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Spatial Accessibility and Proximity Analysis of Primary Health Care Centers in Tribal Areas: A GIS-Based Study of Taloda Tehsil, Nandurbar District, Maharashtra.

Dr. Mohan Arjun Vasave

Abstract:

The spatial accessibility of primary healthcare services remains a significant challenge in rural and tribal areas, where scattered settlement patterns, geographical barriers and the unequal distribution of healthcare facilities contribute to regional disparities in access to essential health services. This study looks at the spatial accessibility and proximity of Primary Health Centres (PHCs) in Taloda Tehsil, Nandurbar District, Maharashtra using GIS techniques. Five PHCs are considered in the study: Borad, Pratappur, Somaval, Walheri and Modalpada, which cover 58 villages with a total population of 72,772. The study utilises a combination of spatial and non-spatial data from the ALOS PALSAR DEM, OpenStreetMap, Survey of India topographical maps, field surveys and the Census. QGIS was used to perform population distribution, multi-buffer proximity and road network analysis to examine the spatial relationship between the villages, the PHCs and the Sub-District Hospital (SDH) at Taloda. The findings indicate that Pratappur PHC serves the largest population (35.60%), followed by Borad (20.60%), Somaval (17.71%), Modalpada (13.49%) and Walheri (12.60%). The total distance of the fastest routes from the five PHCs to the SDH is 72.62 km and the shortest routes are 70.56 km. Borad has the longest route distance of the PHCs while Pratappur has the shortest. The proximity analysis also shows variation in the distribution of villages within the 1-5 km buffer zones of the PHCs. The results demonstrate that the spatial relationship between the health care facilities and the surrounding villages is not uniform across the study area. The study highlights the value of GIS based spatial analysis in understanding the availability of health care and can be used to help identify those settlements that may require more attention in terms of the organisation of health care.

Keywords: *GIS; Spatial accessibility; Primary Health Centres; Proximity analysis; Road network analysis; Tribal areas; Taloda Tehsil; Nandurbar District.*

Introduction:

Access to good quality healthcare is a key enabler of human development, social well-being and regional development (Miranda-Lescano et al., 2022) . The mere presence of health facilities does not necessarily mean that people can access them. Location, distance from settlements, road connectivity and travel time all play a role in determining access (Balsa-Barreiro et al., 2025). This is especially true in rural, hilly and tribal areas where settlements are widely dispersed and the transportation infrastructure may be very limited. In such areas geographical barriers can lead to increased time, cost and difficulty in accessing health facilities and therefore can have a significant impact on the actual use of available health services (Singh et al., 2026). It is therefore important to understand the spatial distribution and accessibility of primary health care facilities if we are to achieve equitable access to health care and to build up the rural health infrastructure (Dang et al., 2026).

In India the public health system is a hierarchical one with Sub Health Centres, Primary Health Centres (PHCs), Community Health Centres (CHCs), Sub-District Hospitals and District Hospitals. The PHC is of course a critical element in the system as it provides the essential preventive, promotive and curative care and is the first point of referral for the rural population (Mustafa et al., 2021). The Government of India has through the Indian Public Health Standards (IPHS) laid down population based norms for the distribution of health facilities. The revised IPHS guidelines recommend a PHC for a population of 30,000 in the plains and 20,000 in the hilly and tribal areas (Ministry of Health and Family Welfare, 2022). These differing norms are a recognition of the geographical and demographic realities of the tribal and remote areas. (Kumar et al., 2026) Quality of care is also dependent on the spatial relationship between the health centres, the villages around them, the population distribution and the transport infrastructure available (Patil et al., 2025).

Healthcare service accessibility is a multi-dimensional concept which is essentially about the relationship between the location of the service and the population that it is intended to serve (Cabrera-Barona et al., 2016).

