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Geographical accessibility of emergency neonatal care services in Ethiopia: analysis using the 2016 Ethiopian Emergency Obstetric and Neonatal Care Survey

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ABSTRACT

Introduction Access to emergency neonatal health services has not been explored widely in the Ethiopian context. Accessibility to health services is a function of the distribution and location of services, including distance, travel time, cost and convenience. Measuring the physical accessibility of health services contributes to understanding the performance of health systems, thereby enabling evidence-based health planning and policies. The physical accessibility of Ethiopian health services, particularly emergency neonatal care (EmNeC) services, is unknown.

Objective To analyse the physical accessibility of EmNeC services at the national and subnational levels in Ethiopia.

Methods We analysed the physical accessibility of EmNeC services within 30, 60 and 120 min of travel time in Ethiopia at a national and subnational level. We used the 2016 Ethiopian Emergency Obstetric and Neonatal Care survey in addition to several geospatial data sources.

Results We estimated that 21.4%, 35.9% and 46.4% of live births in 2016 were within 30, 60 and 120 min of travel time of fully EmNeC services, but there was considerable variation across regions. Addis Ababa and the Hareri regional state had full access (100% coverage) to EmNeC services within 2 hours travel time, while the Afar (15.3%) and Somali (16.3%) regional states had the lowest access.

Conclusions The physical access to EmNeC services in Ethiopia is well below the universal health coverage expectations stated by the United Nations. Increasing the availability of EmNeC to health facilities where routine delivery services currently are taking place would significantly increase physical access. Our results reinforce the need to revise service allocations across administrative regions and consider improving disadvantaged areas in future health service planning.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This is the first study to investigate the accessibility of emergency neonatal care services in Ethiopia, estimating the geographical accessibility of health services accounting for land cover, elevation, hydrographical and road network travel barriers as well as human resource availability.

⇒ This approach can be used in other applications of access to healthcare in Ethiopia and elsewhere.

⇒ Our study addressed only geographical accessibility while access can be measured considering other aspects, including financial feasibility and consumer preferences.

⇒ While we relied on assumptions about the maximum permitted travel speed in Ethiopia, this was not sensitive to a 25% reduction in the maximum travel speed.

⇒ The health facilities' maximum capacity data were based partly on the WHO estimate of births per skilled birth attendant per year due to the lack of standard records in Ethiopia.

INTRODUCTION

Access is an essential concept in health policy and health services provision.[1–3] It is an important part of health, enabling the opportunity to obtain healthcare when needed.[4] Access to health services has multiple dimensions, including financial and physical access.[5 6] Factors such as income, media exposure, level of education and healthcare-seeking behaviours are accessibility factors that facilitate or hinder access to healthcare. Physical accessibility indicates the relationship between healthcare location and the population seeking access, considering transportation infrastructure, travel time, distance and cost.[2 3 7]

Health services access and utilisation are strongly associated, as utilisation is an indication of revealed accessibility.[8] Accessibility to health services is a function of the distribution and location of health services, including distance, travel time, travel cost and convenience.[9] Traditional approaches to measuring accessibility typically estimate the availability of health facilities within a certain

distance of a given population.[10 11] However, methods to estimate the travel time to services, accounting for travel time across varying terrain and road surfaces, and financial availability are crucial to understanding the actual accessibility to health services.[12 13]

Accessibility to Emergency Obstetric and Neonatal Care (EmONC) and Emergency Newborn Care (EmNeC) services are important determinants of maternal and neonatal survival.[14] Lack of access to these services hinders facility-based delivery and skilled care provider follow-up.[15 16] EmONC and EmNeC have some services in common, but EmONC contains maternal and newborn care, while EmNeC focuses solely on neonatal care services. The WHO handbook for monitoring EmONC advises a minimum of five EmONC facilities per 500 000 population and access within 2 hours of travel time.[17] Of the five facilities, one should be a comprehensive EmONC service.

EmNeC services consist of seven signal functions complementing the EmONC signal functions. The signal functions include antenatal corticosteroids, antibiotics for premature rupture of membranes, antibiotics for neonatal infections, kangaroo mother care, resuscitation with bag and mask, administration of oxygen and intravenous fluids.[18] Health facilities providing all these signal functions are considered to be fully EmNeC health facilities.

