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Assessing Accessibility to Maternal Health Facilities in Turkana County, Kenya

Abstract

Maternal health remains a major public health concern in Kenya, particularly in rural and remote regions where access to healthcare facilities is limited. Turkana County, located in northwestern Kenya, experiences the country's highest maternal mortality rate, driven by large distances, poor infrastructure, and difficult terrain. This project sets out to assess the spatial accessibility of maternal health facilities in Turkana County. By integrating data on population density, elevation, slope, land cover, road networks, and health facility locations, a weighted accessibility model was developed to identify areas of high and low service reach. The analysis revealed that while central and southern Turkana are relatively well served, large portions of the north and east remain inaccessible. These findings highlight spatial inequities in maternal healthcare access and suggest priority regions for future investment, such as the expansion of mobile health services and infrastructure improvements.

Introduction and Problem Statement

Maternal health remains a significant public health concern in Kenya, particularly in rural and remote counties where access to skilled birth attendants and maternity wards, let alone emergency obstetric care, is limited. Despite national and global efforts to reduce maternal mortality, significant disparities persist across regions. Kenya's national maternal mortality rate stands at approximately 367 deaths per 100,000 live births, compared to a global average of 197 deaths per 100,000 (WHO, 2023). However, in Turkana County, the largest and among the most geographically isolated regions of Kenya, the situation is significantly worse, with an estimated 1,794 maternal deaths per 100,000 live births (KNBS & MoH, 2022).

A complex interaction of environmental, infrastructural, and social factors shapes Turkana's extreme maternal mortality rates. The county's arid to semi-arid landscape spans over 68,000 square kilometers, characterized by low population density, scattered and indigenous settlements, and poor road infrastructure (World Bank, 2015). These physical barriers create vast distances between communities and essential maternal health facilities. Limited healthcare infrastructure, combined with a shortage of skilled personnel, further constrains women's ability to receive timely care during pregnancy and childbirth.

Access to maternal health services is a critical determinant of maternal and neonatal outcomes. The World Health Organization emphasizes that proximity and physical accessibility to health facilities play a key role in reducing preventable maternal deaths. However, in Turkana County, long travel distances, impassable terrain, and limited transportation options often result in delays in seeking or receiving care. These are factors that can mean the difference between life and death.

This project applies spatial analysis to evaluate accessibility to maternal health facilities in Turkana County. The study integrates demographic, infrastructural, and terrain data to identify spatial disparities in service accessibility. The results are intended to inform evidence-based strategies for improving maternal healthcare coverage and advancing Kenya's progress toward Sustainable Development Goal 3 (SDG 3): ensuring healthy lives and promoting well-being for all.

Despite progress in national maternal health programs, Turkana County continues to experience the highest maternal mortality rate in Kenya. Women in remote settlements face significant physical and infrastructural barriers to accessing the services and personnel that they need. Poor road conditions, long distances between facilities, and difficult terrain make it even harder for these women to receive the care that they need.

There is currently limited spatial understanding of how these barriers interact to shape accessibility across the county. Without a comprehensive spatial assessment, policymakers and planners struggle to identify underserved areas and prioritize resource allocation effectively.

This study seeks to evaluate spatial accessibility to existing maternal health facilities in Turkana County. Specifically, it aims to (1) map accessibility to maternal health services, and (2) identify high-risk zones where physical and infrastructural barriers most severely limit service reach. By revealing patterns of inequity in spatial access, this analysis provides a foundation for targeted interventions to improve maternal health outcomes in Turkana and similar remote regions.

