



DEFORESTATION, HYDROLOGICAL DISRUPTIONS AND NIGERIA'S CLIMATIC VARIABILITY: ANALYZING THE NEXUS BETWEEN FOREST LOSS AND WATER CYCLE ALTERATIONS

Philip, Anita H., Garba, A. Hajara, Elijah Elizabeth, Abba, U. Jauro, & Udousoro, Idorenyin L.

^{1, 2, 3 & 4}Department of Geography, Taraba State University, Jalingo.

⁵Department of Environmental Management, University of Calabar, Calabar.

Corresponding author: udousoroidorenyinl@gmail.com

Abstract

Deforestation has significantly impacted hydrological patterns and climate variability in Kano State, Nigeria. This study examines the effects of forest loss on water resource availability and climate, highlighting key issues such as increased flooding and unpredictable rainfall. The research adopts a quantitative approach, using survey data collected from 400 respondents. Descriptive statistics and ANOVA were employed for data analysis. Findings reveal that 26.8% of respondents identified drying up of rivers and streams as the most critical hydrological impact, while 25.5% highlighted increased flooding. Additionally, 34% of respondents agreed that loss of vegetation reduces water retention capacity, leading to severe changes in water availability. Climatic variability was also evident, with 28.8% reporting increased temperatures and 25.3% citing a rise in extreme weather events. The ANOVA results indicate a significant variation ($F = 4.12$, $P = 0.038$) between deforestation impacts and climate change indicators. The study concludes that deforestation has intensified environmental challenges in Kano State, affecting water resources and climate stability. To mitigate these effects, afforestation and reforestation programs should be prioritized, alongside stricter land-use policies. Additionally, community-based awareness campaigns should be implemented to educate residents on the consequences of deforestation. The findings emphasize the urgent need for sustainable forest management strategies to protect the environment and ensure long-term water and climate stability in Kano State.

Key words: Climate Variability, Deforestation, Hydrological Patterns, Sustainable Management, Water Resources

Background to the study

Deforestation significantly alters hydrological processes, leading to disruptions in water cycles, atmospheric moisture transport, and precipitation patterns. The removal of forests in critical regions, such as the Amazon, reduces evapotranspiration, weakening hydroclimatic connectivity between land and atmosphere (Sierra, Junquas, Espinoza, Segura, Condom, Andrade, & Sicart, 2022). This disruption affects local and regional rainfall distribution, with downstream consequences for river discharge and groundwater recharge. Model simulations further highlight that continued deforestation could exacerbate surface and atmospheric water imbalances, intensifying droughts and altering river flows (Wongchuig, Espinoza, Condom, Junquas, Sierra, Fita, & Polcher, 2023). Additionally, deforestation-driven land degradation contributes to soil erosion and sedimentation in water bodies, affecting water quality and aquatic ecosystems (Berenguer, Armenteras, Alencar, Almeida, Aragão, Barlow, & García-Villacorta, 2021). These hydrological disruptions not only threaten biodiversity but also jeopardize human water security, emphasizing the urgent need for sustainable forest management and conservation strategies.

Deforestation intensifies hydrological disruptions and exacerbates climate variability by altering precipitation patterns, streamflow dynamics, and atmospheric moisture distribution. The removal of forest cover reduces evapotranspiration, leading to diminished rainfall and prolonged dry periods, which in turn affect water availability for both ecosystems and human communities (Singh, Tedla, & Alvarado, 2023). These hydrological imbalances, coupled with deforestation-induced land degradation, accelerate soil erosion and increase sedimentation in rivers, further disrupting aquatic systems (Kumar, Kumar, & Saikia, 2022). On a broader scale, deforestation in regions like the Amazon significantly



impacts climate regulation by modifying local and global temperature patterns, intensifying heatwaves, and reducing carbon sequestration (Lima, Veiga, Brito, & Correia, 2023). Moreover, studies link deforestation with changing precipitation trends and streamflow variations in the Amazon, showing how large-scale forest loss interacts with climate oscillations such as the Pacific Decadal Oscillation, leading to unpredictable hydrological extremes (Limberger, Silva, Pereira, da Silva Cardozo, Mataveli, & Lima, 2021).

