

Geographical Accessibility to Comprehensive Emergency Obstetric and Newborn Care in Nepal

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Research Article

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Abstract

Background

Timely access to Comprehensive Emergency Obstetric and Newborn Care (CEmONC) is important for preventing maternal and neonatal deaths. Although Nepal has made substantial progress in reducing maternal and neonatal deaths over recent decades, there is still a lack of granular subnational evidence on progress, equity, and physical access to (CEmONC) services especially in geographically diverse and inaccessible areas. Limited subnational evidence on spatial accessibility to CEmONC facilities constraints effective Health system Planning and referral networks.

Methods

This study assessed geographical accessibility to CEmONC facilities across Nepal using GIS- based travel-time modelling. Locations of CEmONC facilities were integrated with a motorized friction surface to estimate least-cost travel times. Areas with no population of women aged 15–49 years were masked using a gridded population layer. Travel times were categorized into five ranges: 0–30 minutes, 30–60 minutes, 60–120 minutes, 120–240 minutes, and > 240 minutes). data. Geographical accessibility inequalities were quantified using the Lorenz curve, Gini coefficient and Theil L index.

Results

Geographical accessibility to CEmONC facilities varied significantly across Nepal. Shorter travel times ($\leq$ 30 minutes) were concentrated in the Tarai region and major urban corridors of Hilly region such as Kathmandu, Pokhara, while many areas of Hill and Mountain regions experienced travel times exceeding 60 minutes. The median travel time was approximately 64.73 minutes, indicating that half of the population resides beyond accepted thresholds for timely access to Comprehensive emergency obstetric care. Population-weighted analysis showed that 52.4% of women aged 15–49 years were within 30 minutes of the nearest CEmONC facility, 30.1% within 30–60 minutes, 14.9% within 60–120 minutes, and 2.6% required more than 120 minutes. Inequality analysis of the travel-time surface masked to areas containing women aged 15–49 years showed a Gini coefficient of 0.65 and a Theil L index of 0.86, indicating substantial spatial inequality in geographical accessibility.

Conclusion

Despite the national progress in Maternal and Newborn health outcomes, CEmONC services in Nepal remain markedly uneven. GIS-based travel-time modelling revealed substantial geographical inequities, particularly in remote and mountainous regions. These findings provide substantial evidence to support

equitable Health service planning, strengthen referral networks and improving Safe Motherhood and Sustainable Development Goal targets.

1. Background

Reducing maternal mortality remains a major global public health priority. In 2020, an estimated 287,000 women died from pregnancy-related causes worldwide, equivalent to approximately one maternal death every two minutes¹. Nepal has made substantial progress in reducing maternal and neonatal deaths over recent decades where, the Maternal Mortality Ratio declined from 539 in the year 1996 to 151 in 2021, with the recent fell down to 142 in 2023. Likewise, the Neonatal Mortality Rate fell from 50 in 1996 to 16.6 in 2023. Despite these gains, the current pace of reduction remains insufficient to achieve the SDG targets of reducing maternal mortality to 70 per 100,000 live births and neonatal mortality to 12 per 1,000 live births by 2030².

Emergency Obstetric and Newborn Care (EmONC) comprises essential life-saving interventions for managing major obstetric and newborn complications during pregnancy, childbirth, and the immediate postnatal period. EmONC services are classified into Basic Emergency Obstetric and Newborn Care (BEmONC) and Comprehensive Emergency Obstetric and Newborn Care (CEmONC). CEmONC represents the highest level of facility-based emergency maternal and newborn care, providing all basic emergency obstetric and newborn interventions together with caesarean delivery, safe blood transfusion, and other advanced interventions required to manage severe maternal and newborn complications. The updated WHO EmONC framework emphasizes that effective EmONC systems extend beyond the availability of infrastructure and signal functions to include functional service delivery, continuous service readiness, effective referral systems, quality of care, and integration of maternal and newborn services. Consequently, geographical accessibility to functional CEmONC facilities is increasingly recognized as a critical indicator of health system performance and an essential prerequisite for timely, equitable access to life-saving maternal and newborn care³.

Timely geographical access to CEmONC is a critical determinant of maternal and newborn survival, as obstetric emergencies require rapid access to facilities capable of providing definitive life-saving interventions⁴. Physical accessibility to CEmONC is largely determined by the travel time required to reach the nearest facility. In many low- and middle-income countries, CEmONC services are concentrated in urban and densely populated areas, leaving rural and remote populations with substantially longer travel times and greater transportation costs⁵. These geographical barriers are further exacerbated by poor road infrastructure, difficult terrain, limited transport services, and restricted access to motorized transport, resulting in inequitable access to timely emergency obstetric and newborn care⁶.

Although the Ministry of Health and Population and UNFPA have undertaken EmONC prioritization and network mapping to support provincial planning through facility functionality assessments, referral network analysis, and travel-time modelling, these programmatic initiatives were designed for service

planning rather than evaluating nationwide geographical accessibility to the existing CEmONC network. Consequently, comprehensive evidence describing population access and spatial inequalities in travel-time accessibility to designated CEmONC facilities across Nepal remains limited⁷. This evidence gap is particularly important because delays in reaching an appropriate facility (the second delay in the Three Delays Model) are a major contributor to preventable maternal and newborn mortality, especially for obstetric emergencies requiring caesarean delivery or blood transfusion that are only available at CEmONC facilities⁸. Advances in Geographic Information Systems (GIS) and travel-time modelling now provide robust methods for quantifying geographical accessibility, identifying underserved populations, and generating evidence to strengthen referral systems, improve service planning, and promote equitable access to life-saving maternal and newborn care⁹.

Several geospatial studies have examined geographical accessibility to healthcare services in Nepal, providing important evidence for health service planning. Huang-Fu et al. assessed national geographical accessibility to maternal healthcare services, including antenatal care, delivery services, and postnatal care, and demonstrated that poorer geographical accessibility was associated with lower utilization of maternal health services. Their study also identified substantial spatial disparities, particularly in the northern mountain regions and parts of the Tarai, using high-resolution accessibility mapping and Bayesian geostatistical logistic regression models¹⁰. More recently, Mesic et al. evaluated access to different levels of emergency care capacity in Nepal by integrating hospital readiness, household location, and climate vulnerability data. Their findings highlighted pronounced inequities in timely emergency care access among rural, poorer, and climate-vulnerable populations, underscoring the influence of geographic and socioeconomic barriers on emergency healthcare accessibility¹¹. The increasing application of GIS in Nepal's health sector is further illustrated by Acharya et al. (2025), who used spatiotemporal spatial analyses to examine the dynamics and drivers of COVID-19 incidence, highlighting the potential of geospatial approaches to support evidence-based health planning and resource allocation¹². However, these studies did not specifically quantify travel-time accessibility to designated CEmONC facilities or assess population-level access to these specialized referral services. Thus, a national assessment of geographical accessibility to CEmONC facilities remains an important evidence gap in Nepal.