Data

For this project, the data were sourced from publicly accessible sites (see Table 1). To represent the population of the region, WorldPop (2020) data was used, which had a resolution of 1 km. Granted, population data can change significantly over the course of five years, particularly for the Nilotic communities, who are the indigenous people. However, this data provided a standardized layer that allowed for comparative analysis of population distribution. For the physical terrain variable, to calculate slope and elevation from the NASA SRTM (2021) digital elevation model (DEM) at one arc-second (about 30m) resolution. For land cover, data were collected from the ArcGIS Living Atlas. This raster was last updated in 2020 and had a 300-meter resolution. To obtain data on the road network, two data sets had to be combined due to the lack of information in either of the pre-existing datasets. Open Street Map (2021) and Humanitarian Data Exchange (2018) were the two layers that were merged to create a roads layer. It is important to mention that the data from the Humanitarian Data Exchange (HDX) was sourced from the Government of Kenya. Lastly, data on healthcare facility locations (2021) in Kenya were taken from the website USGEO. The Government of Kenya also provided this data.

Methodology

All spatial data manipulation was done in ArcPro. All layers were clipped to the study area of Turkana, Kenya, projected to WGS 1984 UTM Zone 36N, and had all large bodies of water masked. The roads layer, which consisted of two separate layers, was merged. The select by attribute tool was used on the health facilities layer to only select levels 3, 4, 5, and 6, a scale used in Kenya to measure the different types and complexity of care you will receive (Njuguna, 2017). There was no information describing whether each facility had a maternity ward; instead, the level of hospital (1-6) was deduced from the facility name, and only levels 3 through 6 were selected (those with maternity wards). These facilities consisted of County Referral Hospitals, Sub-County Hospitals, and Health Centers. National hospitals, level 6, were not located in my study area. From there, the kernel density tool was applied to the health facilities layer, the Euclidean distance tool was used on the roads layer, and the slope tool was applied to the DEM layer. Once all layers were rasterized, each layer was classified using the classify tool into five categories: very low risk, low risk, moderate risk, high risk, and very high risk. In this analysis, the term risk refers to the degree of inaccessibility to maternal health facilities. Areas classified as "high risk" represent regions where physical, infrastructural, or demographic barriers make access to care difficult. Conversely, "low-risk" areas are those with greater accessibility to health services. Therefore, risk in this context can be interpreted as the risk of poor access to maternal health facilities.

Each layer was classified manually with the study area as context (Table 2). Once all six layers had been classified, they were separated into health and infrastructure, which included health facilities, distance to roads, and population, and physical terrain, which included land cover, slope, and elevation. Using the raster calculator tool, the health and infrastructure map and the physical map were created. Both maps were unweighted and were used just to get a general understanding of the study area. The weighted vulnerability model also used the raster calculator. This model consisted of health facilities (30%), distance to roads (25%), population (20%), land cover (15%), slope (5%), and elevation (5%). Using this model and the raster calculator tool, an access level map was created. This map was a binary where pixels categorized at very low risk or low risk were accessible, and those classified at moderate risk, high risk, or very high risk were categorized as not accessible. The last form of spatial analysis involved taking the physical terrain layer and creating a binary from it, distinguishing between good and bad physical terrain. This layer was on a continuous scale with units ranging from 3 to 12, so seven was chosen as the middle integer. This value effectively separated accessible lowland terrain from more rugged, high-sloped areas. Pixels that were between 7 and 12 were reclassified to 1, and all other pixels to 0. Then, using the population layer, a similar binary was created, where very high-risk and high-risk populations were assigned a value of 1, and all other pixels were assigned a value of 0. These two layers were multiplied together, and the pixels that returned one were shown, representing areas viable from health facilities or mobile health service locations. A final binary was created using the raster calculator to calculate the uninhabited area and the area with between 0 and 1 people per km^2, which was then used to mask uninhabited land on the map, identifying optimal locations.

