Malaria Incidence in Nigeria: A Geospatial Analysis

Course: i3 Project Interdisciplinary

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Abstract

Malaria is a major public health concern in Nigeria, particularly affecting children under five and pregnant women. This harness Geographic Information Systems (GIS) and interactive story to analyze malaria distribution across Nigeria's36 states and the Federal Capital Territory from 2010 to 2020. Data on temperature, rainfall, land use, population, and malaria cases were collected at the national level and disaggregated to the state level. By integrating environmental and demographic factors, we identify high-risk areas and track seasonal trends in malaria transmission. The findings highlight the influence of climate and population density on malaria prevalence, providing valuable insights for targeted interventions. This study offers a data-driven approach to malaria surveillance, supporting policymakers in deisigning effective public health strategies to reduce the disease burden. The results emphasize the need for region-specific interventions to protect vulnerable populations and enhance malaria control efforts in Nigeria.

Keywords: Malaria, GIS, Public Health, Nigeria, Spati0-Temporal Analysis.

1.0 Introduction

Nigeria bears one of the highest malaria burdens globally, with the disease posing a significant public challenge, particularly for children under five and pregnant women. The persistence of malaria in the country is driven by favorable environmental conditions, such as hot temperature, heavy rainfall, and abundant breeding sites for mosquitoes. Additionally, limited access to healthcare services, especially in rural areas, exacerbates the situation, leading to increased morbidity and mortality (Abdukarim et al., 2023). Despite various interventions strategies, including the widespread distribution of insecticides-treated nets (ITNs), indoors residual spraying, and access to antimalarial medications, malaria remains endemic, especially in tropical and densely populated regions (Adepoju & Akpan, 2017).

This study leverages advanced Geographic information Systems (GIS) techniques and interactive mapping to analyze malaria's spatial and temporal distribution across Nigeria. By integrating environmental, demographic, and healthcare access data, our research aims to:

- Identify high-risks regions where malaria prevalence is most severe

- Examine the role of environmental factors such as temperature, rainfall, and land use in malaria transmission, and
- Evaluate the impact of healthcare accessibility and preventive measures on malaria incidence.

By synthesizing data from multiple sources and employing a geospatial approach, this study builds on previous research (Nakakana et al., 2020) and provides new insights into the transmission dynamics of malaria. The findings will help policymakers and healthcare practitioners develop more effective, evidence-based stratagies to mitigate malaria's impact and enhance targeted interventions in Nigeria.

2.0 Materials and Methods

2.1 Data Collection

This study integrates multiple datasets to analyze malaria distribution in Nigeria, focusing on environmental, demographic, epidemiological factors. The data sources are as follows:

1. **Population Data:**
   State-level population figures were derived from Nigeria's National Population Census. This data helped in understanding population density and its correlation with malaria prevalence.
2. **Land Use Land Cover (LULC) Data:**
   Satellite imagery and national surveys were used to classify regions into urban, agricultural, forested, or waterlogged areas. These classifications provide insight into the ecological conditions that mosquito breeding and malaria transmission (Adepoju & Akpan, 2017)
3. **Environmental Data:**
   Temperature: Data from the Nigeria Meteorological Agency (NMET) was analyzed, focusing on the 20-32° range, which is ideal for mosquito breeding (WHO, 2023).
   Rainfall: Meteorological records were used to identify areas with stagnant water, a crucial factor in mosquito reproduction and malaria transmission.
4. **Malaria Incidence Data:**
   Malaria case reports were obtained from the Malaria Atlas Project
5. **Administrative Boundaries:**
   To ensure accurate geographic representation, World Bank geographic shapefiles were used to map Nigeria's 36 states and the Federal Capital Territory.

By integrating these diverse datasets, this study employs a geospatial approach to identify malaria risk factors, assess seasonal variations, and support targeted interventions strategies.

2.2 Data Processing and Analysis

To analyze malaria distribution effectively. We employed a structured approach to data processing and disaggregation. This ensured that the integration of environmental, population, and epidemiological data provided accurate, state-level insights into malaria risk factors.

2.3 Data Integration

We combined all collected datasets using Python-based data processing tools, including **pandas** for tabular data manipulation, **geopandas** for spatial data analysis, and **rasterio** for handling geospatial raster data. These tools allowed seamless merging and alignment of diverse data sources, ensuring consistency in spatial and temporal coverage.

Population Disaggregation

Since national population figures were available at the country level, we proportionally distributed them across Nigeria's 36 states and the Federal Capital Territory using census data. This step ensured that population density variations were accurately represented at the state level.

Weighting by Land use and Land Cover (LULC)

Recognizing that malaria transmission is influenced by land use patterns, we applied weighting factors to population estimates based on LULC classifications. Urban and agricultural areas were given higher weights due to higher human activity and increased mosquitoes exposure risks, while forested and rural regions were assigned lower weights. This method provided a more realistic representation of malaria risk distribution.

Environmental Risk Calculation

To assess malaria risk, we developed an **Environmental Risk Index (ERI)** by integrating temperature and rainfall data. Given that malaria transmission is overly sensitive to climatic conditions, we assigned risk scores based on:

- **Temperature:** Areas within the 20-3°C range (Optimal for mosquito breeding) received higher scores
- **Rainfall:** Regions with persistent stagnant water, identified through meteorological records were marked as high-risk zones.

By combining these factors, we created a composite index that mapped malaria vulnerability across states.

Malaria Incidence Allocation

Finally, we allocated national malaria case numbers to each state based on the computed risk weights. This method ensured that malaria burden estimates were not only based on raw case reports but also adjusted for environmental and population factors. The final dataset allowed for a more accurate representation of malaria distribution patterns across Nigeria (Abdulkarim et al., 2023; Okunola & Oyeyemi, 2019).

This analytical approach enhances our understanding of malaria hotspots and helps policymakers design more effective, data-driven interventions strategies.

2.3 GIS Techniques and Enviornmental Factors

To analyze malaria distribution and trends across Nigeria, we employed various Geographic Information Systems (GIS) techniques and examined key environmental factors influencing underlying malaria transmission. These methods provided valuable insights into high-risk areas and the underlying conditions driving malaria prevalence.

2.3.1 GIS Techniques

2.3.1.1 Hotspot Mapping

Using ArcGIS online, we conducted spatial cluster analysis to identify malaria hotspot-regions where cases numbers were significantly higher than expected. This technique helped pinpoint areas requiring urgent intervention and allowed for targeted resource allocation in malaria control efforts.

