varies from year to year, causing food shortages and reliance on grain imports and aid during insufficient rainfall periods. The 20th century witnessed severe droughts, with the most devastating one occurring in the late 1960s and extending into the 1980s. The repercussions of this prolonged drought still affect pastoralist communities, who lost entire herds of cattle, sheep, and camels. Recent rainfall patterns continue to be unpredictable, further compounding food security issues.

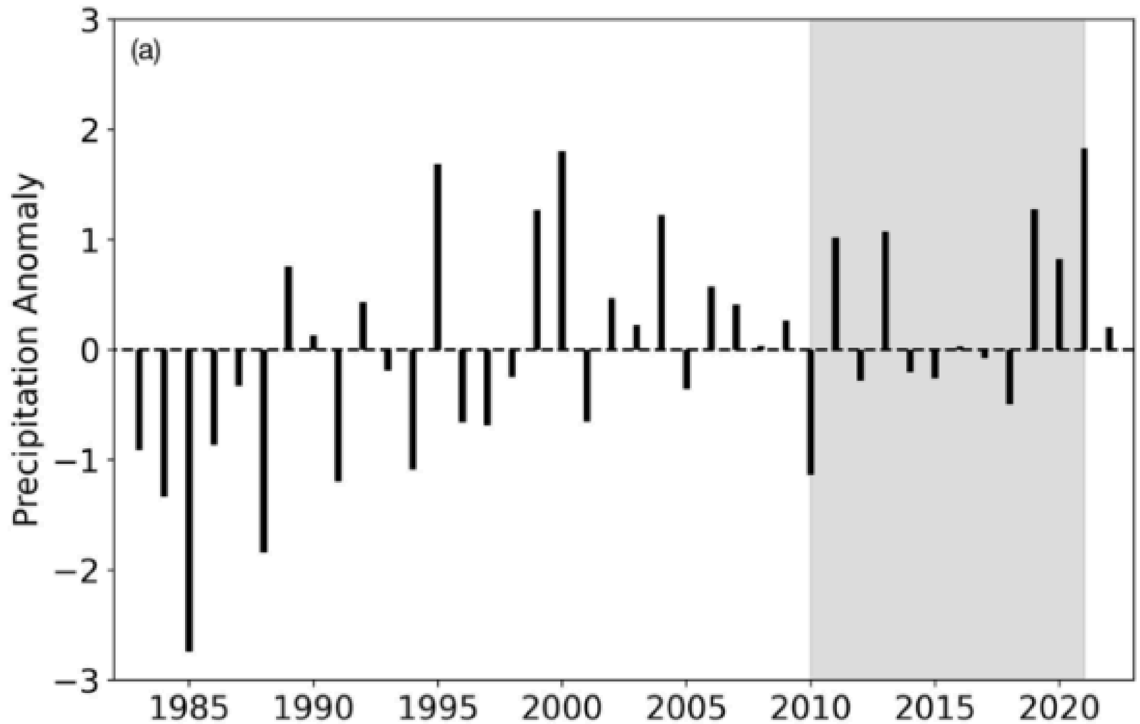


Figure 19 - Precipitation Anomaly across the years 1985-2021 in Sahel

Reason Behind Challenges:

Global dimming is a phenomenon characterized by the reduction in the amount of sunlight reaching the Earth's surface due to atmospheric pollution and the presence of particulate matter. In the Sahel-Sahara region, global dimming played a pivotal role in altering the environmental dynamics, particularly during the 1970s and 1980s. This reduction in sunlight accentuated the severity of drought conditions, disrupted normal rainfall patterns, and cast a long shadow over the region's agricultural and ecological systems. The dimming effect was a contributing factor to the decline in vegetation cover, leading to a significant reduction in forage availability for both wild and domesticated animals. This environmental shift triggered a chain reaction of ecological imbalances, exacerbating food scarcity and further imperiling the region's already fragile ecosystems. Global dimming, therefore, stands as a crucial element in understanding the complex web of factors contributing to desertification and environmental challenges in the Sahel-Sahara region.

What is the current Situation:

Niger's agricultural land, as a percentage of its total land area, has experienced subtle fluctuations over the past few decades. This indicator, **hovering around 24.87% to 36.78%**, reflects the dynamic nature of land use in the country. These fluctuations can be attributed to various factors, including **changes in land management practices, climate variability, and population growth**.

To address the multifaceted challenges posed by limited agricultural land and the increasing vulnerability of rural communities to climate change-induced shocks, several initiatives have been undertaken. Notably, the **World Food Programme (WFP)**, with crucial support from the **U.S. Agency for International Development (USAID)**, has embarked on a strategic mission to revitalize southern Niger's agricultural landscape.

One of the key interventions spearheaded by WFP is the implementation of innovative land rehabilitation activities, primarily centered around the construction of water and soil retention structures known as **"half-moons."** These half-moons are ingeniously designed to **combat land degradation, mitigate the adverse effects of soil erosion, and promote sustainable agricultural practices** in arid ecosystems.

Data and Methodology

Our investigation into the decline and subsequent rise of agricultural land in the Niger region is anchored in two key datasets:

- **Niger Agricultural Land (% of Land Area) - World Bank:** This dataset provides a historical perspective on agricultural land usage in Niger. We rely on it to analyze the changes in agricultural land over time and gain insights into the land-use dynamics in the region.
- **Niger Agriculture and Rural Development - Humanitarian Data Exchange:** This comprehensive dataset offers a wide range of indicators related to agriculture and rural development in Niger. It covers essential aspects such as land use, agricultural production, and rural poverty. This holistic view of the rural landscape forms the foundation for assessing the broader implications of agricultural land transformations.

Our analysis of agricultural land dynamics in the Niger region is rooted in data from various sources, allowing us to discern the decline and subsequent resurgence of agricultural land. The decrease in agricultural land is a matter of concern, impacting rural development, food security, and local livelihoods. Factors contributing to this decline range from environmental challenges, notably desertification, to socio-economic factors.

We draw from a scientific study titled "**Assessing the Impact of Agroecological Interventions in Niger through Remotely Sensed Changes in Vegetation**" to delve deeper into these trends. This study underscores the role of interventions, such as the construction of water and soil retention structures known as "**half-moons**," in rejuvenating degraded lands and boosting agricultural productivity in arid ecosystems. By analyzing vegetation greenness data from Landsat 7 satellite observations, the study illustrates the tangible benefits of these interventions. Vegetation greenness significantly increased following the implementation of half-moon interventions, surpassing pre-intervention levels and even outperforming nearby control areas.

Reasons for Development

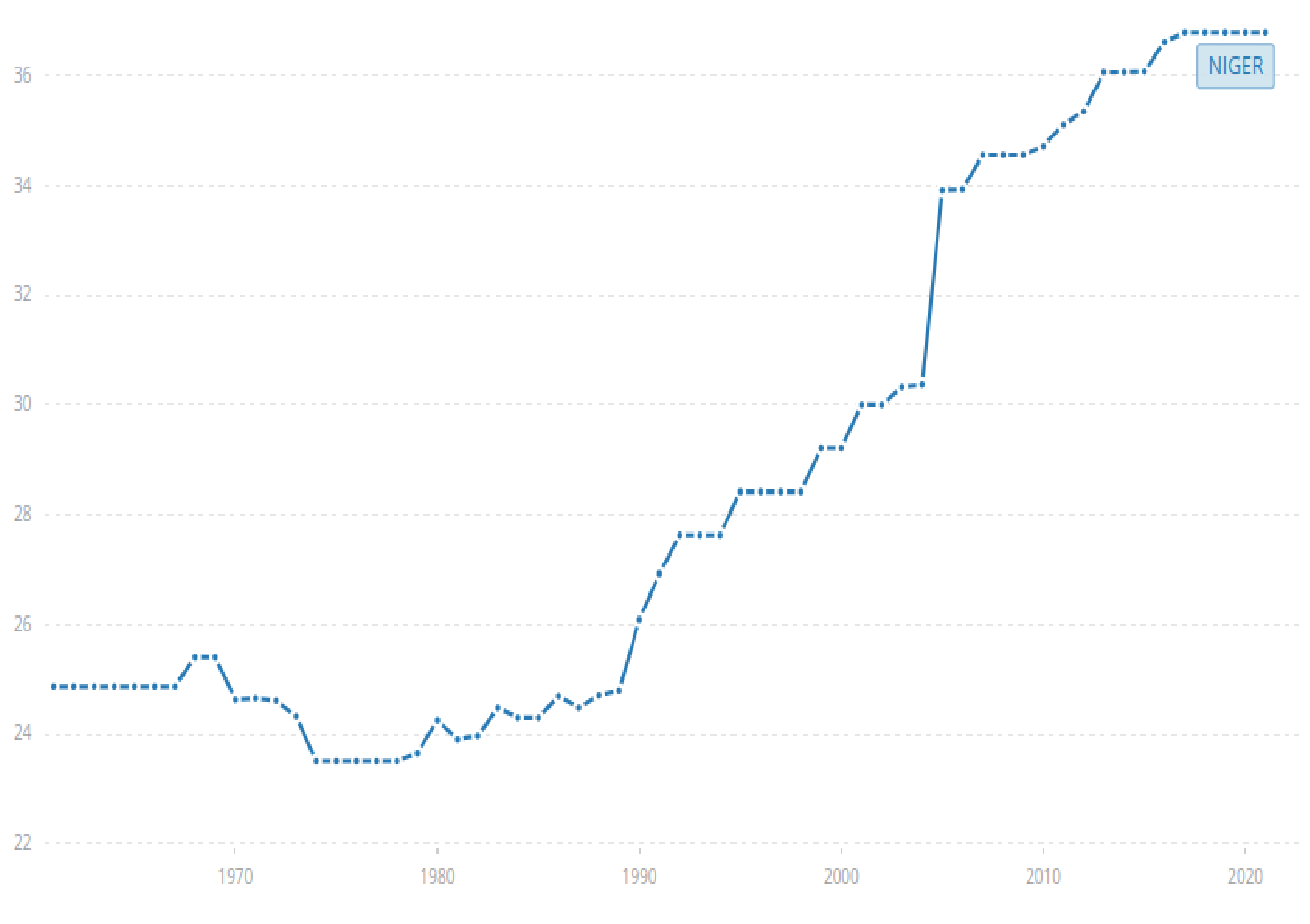


Figure 20 - Graph between Agricultural Land and Year

In the region of Niger, several reasons contribute to the development and increase in agricultural land from **24.87% to 36.78%**:

1. **Efforts by USAID and Development Organizations:** The U.S. Agency for International Development (USAID) and various development organizations have made substantial investments in the Sahel region to enhance resilience through land rehabilitation activities. These initiatives aim to restore degraded lands and improve water conservation to support agriculture and food security.

2. **Water and Soil Retention Structures (Half-Moons):** One key intervention spearheaded by the World Food Programme (WFP), with support from USAID, involves the construction of water and soil retention structures known as "half-moons." These half-moons are strategically designed to combat land degradation, mitigate soil erosion, and promote sustainable agricultural practices in arid ecosystems.

3. **Increased Soil Moisture and Vegetation Growth:** The half-moons help conserve rainwater, providing essential moisture for vegetation growth during the dry periods. This intervention has led to an increase in soil moisture and, consequently, improved vegetative greenness in the region.

4. **Positive Impact on Agriculture:** The analysis of satellite-derived NDVI (Normalized Difference Vegetation Index) data has shown a statistically significant increase in vegetation greenness (by nearly 50%) after the construction of half-moons compared to pre-intervention years. This increase in vegetation greenness has positive implications for both agriculture and livestock grazing.

5. **Resilience to Drought:** By enhancing soil moisture retention and vegetation growth, the interventions have contributed to building resilience to drought conditions. This is critical for subsistence farmers in the Sahel region, where erratic rainfall patterns are a significant concern due to climate change.

6. **Sustainability of Interventions:** The analysis indicates that the positive effects of the interventions have been sustained over time. This sustainability is crucial for ensuring food security and improving the livelihoods of rural communities.

7. **Evidence for Scaling Up:** The results provide actionable evidence supporting the scaling up of half-moon interventions as effective land management practices to increase agricultural production in arid ecosystems. These practices are essential for addressing food security challenges in the region.

In summary, the development of the region's agricultural land from 24.87% to 36.78% can be attributed to the implementation of innovative land rehabilitation activities, specifically the construction of half-moons, aimed at combating land degradation, enhancing soil moisture, and promoting sustainable agriculture in the face of water scarcity and climate change-induced challenges. These efforts have had a positive impact on vegetative greenness and agricultural productivity, contributing to increased food security and resilience for local communities in Niger.

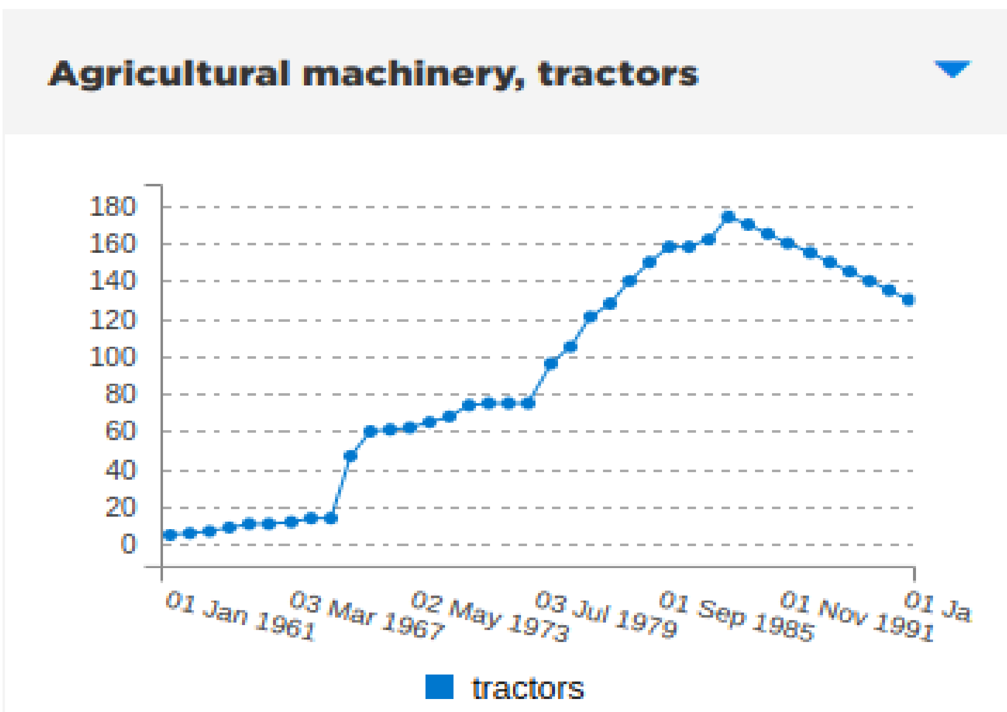


Figure 21 - Increase in Agricultural machinery (tractors) over the years

USAID

Figure 22 - **Logo of USAID**

USAID (United States Agency for International Development), founded in 1961, is the U.S. government's primary agency for administering foreign aid and development assistance. In Niger, USAID plays a vital role in several key areas. It **addresses food security issues** through **initiatives to improve agricultural productivity and food access**, combats health challenges such as malaria and enhances healthcare infrastructure. The agency also **focuses on expanding access to quality education, promoting vocational training, and improving literacy rates**. USAID supports governance and democracy by fostering transparency and accountability, often assisting with elections and civil society initiatives. Given Niger's location in the Sahel region, USAID **collaborates with other U.S. agencies to address security challenges and promote stability**. Additionally, USAID **provides humanitarian aid during crises, delivering emergency assistance to those in need**. These efforts aim to foster sustainable development and improve the lives of the people of Niger and other developing nations.

Figure 23 **- USAID offers help to farmers in Niger**

Introduction of Half-Moon Technology

The use of half moons as a technology for water harvesting in Niger is a significant initiative that has been supported by USAID and other development organizations. The practice involves creating half-moon-shaped ditches in the ground to capture and retain rainwater, effectively improving water management and enhancing agricultural productivity.

Initiation by USAID:

USAID, in collaboration with local partners and NGOs, initiated the promotion of half moons in Niger as part of its broader efforts to address food security and water resource management. This approach gained momentum due to its effectiveness in increasing water availability in arid regions, ultimately boosting crop yields and improving the livelihoods of Nigerien farmers.

Half Moons in Detail:

Half moons are a water harvesting technique in which small, crescent-shaped ditches are dug into the earth, forming a series of low barriers that slow the flow of rainwater and encourage its infiltration into the ground. This method effectively stores rainwater in the root zone of crops and helps recharge groundwater aquifers. Half moons are typically constructed in parallel rows across fields to maximize water capture. The barriers reduce soil erosion and help conserve precious water resources in a region where water scarcity is a persistent challenge.

Figure 24 - **Half Moons**

Statistics:

The implementation of half moons in Niger has yielded impressive results:

- On average, a **single half-moon structure can capture around 5 to 10 cubic meters of rainwater** during the rainy season.
- In a study conducted in Niger, it was found that **half-moon technology increased crop yields by up to 500%**, significantly improving food security.
- The **utilization of half moons has led to increased groundwater levels**, which are critical for sustaining agriculture and providing drinking water.

Impact on Niger's People:

The adoption of half moons has had a profound impact on the people of Niger. By enhancing water availability for agriculture, it has increased crop production, reduced food shortages, and improved the overall standard of living for rural communities. Furthermore, the technology has empowered farmers to mitigate the effects of drought and adapt to the challenges posed by a changing climate. In addition to improved food security, half moons have also contributed to better income prospects and reduced vulnerability to drought-related crises, ultimately supporting the resilience of Niger's population.

In summary, the promotion of half moons for water harvesting in Niger, supported by USAID and other organizations, has proven to be a sustainable and effective solution to combat water scarcity and enhance agricultural productivity, thereby positively impacting the lives of the people in this region.

Other Initiatives by USAID

USAID, or the United States Agency for International Development, is an independent agency of the United States federal government that is primarily responsible for administering civilian foreign aid and development assistance. USAID was founded in 1961 by an executive order issued by President John F. Kennedy. It was created to centralize and coordinate U.S. foreign aid efforts in response to the increasing importance of development assistance during the Cold War and the desire to promote economic and social progress in developing countries.