Results

The original classification map for population displayed most of the land inhabited by five or fewer people per km^2 (Figure 2). Most of the county was within 1 km, if not 4 km, of a road and within 10 km of a health facility (Figures 3 & 4). The county was primarily composed of urban or open grasslands and was relatively flat, with less than 7% slope and 600 m of elevation (Figures 5, 6 & 7). The physical terrain's highest value was 15, and the lowest value was 3 (Figure 9). Health and infrastructure had the highest value of 15, and the lowest value was 4 (Figure 8). The final weighted model had a range value of 4.85 and 1.35 (Figure 10). Both the access level and optimal solutions were on a binary scale (Figures 11 & 12). These showed accessible areas in the central and south-central portions of the country as optimal solutions.

Conclusion

While our analysis of maternal health accessibility in Turkana County answered several of our initial questions, it also raised new ones about the persistent barriers faced by women in this region. Contrary to my expectations, there were several cold spots where there was a relatively short distance to a maternal health facility; however, large pockets of the county, especially in the northern and northeastern regions, remain underserved. These areas coincide with difficult terrain and little to no infrastructure, which severely limit physical access despite apparent proximity on a map.

Based on the weighted accessibility model, the most accessible regions were located in the central and southern parts of Turkana, where road networks are more developed and population density is higher, particularly in Lorugam, Turkwel, Katilu, and Kalemngorok. Conversely, vast areas in the north and east fell outside the desirable area, suggesting that thousands of women remain beyond a practical travel distance from adequate maternal care. The patchy depiction of the model highlights the need for targeted solutions, such as deploying mobile health units or constructing strategically placed health centers. A solution is needed to bridge the accessibility gap in these remote areas.

Additionally, this project underlines the difficulties of relying solely on open-sourced data in a region of the world where less mapping and analysis is taking place. While the process of merging multiple datasets was successful, the data quality was subpar, and combining two layers of subpar data doesn't result in a good layer. However, this just reinforces the importance of mapping in developing nations, particularly in rural regions, for further analysis and solutions for the people living in that region.

Future research could expand on this topic by incorporating additional values like seasonal road conditions or facility capacity. During my time in Kenya, I experienced a wait time upon arrival at a health facility, which would be particularly challenging in emergencies. A network analysis in the context of travel time could also be done, which could be used as another road layer within the model. The analysis of the access level and strategic zone could be further expanded. That analysis could be developed by adding more factors, perhaps only prioritizing strategic zones that are not currently considered accessible. Ultimately, improving maternal health in Turkana County will need more than just increasing health facilities; it will also require continued and sustained investment in the local health care system, an improved and maintained road network, and a community that supports the women who need the care. This analysis is a tiny step in the right direction to help Turkana County, but ultimately, Kenya, in identifying where the most significant impact will be.

Sources

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Table 1: Input variables, sources, and spatial references.

Data Layer	Source	Discription	Resolution	Date
Population	WorldPop	Population estimates for Kenya	1 km	2020
Health Facilities	USGEO	Locations of existing health facilities within Kenya	Vector data	2021
Road Network	OpenStreetMap & HDX	Road data for Kenya	Vector data	2021 & 2018
DEM	NASA SRTM DEM	DEM for Kenya	1 arc second	2021
Administrative Boundaries	Kenya Open Data	Administrative borders for Turkana County	Vector data	2021
Land Cover	ArcGIS Living Atlas	Land Cover for Kenya	300 m	2020

Table 2: Classification of the input variables

	Population (people per km^2)	Distance to Roads	Health Facilities	Land Cover	Slope	Elevation
(1) Very Low Risk	< 50	<1000 m	< 2 km	Urban Developed	<1%	< 300 m
(2) Low Risk	< 500	<4000 m	< 5 km	Open Grasslands	<3%	< 600 m
(3) Moderate Risk	< 1500	<10,000 m	< 10 km	Forest Dense Vegetation	<7%	< 1200 m
(4) High Risk	< 3000	<20,000 m	< 20 km	Cropland Agriculture	<15%	< 1800 m
(5) Very High Risk	> 3000	>20,000 m	> 20 km	Wetland Open Water	>15%	> 1800 m

