Supplemental Appendix

This file provides supplementary figures, tables and methods for "The geographical accessibility of public health facilities and the assessment of its equality in Nepal" by Wen-Rui Cao, Prabin Shakya, Biraj M Karmacharya, Dong Roman Xu, Yuan-Tao Hao, and Ying-Si Lai.

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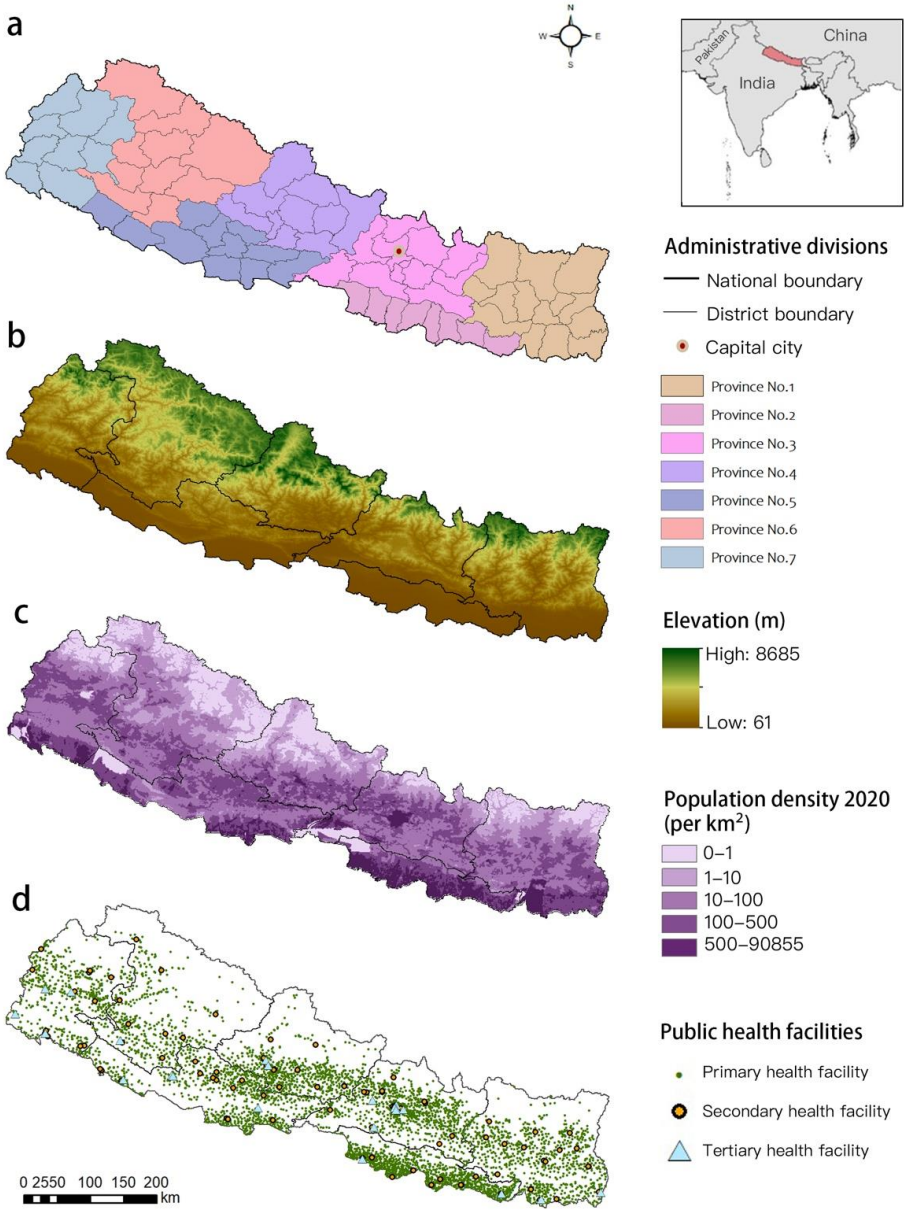

Figure S1. Study area. (a) Provinces and districts in Nepal; (b) Elevation map; (c) population density map; (d) spatial locations of primary, secondary, and tertiary public health facilities.