Here are some key points about USAID and its activities in the region of Niger:

1. **Mission and Objectives**: USAID's primary mission is to promote global peace, prosperity, and security by advancing U.S. foreign policy objectives through humanitarian assistance, economic development, and other foreign aid programs. It aims to reduce poverty, strengthen democratic governance, promote health and education, and foster economic growth in partner countries.
2. **Development Assistance**: In Niger, USAID has been actively involved in various development initiatives. USAID provides assistance to improve food security, access to clean water, health care, and education, as well as support for good governance, economic growth, and efforts to counter terrorism and violent extremism.
3. **Food Security**: Niger has faced recurrent food crises and food insecurity due to factors such as drought and climate change. USAID has implemented programs to improve agricultural productivity, nutrition, and food security in the country. These programs include support for crop diversification, irrigation, and the distribution of food aid.
4. **Healthcare**: USAID has been involved in health programs in Niger to address issues such as maternal and child health, infectious diseases like malaria, and the improvement of healthcare infrastructure. These efforts aim to reduce morbidity and mortality rates.
5. **Education**: Education is a key focus area for USAID in Niger. The agency has supported initiatives to increase access to quality education, improve literacy rates, and promote vocational training to enhance economic opportunities for Niger's population.
6. **Governance and Democracy**: USAID works to strengthen governance and democracy in Niger by supporting initiatives that promote accountability, transparency, and the rule of law. This includes electoral support and assistance for civil society organizations.
7. **Counterterrorism**: Due to Niger's location in the Sahel region, it has been a focus of U.S. efforts to counter terrorism and violent extremism. USAID collaborates with other U.S. government agencies to address security challenges and promote stability in the region.
8. **Humanitarian Aid**: USAID also provides humanitarian assistance during crises such as natural disasters and conflict, including emergency food and shelter to affected populations in Niger.

USAID collaborates with local governments, non-governmental organizations, and international partners to implement its development programs in Niger and other countries. Its goal is to work toward sustainable development and improved living conditions for the people of Niger and other developing nations.

Figure 25 - **Logo of World Food Programme (WFP)**

The World Food Programme (WFP) is a specialized agency of the United Nations dedicated to addressing global hunger and food security issues. It was established in 1961 and has since become one of the world's leading humanitarian organizations, providing food assistance and other essential support to communities in need. WFP's work in Niger has been instrumental in addressing the specific challenges faced by the region.

Formation and Mission:

WFP was created in response to the 1960 Food and Agricultural Organization (FAO) Conference, which highlighted the need for a dedicated program to combat global hunger. Its primary mission is to alleviate hunger, promote food security, and support nutrition and agricultural development in the most food-insecure regions worldwide.

WFP's Impact on Niger:

In Niger, WFP has implemented various programs and initiatives tailored to the unique challenges of the region, including:

1. **Providing Food Assistance**: WFP has been a lifeline for many Nigerien communities during times of food crisis. It provides food aid to vulnerable populations, including those affected by droughts, floods, and food shortages.
2. **Nutrition Programs**: WFP focuses on combating malnutrition, especially in children and pregnant women, by providing specialized nutritional supplements and support to health centers.
3. **School Feeding Programs**: To encourage school attendance and improve child nutrition, WFP supports school feeding programs in Niger, which offer daily meals to students.
4. **Emergency Response**: WFP swiftly responds to emergencies, such as natural disasters and conflict-related crises, by delivering food, clean water, and other essentials to affected populations.
5. **Cash and Voucher Assistance**: In some cases, WFP provides cash or vouchers to beneficiaries, allowing them to purchase food locally, which can stimulate the local economy.
6. **Agricultural and Resilience Programs**: WFP promotes agricultural development and resilience-building initiatives, helping communities adapt to climate change and improve their food security.
7. **Monitoring and Assessment**: The organization conducts extensive monitoring and assessment to understand food security dynamics in Niger and adjust its programs accordingly.
8. **Capacity Building**: WFP works to enhance the capacity of local institutions and communities to manage food security and nutrition programs effectively.
9. **Advocacy and Awareness**: The organization advocates for policies and programs that address food security challenges and raises awareness about the issues facing Niger's population.

WFP's efforts in Niger are instrumental in addressing the region's chronic food insecurity, malnutrition, and vulnerability to environmental shocks. Through its targeted programs and partnerships with local authorities and other organizations, WFP plays a vital role in improving the lives and well-being of the people of Niger, making significant contributions to food security and humanitarian relief in the region.

Statistics:

In the following Tables and Graphs

1. **Graph :** The first graph shows the **number of people who are employed in Agriculture** (percentage of people)

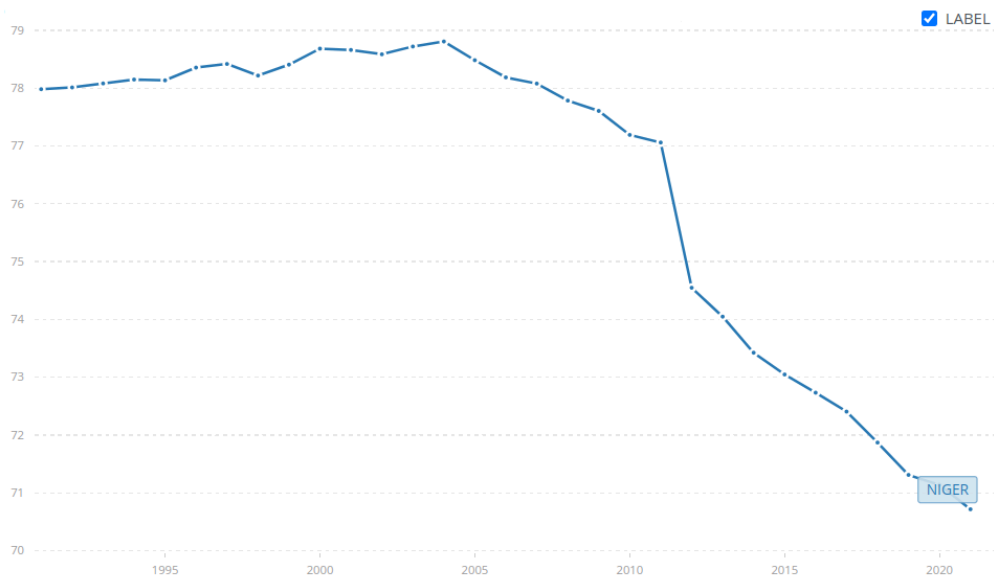


Figure 26 - **Percentage of people employed in agriculture**

Country	Annual millet harvest area (1000 ha)*	Percentage of total millet lands in Africa
Burkina Faso	1221	6.3
Ethiopia	460	2.4
Ghana	170	0.9
Kenya	114	0.6
Mali	2075	10.6
Niger	6877	35.2
Nigeria	1855	9.5
Uganda	140	0.7
Tanzania	298	1.5
Zambia	44	0.2
Total	13254	67.9

* The data are from FAOSTAT for the period from 2015 to 2020

Table 6- Top 10 countries in the world for millet production in 2020

The **image shows the top 10 countries in the world for millet production in 2020**. The data is from the Food and Agriculture Organization of the United Nations (FAO).

Millet is a **staple** food **crop** for millions of people in **Africa & Asia**. It is a drought-tolerant crop that can be grown in a variety of climatic conditions. **Millet is also a good source of calories, protein, and fiber.**

The production of millet has been increasing in recent years, due to a number of factors, including:

- **Increased demand** for millet from both domestic and international markets
- **Improved agricultural practices**, such as the use of high-yielding varieties and better soil management techniques
- **Government support** for millet production, such as subsidies for seed and fertilizer

The increased production of millet is helping to improve food security and nutrition in many parts of the world.

Country	Annual sorghum harvest area (1000 ha)*	Percentage of total sorghum lands in Africa
Burkina Faso	1751	6.2
Ethiopia	1847	6.6
Ghana	260	0.9
Kenya	214	0.8
Mali	1562	5.6
Niger	3693	13.2
Nigeria	5560	19.8
Uganda	297	1.1
Tanzania	699	2.5
Total	15883	56.7

* The data are from FAOSTAT for the period from 2015 to 2020

Table 7 - Top producing countries of sorghum in sub-Saharan Africa

The image shows us the top producing countries of sorghum in sub-Saharan Africa. The table is sorted in descending order of sorghum production (1000 ha).

The **top sorghum producing countries** in sub-Saharan Africa are:

1. **Nigeria (5560)**
2. **Niger (3693)**
3. **Ethiopia (1847)**
4. **Burkina Faso (1751)**
5. **Mali (1562)**
6. **Tanzania (699)**
7. **Uganda (297)**
8. **Kenya (214)**
9. **Ghana (260)**

These countries account for over 75% of the total sorghum production in sub-Saharan Africa.

Sorghum is a staple food crop for millions of people in sub-Saharan Africa. It is a drought-tolerant crop that can be grown in a variety of climatic conditions. Sorghum is also a good source of calories, protein, and fiber.

The production of sorghum in sub-Saharan Africa has been increasing in recent years. This is due to a number of factors, including:

- **Increased demand** for sorghum from both domestic and international markets
- **Improved agricultural practices**, such as the use of high-yielding varieties and better soil management techniques
- **Government support** for sorghum production, such as subsidies for seed and fertilizer

The increased production of sorghum in sub-Saharan Africa is helping to improve food security and nutrition in the region.

Country	Total production (thousand ton)	Harvested area (thousand ha)	Average yield (t/ha)	Rainfed rice (as % of total rice area)
Burkina Faso	367	171	2.14	92
Ethiopia	164	57	2.87	99
Ghana	815	285	2.85	82
Kenya	127	28	4.66	<1
Mali	2972	879	3.39	37
Niger	124	28	4.37	100
Nigeria	8080	5409	1.50	99
Tanzania	3220	1162	2.77	93
Uganda	212	77	2.76	42
Zambia	34	26	1.31	62

Table 8 - National average total rice production

Table with information about the **national average total rice production, harvested area, and average yield** for **Burkina Faso, Ethiopia, Ghana, Kenya, Mali, Niger, Nigeria, Tanzania, Uganda, and Zambia between 2016 and 2020**. It also shows the percentage of area under rainfed conditions, including both lowland and upland environments.

The table shows that the **highest total rice production in 2020 was in Nigeria**, with 8,080 thousand tons, followed by Tanzania with 3,220 thousand tons and Mali with 2,972 thousand tons. The **lowest total rice production in 2020 was in Niger**, with 124 thousand tons, followed by Zambia with 34 thousand tons and Uganda with 212 thousand tons.

The table also shows that the **highest average yield in 2020 was in Kenya**, with 4.66 tons per hectare, followed by Mali with 3.39 tons per hectare and Tanzania with 2.77 tons per hectare. The **lowest average yield in 2020 was in Niger**, with 1.31 tons per hectare, followed by Burkina Faso with 2.14 tons per hectare and Uganda with 2.76 tons per hectare.

The table also shows that the **highest percentage of area under rainfed conditions in 2020 was in Niger**, with 100%, followed by Ethiopia with 99% and Burkina Faso with 92%. The **lowest percentage of area under rainfed conditions in 2020 was in Kenya**, with less than 1%, followed by Nigeria with 1% and Uganda with 42%.

Overall, the table shows that rice production in these countries varies widely, with both total production and average yield varying significantly. The percentage of area under rainfed conditions is also highly variable, with some countries relying almost entirely on rainfed rice production while others have a significant proportion of irrigated rice production.

Crop	Yield (T/ha)	Harvested Area (Million ha)	Total Production (Million metric tonnes)
Millet	0.4492	6.0206	2.736
Sorghum	0.3047	2.5618	0.810
Cowpea	0.1857	4.1001	0.818
Maize	1.0049	0.0082	0.008
Rice	2.5489	0.0158	0.044
Peanut	0.4143	0.4640	0.192

Table 9 - Average yield of major food crops in Niger

The table shows the **average yield of major food crops in Niger from 1999 to 2004 and from 2010 to 2017**. The crops are **millet, sorghum, cowpea, maize, rice, and peanut.**

The **highest average yield is for millet, at 0.4492 tons per hectare**. The **next** highest yields are for **sorghum and cowpea**, at 0.3047 and 0.1857 tons per hectare, respectively. The **lowest** average yields are for **maize, rice, and peanut**, at 1.0049, 2.5489, and 0.4143 tons per hectare, respectively.

The harvested area for each crop is also shown in the table. **Millet** has the **largest harvested area**, at 6.0206 million hectares. The **next** largest harvested areas are for **sorghum and cowpea**, at 2.5618 and 4.1001 million hectares, respectively. The **smallest harvested areas** are for **maize, rice, and peanut**, at 0.0082, 0.0158, and 0.4640 million hectares, respectively.

The total production of each crop is also shown in the table. **Millet has the highest total production, at 2.736 million metric tonnes.** The next highest total productions are for sorghum and cowpea, at 0.810 and 0.818 million metric tonnes, respectively. The lowest total productions are for maize, rice, and peanut, at 0.008, 0.044, and 0.192 million metric tonnes, respectively.

Overall, the table shows that **millet is the most important food crop in Niger**, in terms of both yield and production. Sorghum and cowpea are also important food crops. Maize, rice, and peanut are less important food crops, in terms of both yield and production.

➢ Objectives of the Study:

This **Case Study** will use a **mixed-methods approach to explore the causes of desertification in the Sahel region of Africa. Data** will be collected for a variety of environmental agents, such as **precipitation, temperature, vegetation and** also of human activities, such as **the extent of agricultural land usage, rural to urban shift and also the population.** The data will be analyzed using statistical & data visualization techniques. The study will focus on the following areas:

- **Overpopulation:** The study will investigate how population growth leads to **increased demand for resources**, which can lead to deforestation, overgrazing, and other unsustainable practices.
- **Shift of livelihood from rural to urban:** The study will investigate how rural-to-urban migration leads to the **abandonment of agricultural land**, which can lead to soil erosion and desertification.
- **Climate change:** The study will investigate how climate change leads to **changes in precipitation patterns**, which can lead to droughts and desertification.
- **Lack of vegetation:** The study will investigate how the **loss of vegetation leads to soil erosion** and desertification.
- **Agricultural land:** The study will investigate how unsustainable agricultural practices, such as **overgrazing and deforestation**, combined with the **ever-growing level of agricultural land usage** can lead to desertification.

The **study** will include a **discussion of the implications of the findings for policy and practice**. Our team hopes that this **study will contribute to a better understanding of the causes of desertification and the development of effective strategies to address it**.

This case study will examine the impacts of the aforementioned factors as follows:

- **How overpopulation causes desertification, as shown by the Sahel population?**
- **How climate changes such as rainfall and drought can cause desertification, as demonstrated by the rainfall patterns ?**
- **How lack of vegetation could lead to desertification, as tracked by the extent of vegetation in the Sahel?**
- **Impact of the shift of livelihood from rural to urban on the environment, as analyzed by the rural vs. urban population density**
- **Impact of the increase in agricultural land at the expense of forest cover on the environment, as observed in the agricultural land usage rate and rural development in the Sahel**

The results of this study will help to **identify the key factors that contribute to desertification** in the Sahel and to **develop strategies for mitigating its effects**, some of which are as follows:

- **The rainfall patterns can be used to devise efficient strategies for irrigation and prepare for potential droughts and dry spells.**
- **The information about vegetation can be used to plant trees, restore degraded land, and develop other similar mitigation strategies.**
- **The findings from the agricultural land dataset can be used to understand the risk the country is facing, by losing valuable agricultural land due to desertification and thus, counter measures can be adopted**
- **Data about agricultural and rural development is essential for evaluating strategies to combat desertification in the country by developing ideas to safeguard the abandoned agricultural fields.**

➢ Study Area:

Figure 27 – **Map of the study area (Sahel Region)**

This case study focuses on **Desertification in the Sahel Region**, spanning across **Mauritania**, **Mali**, **Burkina Faso**, **Niger**, **Nigeria**, **Chad**, **Sudan**, and **Eritrea**. The Sahel's semi-arid climate, periodic droughts, and fragile ecosystems make it a critical zone for examining the impacts of desertification.

Materials and Methods:

➢ Datasets used for Case-study:

1. Niger Population (2023) - Worldometer - Dataset to comprehend the **demographic patterns in Niger**, when coupled with data related to desertification, helps capture the impact of population in shaping the desertification trends within the Sahel region.
2. Niger Demographics (2023) - Worldometer **-** Dataset to delve into the intricate **urban-rural divide in Niger,** to understand the influence of agricultural field abandonment on desertification.
3. Niger Precipitation - Climate Change Knowledge Portal - Dataset of precipitation trends in Niger to analyze the **nature of correlation between precipitation & desertification in Niger**.
4. Niger Precipitation - CHIRPS Dataset **-** The CHIRPS 2.0 dataset to analyze rainfall patterns in Niger with various frequencies such as 6-hourly, daily, monthly, annually. We aim to use this to analyze the **nature of correlation between precipitation and desertification** as well.
5. Niger Vegetation - AMMA-CATCH Dataset **-** Dataset to track **Niger's vegetation changes for desertification monitoring and mitigation**.
6. Composite Drought Index - CDI Dataset **-** This dataset on **composite drought indices** provides a valuable tool to assess the severity and impact of droughts in various areas, a major driver of desertification in the Sahel region.
7. Niger Agricultural land - World Bank **-** Dataset to analyze the **decline in Niger's Agricultural land.**
8. Niger Agriculture and Rural Development - Humanitarian Data Exchange **-** Dataset to **investigate indicators for agriculture and rural development in Niger**. The dataset includes information on land use, agricultural production, and rural poverty.
9. Sahel Precipitation - JISAO data **-** Dataset to analyze the **precipitation anomalies in Sahel** region between the years 1901-2017
10. Land Usage - SCIRP Journal **-** Contains data regarding **land-use and land-cover change in the Sahel Area** of Keita Valley, Republic of Niger.

