Community Dental Health (2022) **39,** 27–32
Received 26 January 2021; Accepted 2 June 2021

doi:10.1922/CDH_00024Shrestha06

Innovative methodology to guide planning of dental workforce distribution: a GIS-based study in Nepal

Barsha Shrestha,[1] Saujanya Karki,[2] Estie Kruger[1] and Marc Tennant[1]

[1]*School of Human Sciences, University of Western Australia, Australia;* [2]*Research Unit of Oral Health Sciences, University of Oulu, Finland*

Objectives: To build a predictive model based on the distribution pattern of dentists and population in selective districts of Nepal. ***Method***: Cross-sectional descriptive study conducted using secondary data from the census report and available dentist data of Nepal. Population data were obtained from the most recently available census. For dentists' data, a literature search was carried out in the databases such as PubMed, Google scholar, One Search and Medline. All data were extracted from the integrated database in the Geographic Information System (GIS), and a predictive model was built. ***Results***: Overall, there was an uneven distribution of dentists in Nepal. When the distribution of dentists was compared with the population clusters, it was found that the slope of the population growth was below or equal to (≤) 20,000 for three provinces (2, 6, and 7), which means that lower numbers of dentists are available with respect to population density in these provinces. The slope was above 50,000 for province 3, and the number of dentists was almost half of the total nationwide. The number of dentists correlated with population clusters. ***Conclusion***: There are substantial disparities in the distribution of dentists in Nepal. Dentists were distributed relative to higher population clusters and were unevenly distributed. The Nepal government should make necessary arrangements to address the need for the human workforce in resource-limited settings. The methods used in this study could be applied globally, as the data used are available for most countries.

Keywords*: Nepal, Dental Workforce, Dental services, geographic analysis*

Introduction

One of the major challenges in delivering the Nepalese population with health and dental care service is the complex geography and uneven population distribution. Nepal is a small country, having a total area of 147,181 km^2 (56,956 Square miles) with a population of nearly 26 million in 2011 (Central Bureau of Statistics, 2012). The population is distributed unequally across the country. Among the five developmental regions of Nepal, the Central Development Region comprises the highest population, followed by Eastern and Western Regions, whereas Mid and Far Western Development Regions consist of the lowest (Bakrania, 2015). Nepal has also witnessed rapid urbanisation, doubling its urban population to 20 per cent in 2017 (United Nations Population Fund, 2017). This extreme geographic maldistribution raises specific issues in terms of health service access for the Nepalese population.

A recent study revealed that the dentist to population ratio is 1: 16000 (Shrestha *et al.,* 2017), whereas the World Health Organization reported ratio is 1: 2000 in high-income countries. Despite Nepal's uneven distribution of dentists, inevitably causing disparities in accessing dental care, there are limited national data on the oral health status of the population (Knevel *et al.*, 2015; Karki *et al*., 2018). The first and only Nepal National Oral Health Survey was conducted in 2004 (Yee and Mishra, 2004), with some additional child oral health survey data also available. The lack of data on the oral health needs of the population and small dental workforce complicates an equal distribution of existing dentists in response to varying patterns of oral diseases and socio-demographic factors (Knevel *et al.*, 2015). The Nepal Government, until now, has not been able to keep accurate data on its dental workforce, and clinics in each district, municipality or wards (Knevel *et al.*, 2015). Thus dentistry in Nepal has faced and continues to face, significant workforce issues, in particular, a shortage of dental workforce and an unequal distribution.

Inadequate data on the dental workforce restricts dental services planning. Successful health workforce planning is critical for a sustainable health care system to deliver services to the people in need, to maximise outcomes and minimise costs (Knevel *et al.*, 2017). In addition, understanding the demographic transition and workforce is crucial for health workforce planning and management (Szabo *et al*., 2020). Due to the lack of sustainable health workforce planning, Nepal is witnessing the geographical imbalance of the dental workforce (Knevel *et al.*, 2017). The geographic misallocation of the dental workforce also results in an unequal distribution between underprivilege and privileged populations (Knevel *et al.*, 2017). Equitable distribution of dental health services requires deploying dentists according to population need. Therefore, in the absence of bespoke data, to optimise the workforce in Nepal, this study adopted methods using secondary data described by Wijewardena et al. (2018), Md Bohari et al. (2018) and Jean et al. (2020).