Nepal's diverse topography, dispersed settlements, and uneven distribution of health services create substantial geographical inequalities in access to CEmONC facilities^{10,11}. These inequalities are likely to vary considerably across provinces and districts because of differences in terrain, road connectivity, settlement patterns, population distribution, and the availability and spatial distribution of emergency health facilities. Although previous studies have demonstrated broad geographic disparities in maternal and emergency healthcare accessibility in Nepal, evidence on how access to designated CEmONC facilities varies across individual provinces and districts remains limited^{7,10,11}. Assessing these disparities is particularly important under Nepal's federal health system, where provincial and local governments have increasing responsibilities for health-service planning and resource allocation. Identifying provinces and districts with prolonged travel times can therefore provide geographically

specific evidence to support equitable CEmONC planning, referral-system strengthening, and prioritization of underserved areas^{7,13}.

Geographical accessibility, measured by travel time to CEmONC facilities, is a key determinant of timely emergency care. Although a 2-hour travel-time threshold has long been used for health service planning, recent evidence indicates that shorter travel times (30–60 minutes) are associated with better maternal and perinatal outcomes, while the risk of adverse outcomes increases with longer travel times¹⁴.

Although average travel-time estimates provide an overall measure of geographical accessibility, they may conceal important disparities in access across populations. Quantifying these inequalities using the Lorenz curve, Gini coefficient, and Theil L index provides additional insight into the distribution of accessibility and supports equitable health service planning¹⁰.

In Nepal, (CEmONC) facilities primarily function as referral centers for women and newborns with complications requiring definitive emergency interventions, including caesarean section, blood transfusion, and advanced inpatient newborn care¹⁵. Nevertheless, assessing potential geographical accessibility directly from population locations to designated CEmONC facilities remains important for identifying populations that may face prolonged travel to definitive emergency care. This population-based approach complements referral-system planning by identifying geographically underserved populations and informing equitable planning and strengthening of CEmONC services^{7,16}.

This study aimed to assess geographical accessibility to designated CEmONC facilities in Nepal using GIS-based travel-time modelling. Specifically, the study mapped the spatial distribution of CEmONC facilities, estimated travel time to the nearest facility using least-cost path analysis, quantified population coverage across predefined travel-time thresholds, and assessed geographical disparities in accessibility across provinces, districts, and the rural–urban gradient. Spatial inequality in travel-time accessibility was further evaluated using Lorenz curves, the Gini coefficient, and the Theil L index.

2. Materials and methods

2.1. Study Area

Nepal is a landlocked country in South Asia covering 147,516 km², extending approximately 800 km east–west and 150–250 km north–south, and sharing borders with China to the north and India to the south, east and west. The country is characterized by highly diverse topography, ranging from the low-lying Tarai plains in the south to the Himalayan Mountain range in the north. This complex terrain, together with dispersed settlements and an uneven road network, creates substantial variation in physical accessibility to health services^{17,18}. Administratively, Nepal is divided into seven provinces, 77 districts, and 753 local government units. Following the federal restructuring of the health system in 2017, responsibility for health service planning and service delivery is shared across the federal, provincial, and local governments¹⁹. Comprehensive Emergency Obstetric and Newborn Care (CEmONC)

services are provided through designated referral hospitals distributed across the country; however, geographical accessibility to these facilities varies considerably because of differences in terrain, transport infrastructure, and population distribution^{10,20,21}. Given these geographic and health system characteristics, Nepal provides an appropriate setting for evaluating population-weighted travel-time accessibility to CEmONC services and identifying spatial inequalities that can inform equitable resource allocation, referral planning, and health system strengthening^{10,11,20,21}. The study area and spatial distribution of designated CEmONC facilities are shown in Fig. 1.

[Figure 1. Study area showing Nepal's seven provinces, district boundaries, and the spatial distribution of designated Comprehensive Emergency Obstetric and Newborn Care (CEmONC) facilities included in the analysis].

Workflow Diagram of the Study

The schematic overview of the analytical framework used to estimate travel time to the nearest CEmONC facilities in Nepal. Geocoded facility locations and a friction surface were used to generate a travel-time accessibility raster, which was subsequently combined with the masked population women aged 15–49 years (women of reproductive age), rural–urban classification, provincial and district boundaries to estimate population coverage and evaluate spatial inequalities using the Gini coefficient, Lorenz curve, and Theil L index. The analytical workflow used to estimate travel time to the nearest CEmONC facility and assess population coverage and spatial inequality is presented in Fig. 2.

[Figure 2 Workflow Diagram of the study]

2.2 Data Sources

[Table 1 Data Sources]

Table 1
Data Sources

Dataset	Source	Year	Resolution	Purpose
CEmONC facilities	Family Welfare Division (MoHP) / UNFPA Nepal, Sagun compilation ²¹	2024	Point	Travel-time destination
Administrative boundaries	National Geospatial Platform	2024	Polygon	Province and district levels
Population raster	WorldPop women aged 15–49 years	2020	100 m	Population coverage
Urban–rural classification	National Geospatial Platform	2024	Polygon	Urban–rural comparison
Motorized Friction Surface	Malaria Atlas Project (MAP)	2020	~ 1 km (30 arcseconds)	Represents the estimated travel time (minutes) required to traverse each 1 km grid cell using the fastest available mode of motorized transport. Used to model least-cost travel time to the nearest CEmONC facility.

This study utilized data from multiple sources, including CEmONC facilities, a motorized friction surface, and gridded population estimates of women of reproductive age, as summarized in (Table 1). The list of CEmONC facilities used in this study was obtained from a compilation by Sagun, which documents CEmONC facilities designated under Nepal's Safe Motherhood Programme^{22 13,22}.

The Malaria Atlas Project (MAP) motorized friction surface was used as the travel-cost layer to estimate least-cost travel time to CEmONC facilities. The Malaria Atlas Project (MAP) motorized friction surface was used as the travel-cost layer to estimate least-cost travel time to the nearest CEmONC. The raster was accessed through the MalariaAtlas R package using the getRaster function. The global friction surface used to represent land-based travel cost for motorized transport is provided as Supplementary Fig. 8. This friction surface has been widely applied in healthcare accessibility studies and has previously been implemented in Nepal, supporting its suitability for estimating national-scale geographical accessibility^{6,23}.

Gridded population data for women aged 15–49 years were obtained from WorldPop and used to estimate population-weighted accessibility and travel-time coverage to the nearest CEmONC facility²⁴.

Administrative boundary and urban–rural classification datasets were obtained from the National Geospatial Platform of Nepal and were used to estimate travel-time accessibility across provinces, district level and among urban, peri-urban, and rural populations¹⁷.