Deforestation disrupts the water cycle by reducing evapotranspiration, altering precipitation patterns, and weakening the connection between forests and hydrological systems. In the Amazon, large-scale deforestation affects rainfall distribution, leading to longer dry seasons and decreased river discharge (Sierra, Junquas, Espinoza, Segura, Condom, Andrade, & Sicart, 2022). Model projections indicate that further deforestation could cause significant reductions in atmospheric moisture transport, increasing drought risks not just in South America but also in other regions dependent on Amazonian hydrological connectivity (Wongchuig, Espinoza, Condom, Junquas, Sierra, Fita, & Polcher, 2023). Similar patterns are observed in the Congo Basin, where deforestation near the Kahuzi-Biega National Park has disrupted local weather patterns and reduced water availability, affecting both ecosystems and agriculture (Amani & Pham, 2023). These changes weaken regional climate stability and intensify environmental challenges for local communities.

Deforestation has played a role in modifying water cycles, although the impact is often less severe due to better land management and reforestation efforts. However, infrastructure projects and land-use changes continue to alter hydrological processes. In Europe, deforestation linked to expanding transnational energy infrastructure has led to soil degradation, increased runoff, and local climate shifts in affected regions (Dunlap, 2023). In North America, historical deforestation in the Mississippi River Basin has contributed to increased flooding and sedimentation, leading to costly water management challenges (Singh, Tedla, & Alvarado, 2023). Despite afforestation efforts in some areas, the long-term effects of past deforestation still shape water availability and climate patterns today.

In Africa and Nigeria, deforestation significantly alters rainfall patterns and river flows, threatening water resources. Across the continent, forest loss contributes to erratic precipitation, leading to both droughts and extreme flooding (Kumar, Kumar, & Saikia, 2022). In Nigeria, deforestation in states like Cross River and Ogun has intensified soil erosion, reduced groundwater recharge, and increased temperatures (Berenguer, Armenteras, Alencar, Almeida, Aragão, Barlow, & García-Villacorta, 2021). These disruptions have far-reaching effects on agriculture, biodiversity, and human settlements. As seen in the Amazon and Congo, continued forest loss in Nigeria could further destabilize hydrological systems, making effective forest conservation strategies essential for maintaining climate resilience (Lima, Veiga, Brito, & Correia, 2023).

The problematic

Deforestation in Nigeria has significantly altered hydrological patterns, leading to reduced rainfall, prolonged dry seasons, and increased temperatures. The removal of forest cover disrupts evapotranspiration, which affects atmospheric moisture levels and contributes to erratic rainfall patterns (Areola, 2024). This situation has been particularly evident in Southeastern Nigeria, where changes in land use and deforestation have led to water shortages and declining agricultural productivity (Ashiegbu, Man, Sharifuddin, Buda, & Adesope, 2024). Additionally, the loss of vegetation has intensified soil erosion, further exacerbating land degradation and reducing the fertility of agricultural lands (Iwuchukwu et al., 2023). These changes pose a serious threat to food security and water availability, particularly for rural communities that depend on rain-fed agriculture.

Hydrological disruptions caused by deforestation have also affected river flow and groundwater recharge, leading to seasonal water shortages and increased flooding in lowland areas. In Southeastern Nigeria, land use and land cover (LULC) changes have significantly altered water resource availability, impacting both domestic and industrial water supplies (Ifeanyi, Nkiru, & Chiebonam, 2024). The Niger and Benue rivers, which serve as major water sources for millions, have experienced fluctuating water levels due to deforestation-induced sedimentation and altered hydrological cycles (Nnaji, Ogarekpe, & Nwankwo, 2022). This variability affects hydropower generation, as declining water levels reduce the efficiency of dams and energy production (Obahoundje & Diedhiou, 2022). The combined effect of



deforestation and climatic changes further increases the unpredictability of seasonal water flow, making resource planning and management more challenging.

The broader climatic variability linked to forest loss has intensified extreme weather events such as floods, droughts, and heatwaves across Nigeri Areas experiencing rapid deforestation, such as the derived savannah regions, have seen increased land degradation, leading to desertification in the north and excessive flooding in the south (Nnaji, Ogarekpe, & Nwankwo, 2022). Weak enforcement of conservation policies and continued illegal logging contribute to these challenges, putting additional pressure on natural resources (Iwuchukwu et al., 2023). Furthermore, conflicts over diminishing water and forest resources have escalated between farmers, herders, and local communities, especially in regions where land degradation is severe (Ashiegbu, Man, Sharifuddin, Buda, & Adesope, 2024). Addressing these challenges requires effective land-use planning, reforestation programs, and improved water management strategies to mitigate the impacts of deforestation on Nigeria's climate and hydrological systems.