➢ Data and Methodology:

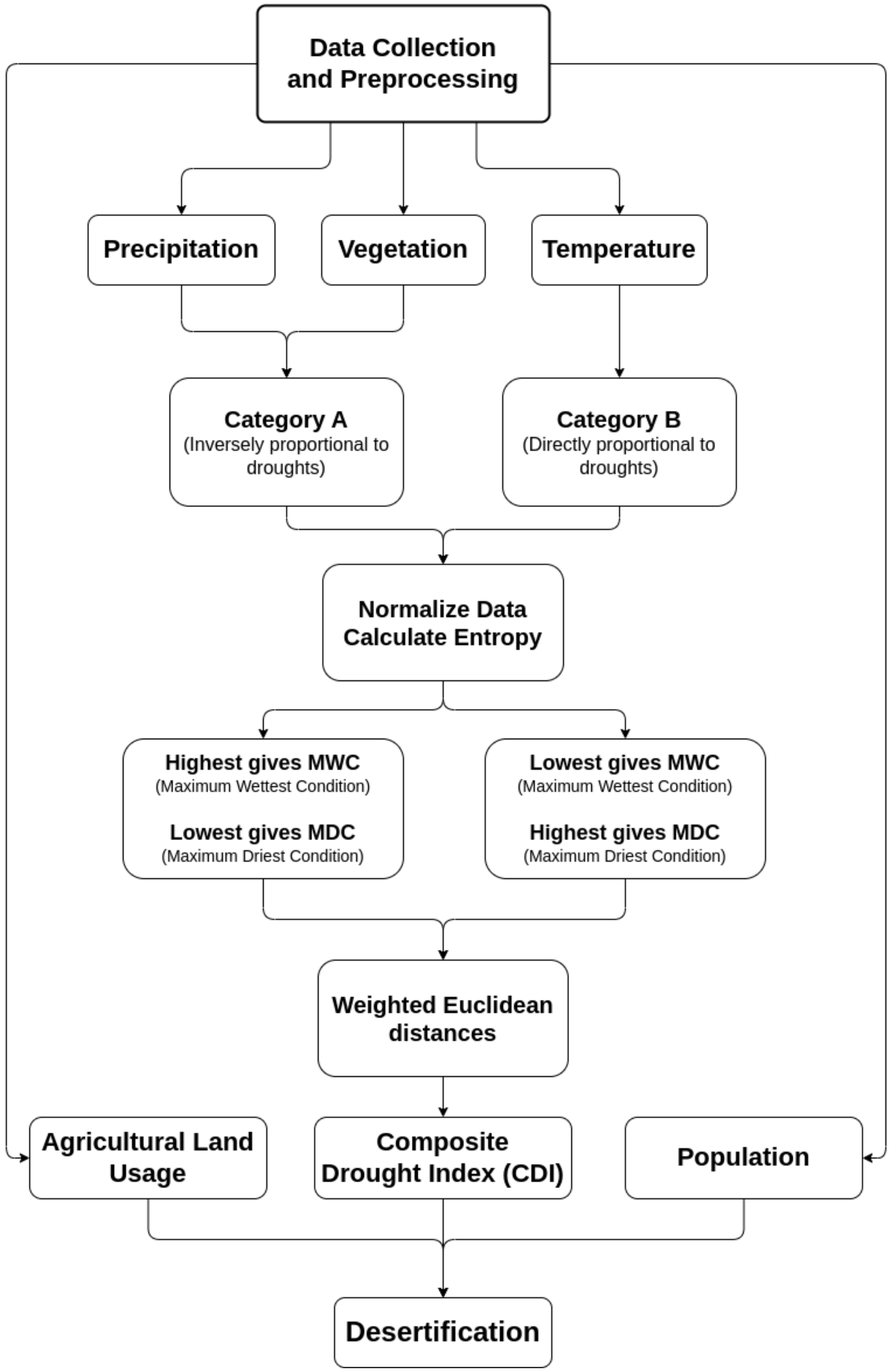


Figure 28 - CDI Calculation Methodology

Results and Discussion:

➢ Data Visualization - Vegetation:

Vegetation dataset collected at two key stations, **WANKAMA_NORD** and **WANKAMA_SUD**, spanning the critical period from 2005 to 2015.

- **Leaf area index (LAI)** is a unitless quantity that measures the **amount of leaf material** in a plant canopy. It is calculated as the **ratio of one-sided leaf area per unit ground area**:

LAI = (leaf area)/(ground area)

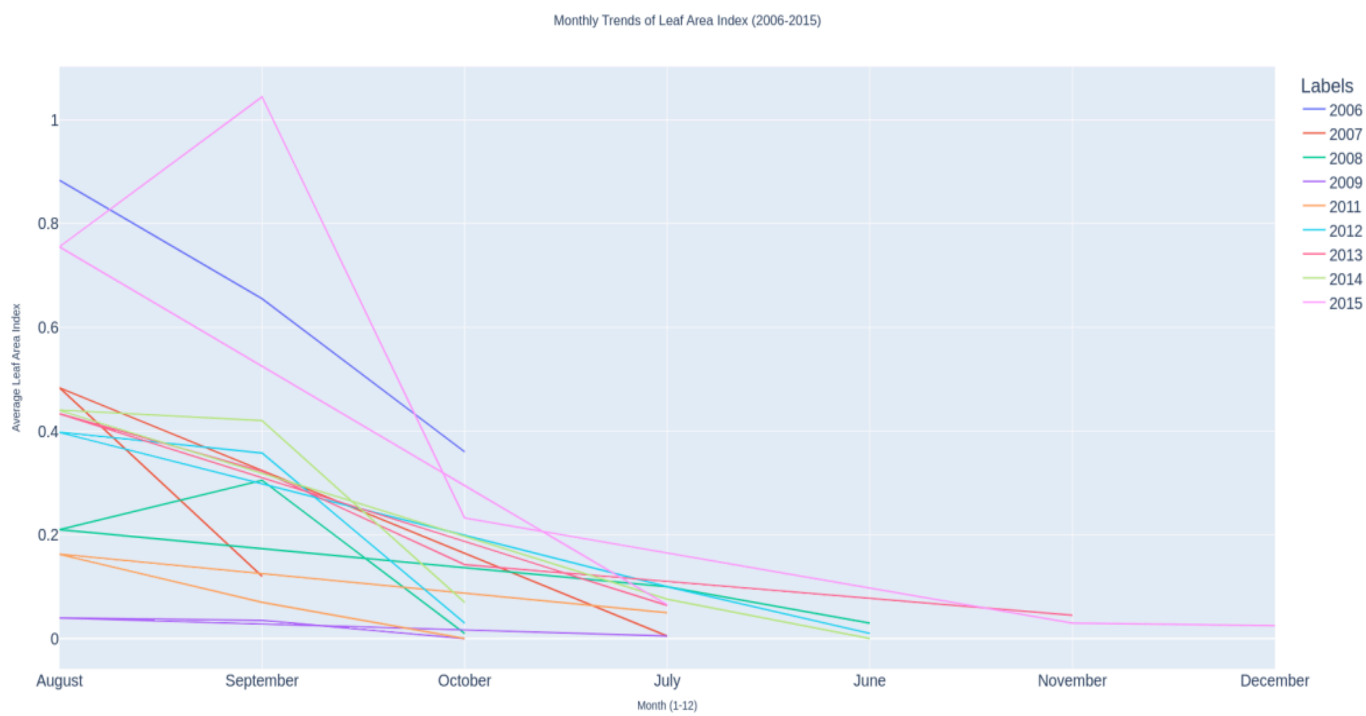


Figure 29 **- Leaf Area Index - WANKAMA_NORD STATION**

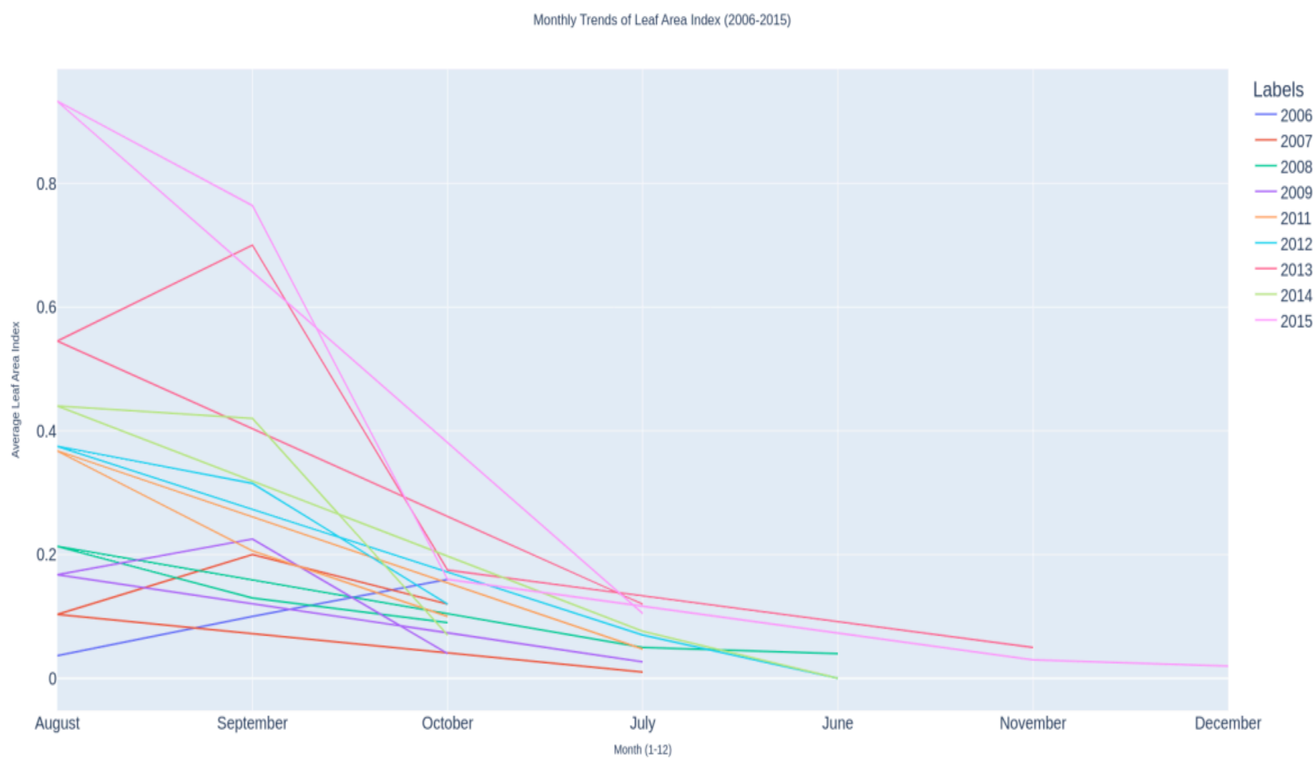


Figure 30 **- Leaf Area Index - WANKAMA_SUD STATION**

The observed decrease in Leaf Area Index (LAI) from August to December in Niger over the years can be attributed to :

- ➔ **Seasonal Phenomena**
- ➔ **Water Stress and Soil Moisture Depletion**
- ➔ **Senescence and Leaf Shedding**
- ➔ **Temperature and Evapotranspiration**
- ➔ **Impact of Climate Variability**

- **Dry biomass** is the **weight of wet biomass minus its moisture content**. **Biomass** is the **mass of living tissue** over a specific area within a given time period.This value is commonly used to compare the relative weight of different biomass samples, and is a useful indicator of their composition and quality.

Figure 31 **- Dry Total Biomass Mean - WANKAMA_NORD STATION**

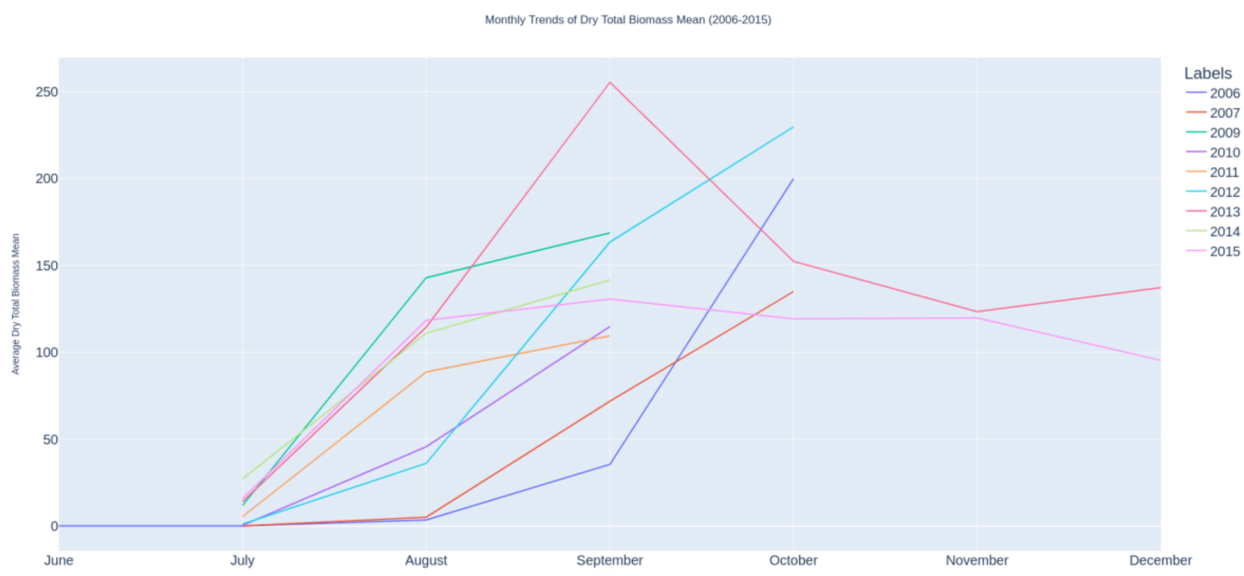


Figure 32 **- Dry Total Biomass Mean - WANKAMA_SUD STATION**

The **fluctuation** in Dry Total Biomass Mean from August to December in Niger, specifically concerning millet and fallow crops is due to

- ➔ **August to September Increase (Millet Growth Period)**
- ➔ **September to December Decrease (Transition to Dry Season)**
- ➔ **Impact of Seasonal Transition**
- ➔ **Cultural Practices and Land Management**

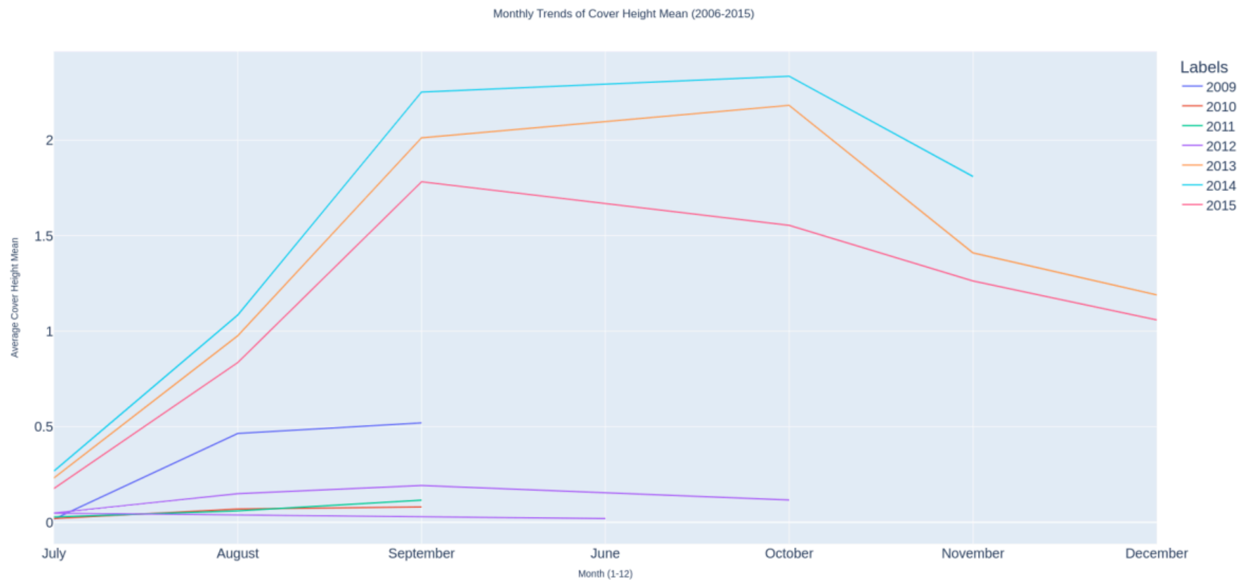


Figure 33 **- Cover Height Mean - WANKAMA_NORD STATION**

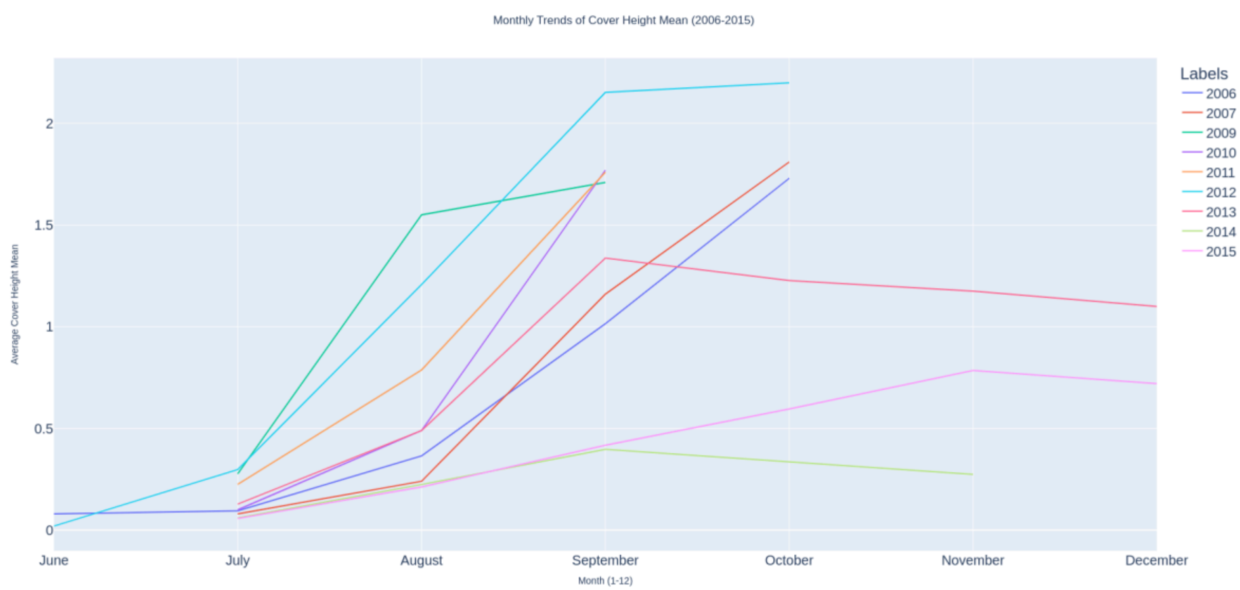
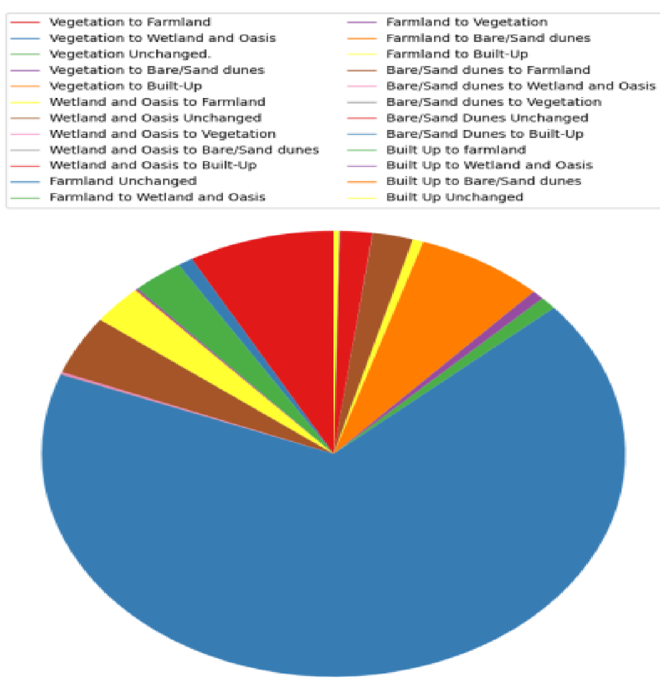