Geographical accessibility is concerned with the distance and travel time to a health service. (Balsa-Barreiro et al., 2025) Hansen (1959) laid the foundational conceptual framework for the understanding of accessibility in spatial planning and subsequent geographical research has developed a range of techniques to measure it in terms of distance, transport connectivity and the distribution of services. Luo and Wang (2003) showed the value of GIS in the measurement of spatial accessibility to health services. They demonstrated the value of spatial accessibility measures and the floating catchment area approach in examining the relationship between the supply of health services and the demand from the population. These are clearly established methodological approaches for the study of the spatial distribution of health services in rural and remote areas.

Medical access is a very significant issue for tribal communities in India. Many of the tribal settlements are in remote, forested, hilly and relatively poorly connected areas. Distance, road conditions, transport availability and the local socio-economic situation will all have an effect on the ability of people to access healthcare (Mseke et al., 2024). In a cross-sectional study of tribal populations across six Indian states, (Sharma et al. 2025). looked at access to healthcare in 24 Primary Health Centre areas and distance was one of the reasons cited for not utilising the available healthcare. The study did also highlight the variation in access to healthcare and the importance of understanding the local context when it comes to the provision of primary healthcare. (Pagar, 2021). The evidence suggests that access to health services should be looked at in terms of both the number of facilities and in relation to the spatial relationships of those facilities to the surrounding settlements and transport infrastructure. (Chen et al., 2023).

GIS has proved to be a very effective tool for the analysis of the spatial organisation and availability of public services. It brings together geographic information from a variety of sources and can be used to identify the spatial relationships between population centres, health facilities and transport infrastructure. Buffer analysis is widely used to assess the proximity of settlements to health care facilities within a number of different distance thresholds. Multi-ring buffer analysis can provide a more detailed picture of the spatial distribution of villages across a range of distance zones (He et al., 2026). Road network analysis can also be used to determine the shortest and fastest routes between health care facilities and key referral centres (Li et al., 2015). These techniques form the basis of a framework for identifying the settlements that are close to health care facilities and those that may be more geographically disadvantaged. (Patil et al., 2025) Luo and Wang (2003) showed that the GIS based assessment of accessibility can be enhanced by taking into account the interaction between the availability of services and the distribution of the population. (Luo & Wang, 2003).

This study looks at the spatial accessibility and proximity of the Primary Health Care (PHC) centres in Taloda Tehsil, Nandurbar district, Maharashtra. It looks at the spatial distribution of the five PHCs and the villages that they serve. The spatial analysis looks at the spatial relationship between the location of the health care facilities, the location of the villages, the population that they serve and the existing road network. A particular focus is on the multi-ring buffer analysis at 1km, 2km, 3km, 4km and 5km to assess the proximity of the villages to the respective PHCs. Road network analysis is also carried out to identify and compare the shortest and fastest routes between the PHCs and the Sub-District Hospital at Taloda. The use of these spatial techniques enables an assessment of the availability of health care at the local level.

The study employs GIS techniques and a range of spatial datasets from various sources (ALOS PALSAR DEM, OpenStreetMap road networks, topographic maps, Census of India population data and field based GPS data). These form the basis of the spatial mapping of health facilities, village centroids, road connectivity and proximity areas. The use of GIS based spatial analysis is expected to enhance our understanding of the spatial distribution of primary healthcare and the relationship between health care facilities and the rural settlements around them. (Yang et al., 2024).

The spatial distribution of health facilities has been the subject of much research in the fields of geography and public health. At the local level however such assessments are still of considerable importance as the access conditions will vary from place to place depending on the pattern of settlement, the terrain and the level of connectivity via transport. A district or regional level assessment may not be sufficient to reflect the access conditions in individual villages. (Verma & Dash, 2020) It is therefore of value to undertake a detailed investigation at the tehsil level in order to identify local territorial variations and to inform health planning. (Dang et al., 2026).

In this context the present study seeks to evaluate the spatial accessibility and proximity of the Primary Health Care Centres in the tribal areas of Taloda Tehsil through the use of GIS based techniques. The study will look at the distribution of PHCs with respect to the village settlements, assess the village proximity via multi ring buffer analysis, compare the fastest and the shortest road routes to the Sub-District Hospital and also look at the population coverage of individual PHCs. The study aims to produce geographical outputs which could be of use to the health planners and the local authorities for better spatial organisation of primary health care services and to identify areas which may require more attention. The study ultimately highlights the importance of incorporating spatial analysis in the coordination of health care to ensure more equitable and accessible primary health care in the rural and tribal areas of Maharashtra.