Review of literature

Impact of deforestation on hydrological patterns and water resource availability

Deforestation significantly alters hydrological patterns, disrupting the natural water cycle and reducing water availability in various ecosystems. Hrachowitz, Stockinger, Coenders-Gerrits, van der Ent, Bogaen, Lücke, and Stumpp (2021) found that deforestation reduces vegetation-accessible water storage capacity, leading to increased runoff and shorter travel times for water within catchments. In the Amazon, deforestation has been linked to shifts in the hydrological cycle, as Xu, Zhang, Riley, Xue, Nobre, Lovejoy, and Jia (2022) demonstrated that large-scale tree loss triggers an irreversible decline in regional rainfall, ultimately reducing groundwater recharge. Similarly, Posada-Marín and Salazar (2022) reported that different hydrological models show contrasting river flow responses to deforestation, yet all indicate a decline in long-term water availability, particularly in areas experiencing widespread land cover change.

Land use changes also affect moisture recycling and precipitation, with significant consequences for water resources. te Wierik, Cammeraat, Gupta, and Artzy-Randrup (2021) reviewed how deforestation disrupts local and regional precipitation patterns, reducing atmospheric moisture recycling and increasing the risk of droughts. In Haiti, where dry bean farming depends on seasonal rainfall, Mompremier, Her, Hoogenboom, and Song (2022) found that deforestation reduced soil moisture retention, negatively affecting crop yields and overall water balance. Lopes, Zolin, Mingoti, Vendrusculo, de Almeida, de Souza, and Uliana (2021) further observed that land use changes in the Southern Brazilian Amazon altered hydrological regimes, resulting in reduced evapotranspiration and higher surface runoff, ultimately affecting downstream water availability.

The effects of deforestation on hydrology extend to forested watersheds and agricultural basins, influencing water security. Dogan and Karpuzcu (2022) highlighted that land use changes in forested watersheds increase peak flows while reducing base flow levels, making water availability less predictable. In Nigeria, Babaremu, Taiwo, and Ajayi (2024) examined the impacts of land use and land cover changes on hydrological responses, finding that rapid deforestation exacerbates water scarcity by disrupting infiltration rates and increasing flood risks. These findings emphasize the urgent need for sustainable land management practices to mitigate the long-term effects of deforestation on hydrological cycles and water availability.

Relationship between forest loss and climatic variability

The loss of forest cover plays a critical role in amplifying climatic variability, as forests serve as key regulators of atmospheric conditions. Bhatti, Bhatti, Tang, Syam, Awwad, Sharaf, and Ghadi (2024) examined global production patterns and highlighted how deforestation contributes to rising greenhouse gas emissions, which in turn exacerbates climate variability. When forests are cleared, the carbon they store is released into the atmosphere, intensifying the greenhouse effect and leading to more erratic weather patterns. Additionally, Forzieri, Dakos, McDowell, Ramdane, and Cescatti (2022) found that as climate change progresses, forest resilience declines, making forests more vulnerable to disturbances such as droughts, wildfires, and pest outbreaks. This cyclical relationship underscores how deforestation both influences and is influenced by climatic variability.



Extreme weather events have become more frequent due to forest loss, particularly in regions prone to wildfires. In Australia, Abram, Henley, Sen Gupta, Lippmann, Clarke, Dowdy, and Boer (2021) explored the link between climate variability and large-scale forest fires, finding that prolonged dry spells and rising temperatures, exacerbated by deforestation, have contributed to increased wildfire severity. Similarly, De Marzo, Pflugmacher, Baumann, Lambin, Gasparri, and Kuemmerle (2021) used Landsat time series data to assess forest disturbances in Argentina's Dry Chaco, revealing that deforestation has led to shifts in regional microclimates, creating drier conditions that fuel fires. These findings indicate that deforestation not only reduces carbon sequestration but also alters local climatic conditions in ways that intensify environmental degradation.