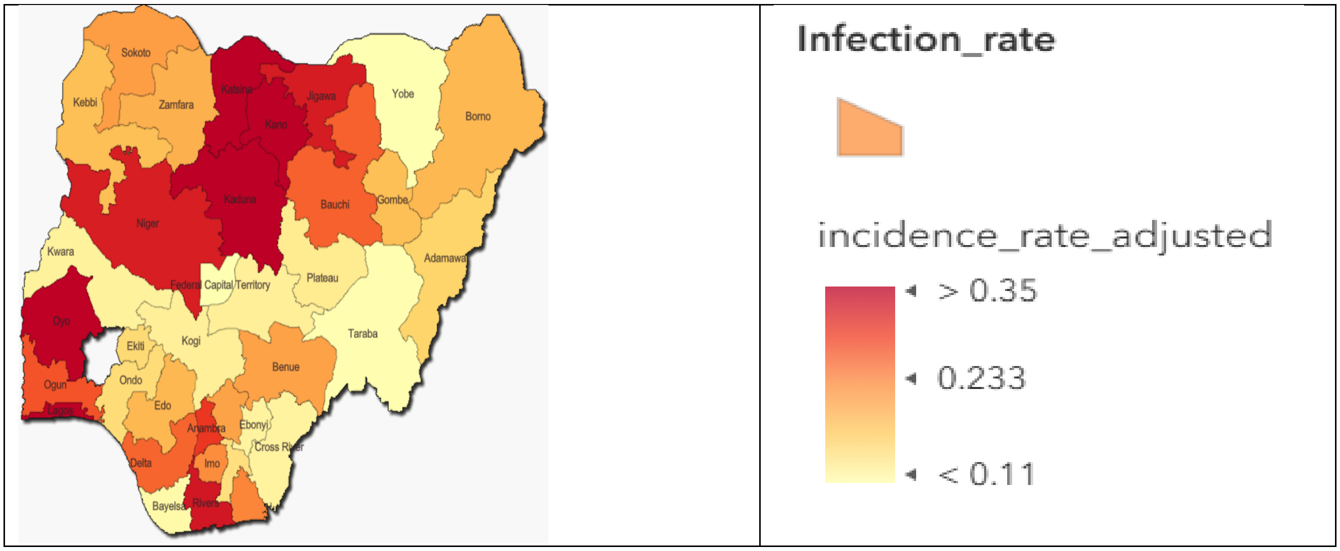

***Fig 2.1:** Malaria risk level*

2.3.1.2 Temporal Trend Analysis

To understand how malaria incidence evolved over time, we created a time-series chart covering the period from 2010 to 2020. These maps visualized changes in malaria prevalence at the state level, highlighting seasonal fluctuations and long-term trends. This analysis enabled us to track the impact of environmental factors and public health interventions over the years.

2.3.1.3 Interactive Visualization

To enhance data accessibility, we developed dashboard and story maps featuring multiple visualization tools:

- **Map**: for comparing malaria incidence across states
- **Bar charts**: to show the most affected areas
- **Pie charts**: To chow the less affected areas
- **Slider**: to visualize through the years

By integrating GIS and interactive tools, this study provides a dynamic, data-driven approach to understanding malaria transmission in Nigeria.

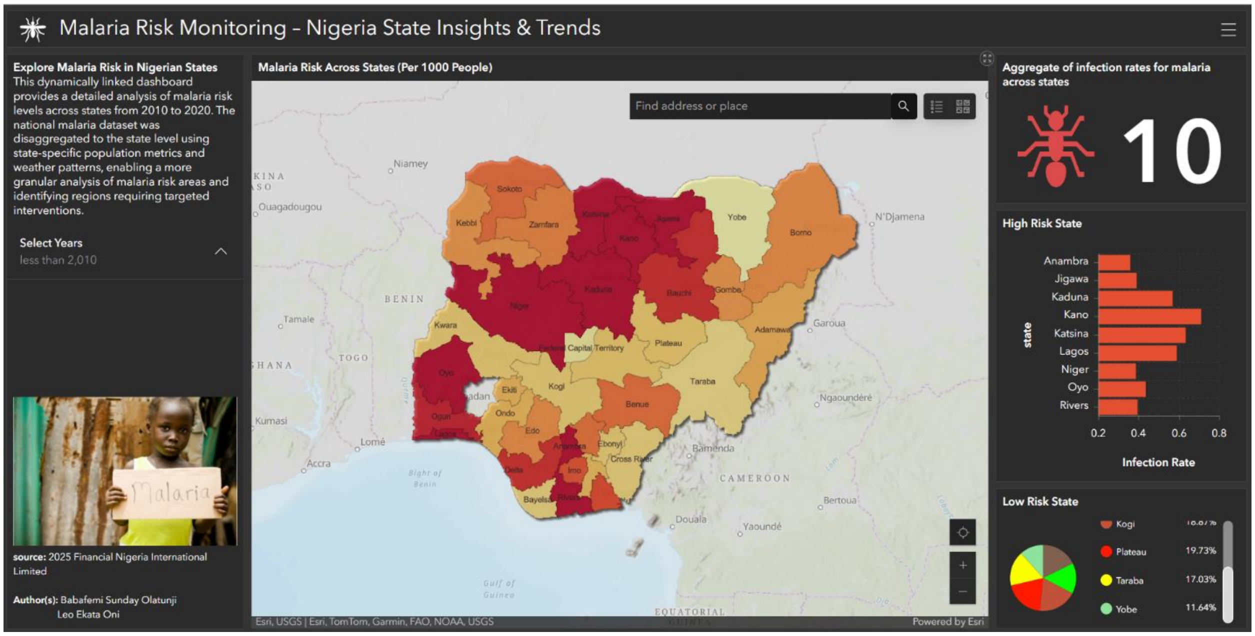

Fig: 2.2: A dashboard displaying the high and low risk states

2.3.2 Environmental Factors Influencing Malaria Transmission

Malaria transmission in Nigeria is strongly influenced by environmental conditions that affect mosquito breeding and survival. Key factors include:

1. **Rainfall**
   Rainfall creates stagnant water pools, which serve as mosquito breeding sites. Areas with moderate to high rainfall, in the southern and central regions, report higher malaria incidences. However, excessive rainfall can sometimes flush out breeding sites, temporarily reducing mosquito populations.