2.3. Travel-time accessibility analysis:

A raster-based least-cost path approach was used to estimate the travel time from each raster cell to the nearest CEmONC facility using Dijkstra's algorithm. The resulting continuous travel-time raster was subsequently classified into five travel-time intervals (0–30, 30–60, 60–120, 120–240, and > 240 minutes) to facilitate interpretation and comparison of geographical accessibility. Population-weighted accessibility was then estimated by overlaying the travel-time raster with the masked WorldPop raster of women of reproductive age (15–49 years). The number and proportion of women residing within each travel-time interval were calculated by summing the population values contained within each travel-time class. In addition, population coverage was summarized at the provincial, district level and across the rural–urban gradient to evaluate spatial disparities in access to CEmONC services.

Population-weighted travel-time accessibility was subsequently aggregated at the provincial and district level to estimate geographical variation in access to CEmONC services across Nepal. To examine differences in geographical accessibility across settlement types, Nepal's administrative units were classified according to the National Geospatial Platform into urban, peri-urban, and rural categories. The population-weighted travel-time distributions were then summarized and compared across these settlement types using the classified travel-time raster and the population raster of women aged 15–49 years.

Data retrieval, Processing, analysis was conducted using R software²⁵. The friction surface was acquired using the MalariaAtlas Package²⁶, while the sf and terra packages were used for the handling and manipulating vector and raster datasets, respectively. Analyses were carried out both at pixel level and up to the provincial and district scales. Here, the Travel-time estimation was performed using the gdistance package, and output were visualized using the ggplot2²⁷, tmap²⁸ and cowplot²⁹ package.

Measures of inequality:

Population-weighted travel-time estimates to the nearest CEmONC facility were used to quantify geographical inequalities in accessibility. The Gini coefficient, Lorenz curve and Theil L index were calculated to evaluate the distribution of travel-time accessibility among women aged 15–49 years. The Gini coefficient summarizes the overall degree of inequality (0 = perfect equality; 1 = maximum inequality), the Lorenz curve illustrates the cumulative distribution of accessibility, and the Theil L index provides a complementary entropy-based measure of inequality. These metrics were derived from the raster-based travel-time surface weighted by the spatial distribution of women of reproductive age.

3. Results

3.1 Geographic Accessibility

[Figure 3 Population-weighted distribution of estimated travel time to the nearest CEmONC facility among women age 15–49 years]

The population-based distribution of estimated travel time to the nearest CEmONC facility among women aged 15–49 years is shown in Fig. 3. The histogram shows a strongly right-skewed distribution of travel times across the population-masked raster cell. Most raster cells have relatively short travel times, with frequency declining as travel time increases. A small number of cells have substantially longer travel times, producing the extended right tail of the distribution.

[Figure 4 Spatial distribution of travel time to the nearest CEmONC facility in Nepal]

Figure. 4. illustrates substantial spatial variation in travel time to the nearest CEmONC facility across Nepal. Areas with travel times of ≤ 30 minutes are concentrated primarily in the southern Tarai and major urban corridors, whereas longer travel times are more prevalent in the hill and mountain regions. Large areas of northern and remote Nepal require > 120 minutes of travel, with some locations exceeding 240 minutes. When the travel time raster was overlayed with gridded population layer of women aged 15–49 years, 52.4% of women were estimated to live within 30 minutes of a CEmONC facility, 30.1% within 30–60 minutes, 14.9% within 60–120 minutes, and 2.6% more than 120 minutes away.

3.2 Population Coverage

[Figure 5 Provincial distribution of women aged 15–49 years by travel time to the nearest CEmONC facility]

Figure. 5. shows the proportion of women aged 15–49 years residing within 30 minutes of a CEmONC facility was highest in Bagmati (88.1%) and Gandaki (84.7%), followed by Koshi (75.1%) and Lumbini (66.2%). The lowest proportions were observed in Karnali (56.2%) and Sudurpashchim (56.4%).

[Figure 6 Urban–rural differences in travel-time accessibility to (CEmONC) facilities in Nepal]

Figure. 6. shows the distribution of travel time varied across urbanization levels. Urban women aged 15–49 years were concentrated at shorter travel times, with the highest density below 30 minutes. Peri-urban women showed a broader distribution, mainly around 30–60 minutes. Rural women had a comparatively wider distribution extending beyond 60, 120, and 240 minutes, indicating greater travel-time burden in rural areas.

Inequality analysis

The Lorenz curve (Figure. 7.) demonstrated substantial inequality in geographical accessibility to CEmONC services across the spatial distribution of women aged 15–49 years, with a pronounced deviation from the line of perfect equality. The Gini coefficient was 0.65, indicating substantial inequality in travel-time accessibility, while the Theil L index was 0.86, further indicating marked inequality in the distribution of travel times. Across 198,295 valid population-containing raster cells, the mean travel time was 181.04 minutes. Together, these measures demonstrate considerable spatial inequality in

geographical accessibility to CEmONC services among areas inhabited by women of reproductive age. This figure is produced from our analysis

[Figure 7 Lorenz curve of geographical accessibility to CEmONC facilities in Nepal, based on raster-level travel time to the nearest facility]

The cumulative distribution curve (Figure. 7.) shows the population-weighted distribution of travel time across population-containing raster cells. The marked deviation of the curve from the 45° reference line indicates substantial variation in travel-time accessibility across the population distribution. The curve remains below the reference line across most of the distribution and rises sharply toward the upper end, indicating that a relatively smaller proportion of the population is associated with substantially longer travel times.

4. Discussion

This study provides a national spatial assessment of geographical accessibility to the CEmONC services in Nepal. The results show significant spatial variations in access to life-saving maternal and newborn health services, which are shaped by Nepal's diverse topography, road network, and unequal distribution of healthcare facilities. The travel-time accessibility maps demonstrate that areas with good access (≤ 30 minutes) are predominantly concentrated in the Tarai and along major urban corridors. These areas benefit from relatively flat terrain, higher road density, and better availability of motorized transport. In contrast, many parts of the hill and mountain regions experiences travel times exceeding 60 minutes, with some areas requiring several hours to reach the nearest CEmONC facility. This geographic trend is consistent with previous studies conducted in Nepal²³ and other low- and middle-income countries which show that rugged terrain and inadequate transportation infrastructure, which substantially limits timely access to emergency obstetric care⁶.

The analysis showed that 52.4% of women aged 15–49 years were within 30 minutes of the nearest CEmONC facility, 30.1% were within 30–60 minutes, 14.9% were within 60–120 minutes, and 2.6% required more than 120 minutes of travel nationally. These results indicate that a significant percentage of women still experiences delays in accessing life-saving emergency obstetric services, especially during obstetric emergencies, despite the fact more than half of the target group has relatively good geographic accessibility. According to similar studies in Nepal and other low and middle-income nations, travel time remains to be a major factor in determining timely maternal healthcare utilization^{6,10,23}.