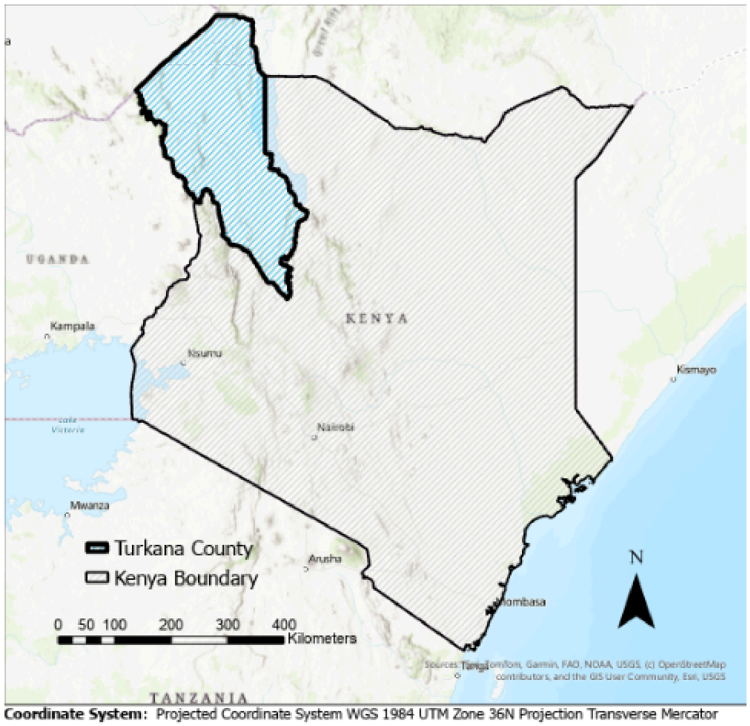
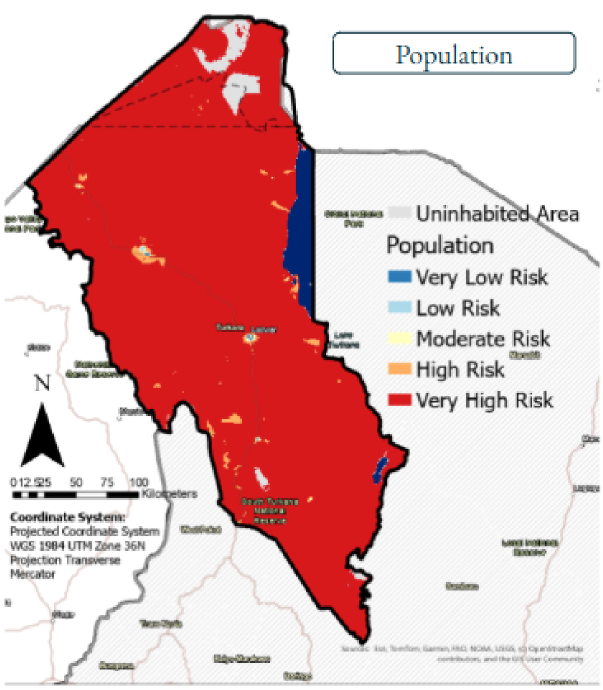


Figure 1: Study area, showing the country of Kenya, but particularly the Turkana country.