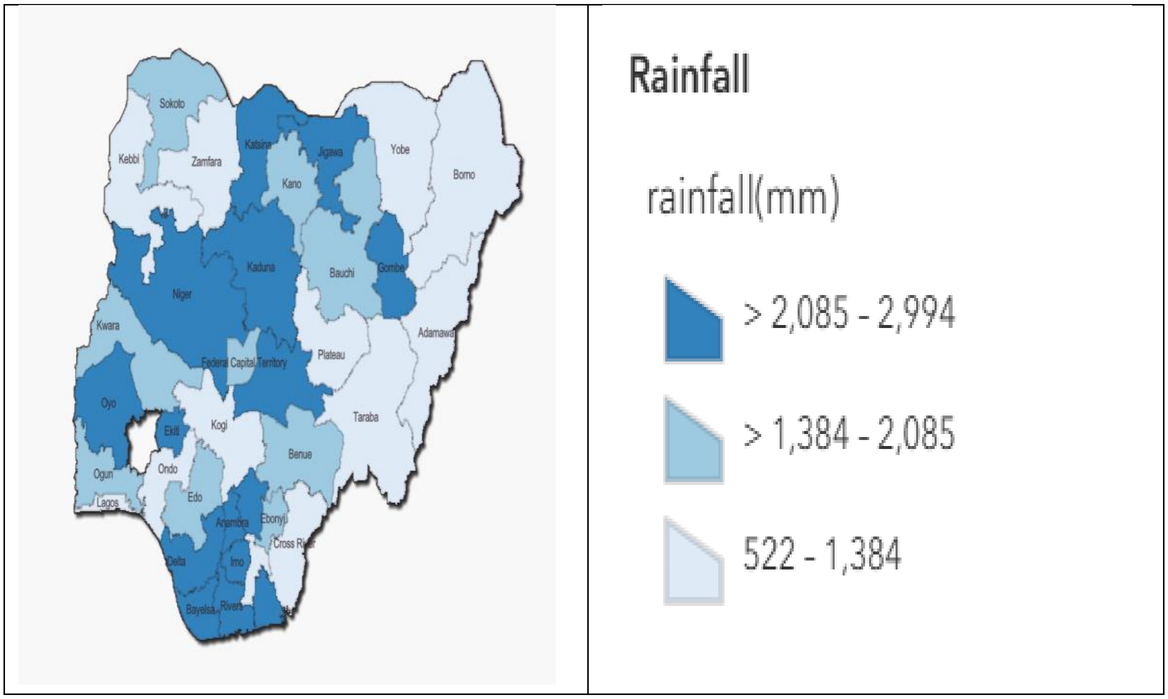

Fig 2.3: *Rainfall across the states*

2. **Temperature**

   Malaria transmission is most efficient within the 20-30°C range, where mosquitoes breed rapidly, and the plasmodium parasite completes its life cycle faster (WHO, 2023), regions consistently within this temperature range experience higher malaria prevalence.

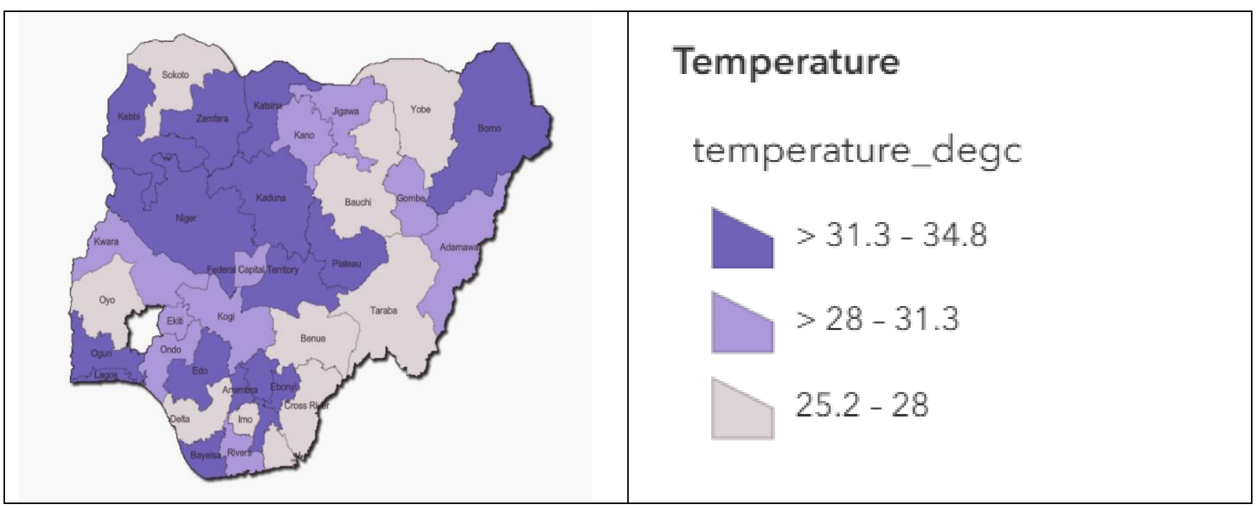

Fig 2:4 *Temperature across states*

3.0 Results

3.1 Spatial Patterns

Our hotspot mapping revealed significant spatial variation in malaria incidence across Nigeria. States in north and central regions, such as Kano, Kaduna, Niger, consistently exhibited higher malaria rates. These areas are characterized by environmental conditions favorable for malaria transmission, including temperature ranges between 20-30°C, frequent rainfall, and large areas of agricultural land where mosquitoes breed. The high population density in these regions also contributes to increased human-mosquito interactions. In contrast, urban centers like Lagos and other southern cities showed notably lower malaria incidence rates, due to better healthcare infrastructure, widespread distribution of insecticide-treated nets (ITNs), and efficient malaria control programs (Nakana et al., 2020). Additionally, our Land use and Land cover (LULC) weighing that region with intensive agriculture, especially those in the middle-belt and northern regions, are particularly vulnerable to malaria. These areas often have artificial water bodies created by irrigation practices, and which provide ideal breeding grounds for mosquitoes.

3.2 Temporal trends

Analysis of malaria incidence data from 2010 to 2020 revealed important temporal patterns in the spread of malaria.

3.2.1 Yearly Fluctuations

Some rates, particularly in the south and southwest, demonstrated a gradual decrease in malaria cases, due to improvements in malaria prevention and control measures, including the distribution of ITNs and indoor residual spraying. However, many other states experienced periodic spikes in malaria incidence, often linked to unusual weather events, such as excessive rainfall or drought, which create additional breeding sites for mosquitoes (WHO, 2023; Okunola & Oyeyemi, 2019). These fluctuations highlight the importance of weather patterns in influencing malaria transmission and the need for timely interventions in response to climate variations. In general, regions with erratic weather experienced more volatile malaria incidence patterns.

The temporal analysis further emphasizes the need for continuous monitoring and adaptable malaria control strategies that respond to seasonal and climate-induced changes.

4.0 Discussion

This study provides crucial insights into the spatial and temporal patterns of malaria transmission in Nigeria, emphasizing the importance of environmental and population factors in shaping malaria prevalence. Our spatial analysis revealed that northern and central states, such as Kano, Kaduna, and Niger, have consistently high malaria rates. These regions, characterized by warm temperatures and frequent rainfall, provide ideal conditions for mosquito breeding. Furthermore, agricultural activities, especially in waterlogged areas, exacerbate the risk. In contrast, urban centers like Lagos exhibit lower malaria incidence, reflecting the benefits of improved healthcare access, sanitation, and more effective malaria control measures.