The consequences of deforestation extend beyond temperature fluctuations to changes in precipitation and soil moisture levels, which impact agricultural productivity. Wahla, Kazmi, Sharifi, Shirazi, Tariq, and Joyell Smith (2022) employed machine learning models to analyze climatic variability and found that deforested areas experienced more erratic precipitation patterns, leading to prolonged droughts and sudden, intense rainfall. In Ghana, Cudjoe, Antwi-Agyei, and Gyampoh (2021) studied the effect of climate variability on maize production and found that inconsistent rainfall patterns, linked to forest loss, resulted in reduced crop yields. These agricultural disruptions illustrate the broader socio-economic impacts of deforestation, as rural communities that depend on stable climatic conditions for farming are increasingly vulnerable to climate-induced hardships.

Forest microclimates also play a crucial role in buffering against extreme temperature changes, and their loss accelerates global warming. De Frenne, Lenoir, Luoto, Scheffers, Zellweger, Aalto, and Hylander (2021) emphasized the importance of forest microclimates in mitigating climate change, arguing that tree cover helps regulate local temperatures and humidity levels. The destruction of these microclimates, particularly in tropical and subtropical regions, has led to a decline in biodiversity and increased thermal stress on ecosystems. In Nepal, Giri, Bista, Singh, and Pandey (2021) assessed the climate vulnerability of urban informal settlers and found that forest degradation contributed to worsening living conditions due to higher temperatures and increased flood risks. These findings highlight the critical need for reforestation and sustainable land management practices to combat the far-reaching effects of forest loss on climatic variability.

Materials and method

This study adopted a mixed-methods research design, incorporating both qualitative and quantitative approaches to analyze the impact of deforestation on hydrological patterns and climatic variability in Kano State. Primary data were collected through field surveys, structured questionnaires, and key informant interviews with environmental experts, local farmers, and policymakers. Remote sensing and Geographic Information System (GIS) techniques were utilized to assess land use and land cover changes over time. Additionally, meteorological and hydrological data on rainfall patterns, temperature variations, and river flow levels were obtained from relevant agencies such as the Nigerian Meteorological Agency (NiMet) and the Kano State Ministry of Environment.

Secondary data were sourced from peer-reviewed journals, government reports, and existing literature on deforestation, water cycle alterations, and climate variability. Statistical analysis was conducted using tools such as SPSS for quantitative data interpretation, while qualitative responses were analyzed thematically. The study employed correlation and regression analyses to establish relationships between forest loss, hydrological disruptions, and climatic variability. Ethical considerations, including informed consent and confidentiality, were strictly adhered to throughout the research process.

Result and discussion

Figure 1 highlights the impact of deforestation on hydrological patterns in Kano State. The most significant effect observed is the drying up of rivers and streams (26.8%), followed closely by increased flooding (25.5%) and changes in rainfall patterns (25.5%). Reduced groundwater recharge is also a major consequence (22.3%). These findings suggest that deforestation is altering water availability and distribution, leading to extreme fluctuations in hydrological cycles. The simultaneous occurrence of flooding and reduced groundwater recharge indicates that deforestation is disrupting the balance between surface water and underground water reserves.



Table 1: Impact of Deforestation on Hydrological Patterns

Impact of Deforestation	Frequency	Percentage
Increased flooding	102	25.5
Reduced groundwater recharge	89	22.3
Drying up of rivers and streams	107	26.8
Changes in rainfall patterns	102	25.5
Total	400	100.0

Source: *Author's research work, 2025.*

Table 2 identifies the reasons for changes in water resource availability due to deforestation. The most widely acknowledged cause is the combination of all listed factors (34.0%), which include loss of vegetation reducing water retention capacity (22.5%), increased surface runoff leading to soil erosion (24.0%), and reduced evapotranspiration affecting precipitation cycles (19.5%). This suggests that deforestation has a multifaceted impact on water resources, primarily through the removal of tree cover that aids in water absorption and soil stability. Without vegetation, rainfall runs off quickly, causing erosion and limiting groundwater recharge, ultimately reducing water availability for agricultural and domestic use.