Figure 34 **- Cover Height Mean - WANKAMA_SUD STATION**

The observed fluctuation in Cover Height Mean from August to December in Niger, particularly concerning millet and fallow crops

- ➔ **August to September Increase (Millet Growth Period)**
- ➔ **September to December Decrease (Harvest and Senescence)**
- ➔ **Seasonal Transition and Water Stress**
- ➔ **Harvesting Practices and Agricultural Management**

Figure 35 - **Land cover changes from 1990 to 2015**



The **largest conversion of land cover within** the 25-year **study period** was from **vegetated land to farmlands .** Likewise, about **54,455 ha of land** was **converted from farmland to sand dunes** and **72 ha of sand dunes were converted to vegetation.** Conversely, **1013 ha of vegetation** were also **converted to sand dunes,** implying that there was **more deforestation compared to afforestation.**

Figure 36 - **Land cover conversions in Yusufari and Yunusari LGAs from 1990 to 2015**

➢ Data Visualization - Agriculture Land in Niger:

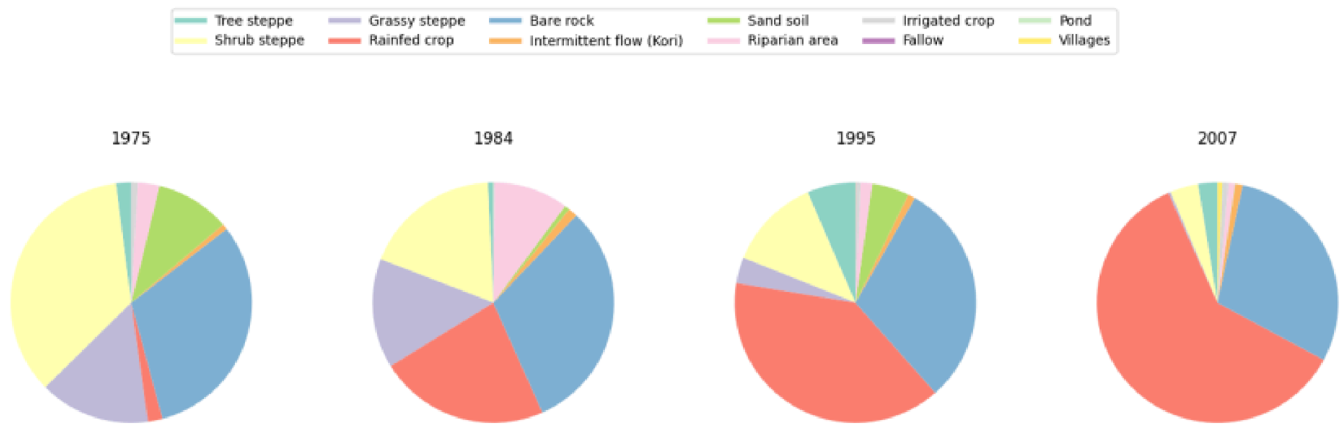


Figure 37 - **Distribution of Land Usage in Keita Valley**

The **observed changes in Keita area's land use/cover** can be attributed to a combination of natural and anthropogenic factors. The merging of land units, influenced by events like the droughts of 1973 and 1984, reflects the impact of climatic conditions on vegetation. The fluctuations in **tree steppe, shrub steppe, and grassy steppe** covers indicate sensitivity to environmental conditions or shifts in land management practices. The **exponential increase in rainfed crop proportion is likely a response to agricultural expansion and land-use intensification**. The **moderate decrease in bare rock and intermittent flow is linked to changing hydrological patterns**. The **contrasting trends in riparian area, sand soil, & irrigated crop units suggest dynamic interactions between water resources & land use**. The appearance and **decline of fallow areas, as well as the increasing ponds, highlight evolving agricultural practices and water management strategies**. Overall, a nuanced understanding of both natural and human-induced factors is essential for a comprehensive analysis of the observed land use/cover changes in Keita area.

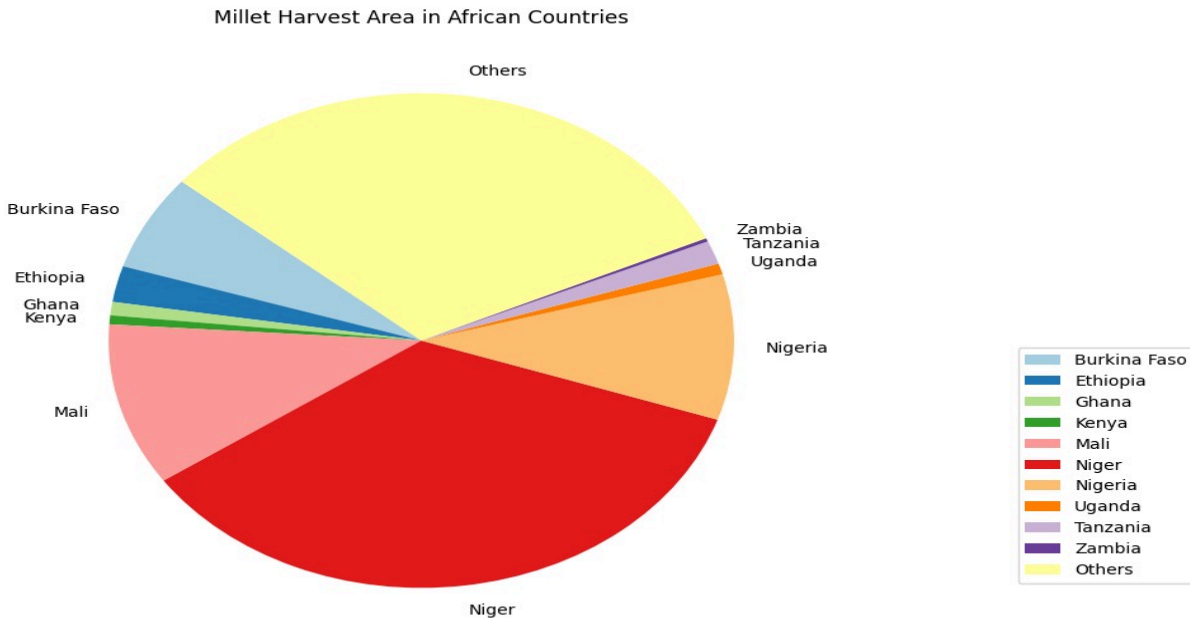


Figure 38 **- Millet harvest area in African Countries**

Millet is a **staple food crop** for millions of people in **Africa** and Asia. It is a drought-tolerant crop that can be grown in a variety of climatic conditions. **Millet is also a good source of calories, protein, and fiber.**

The production of millet has been increasing in recent years, due to a number of factors, including:

- **Increased demand** for millet from both domestic and international markets
- **Improved agricultural practices**, such as the use of high-yielding varieties and better soil management techniques
- **Government support** for millet production, such as subsidies for seed and fertilizer

The increased production of millet is helping to improve food security and nutrition in many parts of the world.

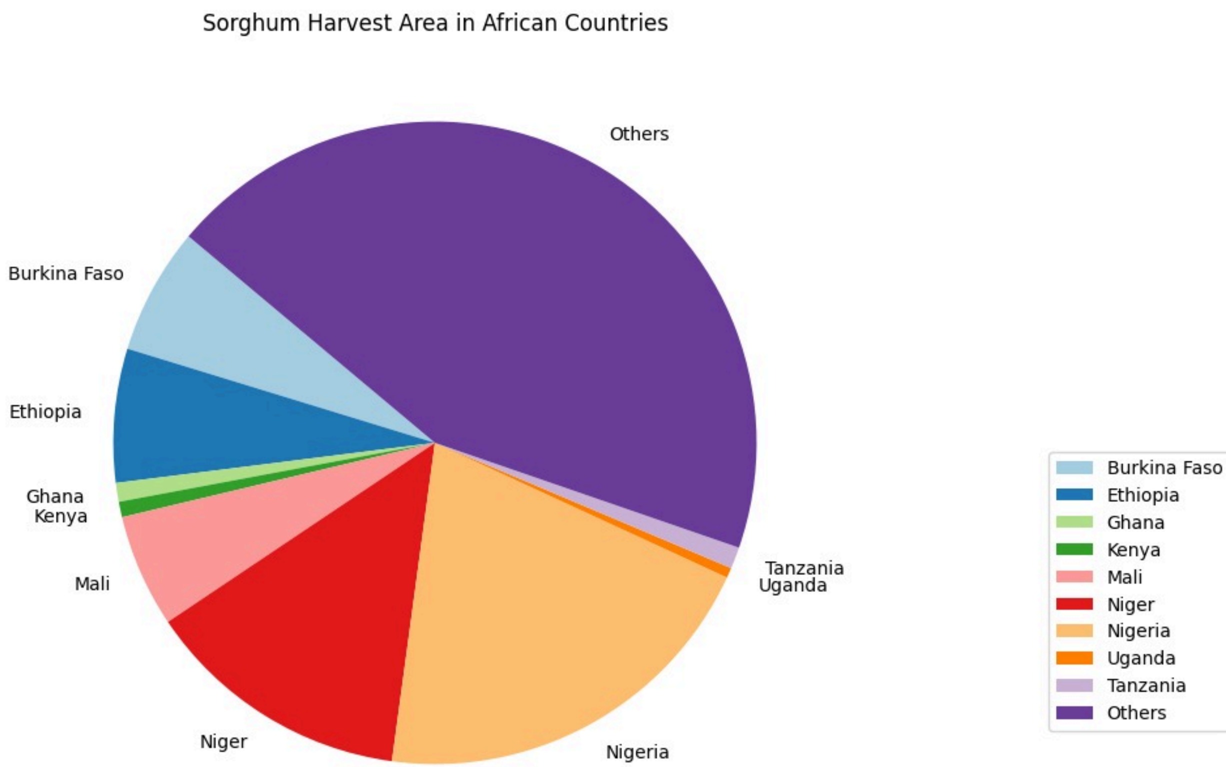


Figure 39 **- Sorghum harvest area in African Countries**

In sub-Saharan Africa, the **top sorghum-producing countries**, led by Nigeria and Niger, **contribute to over 75% of regional production**. **Sorghum, a vital staple**, is renowned for its **drought tolerance and nutritional value**. Recent **production growth** in the region is attributed to rising demand, enhanced agricultural practices, and government support, including **subsidies**. This increased sorghum production is positively impacting food security and nutrition across sub-Saharan Africa.

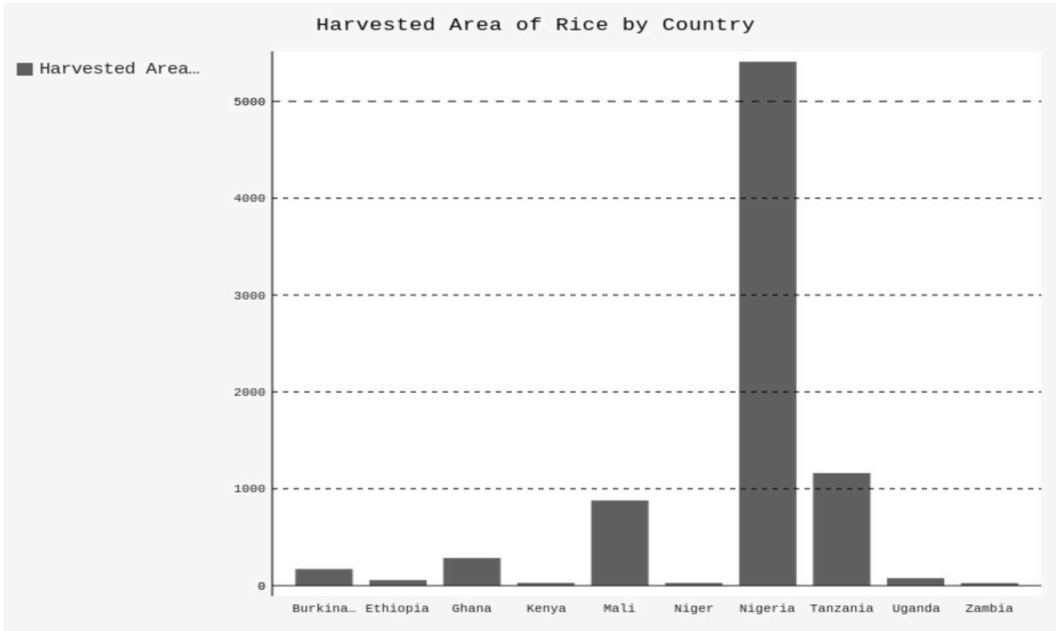


Figure 40 **- Rice harvest area in African Countries**

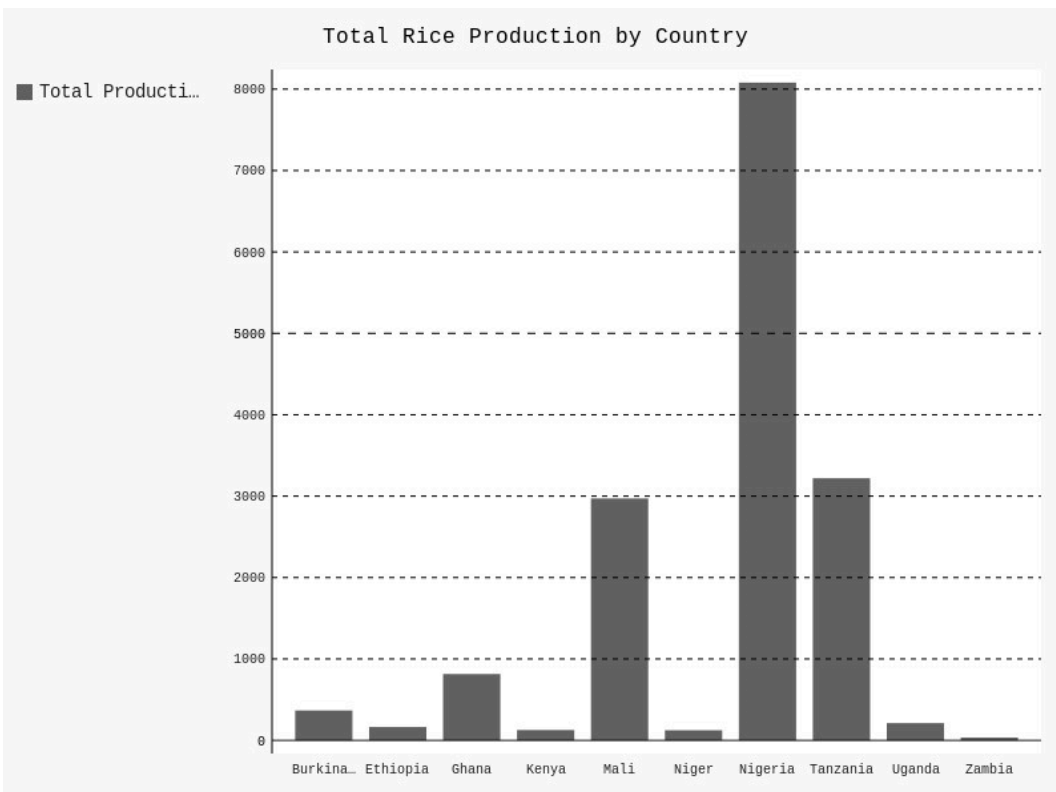


Figure 41 **- Rice production in African Countries**

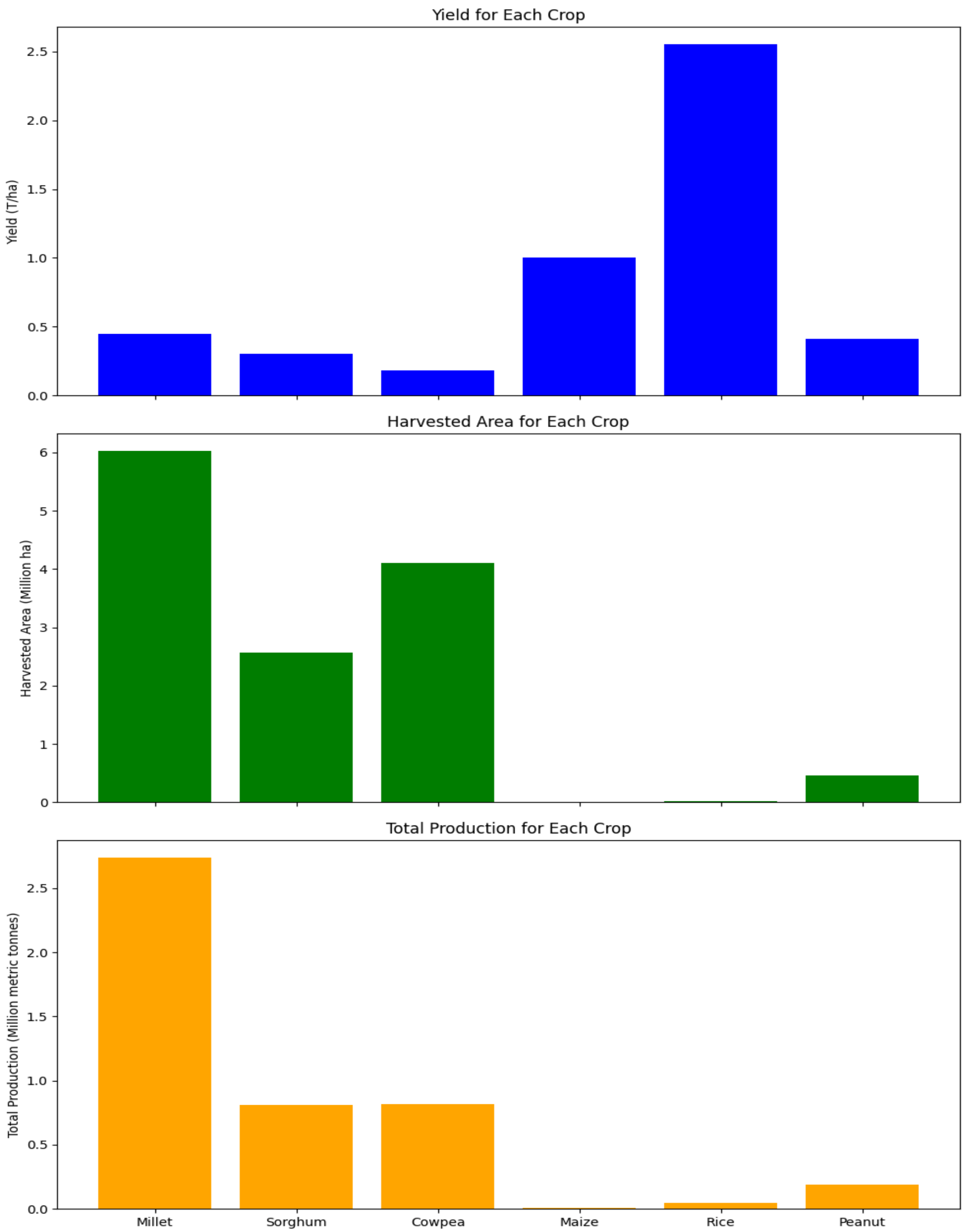


Figure 42 **- Cropwise Metrics in Sahel**

The graphical representation illustrates the **average yield of major food crops in Niger from 1999 to 2004 and from 2010 to 2017**. The included crops are **millet, sorghum, cowpea, maize, rice, and peanut.**

Millet stands out with the highest average yield at 0.4492 tons per hectare, **followed by sorghum and cowpea** at 0.3047 and 0.1857 tons per hectare, respectively. Conversely, **maize, rice, and peanut exhibit lower average yields** at 1.0049, 2.5489, and 0.4143 tons per hectare, respectively.