5.0 Public Health Implication

Based on our findings, several key recommendations emerge for improving malaria control and prevention in Nigeria:

1. **Targeted Intervention:** Resources should be focused on high-risk regions, particularly in the northern and central Nigeria, where malaria incidence is consistently high. These areas, with favorable environmental conditions for mosquito breeding, require intensified efforts, including the distribution of insecticides-treated nets (ITNs), indoor residual spraying, and access to diagnostic and treatment services.
2. **Seasonal Preparedness:** Malaria transmission is highly seasonal, with peaks during rainy season. To reduce transmission, it is essential to strengthen preventive measures ahead of the rainy season. This could include preemptive distribution of ITNs, public health education on malaria prevention, and surveillance for early detection of outbreaks
3. **Data-Driven Strategies:** Real-time GIS tools should be leveraged to monitor malaria incidence and environmental conditions. These tools can provide dynamic, localized data, allowing for quick responses to emerging outbreaks and the identification of high-risk areas in need of intervention.
4. **Cross-Sector Collaboration:** Given the strong link between agriculture and malaria transmission, public health interventions should be integrated with environmental and agricultural strategies. Collaborating with agricultural agencies can help address broader factors, such as water management and land use practices, that contribute to malaria risk (Adepoju & Akpan, 2017)

By implementing these strategies, Nigeria can better manage malaria transmission and work toward reducing its burden on vulnerable populations.

6.0 Limitations

Our study encountered several limitations

- **Data Gaps:** The lack of monthly data hindered a more detailed analysis of seasonal fluctuations and the impact of specific weather events on transmission patterns

- **Scale:** While our analysis at the state level provided useful insights, a more detailed sub-state level analysis could reveal finer patterns of malaria distribution and risk.

Future research should focus on integrating granular temporal data, such as monthly incidence and real-time weather data, and explore advanced predictive modeling techniques to forecast malaria outbreaks. This would improve early warning systems and resource allocation.

7.0 Conclusion

This study highlights the power of Geographic Information System (GIS) and interactive story mapping in understanding and addressing malaria transmission in Nigeria. By integrating multiple datasets; environmental, demographic, and incidence data. We have successfully identified key malaria hotspots and seasonal trends, providing valuable insights into the region's most at risk. Our findings reveal how environmental factors like temperature and rainfall, combined with demographic patterns such as population density and land use, significantly contribute to malaria transmission.

The use of GIS tools enabled us to not only identify high-risk areas but also track the changing patterns of malaria incidence over time, helping to recognize seasonal fluctuations and the impact of weather events on malaria outbreaks. This approach offers a dynamic and scalable method for monitoring disease spread and predicting future trends, making it an effective tool for real-time decision-making in public health.

References

- Abdulkarim, I. A., Yakudima, I. I., Abdullahi, J. G., & Adamu, Y. M. (2023). Geographical Analysis of Malaria in Nigeria – Spatiotemporal Patterns of National and Subnational Incidence. In Y. Adewoyin (Ed.), Health and Medical Geography in Africa: Global Perspectives on Health Geography. Springer, Cham. https://doi.org/10.1007/978-3-031-41268-4_9

- Adepoju, K., & Akpan, G. (2017). Historical Assessment of Malaria Hazard and Mortality in Nigeria-Cases and Deaths: 1955–2015. International Journal of Environment and Bioenergy, 30-46. Retrieved from https://www.nature.com/articles/s41598-019-53814-x

- Nakakana, U. N., Mohammed, I. A., & Onankpa, B. O. (2020). Validation of the Malaria Atlas Project Maps and Development of a New Map of Malaria Transmission in Sokoto, Nigeria: A Cross-Sectional Study Using Geographic Information Systems. Malaria Journal, 19, 149. https://doi.org/10.1186/s12936-020-03214-8

- Okunola, O. A., & Oyeyemi, O. T. (2019). Spatio-temporal Analysis of Association Between Malaria Incidence and Environmental Predictors in Nigeria. Scientific Reports, 9, 17500. https://doi.org/10.1038/s41598-019-53814-x

- World Health Organization. (2023). Report on Malaria in Nigeria 2022. Brazzaville: WHO Regional Office for Africa. Retrieved from https://www.afro.who.int/sites/default/files/2023-08/WEB_7784%20WMR%20-%20Nigeria%202022_2408.pdf

Gitlab Link

https://git.sbg.ac.at/wt24_856.165/malaria-incidence-in-nigeria-a-geospatial-analysis

Story Map Link

https://geoportal22s.zgis.at/portal/apps/storymaps/stories/adb2b64fc6ce4c9eb186a9d026ec240e