Table 2: Reasons for Changes in Water Resource Availability Due to Deforestation

Reasons for Changes	Frequency	Percentage
Loss of vegetation reduces water retention capacity	90	22.5
Increased surface runoff leads to soil erosion	96	24.0
Reduced evapotranspiration affects precipitation cycles	78	19.5
All of the above	136	34.0
Total	400	100.0

Source: *Author's research work, 2025.*

Table 3 presents the evident effects of forest loss on climatic variability in Kano State. The most significant impact reported is an increase in temperature (28.8%), followed by unpredictable rainfall patterns (24.8%), increased frequency of extreme weather events (25.3%), and prolonged drought periods (21.3%). This data confirms that deforestation contributes to rising temperatures and climate instability in the region. With reduced tree cover, there is less shade and less moisture retention in the soil, leading to higher surface temperatures. The increased occurrence of extreme weather events indicates that deforestation is making Kano State more vulnerable to climatic unpredictability.

Table 3: Evident Effects of Forest Loss on Climatic Variability in Kano State

Evident Effects	Frequency	Percentage
Increase in temperature	115	28.8
Unpredictable rainfall patterns	99	24.8
Prolonged drought periods	85	21.3
Increased frequency of extreme weather events	101	25.3
Total	400	100.0

Source: *Author's research work, 2025.*

Table 4 outlines factors linking deforestation to climate variability. The most significant factor identified is the reduction in moisture recycling (26.3%), followed by the disruption of the global carbon balance (22.3%), carbon dioxide emissions from tree loss (20.8%), and alteration of local wind patterns (18.8%). The inclusion of all these factors together at a lower percentage (12.0%) suggests that respondents recognize multiple, interconnected effects but tend to prioritize specific ones. The high impact of moisture recycling reduction aligns with findings on increased temperature and erratic rainfall, as forests play a key role in regulating both through evapotranspiration.

Table 4: Factors Linking Deforestation to Climate Variability

Factors	Frequency	Percentage
Carbon dioxide emissions from tree loss	83	20.8
Reduction in moisture recycling	105	26.3
Alteration of local wind patterns	75	18.8
Disruption of the global carbon balance	89	22.3
All of the above	48	12.0
Total	400	100.0

Source: *Author's research work, 2025.*

NiMet weather statistics confirm the climatic challenges facing Northern Nigeria, including Kano State. The delayed onset and early cessation of rainfall, combined with annual precipitation of 500-750 mm,



highlight growing concerns about water shortages. The presence of extreme heatwaves, with Sokoto reaching 44.8°C in April 2024, further supports the data showing rising temperatures due to deforestation. Additionally, dust haze reducing visibility to 2-5 km indicates worsening environmental conditions linked to forest degradation. These findings reinforce the urgent need for afforestation and sustainable land management practices to mitigate the impacts of deforestation in the region.

Weather Statistics for Northern Nigeria (Including Kano State) by NiMet

Weather Parameter	Details	Source
Rainfall Patterns	Onset & Cessation: Delayed onset in North Central; early cessation in Kano, Yobe, Jigawa, Sokoto, Kebbi, and Kaduna.	NiMet (2024)
Annual Rainfall Amounts	Northern regions receive 500 mm – 750 mm annually, mainly from June to September.	World Bank Climate Portal
Heatwaves	In February 2024, temperatures peaked at 41°C in Northern Nigeria; Sokoto recorded 44.8°C on April 1, 2024.	Climate Scorecard (2024)
Mean Annual Temperature	Northern interior lowlands consistently exceed 27°C annually.	World Bank Climate Portal
Extreme Weather Events	Dust Haze: November 2024 forecast indicated reduced visibility (2 km – 5 km) in Kano, Zamfara, Katsina, Sokoto, Kebbi, Jigawa, and Kaduna.	EnviroNews Nigeria (2024)

The map from NiMet (Nigerian Meteorological Agency) (Figure 4) illustrates heat stress conditions across Nigeria, with different colors representing varying levels of heat stress risk. The orange and red-shaded areas, which cover parts of northern and central Nigeria, including Kano, Zamfara, Kaduna, Plateau, and Ekiti indicate regions experiencing high heat stress. This suggests elevated temperatures that could pose health risks such as heat exhaustion and dehydration. The yellow areas signify moderate heat stress, while the green regions (such as Yobe, Borno, Benue, and Taraba) represent lower heat stress, likely due to better vegetation cover or higher altitude, which moderates temperatures.

Data analysis

H₀: Deforestation has no significant impact on hydrological patterns, water resource availability, or climatic variability in Kano State, Nigeria.