In Ethiopia, the diverse environmental, climatic, socioeconomic and terrain significantly affect health access and outcomes. Inadequate access to healthcare is of particular concern in the rural part of the country, where road and transportation infrastructure are under-developed and access to health services is limited.[19] It is important to understand the contribution of access to health services to the variation of neonatal mortality across sub-national regions in Ethiopia. However, the distribution of EmNeC health services and their access among sub-national areas have not been yet explored.[20 21] Therefore, understanding the accessibility of neonatal health services may assist health planning and service administration.[22 23]

Ethiopia's latest health sector development programme strongly emphasise achieving universal health coverage (UHC),[24] mainly focusing on improving women's and children's health.[25] This study aims to analyse the geographical accessibility of emergency neonatal care (EmNeC) services at national and subnational levels in Ethiopia.

METHODS
Study setting
The Ethiopian health system is based on the primary healthcare approach with three levels of care. The primary level includes primary hospitals, health centres and health posts (the lowest-level facility at a village level). The secondary level includes specialty centres (eg, maternal and child health (MCH) specialty centres), specialty clinics and general hospitals that serve as referral centres for primary hospitals, and the tertiary level includes specialised referral hospitals.[26] Most of the EmNeC signal functions are performed in hospitals and MCH specialty centres.[18] A specialty centre differs from a specialty clinic as specialty centres have inpatient admissions and offer 24 hours emergency services. A specialty centre differs from a hospital in that they do not offer the full spectrum of specialties required for a general hospital.[27]

Population and variables
The target population for this analysis were all live births in Ethiopia taken from the 2016 UN estimates of numbers of live births per 1 km grid square.[28] The primary outcome variable in this study was accessibility to fully functioning EmNeC within 30 min, 1 hour and 2 hours travel time at a national and regional level. Secondary outcomes include accessibility of fully functioning health services through walking travel and access to health facilities with partial EmNeC signal functions. Accessibility was defined as the access from a residence to a health facility within 2 hours of travel time based on the WHO optimal access definition.[29] The facilities were considered to be fully functioning if all the seven signal functions for EmNeC were available in the past 3 months before the survey.

Patient and public involvement
No patient involved.

Data source
We used three data groups for this analysis: statistical, geospatial and national norms data. The statistical data included national and regional population sizes and the number of functional EmNeC health facilities. The geospatial data were regional administrative boundary data, geographical location of all health facilities providing delivery services, road network, hydrographical network, land cover, digital elevation model (DEM) data and spatial distribution of live births in Ethiopia in 2015. The national norms data include the maximum travel speed expected for a motor vehicle on the different road types and the average capacity of health facilities that they could serve.

We used the Ethiopian 2016 EmONC survey, which is a national census of health facilities providing maternal and neonatal services.[18] A total of 3804 health facilities providing delivery services were included in the EmONC survey. Ethiopia's 2016 produced boundary shapefile, a geospatial vector data format matching the level of disaggregation of the subnational statistical data, was accessed through OpenAFRICA[30]; land cover and DEM data of 2015, a representation of the bare ground topographical surface of the Earth were accessed from the DIVA-GIS webpage.[31] The 2015 raster data for live births per 1 km grid square was accessed via the WorldPop webpage.[28] We used OpenStreetMaps via the World Food Programme data repository of 2017[32] to estimate travel speeds for motorised vehicles based on the primary, secondary, and

tertiary and unclassified road surfaces. We used DEM data to estimate the effects of slopes on travel time.[33] The barrier to travel (hydrographical data) was obtained from RCMRD GeoPortal[34] and DIVA-GIS[31] web pages produced in 2015.

We created a travel scenario for walking and motorised transportation based on the land cover structure and road types. We assumed that walking speed ranged from zero km/hour for water bodies to 2.5 km/hour for established residential areas, assuming a pregnant woman in her last month of pregnancy would be able to walk at half the average walking speed as used elsewhere.[35] We assumed driving speeds of 100, 70, 50 and 30 km per hour for primary, secondary, tertiary and unclassified road types based on the country's speed limit.[36] We used these speeds as ambulances would be able to travel at the maximum speed in emergency situations. We also conducted a sensitivity analysis for fully EmNeC services coverage, lowering the maximum vehicle speed by 25%. The road network data were classified based on Ethiopian speed limit norms. The main road classifications in Ethiopia are primary, secondary, tertiary and unclassified.[32] However, the road network data available online includes several classifications, including the linking roads between primary roads-so we need to reclassify into the above four main classifications. Primary, primary link, motorway and trunk roads were classified as primary, secondary and secondary links as secondary, tertiary and tertiary links as tertiary and track and unclassified were merged as unclassified road classes.

We assigned the maximum capacity for each health facility category based on the standard WHO assumption of births per skilled birth attendant per year.[37] We assigned 175, 100, 75 and 50 births per skilled birth attendant per year for hospitals, MCH specialty centres, health centres and clinics. We then multiplied the number of births per year by the number of skilled birth attendants at each facility to estimate the total number of possible births per year at each health facility.