Significant variations in population coverage were observed at the provincial level. With over 80% of women of reproductive age living within 30 minutes of a CEmONC facility, Bagmati and Gandaki provinces demonstrated the greatest population coverage within the 30-minute travel threshold. Madhesh and Sudurpashchim showed moderate population coverage, while Lumbini also showed comparatively high population coverage. In contrast, Karnali and Koshi provinces had the lowest coverage, which was a result of a combination of mountainous terrain, poor road connectivity, and

unequal distribution of health facilities. In order to improve equitable access, province-specific planning, optimal location of CEmONC facilities, and improved referral and transport systems are necessary^{10,23,30}. These results are in line with earlier studies that found persistent geographic disparities in access to maternal health services throughout Nepal.

At the district level, substantial inequalities in geographical accessibility to CEmONC facilities were observed (Supplementary Table 2). Accessibility within 30 minutes was highest in Kathmandu (90.1%), Bhaktapur (100%), Syangja (86.4%), and Gulmi (79.6%), whereas it was below 1% in several remote mountain districts, including Manang, Bajhang, Rasuwa, Humla, Dolpa, Darchula, and Mustang. In these districts, more than 90% of the population required over 120 minutes to reach the nearest CEmONC facility. This pronounced geographic disparity is consistent with previous studies in Nepal showing poorer maternal and emergency healthcare accessibility in mountainous and remote areas compared with more accessible central and southern regions. Despite differences in study populations, facility definitions, and travel-time thresholds, the findings consistently demonstrate persistent geographic barriers to timely emergency maternal care in Nepal^{10,11}.

The inequality analysis revealed substantial disparities in the geographical accessibility of CEmONC services throughout Nepal. A relatively small proportion of the population bears a disproportionately larger share of total travel time, as showed by the high Gini index (0.65), revealing substantial variations in geographical accessibility. Similarly, the Theil L index (0.86) indicates substantial overall inequality in geographical accessibility. These results imply that access to life-saving maternal healthcare is still uneven due to geographic barriers, especially in remote areas. These disparities are comparable to, or greater than, inequalities indicated in other low- and middle-income countries^{6,9,30}.

Geographical accessibility to CEmONC services was found to reflect a distinct rural–urban gradient, with urban populations having much lower travel times than rural populations. This discrepancy is a result of Nepal's difficult topography, poor road connectivity, and the concentration of specialized maternal Health services in cities. Nepal and other low- and middle-income nations have observed similar rural-urban disparities^{6,10,23}. In order to promote equitable access to maternal healthcare, these findings emphasize the necessity of strengthening referral systems, emergency transport, and strategically expanding CEmONC services in underserved rural areas^{9,30}.

The highly right-skewed distribution of travel-time values further highlights these inequalities. Although many locations are relatively near CEmONC facilities, a small yet highly vulnerable segment of the population experiences exceptionally long travel times, as shown by the maximum estimated travel time exceeding 7,500 minutes. These extreme travel-time values indicate the presence of geographically isolated settlements where timely access to emergency obstetric and newborn care is severely constrained. Global accessibility studies have shown similar long-tailed travel-time distributions, which are widely recognized as significant barriers to achieving equitable universal health coverage⁶.

The substantial geographical disparities identified in this study underscore the necessity for Nepal's maternal health policies to integrate spatial accessibility into the planning of CEmONC services. Priority should be given to strategically upgrading existing CEmONC facilities and expanding services in underserved hill and mountain regions, improving emergency transportation and referral networks, and utilizing GIS-based accessibility analyses to direct the evidence-based distribution of maternal health resources. Incorporating these strategies into the Nepal Health Sector Strategy 2022–2030 and the Safe Motherhood and Newborn Health Roadmap 2030 would facilitate more equitable access to life-saving maternal and newborn services and decrease the second delay in reaching care^{6,9,23,30}.

Although Nepal has made notable advances in increasing institutional deliveries and lowering maternal and neonatal mortality, the geographic distribution of CEmONC facilities does not adequately correspond to areas of greatest need. The clustering of services in urban and semi-urban locations systematically disadvantages remote communities, aligning with national evaluations that highlight persistent inequities in service distribution³¹. GIS-based travel-time modelling, as applied in this study, offers a powerful decision-support tool to identify priority areas for strengthening referral networks and improving transport infrastructure or emergency transport schemes³². This study assessed potential geographical accessibility by estimating travel time from residential locations to the nearest designated CEmONC facility. However, CEmONC facilities primarily operate as referral centres, and women with obstetric emergencies are often referred from lower-level facilities rather than travelling directly from home. Therefore, the estimated travel times may not fully capture referral-related delays experienced in routine clinical practice. Future studies integrating referral pathways, transport availability, and facility functionality could provide a more comprehensive assessment of access to emergency obstetric and newborn care. Additionally, population-weighted accessibility was estimated using WorldPop data to better represent women of reproductive age, the travel-time surface was generated for the entire study area, including sparsely populated and uninhabited regions. Future studies should derive accessibility surfaces directly from populated locations to improve policy relevance.

Furthermore, the analysis assumed that all designated CEmONC facilities were equally capable of providing comprehensive emergency obstetric and newborn care. In reality, facility functionality may vary because of differences in staffing, availability of blood transfusion services, surgical capacity, equipment, and service readiness. Incorporating measures of facility functionality into future accessibility analyses would provide a more realistic assessment of effective access to life-saving care. Also, the analysis relied on the globally developed Malaria Atlas Project motorized friction surface, which may not fully capture Nepal-specific road conditions, seasonal accessibility, and transport characteristics. In future development of a Nepal-specific friction surface would further improve the precision of accessibility estimates.

Finally, while this study focuses on geographical accessibility to the nearest CEmONC facilities, it is crucial to understand that geographical accessibility alone does not ensure effective care. Maternal and newborn outcomes are also significantly influenced by facility preparedness, the availability of skilled workers, blood supply, equipment, and 24/7 service functionality³³. Nonetheless, geographic

accessibility is a crucial prerequisite for service utilization, and addressing the significant spatial disparities identified in this study is vital for achieving Nepal's Safe Motherhood objectives and the Sustainable Development Goal targets for reducing maternal and neonatal mortality.

5. Conclusion

Geographical access to CEmONC services in Nepal remains highly uneven, with substantial disparities across different regions of the country. While some populations benefit from relatively timely access to CEmONC facilities, many communities continue to face significant geographic barriers that may limit access to life-saving maternal and newborn health services. These findings underscore the importance of incorporating geographical accessibility into health service planning and resource allocation to promote more equitable access to emergency obstetric and newborn care. The GIS-based methodology applied in this study provides a practical and scalable approach for assessing healthcare accessibility and can be readily adapted in other countries using widely available high-resolution geospatial datasets.