Study Region:

Taloda Tehsil is in the Nandurbar district in the north-west of Maharashtra, India. It is part of the Satpura foothills and is a very rural area. The area's geography, with its dispersed villages and roads, has a significant bearing on the accessibility of health care services, especially for the tribal population. The study area covers approximately 455.10 km², with elevations ranging from 56 to 1,156 meters above mean sea level. The approximate geographical extent of the study area as shown on the study area map is 21°31'12" N to 21°40'48" N latitude and 74°04'48" E to 74°19'12" E longitude .

The district experiences considerable seasonal variations in climatic conditions. According to the meteorological observations supplied for April 2025, the maximum temperature was 46.6°C, while the minimum temperature was 20.1°C. The India Meteorological Department (IMD), Pune, reported seasonal rainfall of 217.4 mm. The study is focused on 58 villages and 5 Primary Health Centres (PHCs) (Borad, Pratappur, Somaval, Walheri and Modalpada). The study database

shows that these PHCs serve a population of 72,772. Of the 5 PHCs, Pratappur has the largest population (25,909), followed by Borad (14,989), Somaval (12,890), Modalpada (9,818) and Walheri (9,166). The Sub-District Hospital (SDH) at Taloda is the main referral hospital for the analysis of road route accessibility from the PHCs.

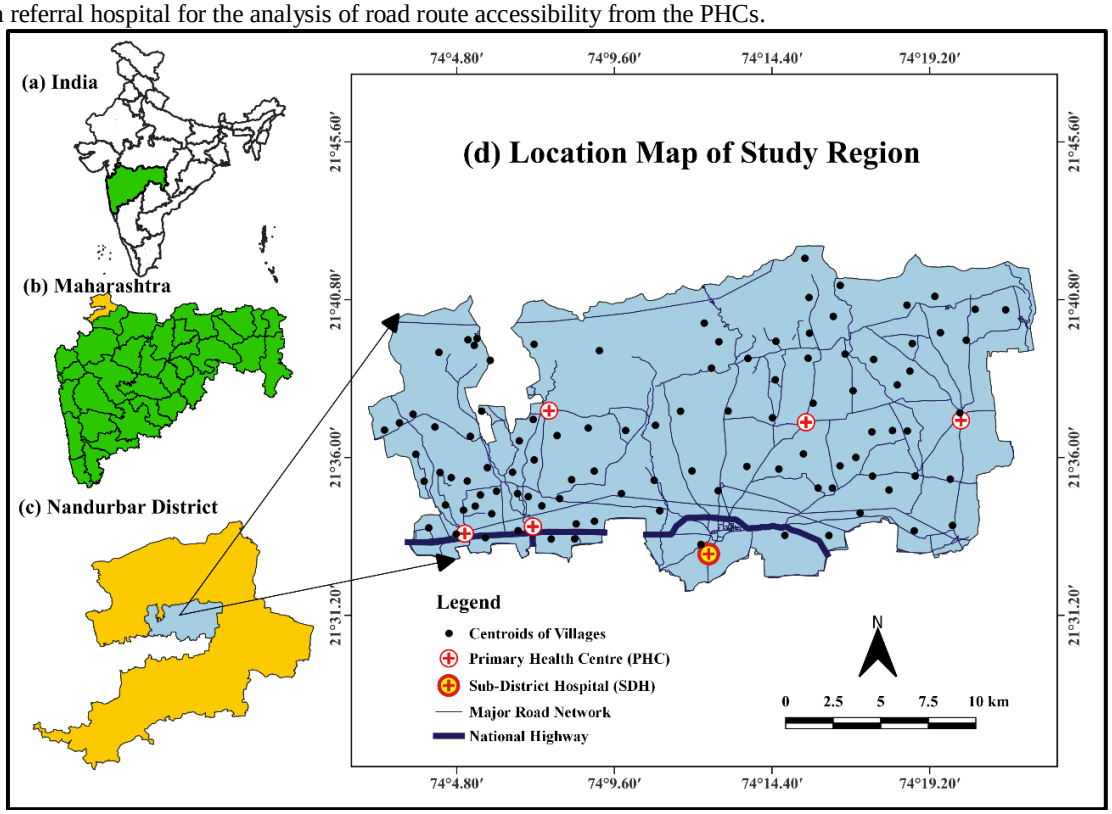

Figure 1. Location map of Taloda Tehsil showing the village locations, the Primary Health Centres, the Sub-District Hospital and the major road network.

Data set and research methodology:

This paper makes use of both spatial and non-spatial datasets to look at the spatial accessibility and proximity of the Primary Health Centres (PHCs) in Taloda Tehsil, Nandurbar District, Maharashtra. A range of geospatial datasets were collected from a variety of secondary sources as well as field surveys in order to assess the distribution of health facilities, road connectivity, population covered and reachability. The datasets used are an ALOS PALSAR Digital Elevation Model (DEM), the OpenStreetMap (OSM) road network, Survey of India topographic maps, GPS field survey data and the Census of India population data.