Data processing and analysis

We integrated multiple geospatial datasets in AccessMod, which is a free, open-source software package developed by the WHO. AccessMod uses geographical information systems (GIS),[38] which are computer-based systems to gather, store, retrieve, analyse and display spatial data, to assess health facilities physical accessibility and geographical coverage.[39] AccessMod models the coverage of catchment areas linked to an existing health facility network integrating population distribution, travel time and the population coverage capacity specific to each health facility in the network.[40] AccessMod computes catchment areas using the least-cost path algorithm.[41] The least-cost path approach calculates the distance between a focal location and all cells in the surroundings, dividing surface areas into grid cells. It identifies the best path from one point to another over a cost surface, identifying the cost of travelling through each grid cell, which has been given

to cost how expensive, it is to pass through that cell.[42] The cost given to each cell is the travelling time to cross the grid cell, which is determined through the travelling speed attributed to the elevation and land cover of the cell. Finally, it produces a point estimate of cumulative access coverage of health services to catchment areas population.

The vector and raster geospatial data files were projected based on Ethiopia's geographical coordinate system at Adindan UTM zone 37N[43] to make it suitable for analysis. A projection is the means by which we display the coordinate system and data on a flat surface, such as a piece of paper or a digital screen. A projected coordinate system is a two-dimensional flat surface, and locations, in this case, are identified by x, y coordinates.[44]

RESULTS
Characteristics of health facilities

A total of 3804 health facilities (100% response rate) were assessed in the 2016 EmONC survey, of which 3789 were providing routine delivery services. A total of 3308 (87.0%) health facilities were fully operating their routine maternal and child services, 458 (12.0%) were fully operating and under redevelopment to expand service coverage, and the remaining 38 (1.0%) were partially operating or under redevelopment during the time of the survey. The majority (91.0%) of health facilities providing delivery services were health centres, and the largest number of fully EmNeC services were primary hospitals (43%). Only 4 (3.4%) fully EmNeC services were health centres (see table 1).

Most health facilities (n=3662, 96.3%, not included in the table) were public, while 83 (2.2%) were private for-profit and 59 (1.6%) were private not-for-profit (faith-based and non-governmental). A total of 116 (3.0%) health facilities were fully EmNeC, and 471 (12.5%) health facilities were with no EmNeC signal functions (see table 2).

Access to health facilities

We estimated that 46.4% of live births in 2016 lived within 2 hours of travel time to fully EmNeC facilities. Approximately one-third of live births (35.9%) had access to a fully EmNeC facility within 1 hour, and 21.4% within 30 min travel time. The access coverage for partially EmNeC facilities (ie, missing one or two signal functions) was 69.1%, 52.2%, and 33.5% within 2 hours, 1 hour and 30 min, respectively. The geographical access coverage to health facilities providing routine delivery services was 78.8% within 2 hours of travel time. Access to fully EmNeC services varied widely among regions, ranging from 15.3% to 100% coverage within 2 hours of travel time (see figure 1). In the sensitivity analysis, when we considered 25% lower vehicle speeds than the maximum allowed driving speed, the coverage for fully EmNeC facilities was 44.0% (see online supplemental appendix 1 for regional access coverage).

Table 1 Frequency and percentages of health facilities providing routine delivery and emergency neonatal care (EmNeC) services, 2016

Health facility type	Normal delivery		Partially EmNeC (five or six signal functions)		Fully EmNeC	
	n	%	n	%	n	%
Referral/specialised hospital	29	0.8	12	0.4	18	15.5
General hospital	103	2.7	59	1.8	39	33.6
Primary hospital	160	4.2	104	3.2	50	43.1
MCH specialised sentre	22	0.6	17	0.5	5	4.3
Health centre	3447	91.0	2999	93.3	4	3.4
MCH specialty clinic	15	0.4	10	0.3	0	0.0
Higher clinic	13	0.3	13	0.4	0	0.0
Total	3789	100	3214	100	116	100

Percentage totaled column-wise indicating the shared of EmNeC functioning at each type of health facility.
MCH, maternal and child health.

Of all live births in Ethiopia in 2016, 7.9% were in areas where fully EmNeC services could be accessed within 2 hours of walking, and only 5.4% were in areas in which a fully EmNeC service could be accessed within 1 hour of walking travel time. Somali, Oromia, Benshangul Gumuz and Amhara regional states had the lowest access coverages to EmNeC facilities for access within 2 hours. The estimates of total live births by regional states are presented as online supplemental appendix 2.

Figure 2 displays the areas that had access to health facilities that provide normal delivery and fully EmNeC services within 2 hours. Access to facilities providing full EmNeC services within 2 hours was lower in the country's eastern, north-eastern and peripheral areas (areas away from the centre and near borders) compared with the coverage of services providing routine delivery services (see figure 2).