Density distribution of public health facilities

A regular 1 × 1 km^2 grid was overlaid to Nepal, resulted in 195,574 pixels. Kernel density estimation (KDE) based on Silverman's Rule-of-thumb bandwidth estimation was adopted to assess the density of different levels of health facilities across the country.[1] Particularly, the bandwidth (r) was calculated according to the formula $r = 0.9 * min\left(SD, \sqrt{\frac{1}{ln(2)}} * D_m\right) * n^{-0.2}$, where n is the total number of health facilities, SD is the standard distance from the geometric mean center, and D_m is the median of distances from facilities to their mean center. The density of health facilities at pixel s is expressed as $\lambda(s) = \sum_{i=1}^{u} \frac{1}{\pi r^2} k\left(\frac{d_{is}}{r}\right)$, where u is the number of health facilities inside bandwidth, d_{is} is the distance from pixel s to health facility i inside the bandwidth, and $k\left(\frac{d_{is}}{r}\right)$ is the weight function of health facility i corresponding to s, modeled by a quartic kernel function with $\frac{d_{is}}{r}$. Above analyses were performed with ArcGIS 10.5.

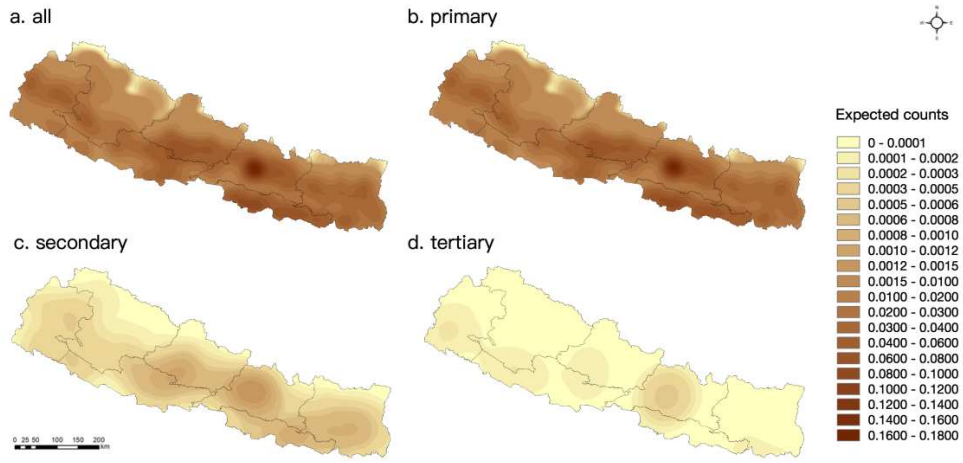

Figure S2. The density distribution map of different public health facility level.

Table S1. Data sources

Data	Temporal reference	Spatial resolution	Source
Population count (UN adjusted)	2020	1 km	https://www.worldpop.org/geodata/listing?id=75
Friction surfaces	2020	1 km	https://malariaatlas.org/research-project/accessibility-to-healthcare/
Nepal health facilities	Up to 22th May 2021	location - specific	https://nhfr.mohp.gov.np/home

Table S2. Road speed settings according to different standards

Road type	Speed used by friction surfaces 2020 (km/h)	Nepal road standard speed (km/h)	Google Maps road speed (km/h)
Trunk	60	50	50
Primary	30	30	30
Secondary	40	40	45
Tertiary	30	30	30
Unclassified	30	30	30
Road	20	20	20
Residential	30	30	30
Service	30	30	30
Track	30	30	30
Pedestrian	20	20	20
Other	20	20	20

Table S3. The population-weighted average travel time to the nearest public health facility based on the three road speed settings

Facility level	Speed used by friction surfaces 2020 under motorized mode (minutes)	Nepal road standard speed (minutes)	Google Maps road speed (minutes)
Any	17.87	17.90	17.87
Primary	17.91	17.95	17.92
Secondary	39.88	40.54	39.74
Tertiary	69.23	72.07	70.27

The formulas of Gini coefficient and Theil *L* index

Based on x_s, the Gini coefficient (*G*) was calculated as following:[2]

$$G = \sum_{k=1}^{N-1} (F_k \Phi_{k+1} - F_{k+1} \Phi_k)$$

Here *N* is the total number of pixels across Nepal, k is the rank in terms of the impedance function value from the lowest to the highest. $F_k = \sum_{s=1}^{k} (p_s/P)$ and $\Phi_k = \sum_{s=1}^{k} (h_s/H)$, represented the cumulative proportion of population and that of impedance function value up to k, respectively. Here $P = \sum_{s=1}^{N} p_s$, $h_s = p_s x_s$, $H = \sum_{s=1}^{N} h_s$, where p_s is the population density at pixel s.