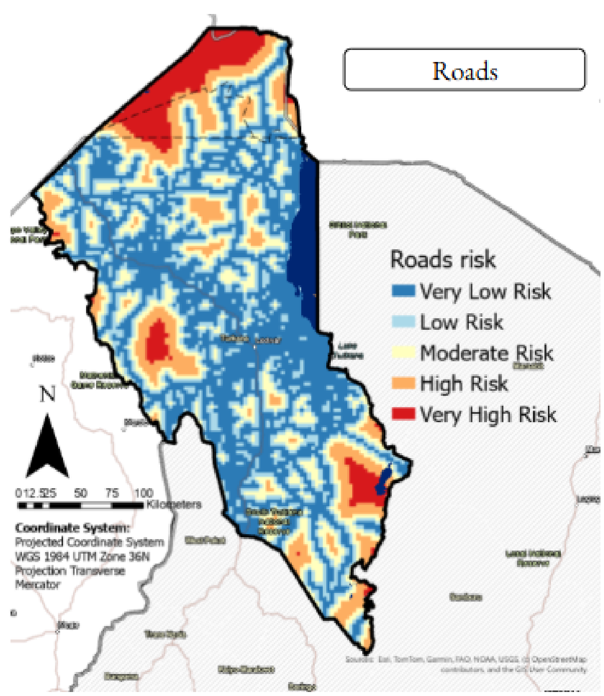
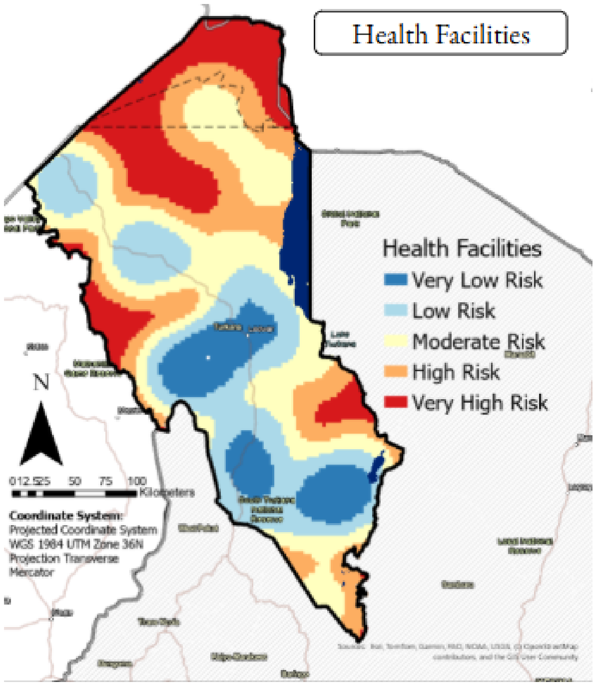


Figure 2: Input variable population, classified between 1-5

Figure 3: Input variable roads, classified between 1-5



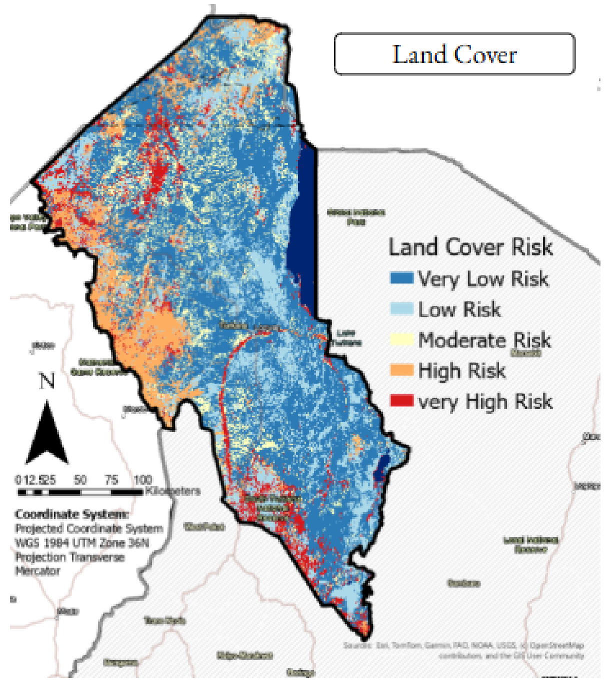
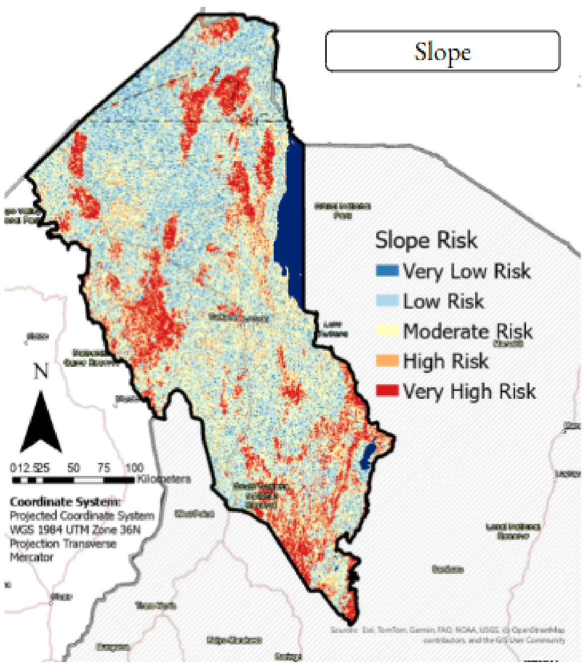