A trend of decreasing access coverage to fully EmNeC services was observed from an hour to 30 min travel time (see figure 3).

DISCUSSION

We found that more than one in two children born in Ethiopia did not have access to fully EmNeC health services in 2016 within a travel time of 2 hours. Nearly two-thirds of live births would have involved travel of more than an hour, and more than three-quarters would have travelled for more than 30 min to access fully EmNeC health facilities.

The coverages we found are considerably below the UHC target of MCH services, defined by the WHO as 95% for low-income and middle-income countries, including Ethiopia.[45] It is also lower than expected UHC stated by the United Nations, with a resolution adopted stating that 90% of all births in the country would be within 2 hours of travel from EmONC/EmNeC facilities to ensure maternal and child UHC.[37 46]

The current access coverage is lower than the study findings on access to basic emergency obstetric and newborn care services in Bangladesh and Malawi. In Bangladesh,

Table 2 Health facility types by Emergency Neonatal Care functionality, Emergency Obestetric and Neonatal Care Survey 2016

| Health facility type	No of signal functions performed											
	7		5 or 6		3 or 4		1 or 2		0		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Referral/specialised hospital	18	60.0	8	26.7	2	6.7	2	6.7	0	0.0	30	100
General hospital	39	37.9	36	35.0	12	11.7	11	10.7	5	4.9	103	100
Primary hospital	50	31.3	56	35.0	29	18.1	19	11.9	6	3.8	160	100
MCH specialised centre	5	21.7	8	35.8	5	21.7	4	17.4	1	4.3	23	100
Health centre	4	0.1	117	3.4	1119	32.4	1763	51.0	456	13.2	3459	100
MCH specialty clinic	0	0.0	2	12.5	3	18.8	5	31.3	6	37.5	16	100
Higher clinic	0	0.0	4	30.8	5	38.5	4	30.8	0	0.0	13	100
Total	116	3.0	231	6.1	1175	30.9	1808	47.5	474	12.5	3804	100

MCH, maternal and child health.
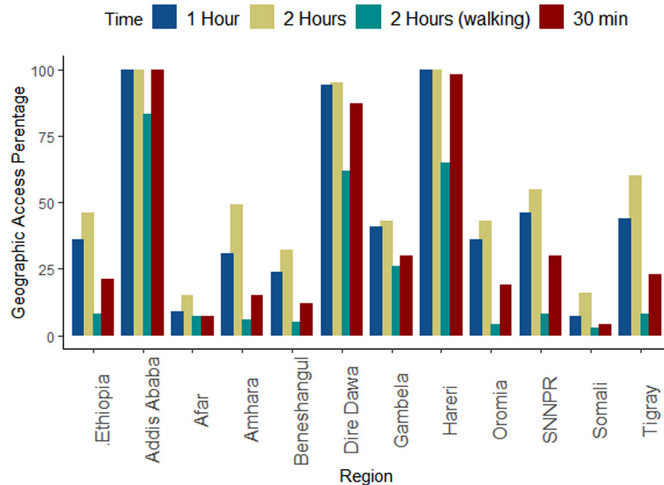
Figure 1 National and regional geographical access coverage to fully functioning EmNeC health facilities within 2 hours, 1 hour and 30 min using motorised and walking composite transportation scenario and within 2 hours through walking travel time in Ethiopia, 2016. EmNeC, emergency neonatal care.

72.0% of live births lived within 2 hours, and 59.0% lived within an hour of travel time from an EmONC facility in 2012.[47] In Malawi, 88.1% of live births could access emergency obstetric and newborn care services within 2 hours and 65.3% within an hour travel time in 2015.[37]

More than three-quarters of live births had access to health facilities providing routine delivery services within 2 hours of travel time. This figure implies that a significant improvement to access EmNeC services could be achieved if more health facilities currently providing routine delivery services had been equipped with EmNeC services. However, it still would be lower than the 90% UHC standard for newborn care services. If we consider access to facilities with EmNeC services that missed zero, one or two signal functions, coverage was 69.0%. Along with expanding infrastructures, meeting the human resource requirements should also be considered. The current workforce in the Ethiopian health system is far below the WHO standard of 4.45 skilled health workers per 1000 population.[48] Ethiopia has a very low health workforce (Medical Doctors, Health Officers, Nurses and Midwives) density per population which was 0.96 per 1000 population in 2018.[49]

Access to fully EmNeC services varied widely among administrative regions. Addis Ababa, Hareri and Dire Dawa had the best access to EmNeC services within 2 hours, and the Afar and Somali regional states had the lowest access coverage. Addis Ababa had full access to EmNeC health facilities within 30 min of travel time. Addis Ababa is the country's capital city, with a large number of public and private health services concentrated in the city. The majority of Hareri and Dire Dawa regions also consist of urban areas, and there is a significant health service access disparity between urban and rural areas in Ethiopia.[50] This suggests the need for a

stronger emphasis on the development of health infrastructure in rural areas and the less developed regional states by equipping health centres with neonatal service signal functions. While a larger number of health centres were built in the country's rural areas serving the majority of the population compared with metropolitan areas, only a few health centres had all seven signal functions, and half of the health centres had one or two signal function services.