The Theil *L* index was calculated as $L = \sum_k (p_k/P) log(X/x_k)$, where $X = H/P$.[3] The decomposition expression of Theil *L* can be written as: $L = L_b + L_w$, where the between-province component $L_b = \sum_j (P_j/P) log(X/X_j)$ and the within-province component $L_w = \sum_j (P_j/P) L_j$ for j^{th} province.

Table S4. The population-weighted average travel time to the nearest public health facility under different travel modes

Facility level	Motorized mode (minutes)	Walking mode (minutes)
Any	17.87	33.97
Primary	17.91	34.23
Secondary	39.88	180.26
Tertiary	69.23	404.37

Table S5. Summaries of the cumulative population percentages with different geographical accessibility (%)

		Travel time (minutes)			
Travel mode	Facility level	<5	<15	<30	<60
Motorized mode	Any	78.47	92.54	96.05	98.27
	Primary	78.15	92.49	96.04	98.27
	Secondary	18.29	35.65	63.93	89.39
	Tertiary	15.54	25.00	37.63	60.61
Walking mode	Any	16.34	55.54	80.24	94.63
	Primary	15.81	54.98	79.81	94.53
	Secondary	1.35	7.85	14.49	25.05
	Tertiary	0.75	5.21	11.13	18.67

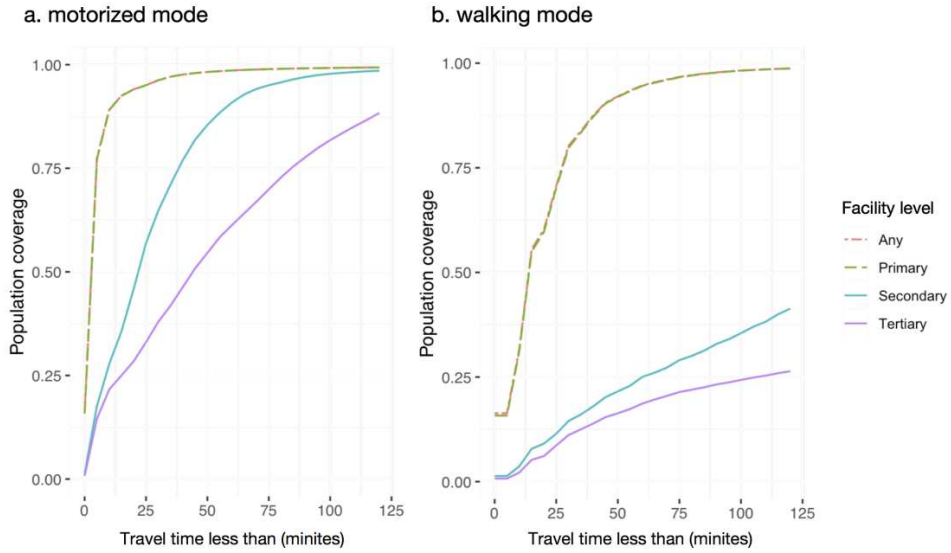

Figure S3. The population coverage of travel time to the nearest public health facility. (a) With motorized mode; (b) with walking mode.

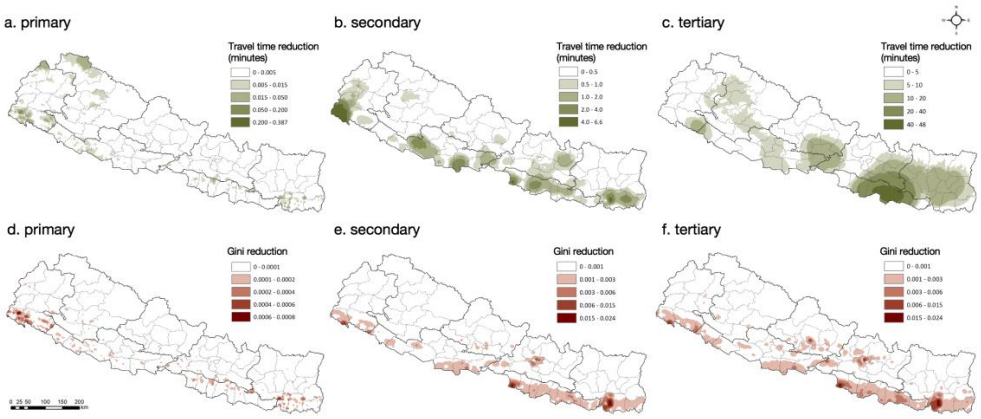

Figure S4. Reductions of travel time and Gini coefficient for new facility placement in Nepal with walking mode.