GitHub Link

https://github.com/euphoricking/malaria-incidence-nigeria

Malaria Incidence Disaggregation

```
# Import necessary libraries
import pandas as pd
import geopandas as gpd
import numpy as np
import matplotlib.pyplot as plt
import rasterio
from rasterio.plot import show
from shapely.geometry import Point


# Load population data
pop_df = pd.read_csv("data/nigeria_population.csv")
# Expected columns: ['State', 'Population']

# Load administrative boundaries (shapefile)
states_gdf = gpd.read_file("data/nigeria_states.shp")
# Ensure the state names in the shapefile match those in the
population data

# Load LULC data (this can be a shapefile or raster; here we assume a
shapefile)
lulc_gdf = gpd.read_file("data/nigeria_lulc.shp")
# Expected columns: ['State', 'LULC_Type'] where LULC_Type might be
categories like 'Urban', 'Agricultural', etc.

# Load environmental data (e.g., average temperature and rainfall per
state)
env_df = pd.read_csv("data/nigeria_environment.csv")
# Expected columns: ['State', 'Avg_Temperature', 'Avg_Rainfall']

# Merge population data into the states GeoDataFrame
states_gdf = states_gdf.merge(pop_df, on="State", how="left")
# Merge environmental data
states_gdf = states_gdf.merge(env_df, on="State", how="left")

# Check the head of the merged GeoDataFrame
states_gdf.head()


# Define a mapping of LULC types to weights
lulc_weight_mapping = {
    "Urban": 1.5,
    "Agricultural": 1.3,
    "Forested": 1.0,
    "Water": 0.5
}
```

```python
# Assume lulc_gdf has columns: ['State', 'LULC_Type']
lulc_gdf["LULC_Weight"] =
lulc_gdf["LULC_Type"].map(lulc_weight_mapping)

# Merge LULC weight into states_gdf
states_gdf = states_gdf.merge(lulc_gdf[["State", "LULC_Weight"]],
on="State", how="left")

# If any state is missing a weight, fill with a default (e.g., 1.0)
states_gdf["LULC_Weight"].fillna(1.0, inplace=True)


# Define temperature parameters
optimal_temp = 26.0
temp_range = 6.0  # a constant to normalize deviation

# Normalize temperature score (closer to optimal yields higher score)
states_gdf["Temp_Score"] = 1 - (abs(states_gdf["Avg_Temperature"] -
optimal_temp) / temp_range)
states_gdf["Temp_Score"] = states_gdf["Temp_Score"].clip(lower=0)  #
ensure non-negative

# Normalize rainfall score
max_rainfall = states_gdf["Avg_Rainfall"].max()
states_gdf["Rain_Score"] = states_gdf["Avg_Rainfall"] / max_rainfall

# Compute combined environmental risk score
states_gdf["Env_Risk"] = states_gdf["LULC_Weight"] *
states_gdf["Temp_Score"] * states_gdf["Rain_Score"]


national_malaria_incidence = 500000

# Compute state weight
states_gdf["State_Weight"] = states_gdf["Population"] *
states_gdf["Env_Risk"]

# Compute total weight across all states
total_weight = states_gdf["State_Weight"].sum()

# Allocate malaria cases to each state proportionally
states_gdf["Allocated_Cases"] = (states_gdf["State_Weight"] /
total_weight) * national_malaria_incidence


# Visualize the allocated malaria cases using a choropleth map
fig, ax = plt.subplots(1, 1, figsize=(12, 8))
states_gdf.plot(column="Allocated_Cases", cmap="OrRd", linewidth=0.8,
ax=ax, edgecolor="0.8", legend=True)
ax.set_title("Allocated Malaria Cases by State in Nigeria")
```

```
plt.axis("off")
plt.show()


# Optionally, export the resulting GeoDataFrame to a new shapefile or
CSV
states_gdf.to_file("output/nigeria_malaria_allocated.shp")
states_gdf.drop(columns="geometry").to_csv("output/nigeria_malaria_all
ocated.csv", index=False)
```

Malaria Incidence Dashboard

```
import dash
from dash import dcc, html, Input, Output
import dash_leaflet as dl
import dash_bootstrap_components as dbc
import plotly.express as px
import pandas as pd
from sqlalchemy import create_engine, text


# Database connection
db_url =
"postgresql://postgres:password@localhost:5432/malaria_incidence"
engine = create_engine(db_url)


# Initialize the Dash app with Bootstrap theme for styling
app = dash.Dash(__name__, external_stylesheets=[dbc.themes.BOOTSTRAP])


# Layout for the dashboard
app.layout = html.Div([
    html.H1("Malaria Incidence Dashboard", style={"textAlign":
"center"}),

    # Filters Section
    html.Div([
        html.Label("Select Year:"),
        dcc.Dropdown(
            id="year-filter",
            placeholder="Select a year",
        ),
        html.Label("Select Indicator:"),
        dcc.Dropdown(
            id="indicator-filter",
            options=[
                {"label": "Mortality Rate (Adjusted)", "value":
```

```
"mortality_rate_adjusted"},
                {"label": "Incidence Rate (Adjusted)", "value":
"incidence_rate_adjusted"},
                {"label": "Infection Prevalence (Adjusted)", "value":
"infection_prevalence_adjusted"},
                {"label": "Effective Treatment (Adjusted)", "value":
"effective_treatment_adjusted"}
            ],
            value="incidence_rate_adjusted",
        ),
        html.Label("Select State:"),
        dcc.Dropdown(
            id="state-filter",
            placeholder="Select a state",
        ),
    ], style={"marginBottom": "20px", "width": "60%", "margin": "0
auto"}),

    # KPI Cards Section
    html.Div([
        dbc.Row([
            dbc.Col(dbc.Card([
                dbc.CardBody([
                    html.H4("Total Incidence", className="card-
title"),
                    html.H2(id="kpi-card-1", className="card-text")
                ])
            ], color="info", inverse=True), width=4),
            dbc.Col(dbc.Card([
                dbc.CardBody([
                    html.H4("Total Mortality", className="card-
title"),
                    html.H2(id="kpi-card-2", className="card-text")
                ])
            ], color="danger", inverse=True), width=4),
            dbc.Col(dbc.Card([
                dbc.CardBody([
                    html.H4("Effective Treatment", className="card-
title"),
                    html.H2(id="kpi-card-3", className="card-text")
                ])
            ], color="success", inverse=True), width=4),
        ])
    ], style={"marginBottom": "20px"}),

    # Base Map Section
    html.Div([
        html.H4("Choropleth Map: Malaria Indicator Distribution",
style={"textAlign": "center"}),
```

```
        dl.Map(
            center=[9.0820, 8.6753],  # Approximate center of Nigeria
            zoom=6,
            children=[
                dl.TileLayer(),
                dl.GeoJSON(
                    id="choropleth",
                    data={},  # Data will be loaded dynamically via
callbacks
                    zoomToBounds=True,
                    hoverStyle={"weight": 3, "color": "red",
"dashArray": ""},
                    options={"onEachFeature": "function(feature,
layer) {layer.bindPopup(feature.properties.popup);}"}
                ),
            ],
            style={"height": "600px", "width": "100%"}
        )
    ], style={"marginBottom": "40px"}),

    # Charts Section
    html.Div([
        dcc.Graph(id="trend"),
        dcc.Graph(id="bar-chart"),
        dcc.Graph(id="correlation"),
    ])
])


# Callback to update filters based on the indicator selection
@app.callback(
    [Output("year-filter", "options"),
     Output("state-filter", "options")],
    [Input("indicator-filter", "value")]
)
def update_filters(selected_indicator):
    with engine.connect() as connection:
        # Query distinct years from the database
        years_query = "SELECT DISTINCT year FROM incidence_data ORDER
BY year"
        years_result = connection.execute(text(years_query))
        years = [row[0] for row in years_result]

        # Query distinct states from the database
        states_query = "SELECT DISTINCT state FROM incidence_data
ORDER BY state"
        states_result = connection.execute(text(states_query))
        states = [row[0] for row in states_result]

    return [
```

```
        [{"label": year, "value": year} for year in years],
        [{"label": state, "value": state} for state in states],
    ]


# Callback to update dashboard elements based on selected filters
@app.callback(
    [Output("choropleth", "data"),
     Output("trend", "figure"),
     Output("bar-chart", "figure"),
     Output("correlation", "figure"),
     Output("kpi-card-1", "children"),
     Output("kpi-card-2", "children"),
     Output("kpi-card-3", "children")],
    [Input("year-filter", "value"),
     Input("indicator-filter", "value"),
     Input("state-filter", "value")]
)
def update_dashboard(selected_year, selected_indicator,
selected_state):
    # Build the SQL query based on selected filters
    query = "SELECT * FROM incidence_data WHERE 1=1"
    params = {}

    if selected_year:
        query += " AND year = :year"
        params["year"] = selected_year
    if selected_state:
        query += " AND state = :state"
        params["state"] = selected_state

    with engine.connect() as connection:
        result = connection.execute(text(query), params)
        filtered_data = pd.DataFrame(result.fetchall(),
columns=result.keys())

    # Prepare GeoJSON for the choropleth map
    geojson_data = {
        "type": "FeatureCollection",
        "features": [
            {
                "type": "Feature",
                "properties": {
                    "state": row["state"],
                    "popup": f"State:
{row['state']}<br>{selected_indicator.replace('_', ' ').title()}:
{row[selected_indicator]}"
                },
                "geometry": {}  # Replace with actual geometry data if
available
```

```
            } for _, row in filtered_data.iterrows()
        ]
    }

    # Create trend line chart
    trend_figure = px.line(filtered_data, x="date",
y=selected_indicator, color="state")
    # Create bar chart comparing the indicator across states
    bar_chart_figure = px.bar(filtered_data, x="state",
y=selected_indicator, color="state")
    # Create scatter plot to explore correlation between rainfall and
the selected indicator
    correlation_figure = px.scatter(filtered_data, x="rainfall(mm)",
y=selected_indicator, color="state")

    # Compute key performance indicators (KPIs)
    kpi1 = filtered_data["incidence_rate_adjusted"].sum()
    kpi2 = filtered_data["mortality_rate_adjusted"].sum()
    kpi3 = filtered_data["effective_treatment_adjusted"].mean()

    return geojson_data, trend_figure, bar_chart_figure,
correlation_figure, kpi1, kpi2, kpi3

# Run the app
if __name__ == "__main__":
    app.run_server(debug=True)
```