In line with this finding, studies showed discrepancies between administrative regions in health services coverage. For example, a study on access to emergency maternal and newborn care services in the neighbouring two regional states (Amhara and Tigray) showed a difference in access to emergency services with 68.0% vs 80.0% in accessing within 2 hours of travel time, and 8.0% vs 25.0% in the percentage of recommended EmONC coverage in Amhara and Tigray, respectively. The public health expenditure per capita was also approximately double in the Tigray regional state compared with the Amhara regional state (US$2.81 vs US$1.50).[51] In this study, the access coverages in Amhara and Tigray regional states were 48.7% and 60.0% within 2 hours of travel time. The difference between these neighbouring regions indicates the trends of inequitable distributions of health services across administrative regions, which could be attributed to the inequitable distributions of resources across regional states in the last three decades.[52] Another study finding from a review of 54 countries on equity of health services showed that Ethiopia is the top among countries with the most significant maternal and newborn service coverage inequalities.[53]

The catchment areas with limited access to EmNeC services within 2 hours, an hour and 30 min are in the eastern (Somali region), north-eastern (Afar region), and western and north-western areas near the borders to South Sudan and Kenya. Only a few areas were located within 30 min of reach to fully EmNeC health facilities, with most EmNeC health services being concentrated in the central, northern and north-western parts of Ethiopia. Afar, Somali and most parts of Benshangul Gumuz and Gambela regional states were mapped with a lower density of access coverage. These are known as comparatively less developed regional states of Ethiopia with considerably lower coverage of MCH outcomes.[25] Furthermore, most areas with lower EmNeC services coverage largely encompassed pastoralist communities that base their livelihood on agricultural activity of animal husbandry.[54]

This finding strengthens previous findings, showing low health coverage and low utilisation of services among the pastoralist communities in Ethiopia.[55 56]