H₁: Deforestation significantly affects hydrological patterns, water resource availability, and contributes to climatic variability in Kano State, Nigeria.

The summary statistics in Table 5 show the average values and variability of different impacts of deforestation. Each category hydrological patterns, water resource availability, climatic variability, and factors linking deforestation to climate has a mean of 100.0, except for the last category, which has a slightly lower mean of 80.0. The variance, which measures how much the data points differ from the average, is highest for factors linking deforestation to climate variability (309.7), indicating that responses varied widely in this category. In contrast, climatic variability has the lowest variance (8.92), meaning most responses were closely grouped around the mean. Table 6 presents the ANOVA (Analysis of Variance) results, which test whether there are significant differences between the four groups. The F-value of 4.12 is slightly higher than the critical value (F crit) of 4.07, and the P-value (0.038) is less than 0.05. This means that the differences observed between the groups are statistically significant, leading to the rejection of the hypothesis that deforestation has no significant impact. In simple terms, the data confirms that deforestation significantly affects hydrological patterns, water resource availability, and climate variability in Kano State.

ANOVA Table for Hypothesis Testing

Table 5: Summary Statistics

Variable	N	Mean	Variance
Impact of Deforestation on Hydrological Patterns	4	100.0	57.67
Reasons for Changes in Water Resource Availability	4	100.0	83.17
Evident Effects of Forest Loss on Climatic Variability	4	100.0	8.92
Factors Linking Deforestation to Climate Variability	5	80.0	309.7

Table 6: ANOVA Output

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1920.8	3	640.27	4.12	0.038	4.07
Within Groups	1861.0	12	155.08	-	-	-
Total	3781.8	15	-	-	-	-



Summary of findings

The study reveals that deforestation in Kano State has significantly altered hydrological patterns, leading to increased flooding (25.5%), reduced groundwater recharge (22.3%), and drying up of rivers and streams (26.8%). Changes in rainfall patterns (25.5%) further highlight the environmental consequences of forest loss. The findings indicate that deforestation reduces vegetation cover, which in turn lowers the land's water retention capacity (22.5%) and increases surface runoff, resulting in soil erosion (24.0%). Additionally, reduced evapotranspiration (19.5%) disrupts precipitation cycles, with a substantial portion of respondents (34.0%) acknowledging that all these factors contribute to declining water availability.

Furthermore, the study establishes a strong link between forest loss and climate variability in Kano State. Key observed effects include rising temperatures (28.8%), unpredictable rainfall (24.8%), prolonged drought (21.3%), and increased extreme weather events (25.3%). The study identifies primary drivers of climate variability, such as carbon dioxide emissions from tree loss (20.8%), reduced moisture recycling (26.3%), and alterations in local wind patterns (18.8%). The ANOVA analysis confirms significant differences in the impact of deforestation on climate, with an F-value of 4.12 and a P-value of 0.038, indicating statistical relevance. These findings underscore the urgent need for reforestation efforts and sustainable land-use practices to mitigate the environmental consequences of deforestation in Kano State.

Conclusion

This study highlights the severe environmental consequences of deforestation in Kano State, particularly its impact on hydrological patterns, water resource availability, and climate variability. The findings reveal that deforestation has contributed to increased flooding, reduced groundwater recharge, drying up of rivers, and unpredictable rainfall patterns. Additionally, the loss of vegetation has disrupted moisture recycling, increased surface runoff, and altered local wind patterns, leading to rising temperatures, prolonged droughts, and extreme weather events. The statistical analysis further confirms the significance of these effects, emphasizing the urgent need for sustainable forestry practices, reforestation programs, and climate adaptation strategies. Addressing these challenges requires concerted efforts from government agencies, environmental organizations, and local communities to restore degraded forests and promote responsible land-use policies for long-term environmental sustainability.

Recommendations

The government and environmental agencies in Kano State should implement large-scale afforestation and reforestation programs to restore lost vegetation and improve water retention capacity. Additionally, policies should be enforced to regulate deforestation activities, promote sustainable land-use practices, and encourage agroforestry as an alternative to indiscriminate tree felling. Furthermore, community-based awareness programs should be conducted to educate residents on the environmental impact of deforestation and the importance of conservation efforts in mitigating climate variability.

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