Declarations

Ethics approval and consent to participate

This study used secondary, publicly available and geospatial datasets and did not involve direct recruitment of human participants or collection of identifiable individual-level data. Therefore, ethical approval and informed consent were not required.

Consent for publication

Not applicable. This study does not contain individual participant data, images, or other personally identifiable information requiring consent for publication.

Availability of Data and Materials

The study used publicly available and/or openly accessible secondary datasets, including publicly available geospatial, population, administrative boundary, and friction-surface data. The data sources and access information are provided in the manuscript and reference list. Derived datasets generated during the analysis are available from the corresponding author upon reasonable request, subject to applicable data-use conditions.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

AC and BKA conceptualized the study and contributed equally to the study design, methodology, analysis, interpretation of results, and manuscript preparation. AC drafted the manuscript and was primarily responsible for data collection and analysis, with BKA providing supervision and guidance throughout the study. Both authors critically reviewed and approved the final version of the manuscript.

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Figures

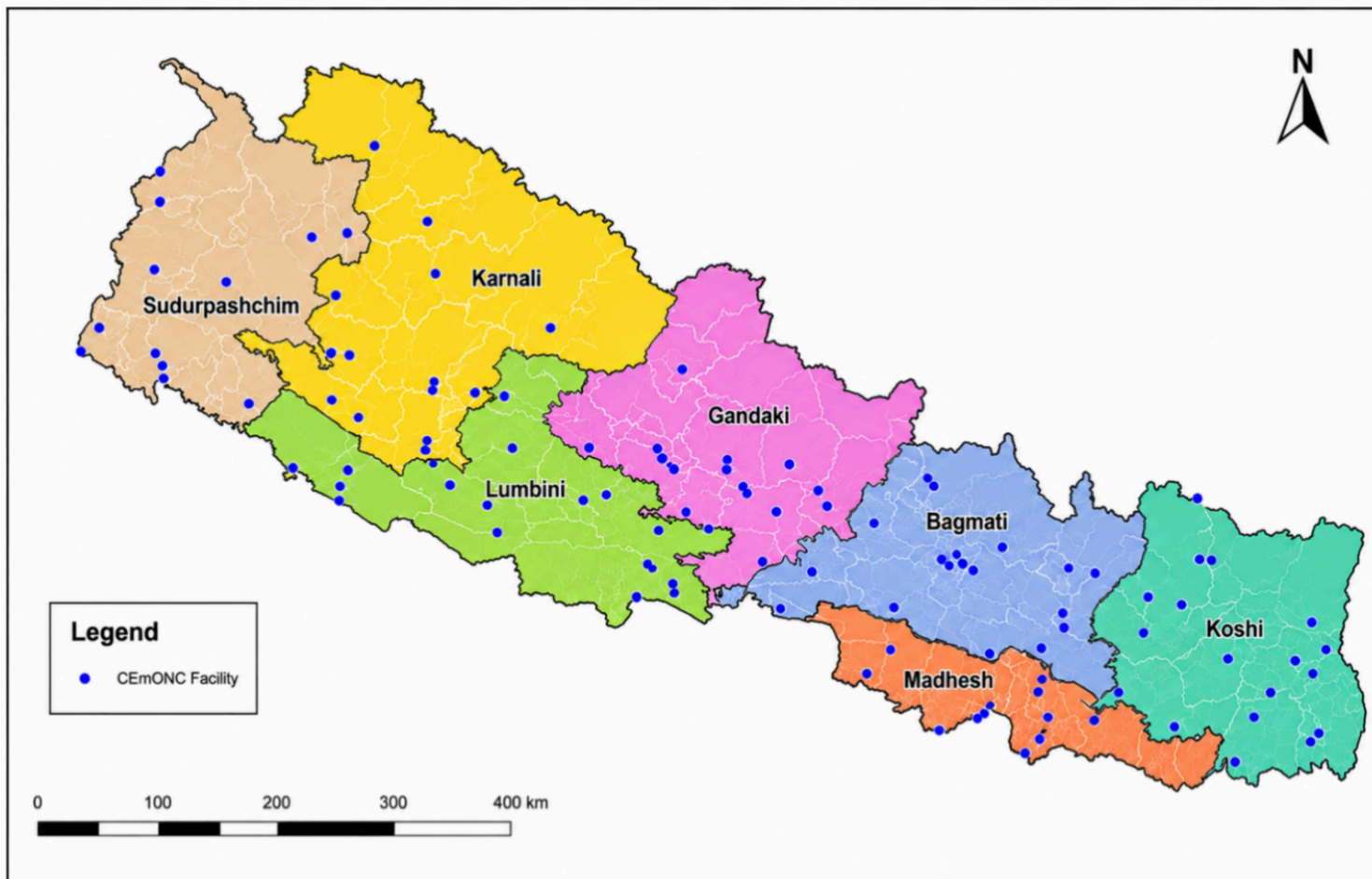


Figure 1

Study area showing Nepal's seven provinces, district boundaries, and the spatial distribution of designated Comprehensive Emergency Obstetric and Newborn Care (CEmONC) facilities included in the analysis.