Strength and limitations

This is the first study investigating the geographical accessibility of emergency newborn care in Ethiopia. We estimated the geographical accessibility to health services accounting for land cover, elevation, hydrographical and road network travel barriers as well as human resources
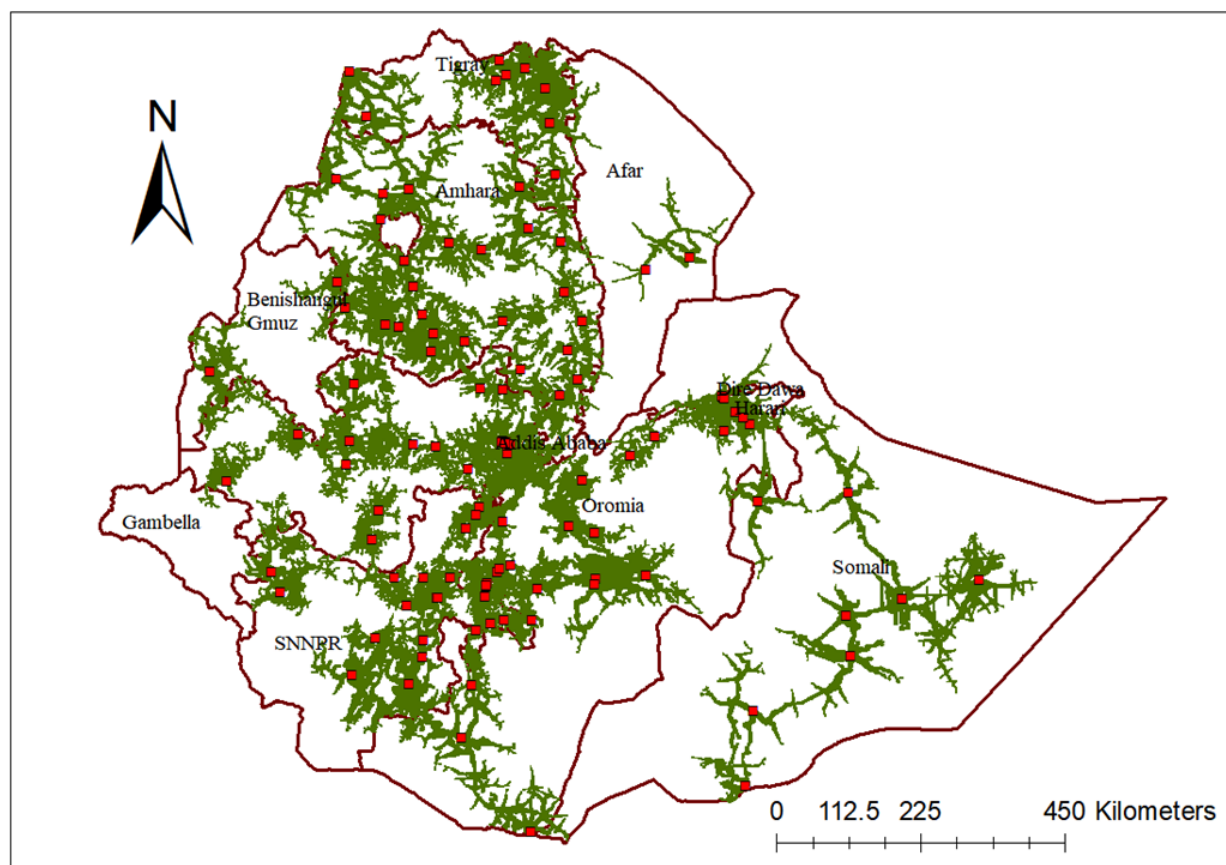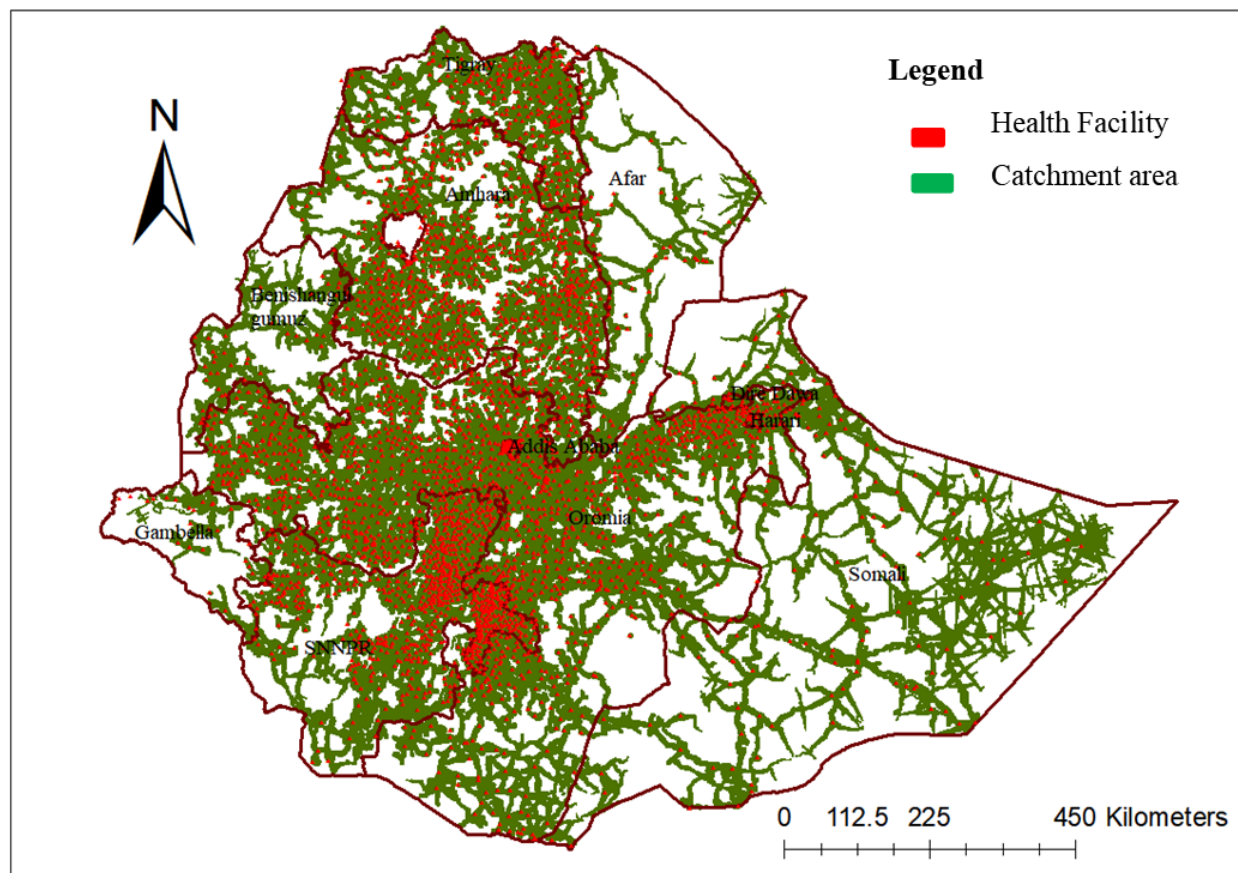