Figure 4: Input variable health facilities, classified between 1-5

Figure 5: Input variable landcover, classified between 1-5



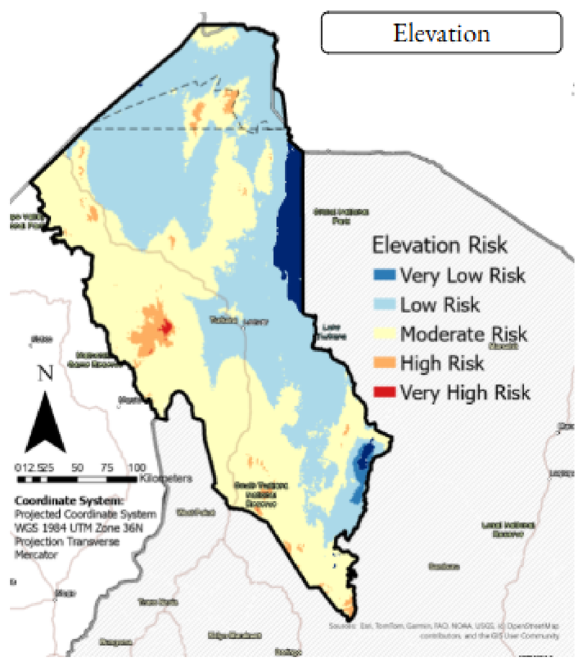


Figure 6: Input variable slope, classified between 1-5

Figure 7: Input variable elevation, classified between 1-5

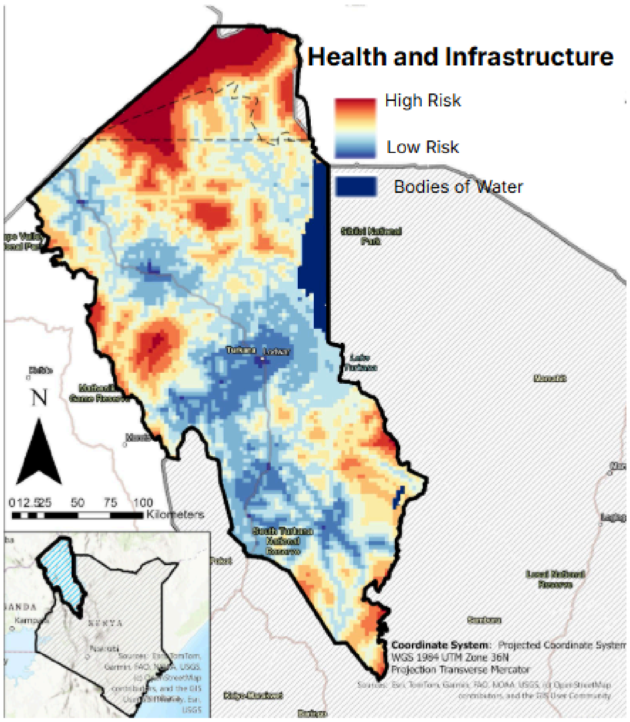


Figure 8: Health and Infrastructure model, an equally weighted projection of roads, health facilities, and population.