The graph also depicts the **harvested area for each crop, with millet having the largest area at 6.0206 million hectares**. Sorghum and cowpea follow with 2.5618 and 4.1001 million hectares, respectively. In contrast, maize, rice, and peanut have smaller harvested areas at 0.0082, 0.0158, and 0.4640 million hectares, respectively.

Total production figures are presented in the graph as well, with **millet leading at 2.736 million metric tonnes**. Sorghum and cowpea follow closely with 0.810 and 0.818 million metric tonnes, respectively. Conversely, maize, rice, and peanut exhibit lower total production at 0.008, 0.044, and 0.192 million metric tonnes, respectively.

In summary, the graph emphasizes **millet as the most significant food crop in Niger**, both in terms of yield and production, while sorghum and cowpea also hold importance. **Maize, rice, and peanut are comparatively less prominent** in terms of both yield and production.

➢ Data Visualization - Precipitation:

Figure 43 - **Mean Rainfall Over Time**

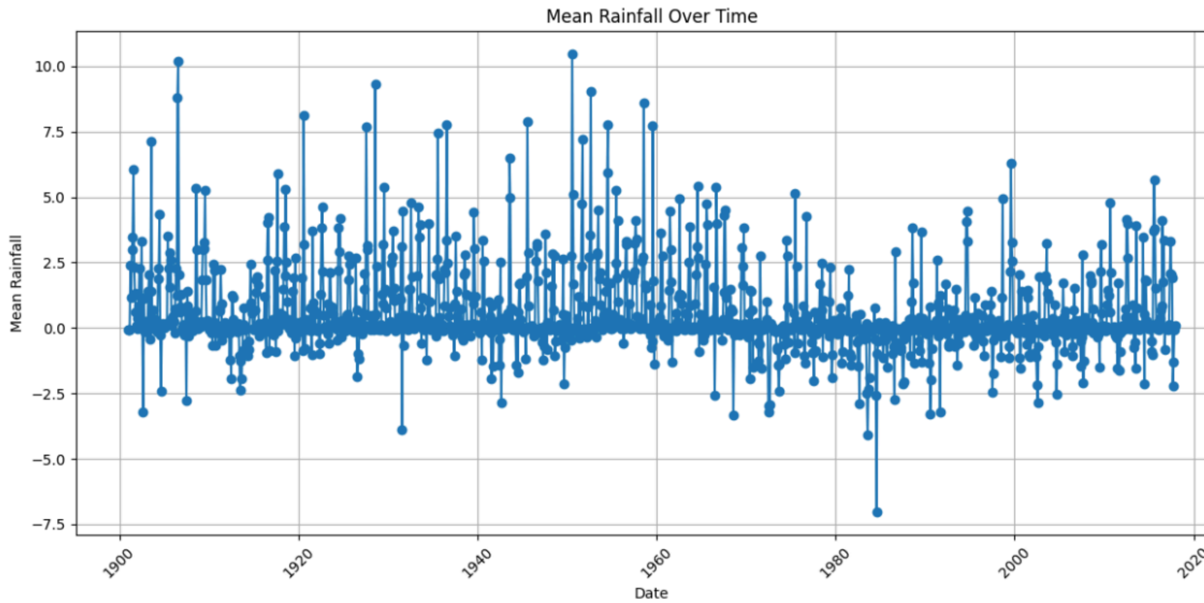


Figure 44 - **Mean Monthly Rainfall over Different Periods**

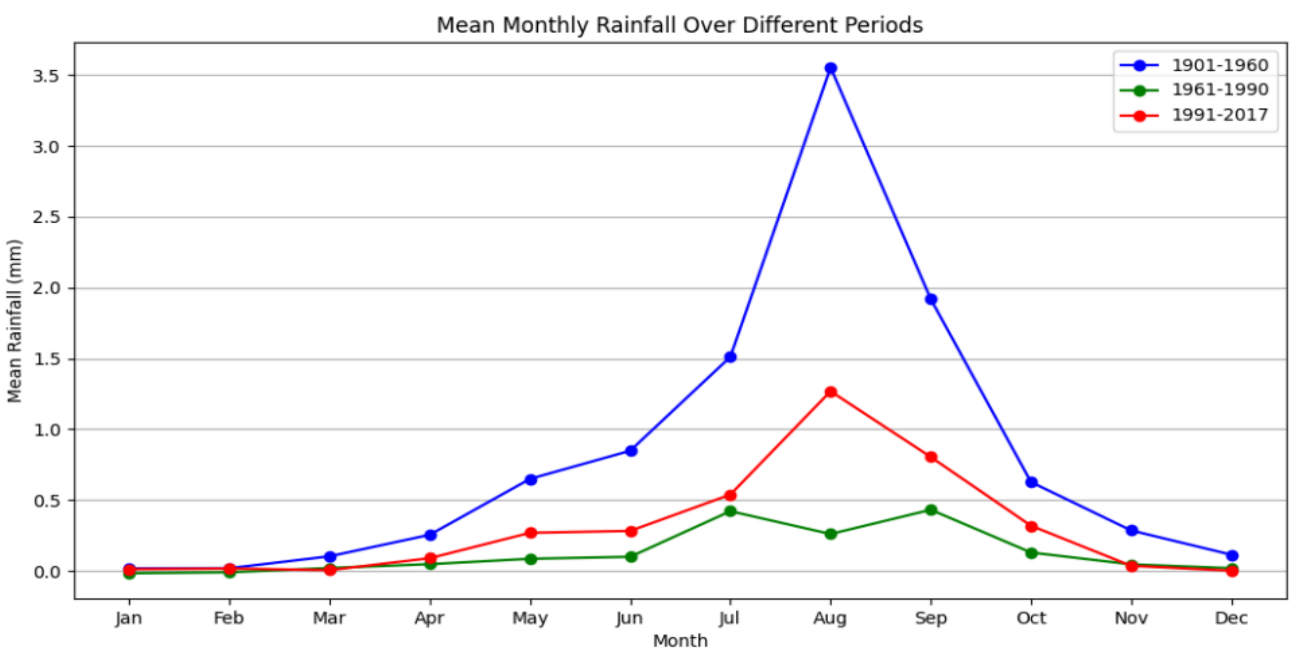
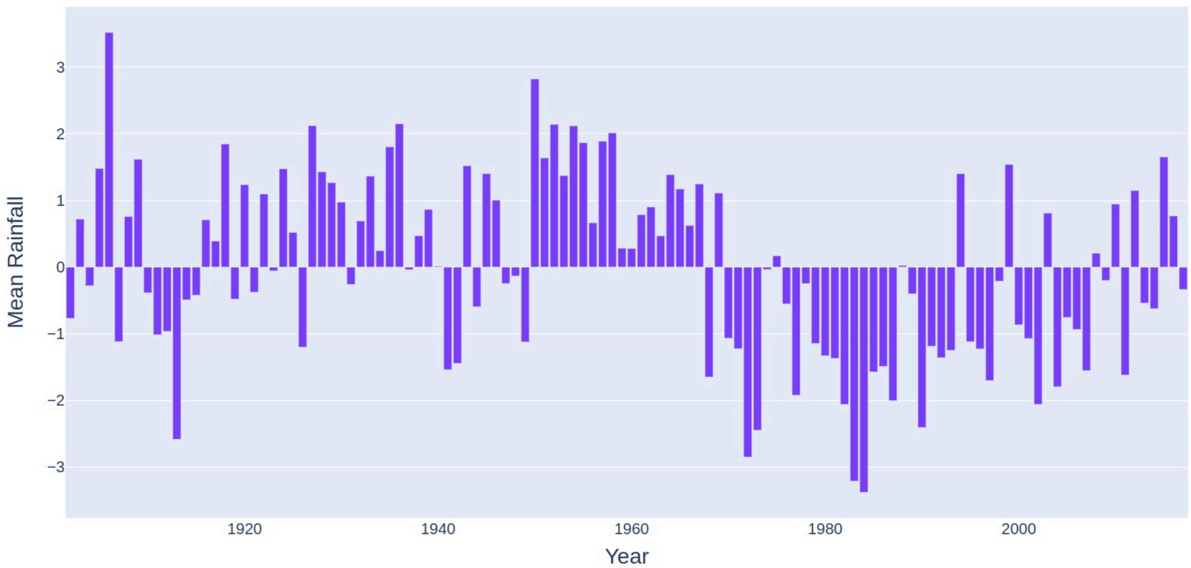
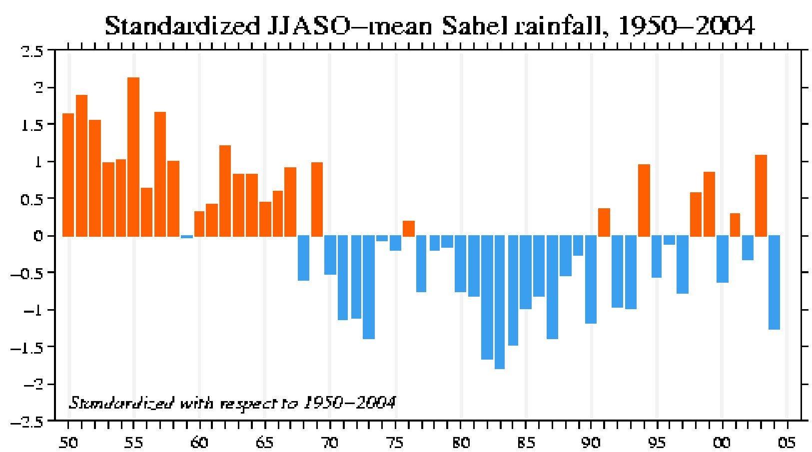


Figure 45 **- Annual Mean Rainfall across Years**



Prior to the desertification period between 1961 & 1990, the **region experienced its highest recorded rainfall**, indicating a relatively lush environment. However, **during the desertification period**, **precipitation levels plummeted to their lowest**, signaling a critical phase of environmental degradation. Despite improvement **post-1990, the rainfall has not fully recovered to its pre-1960 levels**, suggesting a persistent impact of desertification. This prolonged alteration in precipitation patterns have profound consequences on ecosystems, agriculture, and livelihoods in the Sahel region, underscoring the long-lasting effects of environmental challenges



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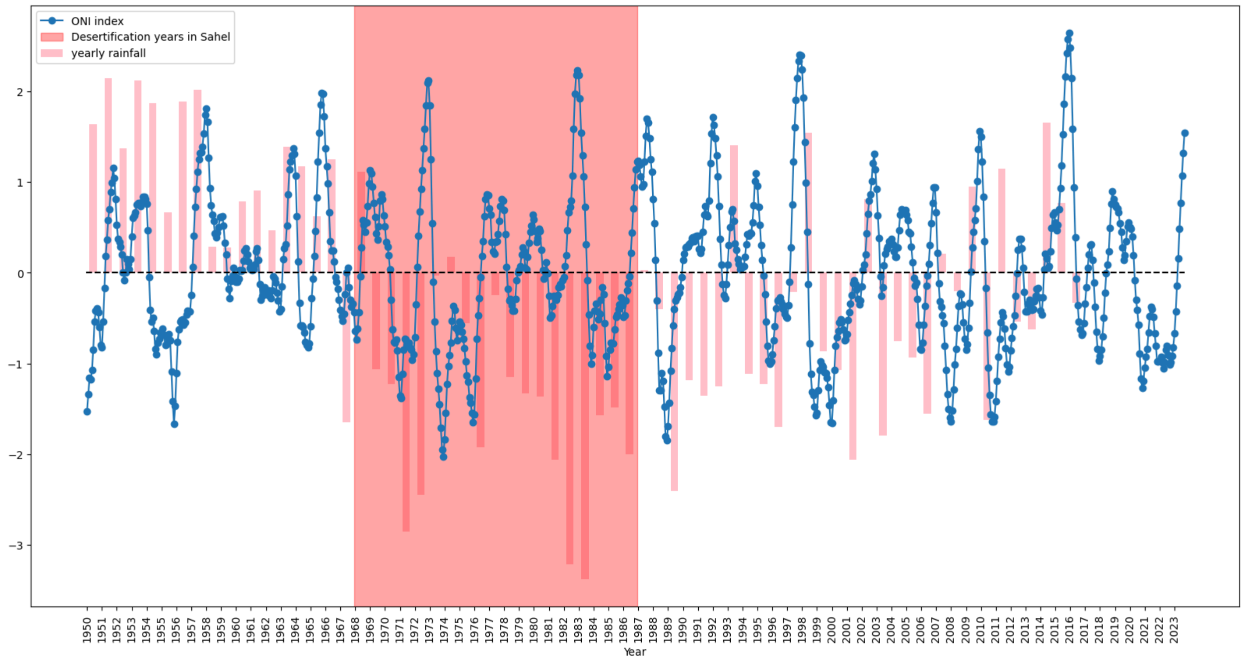
The graph derived from the discovered open dataset seamlessly corresponds with the graphical representation in a research paper. This convergence in patterns and trends serves as a substantial validation, attesting to the precision of our dataset and fortifying the credibility of our analytical approach.

Figure 46- **ONI Index across Years**



The **Oceanic Niño Index (ONI) is NOAA's primary indicator for monitoring the ocean part of the seasonal climate pattern** called the **El Niño-Southern Oscillation**, or “ENSO” for short. (The atmospheric part is monitored with the Southern Oscillation Index.) The **ONI tracks the running 3-month average sea surface temperatures in the east-central tropical Pacific between 120°-170°W**, near the International Dateline, and whether they are warmer or cooler than average. NOAA considers El Niño conditions to be present in the ocean when the ONI in that area, known as the Niño-3.4 region, is +0.5 or higher, meaning surface waters in the east-central tropical Pacific are 0.5 degrees Celsius (0.9 degrees Fahrenheit) or more warmer than average. Above is a graph to illustrate the effect of ONI index and the precipitation of rainfall. We can see that in the **initial desertification phase, the ONI indexes are consistently greater than 0.5** which indicate El Nino conditions in the ocean, as discussed earlier can lead to drought conditions in Sahel. Please note that even though it can be a factor, the precipitation of Sahel is a complex process and is not solely dependent on this.

An important point to be noted here is the improvement in the rainfall pattern across the years, the lack of which previously was responsible for the extensive drought. The reason for the previous scanty rainfall pattern and the recent improvement can be partially attributed to the complete aerosol ban in 1994. This ban influences the precipitation levels by the phenomenon of **Global Dimming**. Due to the reduction of the aerosol content, there has been a reduction in the extent of global dimming and hence, the precipitation pattern has become more regular.