The ALOS PALSAR DEM (10m spatial resolution) was used to characterise the terrain of the study area. The road network derived from OpenStreetMap was used for the shortest and fastest route analysis between the five PHCs and the Sub-District Hospital at Taloda. Survey of India topographic maps (1:50,000 scale) were used to identify and delineate the locations of the health facilities. Field survey observations collected via a Garmin eTrex 30 GPS unit were used to verify the geographic locations of the selected facilities (ground truth accuracy stated to be ~6m). Population data from the Census of India was used to look at the population distribution and the proximity of villages to the PHCs.

All the spatial data was processed and analysed in a GIS environment. Spatial mapping, buffer proximity analysis and road network route analysis were all carried out in order to assess the spatial distribution and availability of primary care facilities. Table 1 details the datasets, their sources, formats and applications.

Table 1. Details of datasets and their sources used in the present study

Sr. No.	Dataset	Source	Data type / resolution	Purpose in the study
1	ALOS PALSAR DEM	Alaska Satellite Facility / NASA Earthdata	Raster, 10 m	To examine elevation and terrain characteristics
2	Road network	OpenStreetMap (OSM)	Vector	To analyse the fastest and shortest routes
3	Topographical maps	Survey of India, 1:50,000	Map data	To identify and demarcate PHC locations
4	Population data	Census of India	Non-spatial data	To analyse population distribution and PHC proximity
5	Field survey	Garmin eTrex 30 GPS receiver	GPS coordinates; stated accuracy 6 m	To verify healthcare facility locations

Source: Compiled by the researcher from secondary data sources and field survey.

Results and Discussion:

1. PHC-wise Population Distribution and Population Coverage :

The results are very varied in terms of population distribution and the number of villages served by each PHC. Pratappur PHC has the highest population at 25,909 (35.60% of the total population) and covers 19 villages. That means over a third of the total population of the study area is served by this one PHC. Borad PHC is second at 14,989 (20.60%) covering 11 villages. Somaval PHC covers 12,890 (17.71%) in 9 villages. Modalpada PHC covers 9,818 (13.49%) in 11 villages. Walheri PHC has the lowest population at 9,166 (12.60%) and covers 8 villages.