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Abstract

This study offers a data-driven approach to malaria surveillance, supporting policymakers in deisigning effective public health strategies to reduce the disease burden. The results emphasize the need for region-specific interventions to protect vulnerable populations and enhance malaria control efforts in Nigeria.

Introduction

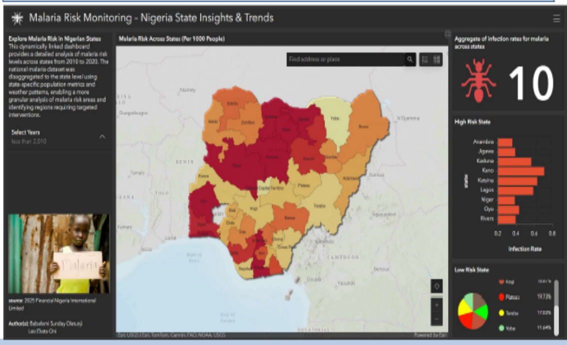
Nigeria bears one of the highest malaria burdens globally, with the disease posing a significant public challenge, particularly for children under five and pregnant women.The persistence of malaria in the country is driven by favorable environmental conditions, such as hot temperature, heavy rainfall, and abundant breeding sites for mosquitoes. Additionally, limited access to healthcare services, especially in rural areas, exacerbates the situation, leading to increased morbidity and mortality (Abdukarim et al., 2023).

Materials and Methods

Population data, Land use Land Cover Data,Environmental data, Malaria incidence data and Data on Administrative boundaries were collected and used. A well structured approach to data processing and disaggregation. This ensured that the integration of environmental, population, and epidemiological data provided accurate, state-level insights into malaria risk factors.

Result

- The hotspot mapping revealed significant spatial variation in malaria incidence across Nigeria.
- Analysis of malaria incidence data from 2010 to 2020 revealed important temporal patterns in the spread of malaria
- The temporal analysis further emphasizes the need for continuous monitoring and adaptable malaria control strategies that respond to seasonal and climate-induced changes.



Technique Used

Geographic Information Systems (GIS) techniques and examined key environmental factors influencing underlying malaria transmission were examined.

Conclusions

This study highlights the power of Geographic Information System (GIS) and interactive story mapping in understanding and addressing malaria transmission in Nigeria. the findings reveal how environmental factors like temperature and rainfall, combined with demographic patterns such as population density and land use, significantly contribute to malaria transmission.The use of GIS enabled us to identify high-risk areas also track the changing patterns of malaria incidence over time, helping to recognize seasonal fluctuations and the impact of weather on malaria outbreaks.

Babafemi Sunday Olatunji

Ekata Leo Oni

REFERENCE

Abdulkarim, I. A., Yakudima, I. I., Abdullahi, J. G., & Adamu, Y. M. (2023). Geographical Analysis of Malaria in Nigeria – Spatiotemporal Patterns of National and Subnational Incidence. In Y. Adewoyin (Ed.), Health and Medical Geography in Africa: Global Perspectives on Health Geography. Springer, Cham. https://doi.org/10.1007/978-3-031-41268-4_9

Acknowledgements

Special thanks to everyone involved in this project – colleagues, project supervisors.

Metadata Documentation

Title:

Malaria Risk, Weather Patterns, and Population Data Analysis in Nigeria

Creator:

Babafemi Sunday Olatunji

Ekata Leo Oni

Subject:

Malaria Prevalence. Incidence, mortality, weather patterns, population distribution, Nigeria, spatial analysis

Description:

This dataset provides a state-level analysis of malaria-related factors in Nigeria, disaggregated from national-level malaria data using state-specific population and weather patterns, it combines malaria indicators, demographic data, and environmental variables to explore spatial and temporal relationships. The datasets support public health research, resource allocation, and decision-making for malaria control efforts.

Publisher:

Babafemi Sunday Olatunji

Ekata Leo Oni

PLUS

Contributor:

World bank data catalogue

National Population commission

Malaria Atlas Project

Nigerian Meteorological Agency (NiMET)

Date:

December 2025

Type:

Dataset

Format:

CSV, Shapefile, GeoJSON

Identifier:

https://zgis.maps.arcgis.com/home/item.html?id=e8825b5839524b489a16b7f197e0237d

Source:

Malaria Atlas Project: Malaria Data

National Population Commission: Population Data

Nigerian Meteorological Agency: Weather Data

World Bank Data Catalogue: Nigeria Administrative Boundaries

Language:

English

Relation:

https://data.malariaatlas.org/trends?year=2022&metricGroup=Malaria&geographicLevel=admin0&metricSubcategory=Pf&metricType=rate&metricName=incidence

Coverage:

Spatial: All states in Nigeria

Temporal: Data from 2010 to 2022

Rights:

Monthly timesheet for MSc Geoinformatics I3 Project

IDENTIFICATION OF THE PROJECT & PARTICIPANT(S)