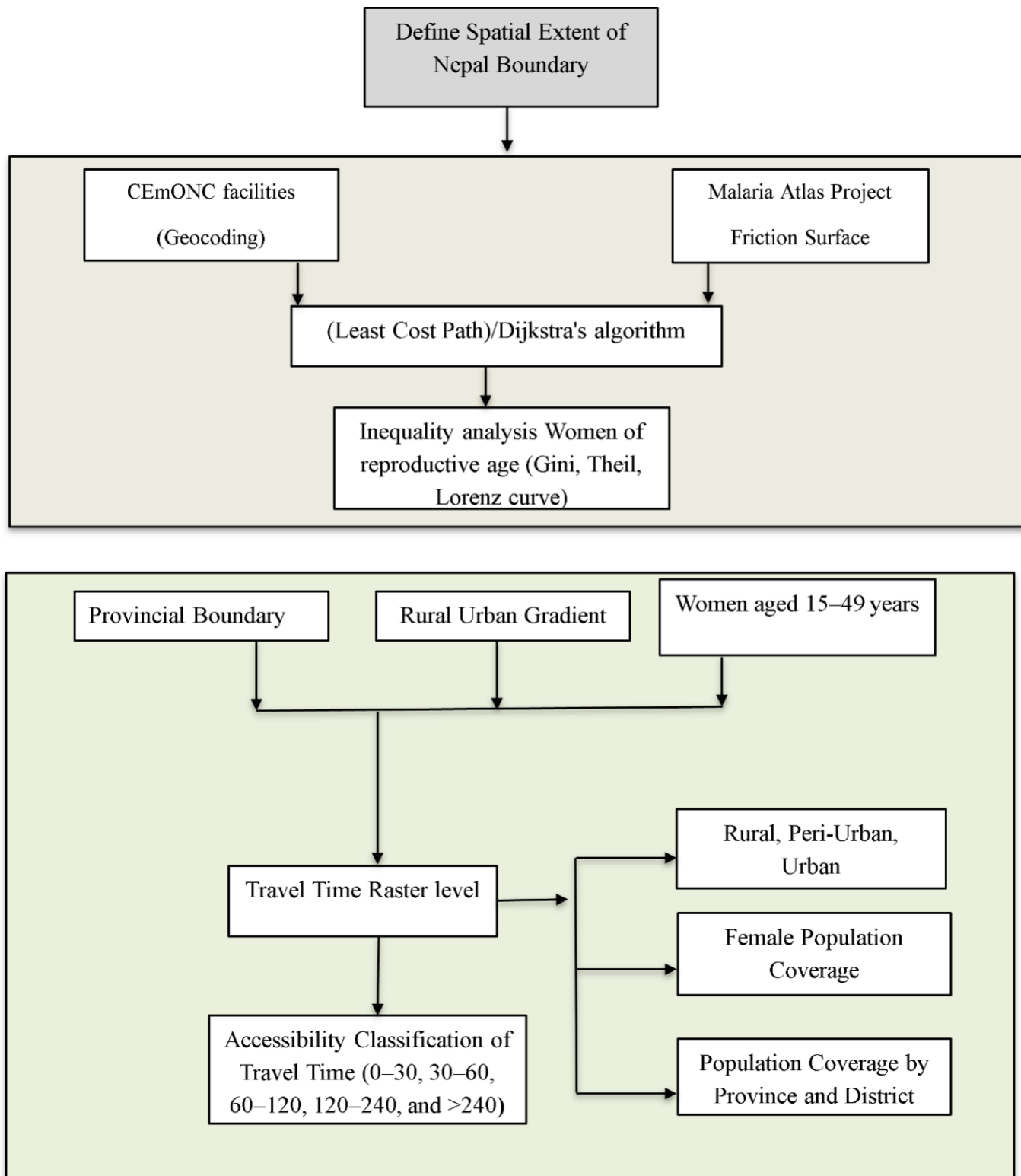


Figure 2

Workflow Diagram

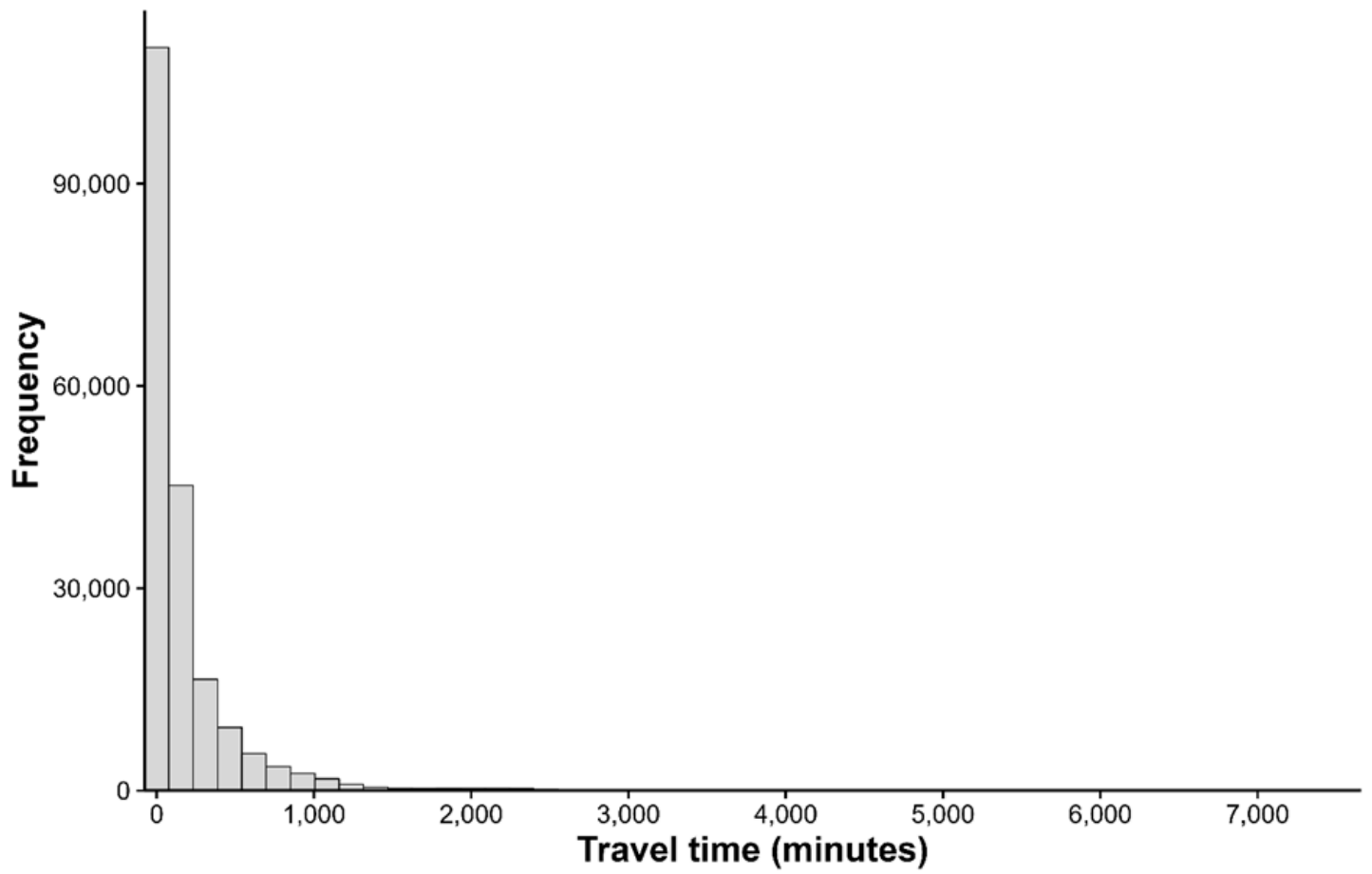


Figure 3

Population-weighted distribution of estimated travel time to the nearest CEmONC facility among women age 15-49 years