Table No. 2. PHC-wise population distribution, population ratio and village coverage in Taloda Tehsil

Sr. No	No. of PHC	Population	%	Population Ratio	No. of Villages	Name of Villages
1	Borad	14989	20.60	1:1,363	11	Borad, Ashte, Kharwd, Mod Kalamsare, Chotadhanpur, Nyuban, Kadhle, Ban, Lakhapur and Karde.
2	Pratappur	25909	35.60	1:1,364	19	Pratappur, Salsadi, Ranzani Navagain, Gopalpur, Chinode Ranipur, Selingpur, Mohida, Umari, Chaugaon Bk, Talve, Moewad, Rozave, Kothar Bandhare, Sawarpada, Dhanpur, Padalpur.
3	Somaval	12890	17.71	1:1,432	09	Somaval Bk, Somaval kh, Nalgavhan, Khushgavhan, Lobhani Govanipada, Belipada, Rajvihir Budhaval
4	Walheri	9166	12.60	1:1,146	08	Walheri, Ekdhad, Dekati, Sojarabara, Amoni, Mal, kh,, Biyamal, Pimparapada
5	Modalpada	9818	13.49	1:893	11	Modalpada, Rampur, Ziri , Padhadi Shirve, Umarkuwa, Ratanpada Amalpada, Sorapada, Retapada Ranapur
Total		**72772**	**100.00**	**1:1,255**	**58**	**58**

Source: Compiled and calculated by the researcher from the study database.

The population ratio further underscores the differences in the average population represented by each village within each PHC area. Somaval has the highest ratio at 1:1,432, followed by Pratappur (1:1,364), Borad (1:1,363) and Walheri (1:1,146). Modalpada has the lowest ratio at 1:893. The overall average is around 1:1,255. The variation in the ratios clearly demonstrates that the village population is not evenly distributed across the PHC areas. The relatively high average population per village in Somaval and Pratappur will no doubt have an impact on the way healthcare services are planned and funds are allocated.

From a spatial health care perspective the findings show that the PHCs serve different numbers of people and different numbers of villages. Pratappur has the highest population coverage and the highest number of villages, whereas Somaval has the highest average population per village. A higher population ratio does not necessarily mean that the health care is any better or any worse. The actual accessibility will also be determined by the distance between the villages and the PHCs, road connectivity, terrain and travel time. So the findings on population provide a demographic basis for the subsequent analysis of proximity and road network accessibility.

2. Proximity Analysis of Primary Health Centers:

Table 3 and Figure 2 show the multi-buffer proximity analysis of the five PHCs in Taloda Tehsil. The analysis was carried out in QGIS by creating 1km, 2km, 3km, 4km and 5km buffer zones around each of the PHCs to look at the spatial distribution of the villages in relation to the health facilities. The map shows the proximity zones, the village centroids, the PHC locations and the major road network.

The results show variation in the number of villages within different buffer zones. Pratappur PHC has the widest village coverage, with 19 villages recorded across the five distance categories. Among these, the highest number of villages (8) is recorded in the 4 km zone, followed by 6 villages in the 5 km zone. Borad PHC covers 11 villages: 5 in the 4 km zone and 4 in the 5 km zone. Somaval PHC covers 9 villages, of which 4 are recorded in the 2 km zone, while 2 villages are recorded in both the 1 km and 5 km zones. Walheri PHC covers 8 villages, with 4 villages in the 5 km zone. Modalpada PHC covers 11 villages, including 5 villages in the 4 km zone and 2 villages in the 2 km and 5 km zones.

The spatial pattern in Figure 2 shows villages at varying distances from their respective PHCs. Somaval has a relatively higher number of villages in the nearer buffer categories (particularly the 2km category). Borad, Pratappur and Modalpada on the other hand have a relatively higher number of villages in the 4km and 5km categories. There is thus a clear variation in the distribution of villages with respect to their distance from the PHC.

Table No:03 Proximity analysis of Taloda Tahsil

Sr. No	**No. of PHC**	**Multi Buffer Zone (km)**	**No. of Villages**	**Name of Villages in Buffer Zone**
1	Borad	1	1	Borad
		2	0	No. village found
		3	1	Ashte