➢ Data Visualization - Population:

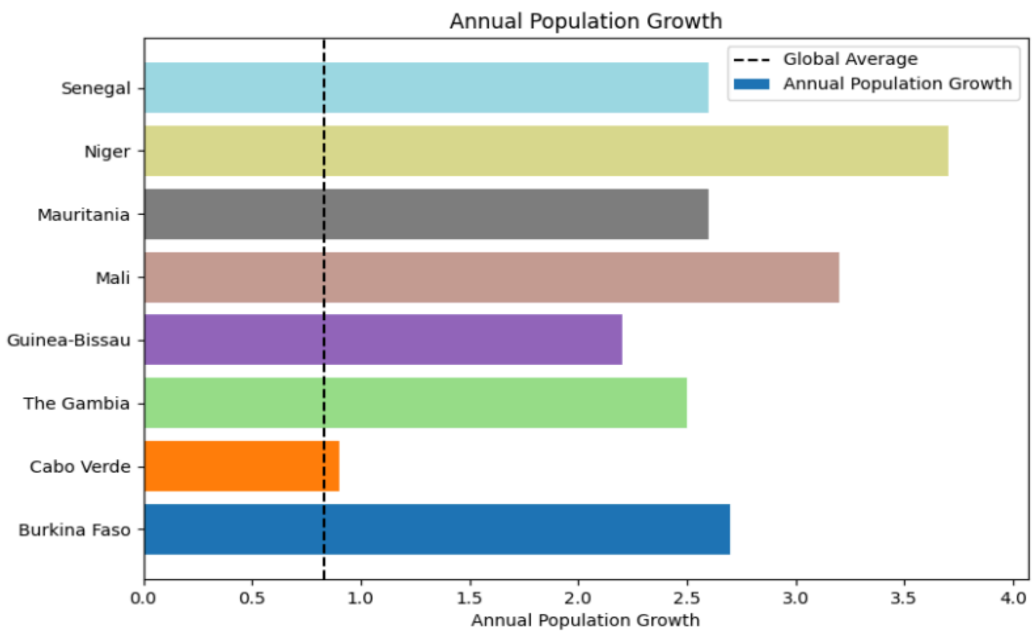


Figure 47 - **Annual Population Growth**

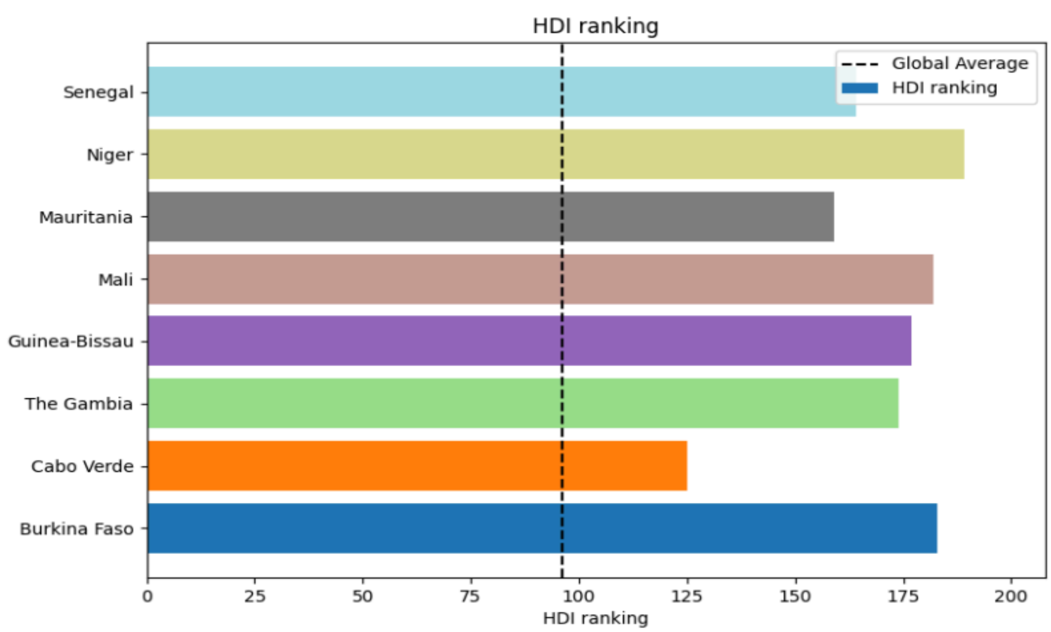
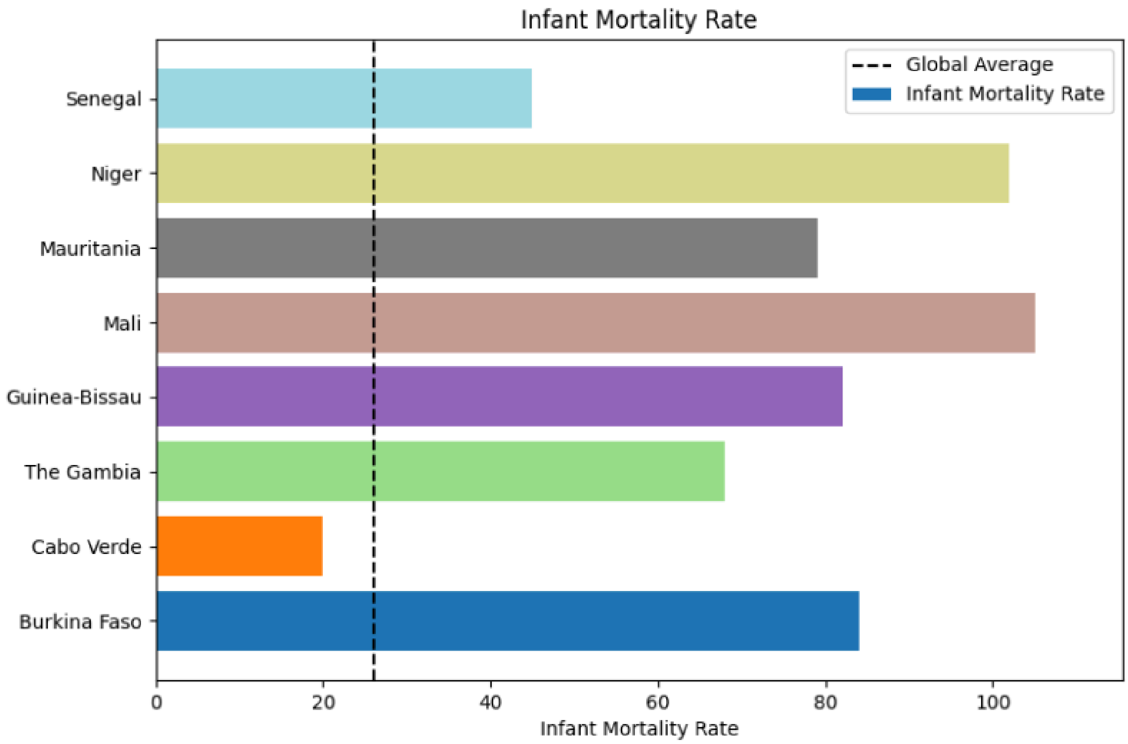


Figure 48 - **HDI Ranking**



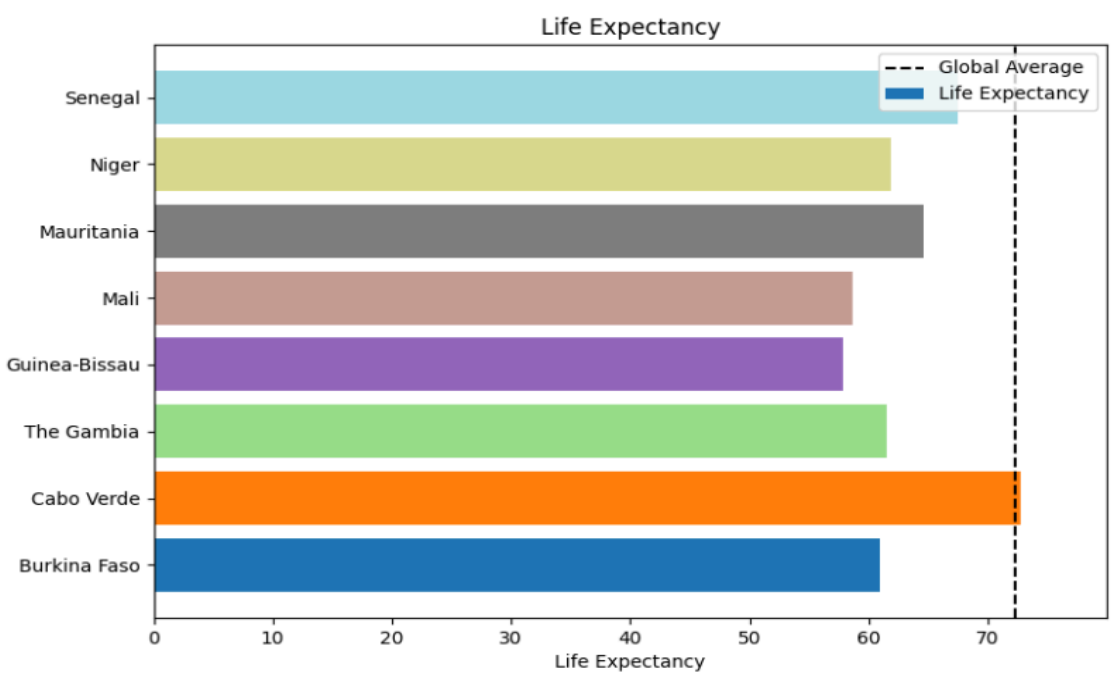


Figure 49- **Life Expectancy in Sahel Region**

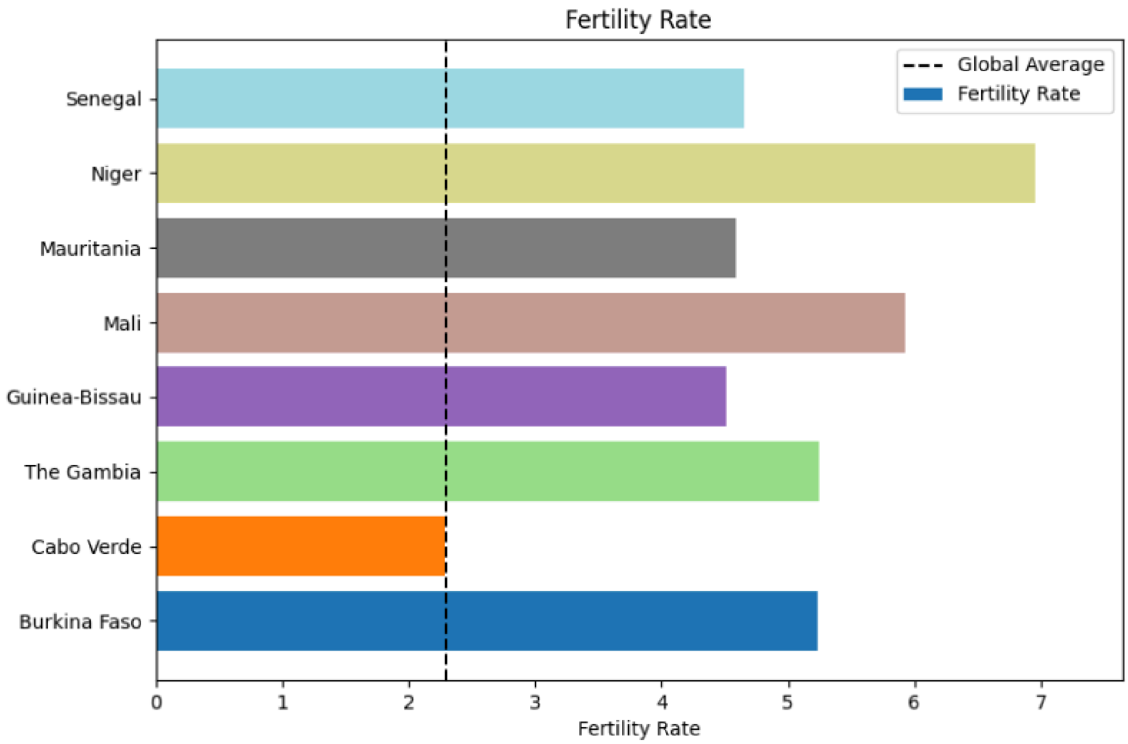


Figure 50 - **Fertility Rates in Sahel Region**

The fertility rate, life expectancy, HDI ranking, population growth rate, and infant mortality rate collectively provide a comprehensive view of the socio-economic and demographic landscape in Guinea-Bissau, Senegal, Niger, Mauritania, Mali, Gambia, Cabo Verde, and Burkina Faso. The consistent **lag behind the global average in these indicators across most of these nations underscores shared challenges in healthcare, education, and economic development**. The suboptimal fertility rates in these countries contribute to slower demographic transitions, affecting economic productivity and development. Low life expectancy and high infant mortality rates point to challenges in healthcare infrastructure and access. The Human Development Index (HDI) rankings further emphasize the need for concerted efforts to improve living standards and well-being.

The observed disparities indeed contribute to the environmental issues, such as desertification, as socio-economic factors play a significant role in shaping land-use practices.

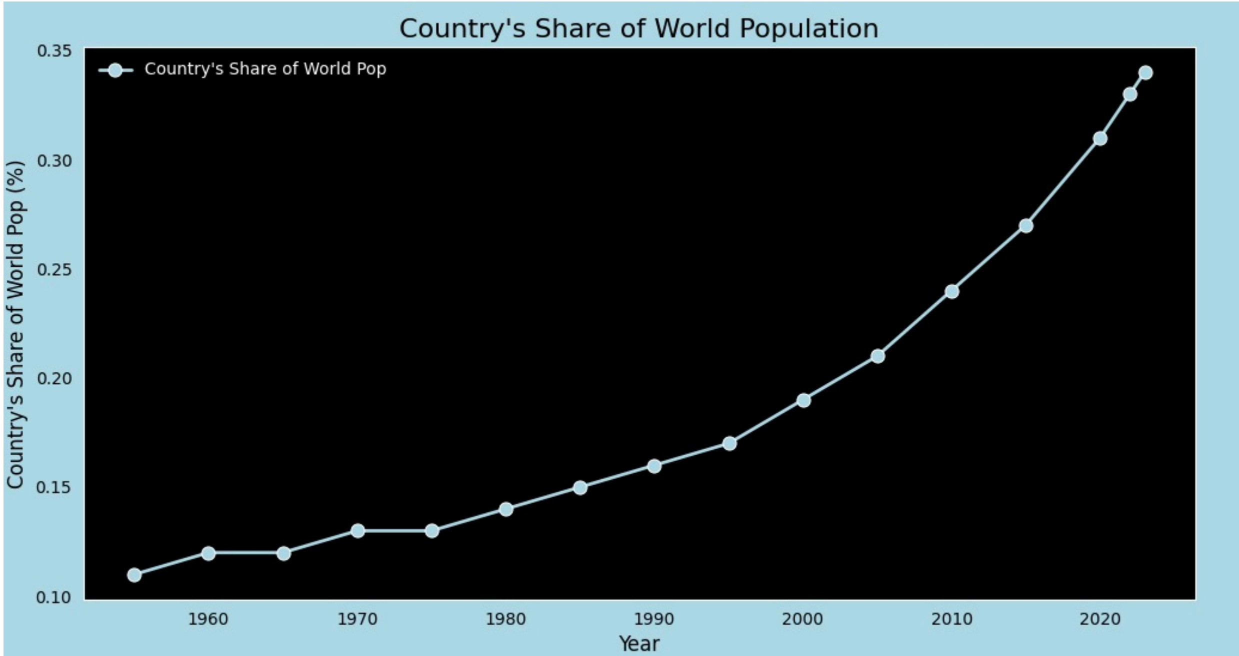


Figure 51 **- Country’s Share of World Population**

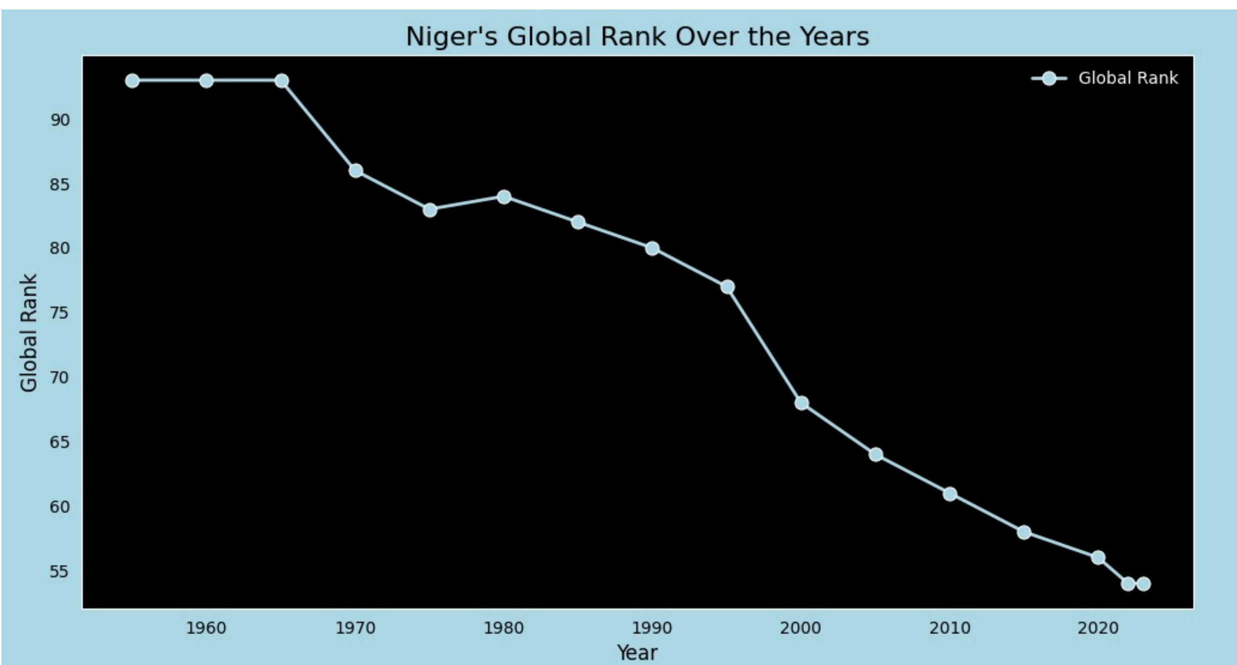


Figure 52 **- Niger’s Global Rank over the Years**

Data Visualization obtained from Open Dataset

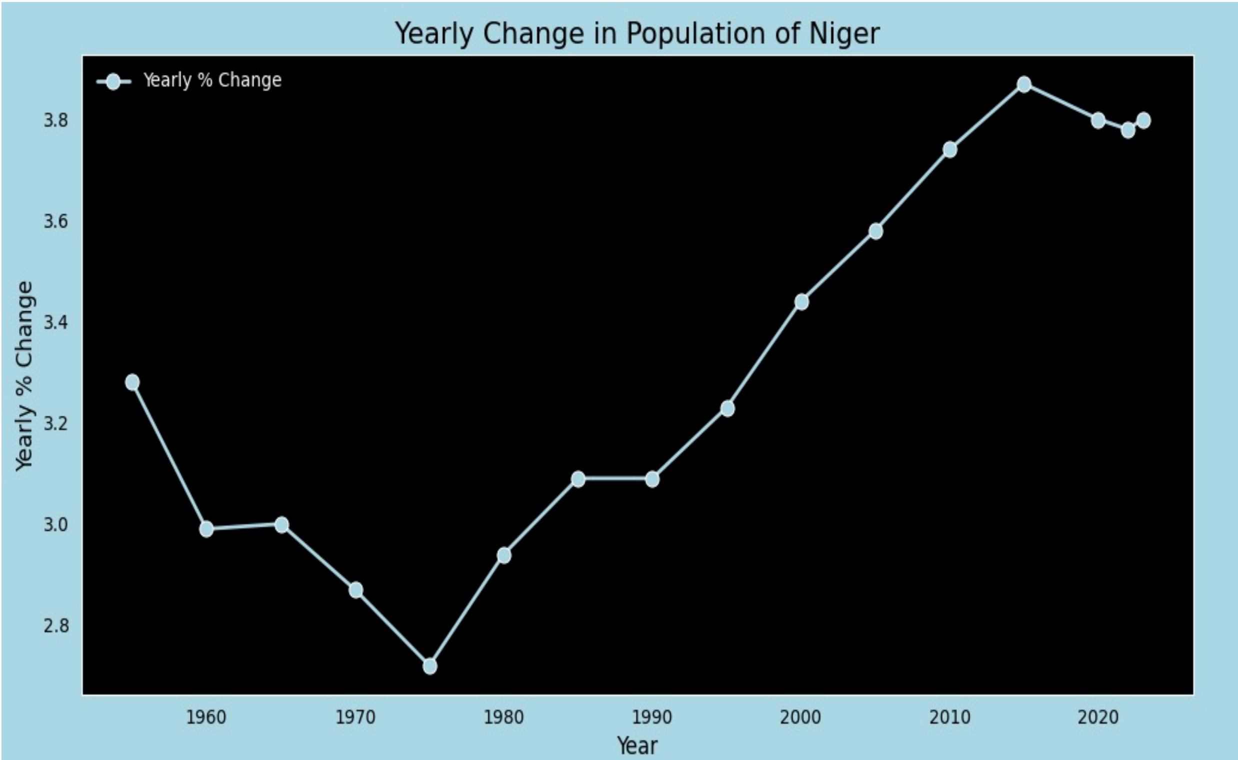
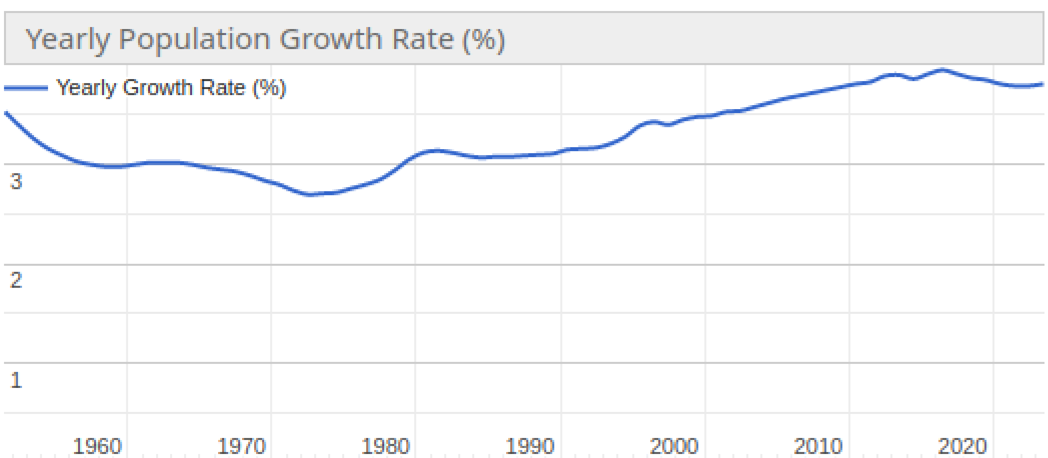


Figure 53 - **Yearly change in Population of Niger**

Data Visualization on Worldometer



The yearly population change graph obtained for Niger from an open dataset seamlessly corresponds with the graph found on Worldometer. The congruence in trends and figures not only underscores the accuracy of our dataset but also validates the robustness of our analytical methodology.