Firstname Lastname	Babafemi Sunday Olatunji
Project Acronym	MRMN
Project Title	Malaria Incidence in Nigeria: A Geospatial Analysis

TIME **Winter Term 2024/25**

Day	Time (from)	Time (to)	Hours	Project related activities: Activity (description of activity and concerned work package)
1.			0:00	
2.			0:00	
3.			0:00	
4.	8:30	12:30	4:00	Kick off session I3
5.	8:00	12:00	4:00	Researching on project topic
6.			0:00	
7.	11:00	13:00	2:00	Researching on project topic
8.	15:00	18:00	3:00	Researching on project topic
9.	9:00	12:00	3:00	Researching on project topic
10.	12:00	16:00	4:00	Researching on project topic
11.	8:30	12:30	4:00	Finalizing on topic selection (Malaria Incidence
12.	8:00	12:00	4:00	Working on Abstract
13.			0:00	
14.	8:00	10:00	2:00	Working on Abstract/ Submission
15.	15:00	18:00	3:00	Literature review on Malaria Incidence
16.	9:00	12:00	3:00	Literature review on Malaria Incidence
17.	12:00	16:00	4:00	Literature review on Malaria Incidence
18.	8:30	12:30	4:00	Project Management + Git Lab
19.	8:00	12:00	4:00	GitLAB Setup/ Work Packages
20.			0:00	
21.	8:00	10:00	2:00	Work Packages Finalized + Wiki
22.	15:00	18:00	3:00	Issues, Issues Board and label created + Task Allocation
23.	9:00	12:00	3:00	Working on Project Approach
24.	12:00	16:00	4:00	Working on Project Approach + Initial Presentation Prepared
25.	8:30	12:30	4:00	Initial Presentation/ Research Plan
26.	8:00	12:00	4:00	Adjusting work packages, Project idea, Methodology based on feedback from initial Presentation
27.			0:00	
28.	8:00	10:00	2:00	Working on Risk Management
29.	15:00	18:00	3:00	overall re-structuring of the GitLAB setup
30.	9:00	12:00	3:00	Working on Extended Abstract
31.	12:00	16:00	4:00	Metholodolgy and Possible Result for Extended Abstract
			80:00:00	

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TIME Winter Term 2024/25

Day	Project related activities			
	Time		Hours	**Activity** (description of activity and concerned work package)
	(from)	(to)		
1.	8:30	12:30	4:00	Extended Abstract Finalized/ Submission
2.	8:00	12:00	4:00	Literature Review on Weather Pattern
3.			0:00	
4.	11:00	13:00	2:00	Adjusting Project Methdolody based on feedback from Extended Abstract Submission
5.	15:00	18:00	3:00	Literature Review on Weather Pattern
6.	9:00	12:00	3:00	Literature Review on Weather Pattern
7.	12:00	16:00	4:00	Literature Review on Weather Pattern
8.	8:30	12:30	4:00	WP1:Project Planning and Management + Consultation
9.	8:00	12:00	4:00	Sourcing for datasets
10			0:00	
11.	8:00	10:00	2:00	Sourcing for datasets
12.	15:00	18:00	3:00	Sourcing for datasets
13.	9:00	12:00	3:00	Sourcing for datasets
14.	12:00	16:00	4:00	Sourcing for datasets
15.	8:30	12:30	4:00	WP2: Data Collection and Cleaning + Consultation
16.	8:00	12:00	4:00	Sourcing for datasets
17.			0:00	
18.	8:00	10:00	2:00	sourcing for datasets
19.	15:00	18:00	3:00	sourcing for datasets
20.	9:00	12:00	3:00	sourcing for datasets
21.	12:00	14:00	2:00	Gitlab Update
22.	8:30	12:30	4:00	WP2: Data Collection and Cleaning + Consultation
23.	8:00	10:00	2:00	Data Sourcing: National Malaria Data Acquisition
24.			0:00	
25.	8:00	10:00	2:00	Data Sourcing: State-Level Population Acquisition
26.	15:00	18:00	3:00	Data Sourcing: State-Level Population Acquisition
27.	9:00	12:00	3:00	Data Sourcing: Rainfall and Temperature Acquisition
28.	12:00	14:00	2:00	Data Sourcing: Land Use Land Cover
29.	8:30	12:30	4:00	WP3: Data Collection and Cleaning + Disaggregation + Consultation
30.	8:00	10:00	2:00	Tutorial on Disaggregation Process
			80:00:00	

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TIME **Winter Term 2024/25**

Day	Time (from)	Time (to)	Hours	Project related activities: **Activity** (description of activity and concerned work package)
1.			0:00	
2.	11:00	13:00	2:00	Data cleaning and preprocessing (Excel)
3.	15:00	18:00	3:00	Tutorial on Disaggregation Process
4.	9:00	12:00	3:00	Tutorial On Disaggregation
5.	12:00	16:00	4:00	Tutorial On Disaggregation
6.	8:30	12:30	4:00	Mid term Presentation + GitLab Update
7.	8:00	10:00	2:00	Adjusted Project idea, Methodology based on feedback from Mid Term Presentation
8.			0:00	
9.	8:00	10:00	2:00	Getting Familiar with Pandas, Geopandas, Rasterio for Disaggregation
10.	15:00	18:00	3:00	Malaria Incidence disggregation to state level
11.	9:00	12:00	3:00	Malaria Incidence disggregation to state level
12.	12:00	16:00	4:00	Malaria Incidence disggregation to state level (Finalized)
13.	8:30	12:30	4:00	WP2: Data Collection and cleaning + Storage + Consultation + GitLAB Update
14.	8:00	12:00	4:00	Joining the Malaria incidence data to Nigeria state Boundaries
15.			0:00	
16.	8:00	10:00	2:00	Metadata Description
17.	15:00	18:00	3:00	Storing data on Geodatabase
18.	9:00	12:00	3:00	Storing data on Geodatabase
19.	12:00	16:00	4:00	Publishing datasets to the Server
20.	8:30	12:30	4:00	WP3: Temopral Analysis + Consultation
21.	8:00	12:00	4:00	Temporal Analysis with Python
22.	12:00	16:00	4:00	Temporal Analysis with Python
23.	8:00	10:00	2:00	Temporal Analysis with Python
24.	15:00	18:00	3:00	Temporal Analysis with Python
25.			0:00	
26.			0:00	
27.	8:30	12:30	4:00	WP4: Spatial Analysis
28.	8:00	13:00	5:00	Malaria risk Level Map
29.			0:00	
30.	8:00	10:00	2:00	Malaria risk Level Map
31.	15:00	17:00	2:00	Temperature Mapping Across States
			80:00:00	

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TIME **Winter Term 2024/25**