		4	5	Kharwd, Mod, Kalamsare, Chotadhanpur, Nyuban
		5	4	Kadhle, Lakhapur, Karde, Ban
2	Pratappur	1	1	Pratappur
		2	2	Salsadi, Ranzani
		3	2	Navagaon, Gopalpur
		4	8	Chinode, Ranipur, Selingpur, Mohida, Umari, Chaugaon Bk, Talve, Morwad
		5	6	Rozave, Kothar, Padalpur, Bandhare, Sawarpada, Dhanpur
3	Somaval	1	2	Somaval, Bk, Somaval Kh,
		2	4	Nalgvahan. Khushgavan, Lobhani, Gavanipada
		3	1	Belipada
		4	0	No. village found
		5	2	Rajvir, Budhawal
4	Walheri	1	1	Walheri
		2	1	Ekdhad
		3	1	Dekati
		4	1	Sojarabara
		5	4	Amoni, Mal, Biyamal, Pimparapada
5	Modalpada	1	1	Modalpada
		2	2	Rampur, Zeri,
		3	1	Padhadi
		4	5	Shirve, Rampur, Umarkhuwa, Ratanpada, Amlapada
		5	2	Sorapada, Retapada

Source: Computed by the author in QGIS software.

The proximity analysis as a whole does demonstrate the utility of the GIS based multi-buffering approach in terms of assessing the spatial relationship between the villages and the PHCs. Villages in the outer buffer zones will obviously have to travel a greater distance to get to a PHC than those in the inner buffer zones. The straight line buffer distance however does not equate to actual road distance or travel time. The results should therefore be interpreted in conjunction with the road network analysis to give a more complete picture of the accessibility of medical services in Taloda Tehsil.

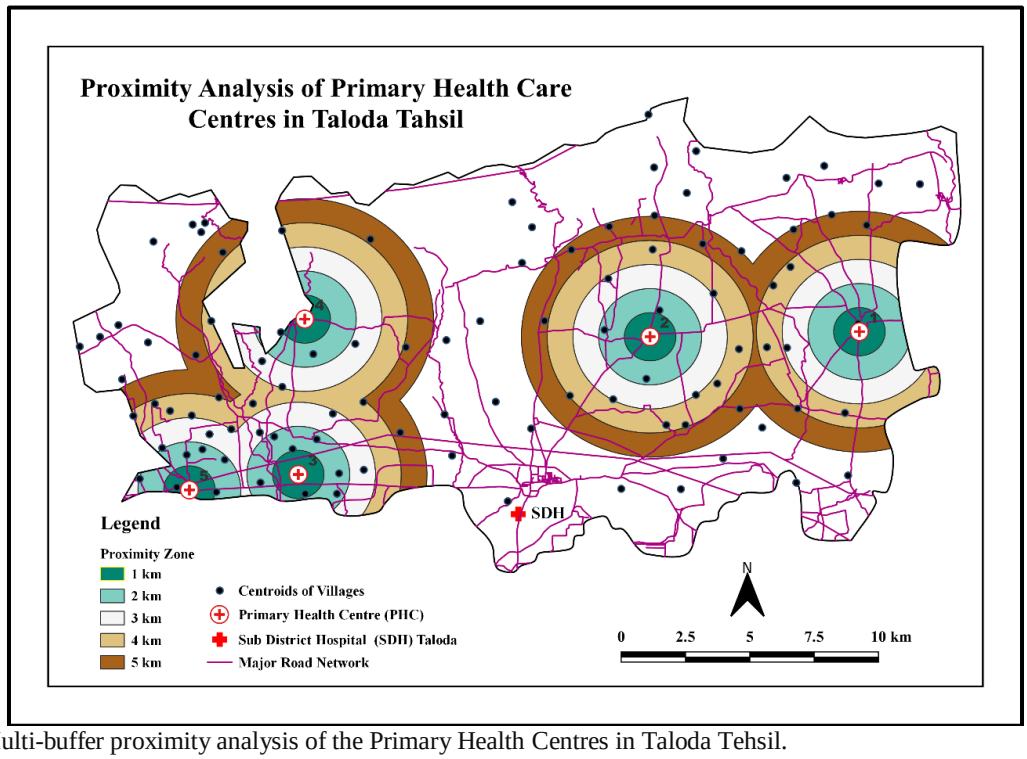

Figure 2. Multi-buffer proximity analysis of the Primary Health Centres in Taloda Tehsil.