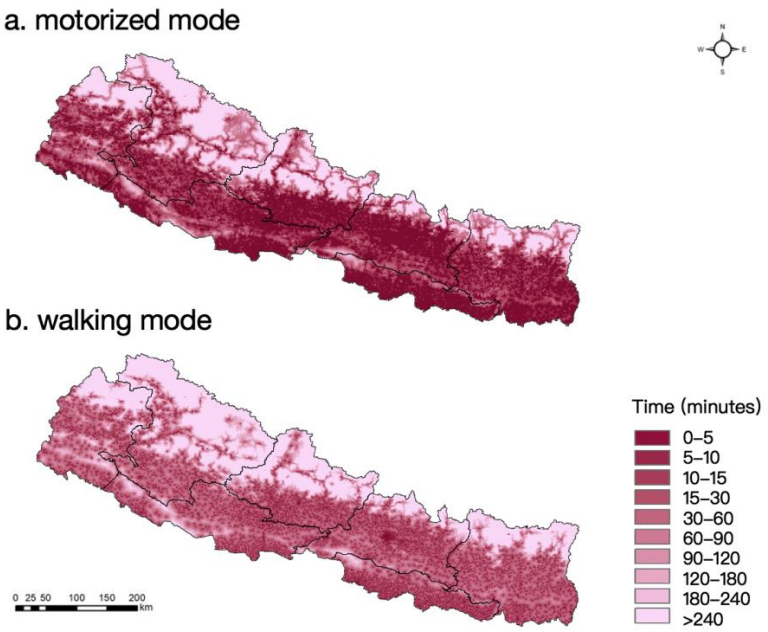

Figure S5. Geographical accessibility according to travel times to the nearest health facilities (either public or non-public) with different travel modes. (a) The motorized mode; (b) the walking mode.

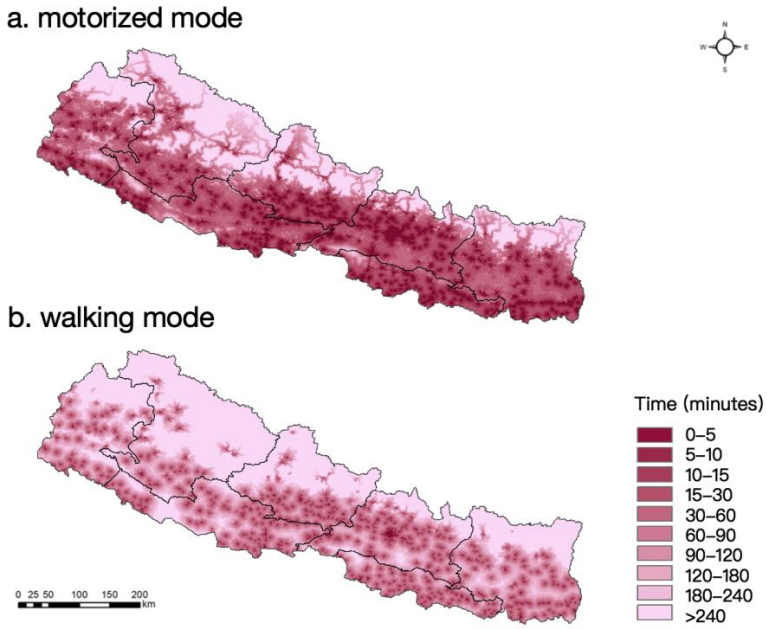

Figure S6. Geographical accessibility according to travel times to the nearest non-public health facilities with different travel modes. (a) The motorized mode; (b) the walking mode.

References

1 Silverman BW. Density Estimation for Statistics and Data Analysis. London: Chapman and Hall; 1986.

2 Anand S. Inequality and Poverty in Malaysia: Measurement and Decomposition. New York: Oxford University Press; 1983: 311–313.

3 Theil H. Economics and Information Theory. Amsterdam: North-Holland; 1967:125–127.