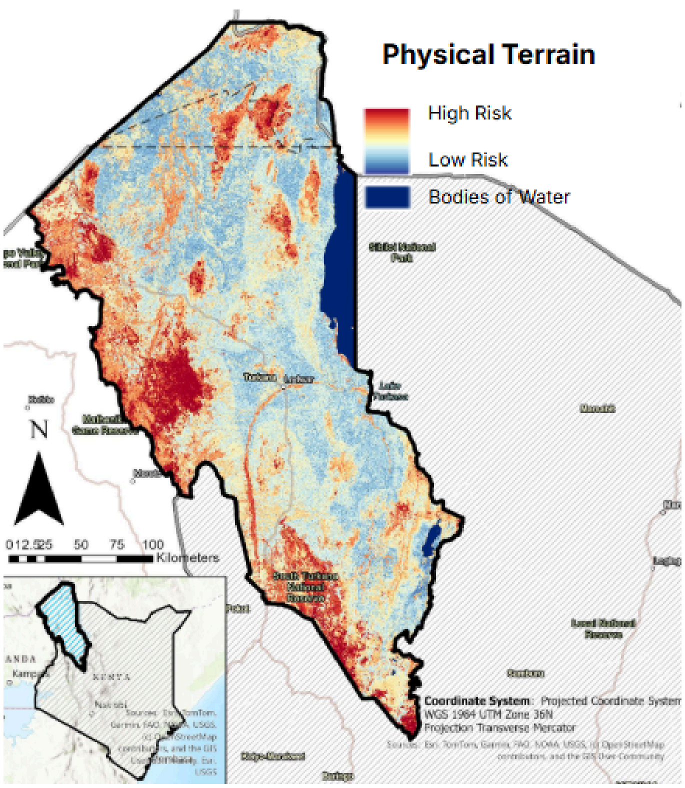


Figure 9: Physically terrain model, an equally weighted projection of landcover, slope, and elevation