3. GIS-Based Route Network Analysis of Primary Health Centers:

Table 4 and Figure 3 show the fastest and shortest route distances between the five PHCs and the Sub-District Hospital (SDH) at Taloda. The route analysis was carried out using QGIS to determine road connectivity and alternative routes between the various health facilities. In Figure 3, the red lines represent the fastest routes and the blue lines the shortest routes. The combined distance of the fastest routes is 72.62 km, as against 70.56km for the shortest routes. The shortest routes therefore are 2.06km shorter. Of the five PHCs, Borad has the longest fastest route at 18.06km, Walheri at 17.47km,

Modalpada at 15.47 km, Somaval at 11.13 km, and Pratappur at 10.49 km. The same pattern is seen with the shortest routes, with Borad again having the longest at 17.21km and Pratappur the shortest at 9.76km.

Table 4. Fastest and shortest route distances between the PHCs and Taloda Sub-District Hospital.

Sr. No	Name of Primary Health Centre (Sarting Point)	Sub District Hospital (Destination Point)	Fastest Route (km^2)	Shortest Route (km^2)	Duration (H/M)	
					FR	SR
1	Borad	SDH Taloda	18.06	17.21	0.37	0.38
2	Pratappur	SDH Taloda	10.49	9.76	0.24	0.25
3	Somaval	SDH Taloda	11.13	11.13	0.19	0.19
4	Modalpada	SDH Taloda	15.47	15.47	0.25	0.25
5	Walheri	SDH Taloda	17.47	16.99	0.37	0.39
Total =			72.62	70.56	1.42	1.46

Source: Computed by the author in QGIS software. *SDH= Sub District Hospital

The comparison shows that Pratappur PHC has the closest road link to the SDH whereas Borad PHC has the greatest route distance. Somaval and Modalpada have the same route distances for both options (11.13 km and 15.47 km respectively). The differences between the fastest and shortest route for Borad, Pratappur and Walheri all indicate that there are alternative road links. The variation in the differences between the fastest and shortest route for these three sites highlights the importance of road network configuration in terms of the geographical connectivity of the health facilities.

Overall the GIS based route analysis is useful in terms of looking at the spatial relationship between the primary health centres and the referral facilities. The longer route distances from Borad and Walheri would obviously add to the travel burden for patients who are travelling to Taloda SDH for referral. The course actual medical service access will also be a function of road conditions, transport available and time taken to travel. The route analysis therefore provides a very useful basis for identifying the geographical differences in terms of referral connectivity across the Taloda Tehsil.