Day	Project related activities			
	Time		Hours	Activity (description of activity and concerned work package)
	(from)	(to)		
1.	9:00	12:00	3:00	
2.	12:00	14:00	2:00	
3.	8:30	12:30	4:00	Rainfall Mapping Across States
4.	8:00	10:00	2:00	Rainfall Mapping Across States
5.			0:00	
6.			0:00	
7.	15:00	17:00	2:00	Dashboard development + GitLAB Update
8.	9:00	12:00	3:00	Dashboard development (Malaria Risk Level)
9.	12:00	16:00	4:00	Dashboard development (Malaria Risk Level)
10.	8:30	12:30	4:00	WP5: Visualization + Consultation + GitLAB
11.	8:00	10:00	2:00	Dashboard development (Malaria Hotspot vs Weather Pattern)
12.			0:00	
13.	15:00	17:00	2:00	Dashboard development (Malaria Hotspot vs Weather Pattern)
14.	9:00	12:00	3:00	Dashboard development (Malaria Hotspot vs Weather Pattern)
15.	12:00	14:00	2:00	Story Maps Development
16.	12:00	14:00	2:00	story Maps Development
17.	8:30	12:30	4:00	WP6: Research Documentation + Consultation + GitLAB Update
18.	8:00	10:00	2:00	Story Maps Development Continuation
19.			0:00	
20.	15:00	17:00	2:00	Story Maps Development Continuation
21.	16:00	17:00	1:00	Project Report Documentation (Introduction)
22.	9:00	10:00	1:00	Project Report Documentation (Material & Methodology)
23.	12:00	14:00	2:00	Project Report Documentation (Result)
24.	8:30	12:30	4:00	Final Presentation + Gitlab Update
25.	8:00	9:00	1:00	Adjusting final product based on feedback from Final presentation
26.			0:00	
27.	12:00	13:00	1:00	Project Report Documentation (Discussion)
28.	16:00	17:00	1:00	Project Report Documentation (Conclusion)
29.	9:00	10:00	1:00	Gitlab Update and final documentation roundup
30.	12:00	13:00	1:00	Gitlab Update and final documentation roundup
31.	8:30	12:30	4:00	Final documentation and Report
			60:00:00	

Monthly timesheet for MSc Geoinformatics I3 Project

IDENTIFICATION OF THE PROJECT & PARTICIPANT(S)

Firstname Lastname	Ekata Leo Oni
Project Acronym	MRMN
Project Title	Malaria Incidence in Nigeria: A Geospatial Analysis

TIME Winter Term 2024/25

Day	Time (from)	Time (to)	Hours	Project related activities: **Activity** (description of activity and concerned work package)
1.			0:00	
2.			0:00	
3.			0:00	
4.	8:30	12:30	4:00	Kick off session I3
5.			0:00	
6.			0:00	
7.	18:00	22:00	4:00	Researching on project topic
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15.	18:00	22:00	4:00	Literature review on Malaria Incidence
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17.	18:00	22:00	4:00	Project Management + Git Lab
18.	18:00	22:00	4:00	GitLAB Setup/ Work Packages
19.			0:00	
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21.	18:00	22:00	4:00	Work Packages Finalized + Wiki
22.	18:00	22:00	4:00	Issues, Issues Board and label created + Task Allocation
23.	18:00	22:00	4:00	Working on Project Approach + Initial Presentation Prepared
24.	18:00	22:00	4:00	Initial Presentation/ Research Plan
25.	18:00	22:00	4:00	Adjusting work packages, Project idea, Methodology based on feedback from
26.			0:00	
27.			0:00	
28.	18:00	22:00	4:00	Working on Risk Management
29.	18:00	22:00	4:00	overall re-structuring of the GitLAB setup
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31.	18:00	22:00	4:00	Metholodolgy and Possible Result for Extended Abstract
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Monthly timesheet for MSc Geoinformatics I3 Project

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6.	18:00	22:00	4:00	Literature Review on Weather Pattern
7.	18:00	22:00	4:00	WP1:Project Planning and Management + Consultation
8.	18:00	22:00	4:00	Sourcing for datasets
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10			0:00	
11.	18:00	21:00	3:00	Sourcing for datasets
12.	18:00	21:00	3:00	Sourcing for datasets
13.	18:00	22:00	4:00	Sourcing for datasets
14.	18:00	22:00	4:00	Sourcing for datasets
15.	18:00	22:00	4:00	WP2: Data Collection and Cleaning + Consultation
16.			0:00	
17.			0:00	
18.	18:00	22:00	4:00	sourcing for datasets
19.	18:00	21:00	3:00	sourcing for datasets
20.	18:00	22:00	4:00	Gitlab Update
21.	18:00	22:00	4:00	WP2: Data Collection and Cleaning + Consultation
22.	18:00	23:00	5:00	Data Sourcing: National Malaria Data Acquisition
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27.	18:00	22:00	4:00	Data Sourcing: Land Use Land Cover
28.	18:00	22:00	4:00	WP3: Data Collection and Cleaning + Disaggregation +
29.	18:00	22:00	4:00	Tutorial on Disaggregation Process
30.			0:00	
			80:00:00	

Monthly timesheet for MSc Geoinformatics I3 Project

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7.			0:00	
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14.			0:00	
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16.	18:00	23:00	5:00	Metadata Description
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20.	18:00	23:00	5:00	Temporal Analysis with Python
21.			0:00	
22.			0:00	
23.	18:00	21:00	3:00	Temporal Analysis with Python
24.	18:00	22:00	4:00	WP4: Spatial Analysis
25.			0:00	
26.			0:00	
27.	18:00	22:00	4:00	Malaria risk Level Map
28.			0:00	
29.			0:00	
30.	18:00	22:00	4:00	Malaria risk Level Map
31.	18:00	22:00	4:00	Temperature Mapping Across States
			80:00:00	

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	(from)	(to)		
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2.	18:00	21:00	3:00	Rainfall Mapping Across States
3.	18:00	21:00	3:00	Rainfall Mapping Across States
4.			0:00	
5.			0:00	
6.			0:00	
7.	18:00	21:00	3:00	Dashboard development + GitLAB Update
8.	18:00	21:00	3:00	Dashboard development (Malaria Risk Level)
9.	18:00	21:00	3:00	Dashboard development (Malaria Risk Level)
10.	18:00	21:00	3:00	WP5: Visualization + Consultation + GitLAB
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12.			0:00	
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17.	18:00	21:00	3:00	WP6: Research Documentation + Consultation + GitLAB Update
18.			0:00	
19.			0:00	
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25.			0:00	
26.			0:00	
27.	18:00	21:00	3:00	Project Report Documentation (Discussion)
28.	18:00	20:00	2:00	Project Report Documentation (Conclusion)
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31.	18:00	20:00	2:00	Final documentation and Report
			60:00:00	