Data Visualization obtained from Open Dataset

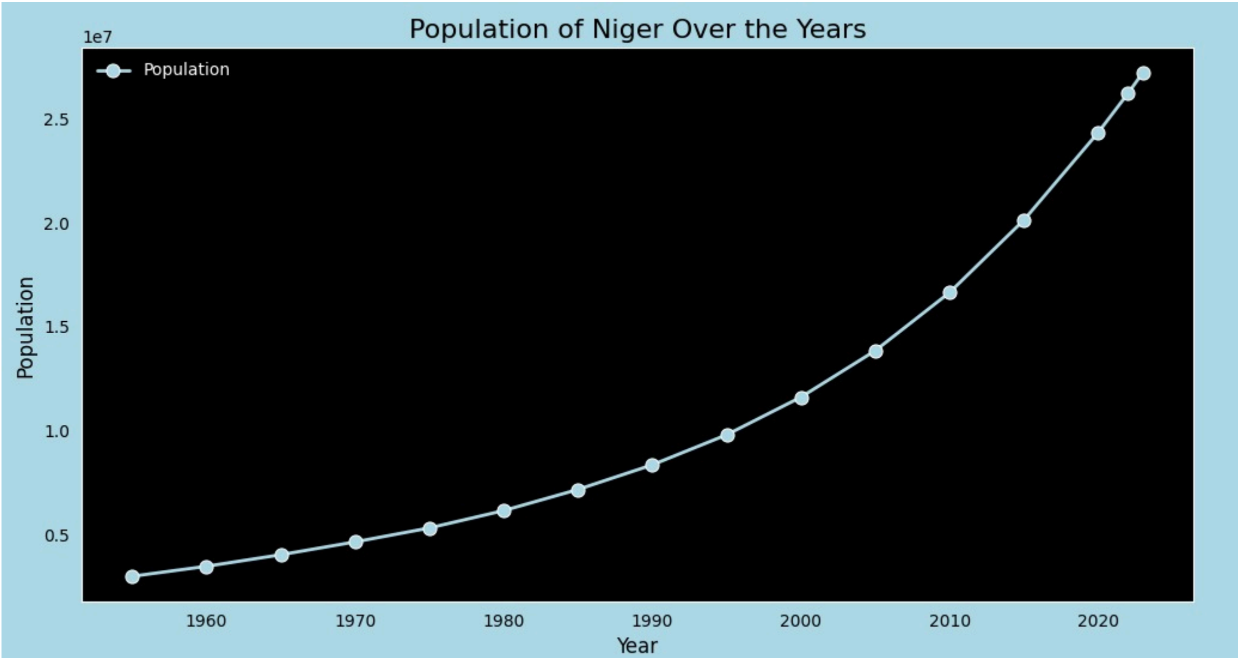
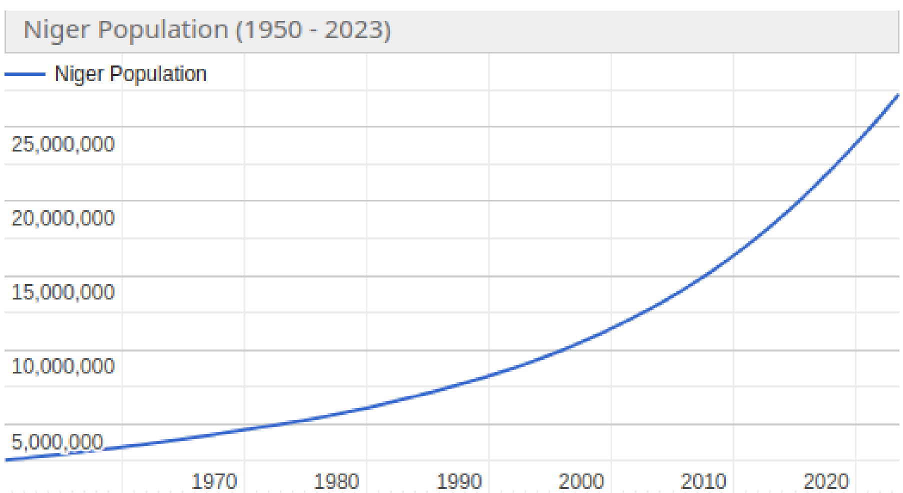


Figure 54- **Population of Niger over the Years**

Data Visualization on Worldometer



The annual population trends obtained for Niger, sourced from an open dataset, reveal a large similarity with the data presented on Worldometer. This alignment in both trends and numerical values not only substantiates the precision of our dataset but also serves as a compelling validation of the soundness of our analytical approach.

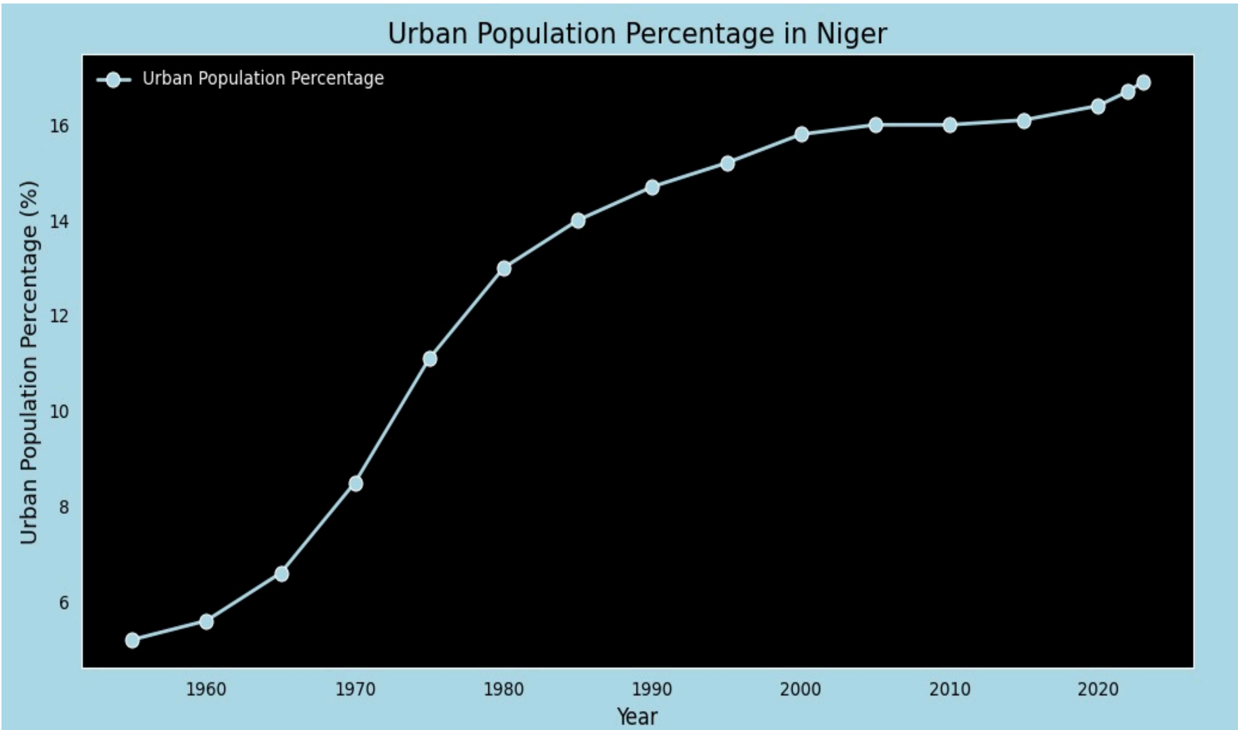


Figure 55 **- Urban Population Percentage in Niger**

The data spanning from 1950 to 2021 reveals a concerning trend in Niger's population dynamics. The steady increase in Niger's share of the world population, accompanied by a consistent rise in its global rank over the years, highlights the magnitude of population growth in the country. The urban population percentage in Niger has also shown an upward trajectory, reflecting rapid urbanization.

The yearly change in population for Niger, expressed as a percentage, further **underscores the alarming nature of this demographic expansion, suggesting a compounding effect**. The overall population in Niger has experienced a substantial surge, exacerbating concerns about resource depletion, environmental stress, and contributing to the issue of desertification.

This population growth poses **significant challenges to sustainable development, as the strain on resources intensifies**. Addressing the root causes of this population surge, such as improving healthcare, education, and family planning, becomes imperative to mitigate the impact on the environment and enhance resilience to desertification. A comprehensive approach, incorporating both population management and sustainable development strategies, is essential for tackling these interconnected challenges in Niger.

➢ Data Visualization - CDI:

Influence of various factors on the likelihood of droughts

From the research paper, the factors **Precipitation** and **NDVI** (**N**ormalized **D**ifference **V**egetation **I**ndex) were categorized into the same class and the **LST** values were placed in another class. This was done to describe the opposite effect these factors have on the drought susceptibility of an area.

Higher values of precipitation in an area is generally a good measure of **lesser chances of droughts** due to ample amount of water that can be utilized by plant life. Similarly, **higher NDVI values** indicate the presence of vegetation and hence, from which we can infer the **absence of drought**. It is due to these reasons that it is justified to group these quantities together, both of them showing **negative correlation** with the drought susceptibility likelihood of an area.

Coming to the **LST** data, it indicates the temperature levels in that area. **Higher LST values** naturally show more heat retained in that area, which considerably reduces the quality of plant life as well as the water retaining capacity of the land in that area, hence reducing the soil quality, which can ultimately lead to **higher chances of drought**. All of these impacts necessitates the need to place LST in a category different from the other two factors, as this shows **positive correlation** with the drought susceptibility likelihood of an area.

From the above discussion, we must be able to visually observe which areas are more likely to experience droughts. They can be detected by using the plots of **Precipitation**, **NDVI** and **LST**, where the areas in which the values of precipitation and NDVI are **less** and the value of LST is **higher** are more susceptible to drought.

The **CDI** variable aims to capture this correlation between these factors using a single value. We present side-by-side plots of CDI and these factors to help infer how well CDI captures the inter-dependence. These plots are spaced out across different time-scales to demonstrate the robustness of this quantity