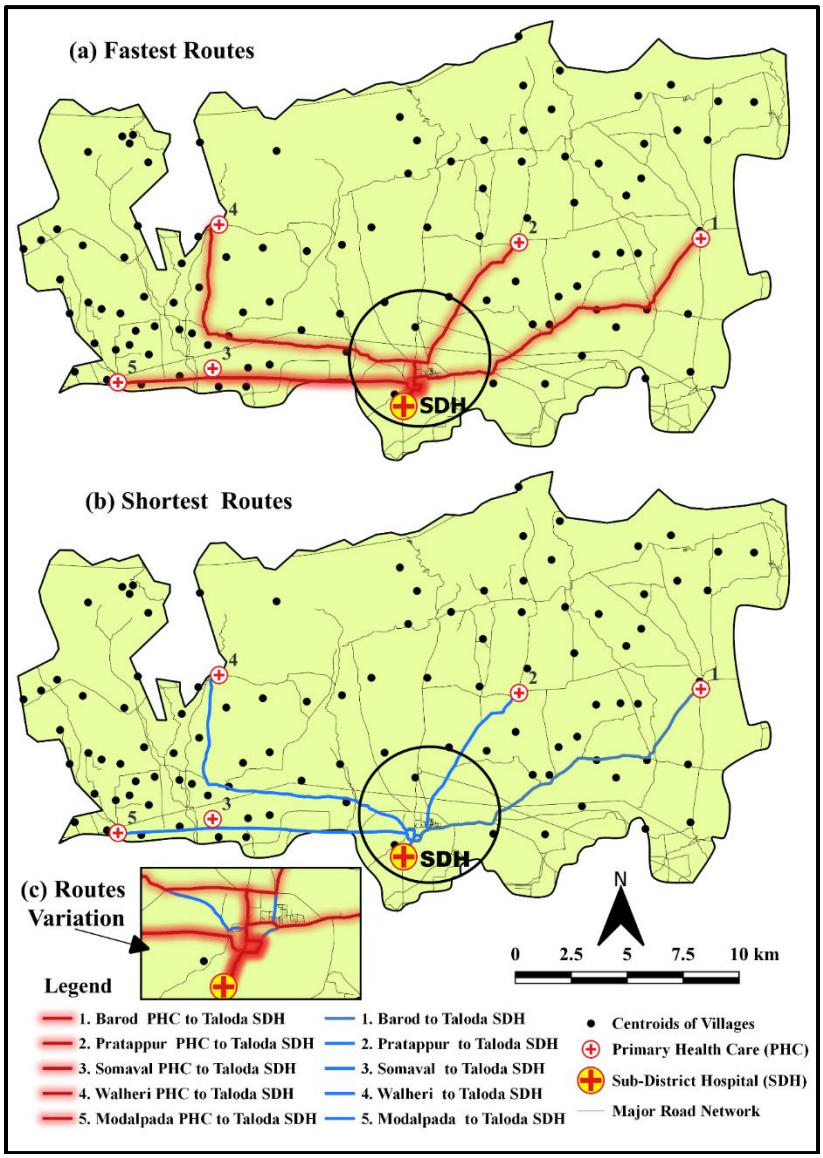

Figure 3. The fastest and shortest routes linking the Primary Health Centers with the Taloda Sub-District Hospital.

Conclusion:

The study looked at the spatial accessibility and proximity of Primary Health Centres (PHCs) in the tribal areas of Taloda Tehsil, Nandurbar District, Maharashtra using GIS techniques. The focus was on population distribution, village coverage, road network connectivity, and multi-buffer proximity to assess the spatial distribution of the PHCs. The five PHCs cover a total population of 72,772 in 58 villages. Pratappur PHC has the highest population (35.60%), followed by Borad (20.60%), Somaval (17.71%), Modalpada (13.49%), and Walheri (12.60%). The average population per village varies from 893 (Modalpada) to 1,432 (Somaval).

The road network analysis shows that the total fastest route distance from the 5 PHCs to the Taloda Sub-District Hospital (SDH) is 72.62 km and the total shortest route distance is 70.56 km. Pratappur PHC has the shortest route distance to the SDH and Borad PHC has the longest. There is clearly a variation in the road connectivity of the PHCs to the SDH.

The multi-buffer proximity analysis also picks up on the variation in the geographical spread of villages around the PHCs. Pratappur has the highest number of villages (19), Borad and Modalpada have 11 each, Somaval has 9 and Walheri has 8. The distribution of villages across the 1-5km buffers shows that the villages are spread out at different distances from their respective PHCs. This again underscores the importance of taking into account the geographical spread of villages when looking at the availability of primary healthcare in the rural and tribal areas.

The study shows that GIS based population analysis, road network analysis and multi-buffering are useful techniques for assessing the spatial distribution and geographical accessibility of primary health care facilities. The results could be of value in health planning in that they enable one to assess the level of population coverage, the proximity of villages and the degree of referral connectivity. Improved transport connectivity and better account of the spatial distribution of remote settlements would be expected to improve access to primary health care in Taloda Tehsil. Future work could build on this by incorporating actual travel times, road conditions, population weighted accessibility and patient data from the field.

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I would like to express my sincere gratitude to all those who have contributed to the successful completion of my research study entitled “Spatial Accessibility and Proximity Analysis of Primary Health Care Centers in Tribal Areas: A GIS-Based Study of Taloda Tehsil, Nandurbar District, Maharashtra.”

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Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of thesis paper.

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