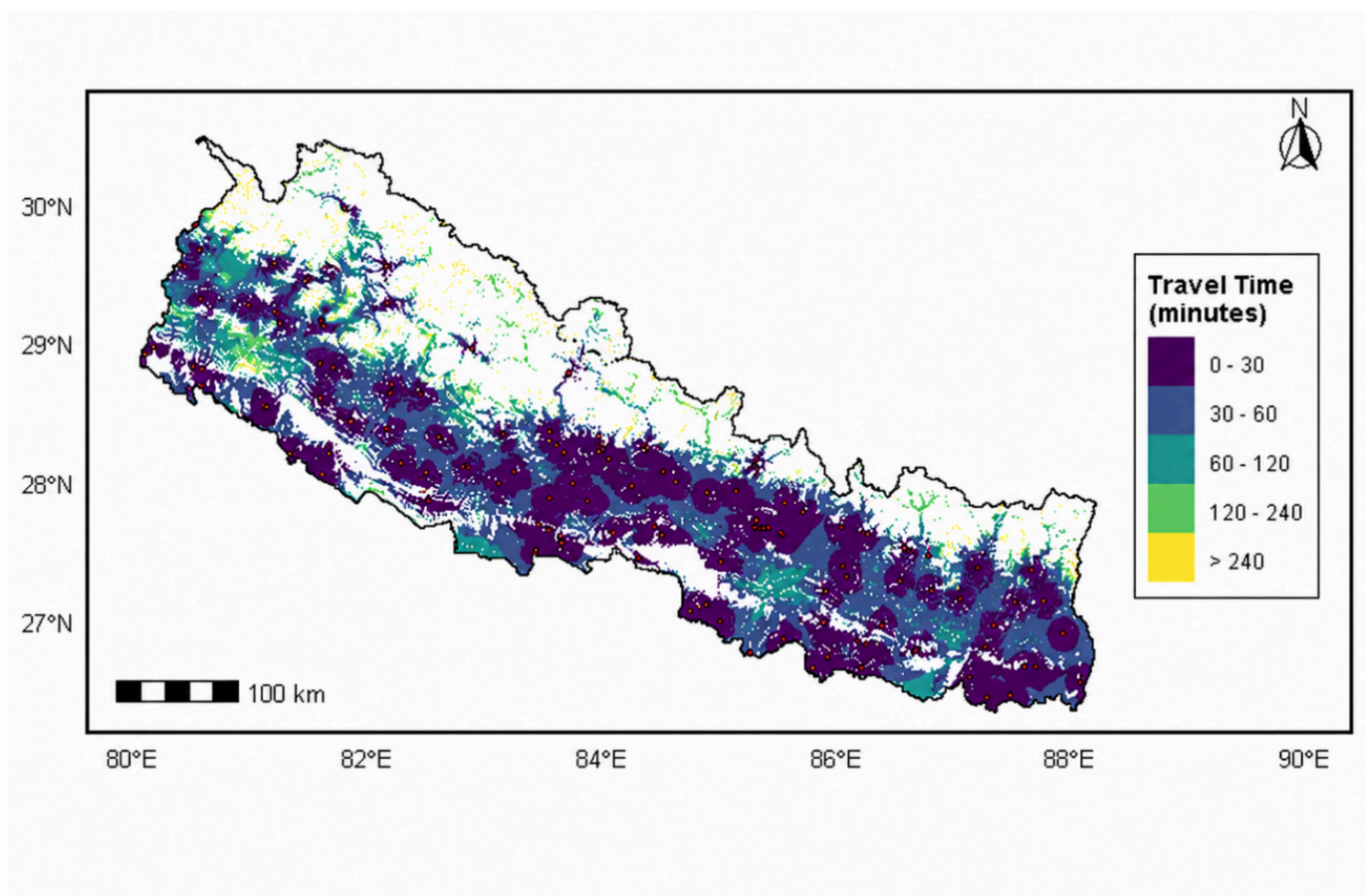


Figure 4

Spatial distribution of travel time to the nearest CEmONC facility in Nepal

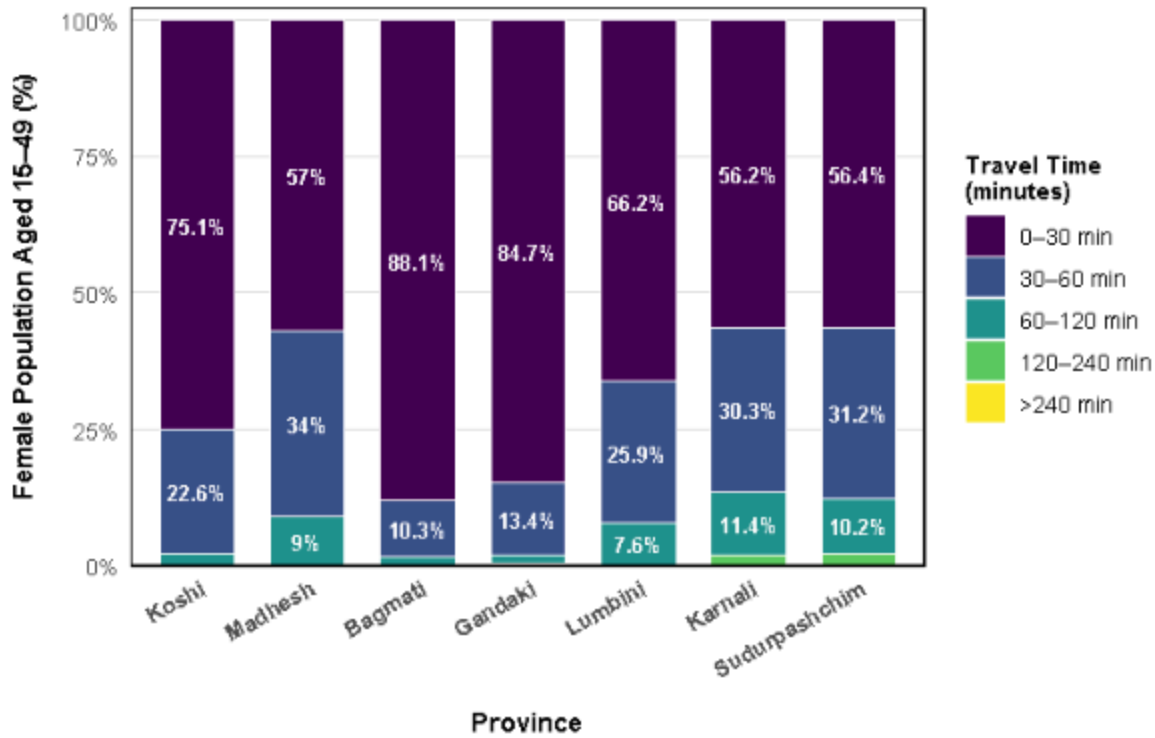


Figure 5

Provincial distribution of women aged 15–49 years by travel time to the nearest CEmONC facility