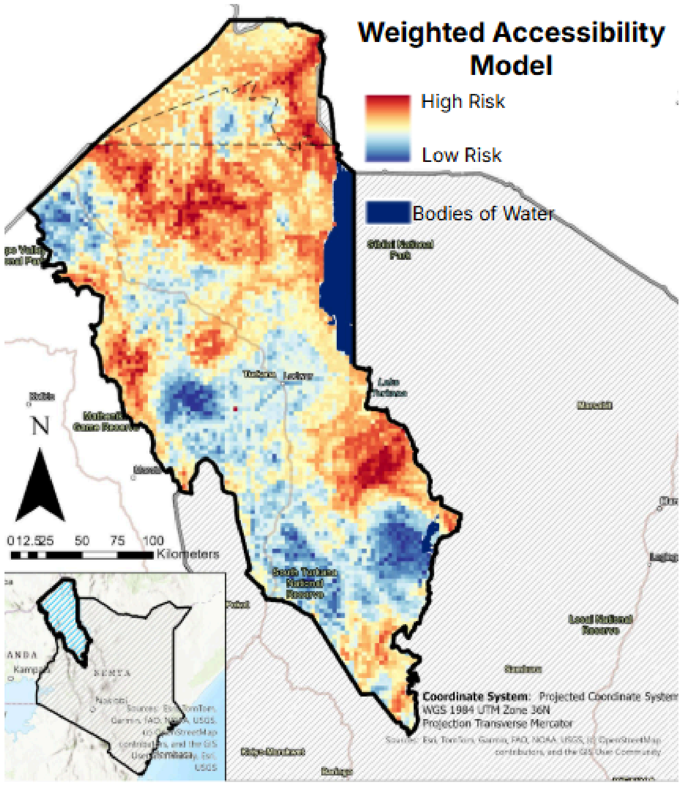


Figure 10: Weighted accessibility map

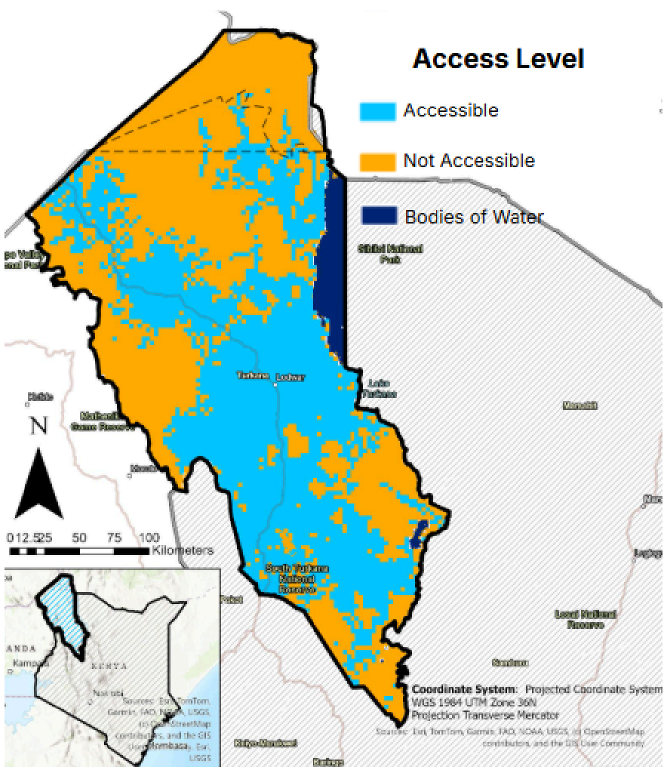


Figure 11: Access level on a binary scale (1 or 0)

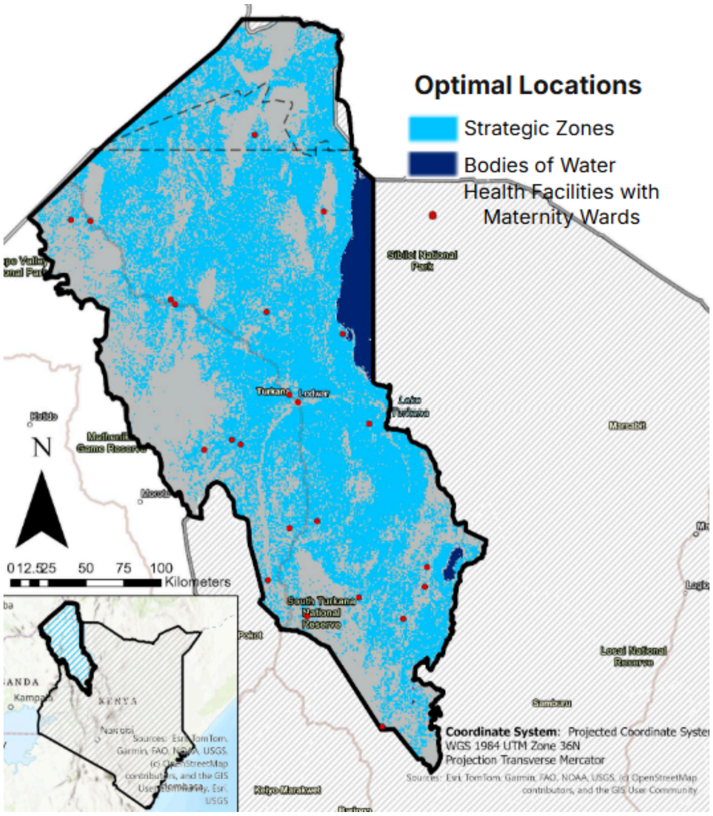


Figure 12: Optimal locations with current health facilities overlayed