Measurements for the year 2000

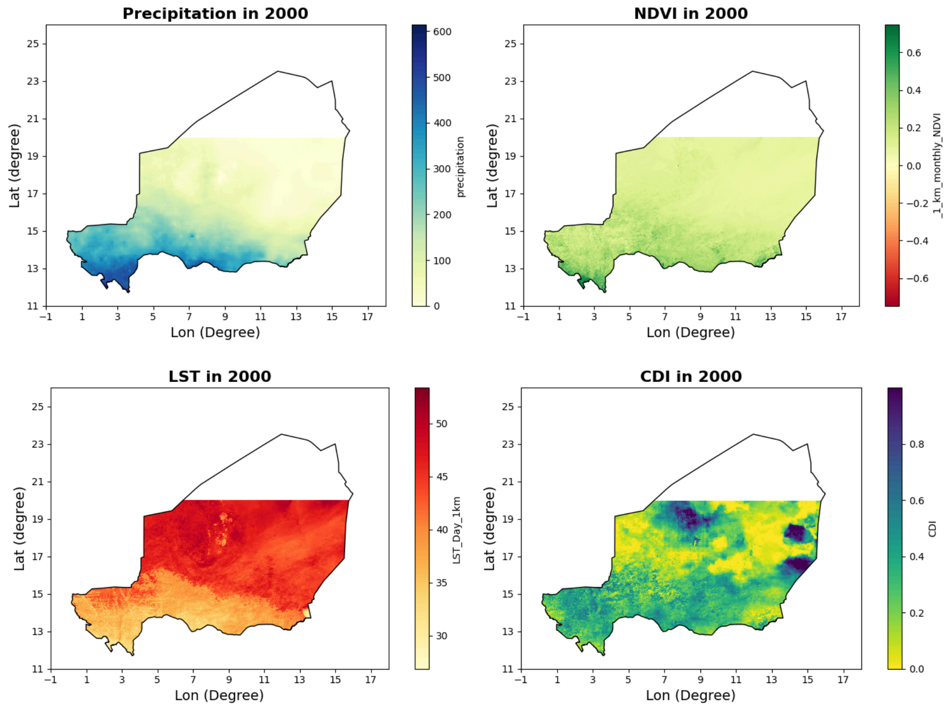


Figure 56 - Measurements of CDI for the year 2000

Measurements for the year 2005

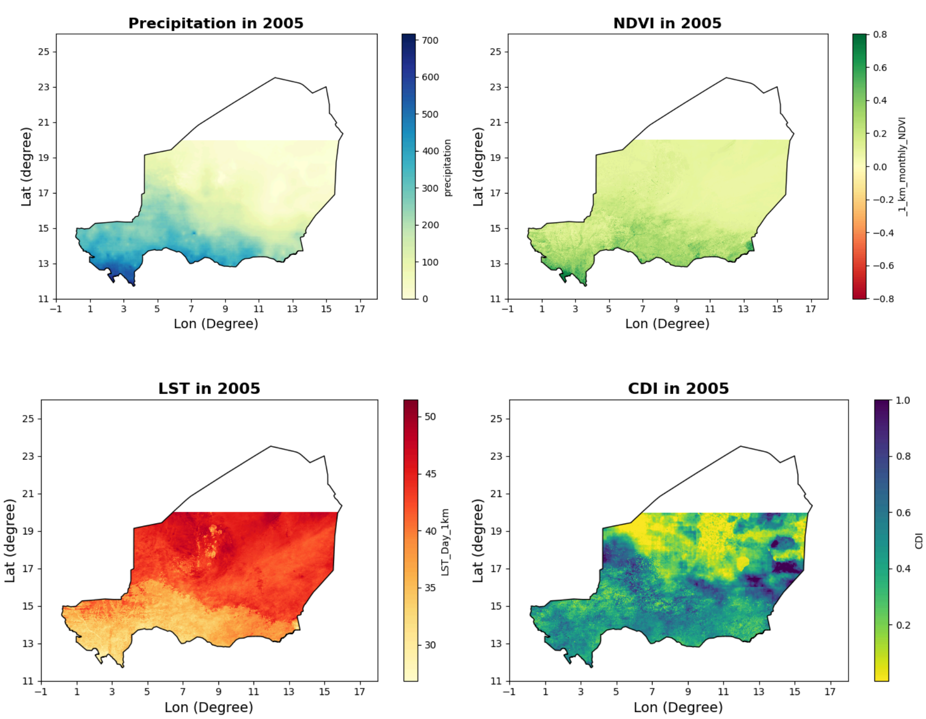


Figure 57 - Measurements of CDI for the year 2005

Measurements for the year 2010

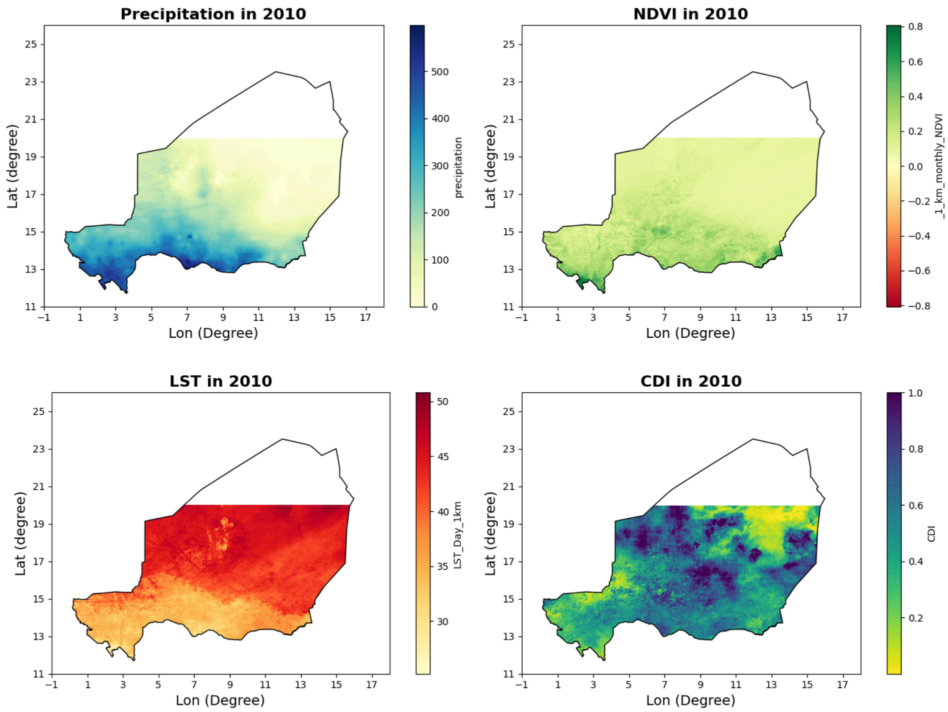


Figure 58 - Measurements of CDI for the year 2010

Measurements for the year 2015

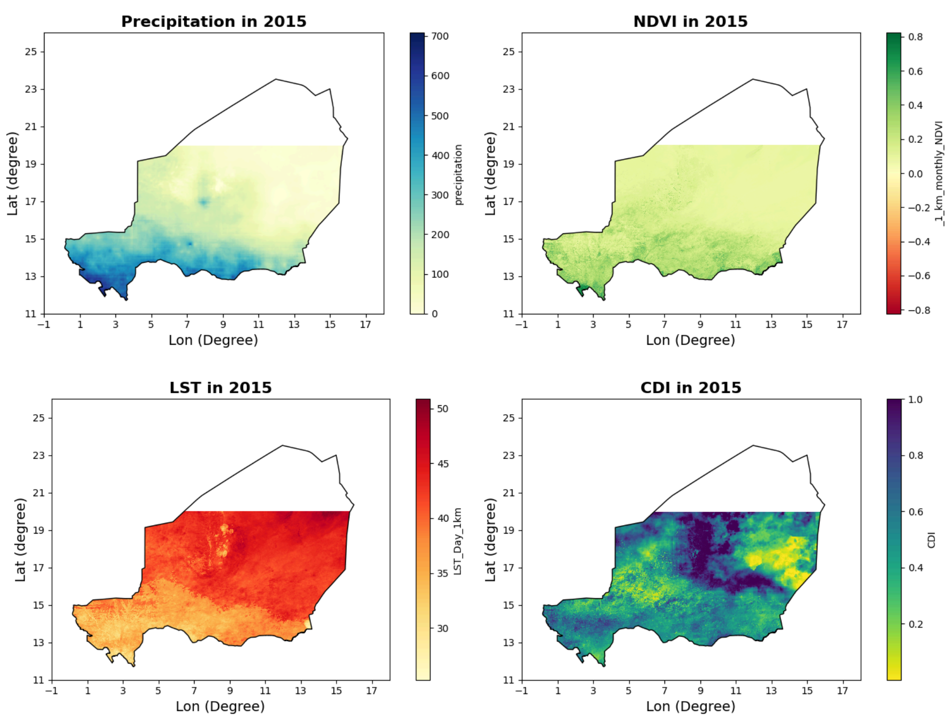


Figure 59 - Measurements of CDI for the year 2015

Measurements for the year 2020

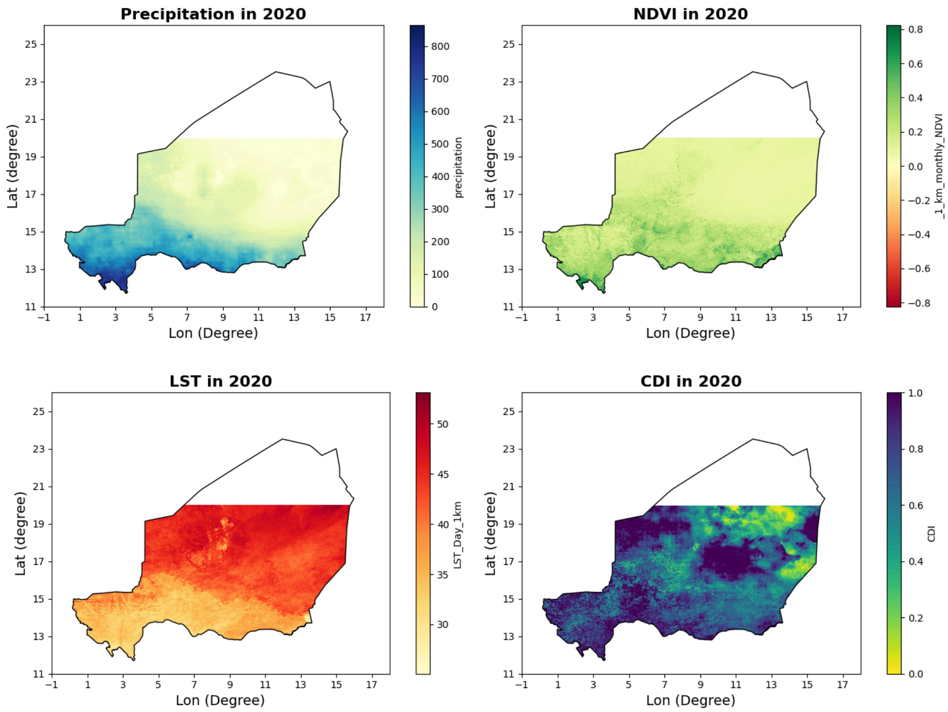


Figure 60 - Measurements of CDI for the year 2020

As we can observe from the above plots, as we move towards the **southwest part** of the Niger region, we observe **increased** levels of **precipitation**, **higher** amounts of **vegetation**, due to which **lesser** amounts of **heat is retained** by the land, which is also reflected in the **lower LST** values. All of these are good indications for **better land and soil quality**. This is also reflected in the **higher** values of **CDI** in these regions. On the other hand, during the initial years, the central Niger region has **abnormally low precipitation** values, and naturally **lower vegetation** expanse, which also provides no cover to the land and exposes it to the extreme heats, most of which is retained, thereby **increasing** the **LST** values. These **dry and arid conditions** are indicative of **droughts**, which is also reflected by the **CDI**, which has **lesser value** in this region.

But as the years progress, be it due to better water management systems, or improved agricultural practices, the **vegetation** cover has been **increasing steadily**, which paired with **better rainfall patterns** has created better conditions in the Niger region, which is also reflected in the similar **increase pattern** of the **CDI** values.

➢ Data Visualization Website:

[VISIT HERE] [VIEW CODE]

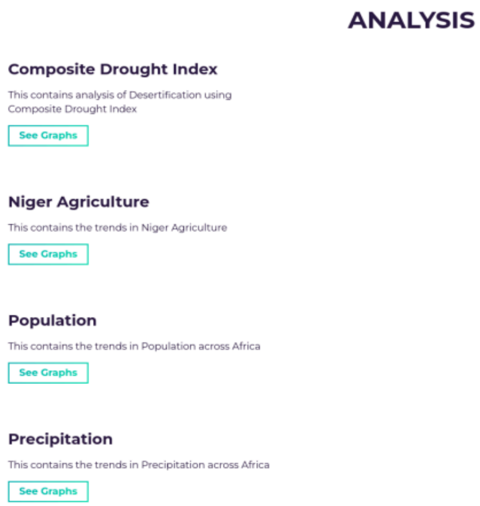


Figure 61 - **Picture of Website**

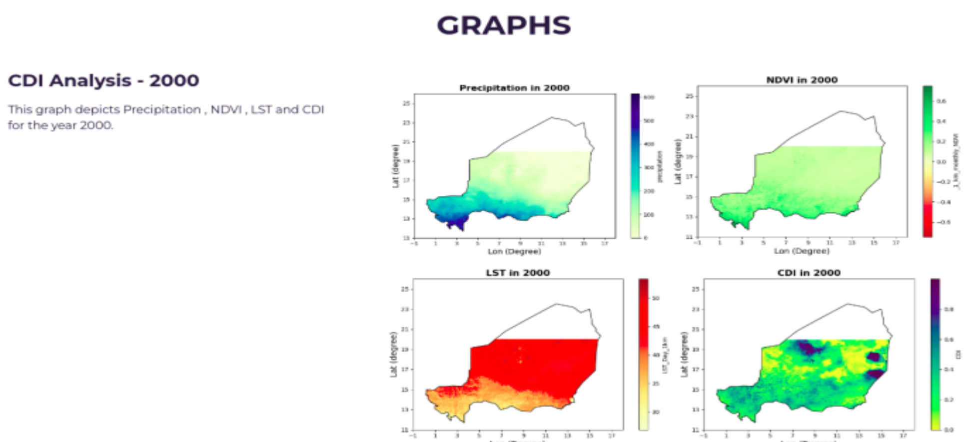


Figure 62 **- CDI Analysis - 2000**

Explore desertification in the Sahel on our **newly launched static website**, featuring insightful graphs on the **Composite Drought Index, precipitation, vegetation, agricultural land, and population trends**. Built for seamless navigation using **Parcel**, this user-friendly platform offers a quick and responsive experience. Uncover the nuances of desertification with our project, combining advanced data visualization and environmental awareness in one concise space.

This data visualization website is designed to showcase and analyze the impacts of desertification in the Sahel region of Africa. It utilizes **Bootstrap**, **VanillaJS**, and **jQuery for front-end development and Parcel for bundling and deployment on Netlify**. The website features interactive data visualizations, including time-series charts, heat maps, and scatter plots, to present insights into various aspects of desertification, such as land cover changes, precipitation patterns, and vegetation loss.

Technical Overview

- **Front-End Development:**
    - **Bootstrap:** Used for responsive web design and basic styling
    - **VanillaJS:** Employed for interactive elements and data manipulation
    - **jQuery:** Leveraged for Advanced DOM manipulation and cross browser compatibility
- **Bundling and Deployment:**
    - **Parcel:** Utilized for building and bundling the front-end code
    - **Netlify:** Chosen for hosting and continuous deployment

```html
<!-- **** Projects Section **** -->
<section id="projects">
  <div class="container">
    <div class="project-wrapper">
      <h2 class="section-title dark-blue-text">Graphs</h2>


      <!-- Notice: each .row is a project -->
      <div class="row">
        <div class="col-lg-4 col-sm-12">
          <div class="project-wrapper__text load-hidden">
            <h3 class="project-wrapper__text-title">CDI Analysis - 2000</h3>
            <div>
              <p class="mb-4">
                This graph depicts Precipitation , NDVI , LST and CDI for the year 2000.
              </p>
            </div>
          </div>
        </div>
        <div class="col-lg-8 col-sm-12">
          <div class="project-wrapper__image load-hidden">
            <img alt="Project Image" class="img-fluid" src="./assets/cdi/2000.png" data-action="zoom" />
            </a>
          </div>
        </div>
      </div>
      <!-- /END Project -->
```

Frameworks and Libraries:

Conclusions:

- The objective of this report was **to perform a literature review** on the impacts of various factors such as **precipitation, temperature, vegetation** and also of **human activities, such as the extent of agricultural land usage, rural to urban shift** and also the **population.**
- Climate and precipitation in Sahel is one of the main factors in desertification of Sahel and this study further reinforces this fact. **Climate is influenced by many factors such as ITF (Inter tropical front) , Temperature, evaporation etc**. Temperature and evaporation is different for the north and south part of Sahel although the trends are largely the same and increase during the months of March to May. Precipitation in Sahel can be described as irregular and these **irregularities can be of two types, irregularities within one cycle and variations in rainfall between years**. If rainfall is irregular within a cycle then even though the rainfall is above average, Not all of it is gonna be useful for plant germination and this can cause drought as was the case in 1968. Variations in rainfall between years can also cumulatively lead to drought of catastrophic proportions. Rainfall is influenced by various factors like El Nino, ITF. ITCZ (Inter tropical convergence zone) etc. Overall precipitation is complex to predict based on a single parameter, but it played an important role in desertification of Sahel.
- The study shows how population changes play a role in causing desertification in the Sahel region. Urbanization, resource needs, water shortages, high birth rates, job problems, and migration all add to the environmental problems in Sahelian countries. Governments have put in place policies to deal with these issues, showing they understand the need for lasting development. Yet, the issue is complex, emphasizing the need for joint strategies that handle both population challenges and environmental sustainability. This is crucial for a strong and successful future in the Sahelian region.
- Given the highlighted remote sensing results, NDVI time series trajectory, reconciled climate records, statistical analysis and previous literature, it can be inferred that desertification in the study area [**Yusufari-Yunusari Region**] is less a product of climate change and more a function of human activities and factors leading to the conversion of land cover, e.g., unsustainable agricultural practices, such as the over-cropping of marginal or fragile land, overgrazing, poverty, population pressure and poor government policies.The **three major indicators of increasing aridity, namely the expansion of sand dunes, declining vegetation cover, and shrinking of wetlands and water bodies**, have intensified in the study area over the 25-year study period analyzed. This implies that up to 130,000 ha of land might become sand dunes if the socio-economic activities and management practices remain as usual and if the current no-policy framework situation persists.

- **By including precipitation**, **vegetation** and **temperature data in the computation of the composite drought index (CDI)**, the combined impacts of meteorological and agricultural droughts can be assessed with **more accuracy.** The motivation behind including different types of variables/quantities in the estimation of the drought index is to encompass the **interdependence** between these factors. Based on the computed index values, various **thresholds** are set to determine the **intensity of the drought**. These thresholds can be suitably set to **reduce** the **number of categories** of drought intensities as well as produce better results. The accuracy of the predictions can also be improved by **considering other factors** such as soil moisture, which can provide better insights into understanding land quality and desert susceptibility.
- In summary, **Niger's agricultural landscape**, vital for the majority of its population, has historically faced challenges such as erratic rainfall and global dimming. However, innovative interventions, particularly the introduction of **half-moon** technology supported by **USAID and the World Food Programme**, have significantly increased agricultural land, improved soil moisture, and enhanced vegetation growth. This has not only boosted productivity but also increased resilience to drought, positively impacting rural communities. The success of these initiatives highlights the importance of sustainable land management in addressing climate change effects and promoting food security. The collaboration between USAID, development organizations, and local communities demonstrates the potential for **transformative solutions** in addressing complex agricultural and environmental challenges.

Acknowledgements:

We would like to express our gratitude to the various organizations and individuals who contributed to making this case study possible. In particular, we thank the **World Bank, Worldometer, Climate Change Knowledge Portal, AMMA-CATCH program, and the Joint Institute for the Study of the Atmosphere and Ocean** for curating and sharing the data that made this study achievable and served as the backbone of our analysis. **We hope our findings not only add to the academic understanding** of desertification dynamics **but also contribute in a meaningful way** to ongoing local and global efforts to address this critical issue for the Sahel region and beyond.

References:

1. Ibrahim, E. S., Ahmed, B., Arodudu, O. T., Abubakar, J. B., Dang, B. A., Mahmoud, M. I., Shaba, H. A., & Shamaki, S. B. (25th April 2022). **Desertification in the Sahel Region: A Product of Climate Change or Human Activities? A Case of Desert Encroachment Monitoring in North-Eastern Nigeria Using Remote Sensing Techniques**. [CrossRef]
2. Osei-Hwedie, B. Z., Kurantin, N., & Osei-Hwedie, K. (January 2019). **Globalization and Environmental Degradation in Sub-Saharan Africa**. [CrossRef]
3. Garba, I., Abdourahamane, Z. S., & Mirzabaev, A. (January 2023). **A Drought Dataset Based on a Composite Index for the Sahelian Climate Zone of Niger**.[CrossRef]
4. Bai, Y., Bogati, R., Fu, C., & Inmuong, Y. (December 2022). **Community-based wildlife conservation in Maasai Mara, Kenya. In Case studies on ecosystem-based approaches for resilient livelihoods in developing countries (pp. 53-56)**. United Nations Environment Programme.[CrossRef]
5. UNEP (2012). **Sahel Atlas of Changing Landscapes: Tracing trends and variations in vegetation cover and soil condition**. United Nations Environment Programme, Nairobi.[CrossRef]
6. Nicholson, S. E., Dezfuli, A. K., & Klotter, D. (February 2012). **A Two-Century Precipitation Dataset for the Continent of Africa**.[CrossRef]
7. Nwokoro, I. I. C., & Dekolo, S. O. (2012). **Land use change and environmental sustainability: the case of Lagos Metropolis.[**CrossRef**]**
8. Faye, A., Dieye, M., Diakhaté, P. B., & Beye, A. (2021). **Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.**[CrossRef]

Appendix:

Calculation of CDI:

- It is evident from plain observation that LST has a positive correlation with drought occurrence because a higher LST corresponds to more drought conditions. Whereas, in the case of precipitation and NDVI values, we can infer that they have a negative correlation with CDI, as higher values of these variables contribute to wet spells.
- Hence, they are divided into two categories, with LST in category **A**, and precipitation and NDVI in category **B**.
- First these values are normalized, and their **entropy measure e_k** is calculated for each variable using their time input data as follows:

$$e_k = \frac{-\sum_{i=1}^{m} r_{ki}\, ln(r_{ki})}{ln(m)},$$

where r_{ki} is the normalized value of x_{ki} which corresponds to the value of the kth variable with time index i (i = 1, 2, …, m), where

$$r_{ki} = \frac{x_{ki}}{\sum_{i=1}^{m} x_{ki}}$$

- Then, the **degree of diversification D_k** is calculated as:

$$D_k = 1 - e_k$$

- Using this D_k, we calculate the **entropy weights Ew_k** as follows:

$$Ew_k = \frac{D_k}{\sum_{j=1}^{k} D_k}$$

- The variables **Maximum Driest Condition (MDC)** and **Maximum Wettest Condition (MWC)** are calculated using the normalized values of the variables r_{ki} as follows:

$$MDC_k = \{max(r_{ki}),\ if\ k \in A;\ min(r_{ki}),\ if\ k \in B\}$$

$$MWC_k = \{min(r_{ki}),\ if\ k \in A;\ max(r_{ki}),\ if\ k \in B\}$$

- Two penultimate variables, S_i^- and S_i^+, used to calculate CDI are computed as follows:

$$S_i^- = \sqrt{\sum_{k=1}^{n} Ew_k [r_{ki} - MDC_k]^2}$$

$$S_i^+ = \sqrt{\sum_{k=1}^{n} Ew_k [r_{ki} - MWC_k]^2}$$

which denote the weighted Euclidean distance between the present condition (PC) and the MDC and MWC respectively.

- Finally, CDI is calculated using these two variables as follows:

$$CDI_i = \frac{S_i^-}{S_i^- + S_i^+}$$