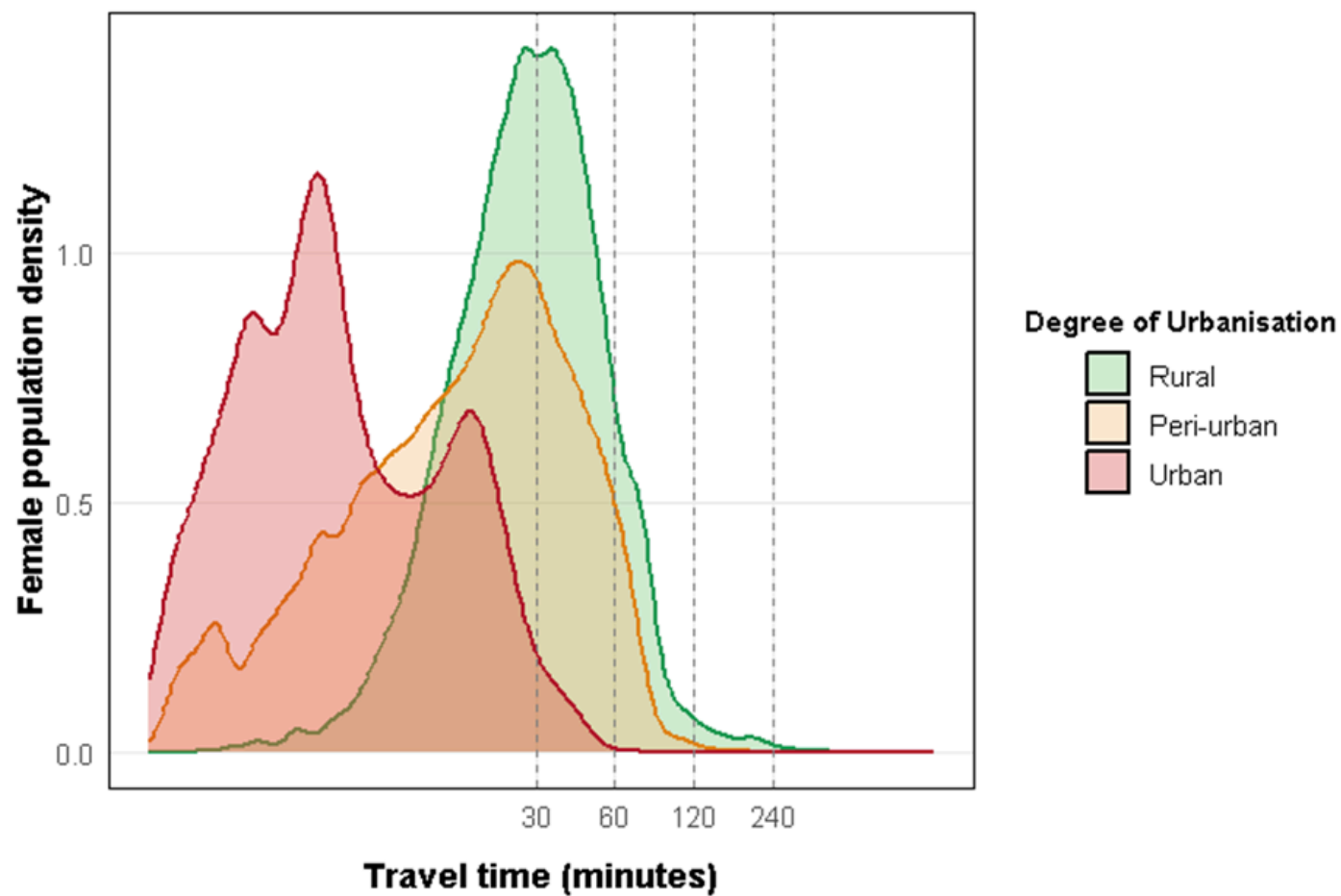


Figure 6

Urban–rural differences in travel-time accessibility to (CEmONC) facilities in Nepal

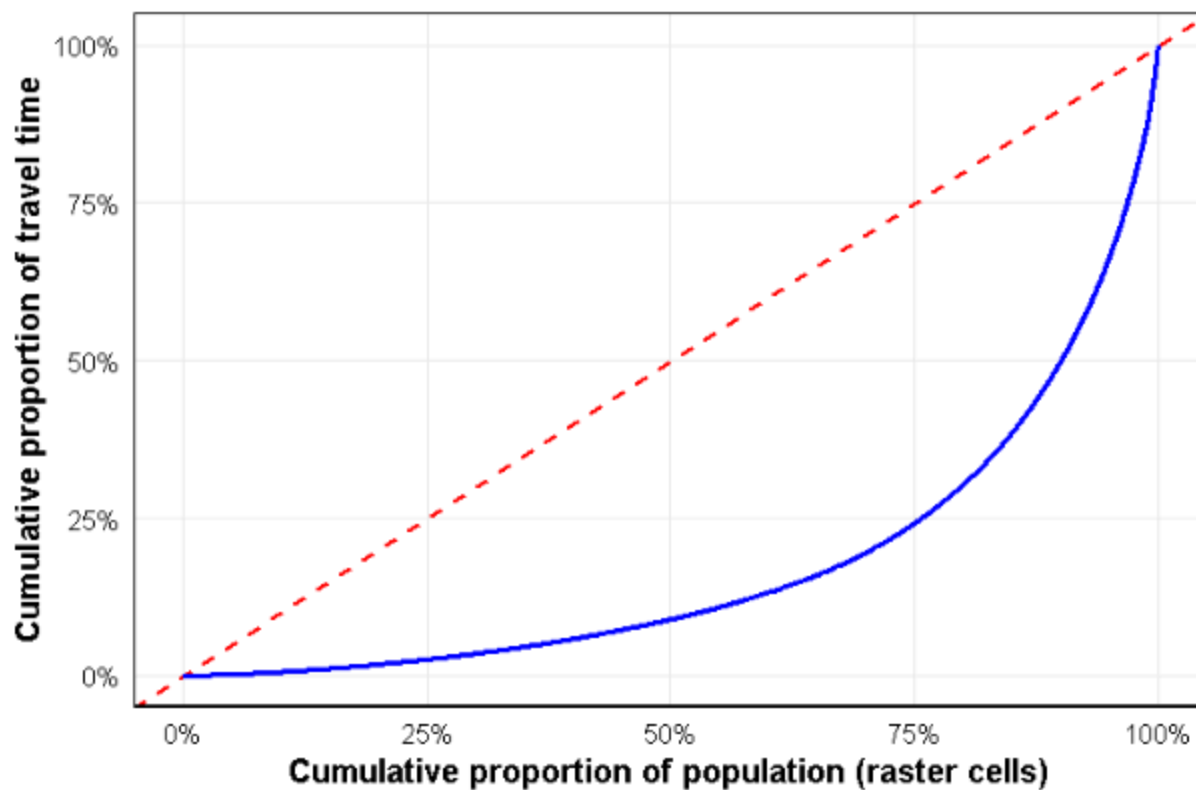


Figure 7

Lorenz curve of geographical accessibility to CEmONC facilities in Nepal, based on raster-level travel time to the nearest facility

Supplementary Files

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