Figure 2 Catchment areas (dark green) of facilities accessible to routine delivery services (upper panel) and fully EmNeC services within 2 hours (lower panel) travel time. EmNeC, emergency neonatal care.
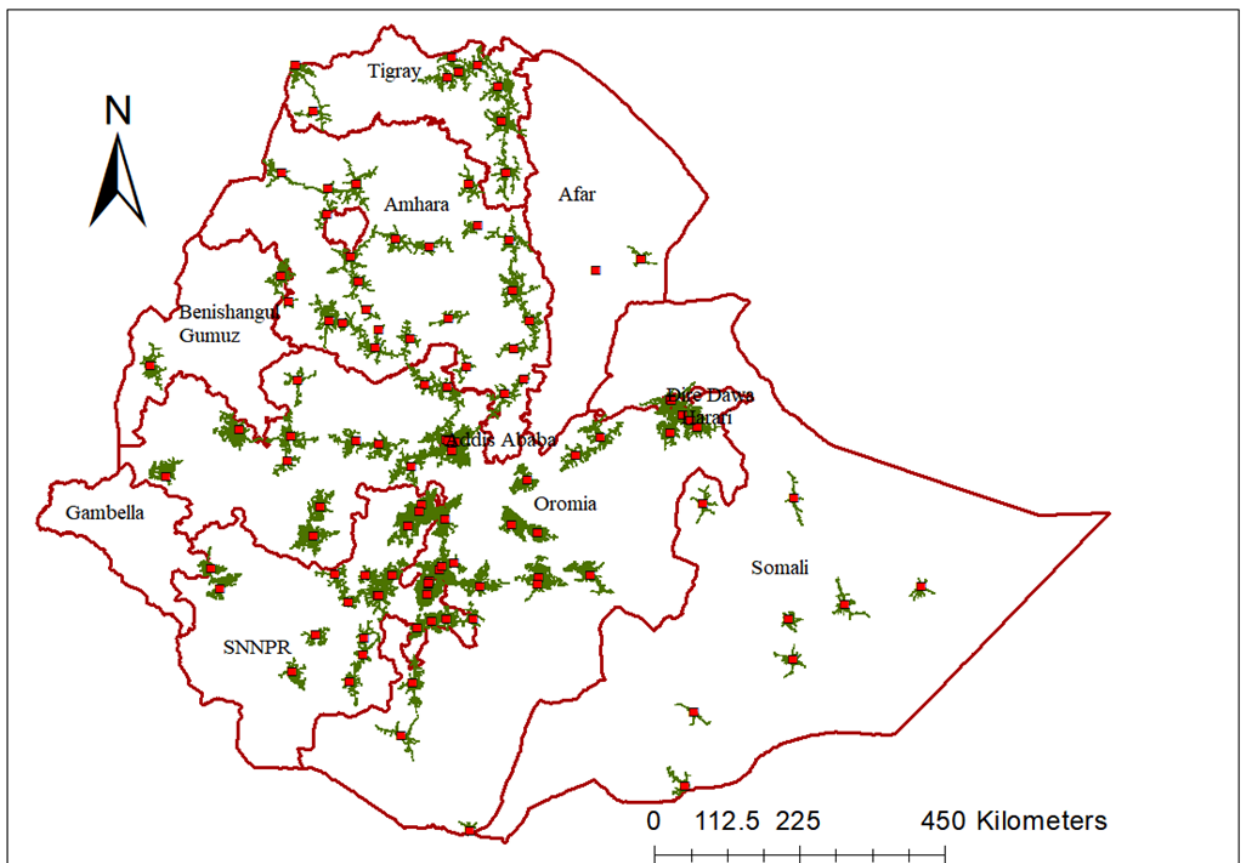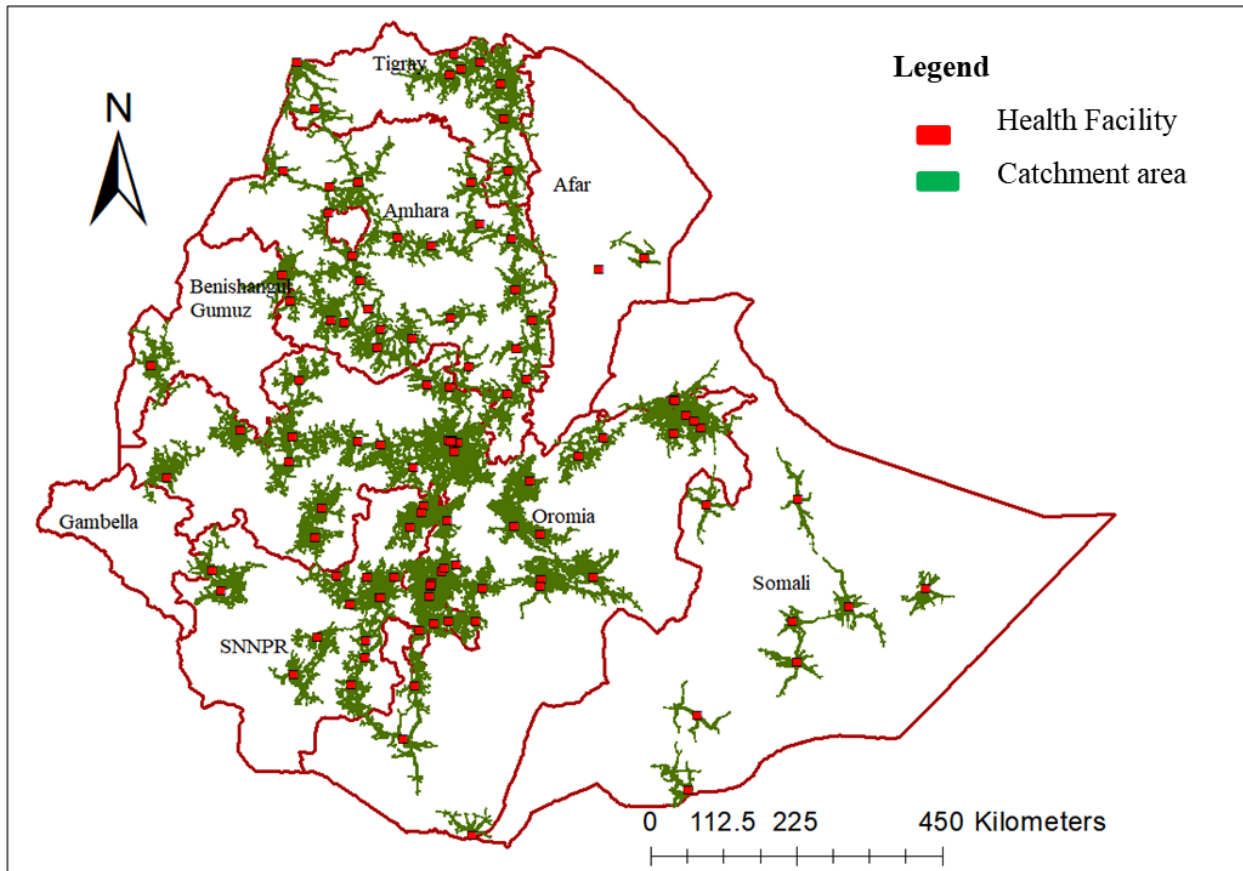
Figure 3 Catchment areas (dark green) of facilities accessible to fully EmNeC services within an hour (upper panel) and 30 min (lower panel) travel time. EmNeC, emergency neonatal care.

availability. The findings indicated the overall gaps and regional disparities in EmNeC services. It is important to note that accessibility can be measured and evaluated from multiple aspects, while our study focuses on the geographical dimension of accessibility. We assumed that ambulances could travel at the maximum permitted speed in Ethiopia. However, we also showed that reducing this maximum speed by 25% did not affect the coverage estimates considerably. Furthermore, the health facilities' maximum capacity considered in the model for each health facility category was based on the WHO assumption of births per skilled birth attendant per year, due to the lack of standard records in Ethiopia.

Conclusion and recommendations

We estimated the geographical access coverage to EmNeC services taking into account travel barriers and health facility capacity. The geographical access to emergency newborn care services in Ethiopia is considerably below the UHC expectations. Information on geographical accessibility to EmNeC health services should systematically be monitored to observe progress towards UHC to neonatal health services, thereby optimising the strategies towards reaching sustainable development goals. In addition, scaling up the EmNeC signal functions to health facilities currently providing EmONC services and, in the long run, to facilities that currently provide routine delivery services would significantly increase the geographical access coverage of EmNeC services.

Our results reinforce the need to revise the service allocations across administrative regions and strong financial support for the disadvantaged areas in future health service planning endeavours. Extensive monitoring and evaluation at every level need to be carried out in order to narrow the inequalities in the accessibility of newborn emergency services across administrative regions.

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