The aim of this study was to build a predictive model of dentist distribution based on the distribution of the population in selective districts of Nepal, correlating the distribution of dentists and the population using census data and qGIS tools.

Correspondence to: Dr. Estie Kruger Email: estie.kruger@uwa.edu.au

Method

The cross-sectional descriptive study was conducted using secondary data from the Census report of Nepal, Central Bureau of Statistics and available data on Nepalese dentists. Data were collected from July to November 2019. The data used were open access and freely available, and as such, ethical clearance was not needed.

All the population data were obtained from the most recently available Nepal population and housing census (2011) and population of 753 local units (2011) from the Government of Nepal, National planning commission, Central Bureau of Statistics. Nepal is divided into seven provinces and seventy-seven districts. The districts are divided into 753 local units (metro cities, sub-metro cities, municipalities and gaunpalika). Each local unit is divided into wards. Based on highest population numbers, Morang, Sarlahi, Kathmandu, Kaski, Rupendehi, Surkhet, and Kailali districts were selected out of 77 districts from Province 1, 2, 3, 4, 5, 6 and 7, respectively. Provinces 3, 4, 6 and 7 are also named as Bagmati, Gandaki, Karnali, and Sudhurpachim, respectively. The geographic boundary file of Nepal in a shapefile format was obtained from the humanitarian data exchange website (https://data.humdata.org/dataset/admin-shapefiles-of-nepal-mofald).

A literature search was conducted using PubMed, Medline, One-search and Google Scholar, to access data on statistics of dentists in Nepal during July to November 2019. The search strategy included the following terms: dentist or/and oral health workforce or/ 'AND' Nepal. Only one study met the inclusion criteria (Shrestha *et al*., 2017) and reported a census of Nepalese dentists.

Data on dentists and population from each district were analysed using qGIS software. Quantum Geographic Information System (qGIS) (Version 3.4, qGIS Development Team, GNU General Public License, Essen, Germany) is an open-source mapping software to analyse geospatial data. Districts with the largest populations were selected for analysis from each province. The centroid of every selected district was established by the software. Then, the ward with the densest population from each selected district was determined and considered as the densest ward code and served as a proxy to represent the midpoint of the district. The distance outward from that densest ward code to the centroid of each other ward was measured using distance matrix. A distance matrix is a tool on qGIS that is useful when working with two datasets to evaluate which point from one layer is closest to another point in the second layer. All geographical data and linked population data were imported and analysed using Microsoft Excel (version 16.0; Microsoft, Redmond, USA).

All data were extracted from the integrated database in qGIS into Microsoft Excel 2010. Descriptive analysis, including the number of populations of each selected district within 10 km and construction of scatterplots were completed using Microsoft Excel. A scatterplot was used for visual comparison between cumulative distance and population number of each selected district within 10 km from the centroid of the district. Based on the gradient of a slope, the proportion of dentists with respect to population clusters was categorised into three categories: low (≤20,000), medium (>20,000 to ≤50,000) and high (>50,000). The Pearson correlation coefficient (R^2) was used to determine the correlation between pattern of distribution of population and a number of dentists.

Results

The densest populated wards were found to be Biratnagar-1, Malagawa-2, Kathmandu-3, Lekthnath-4, Butwal-11, Birendranagar-6 and Tikapur-7 from Morang, Sarlahi, Kathmandu, Kaski, Rupendehi, Surkhet and Kailali districts, respectively (Figure 1).

The distance matrices were then analysed using qGIS, and further descriptive analysis was completed using Microsoft Excel. An example of one district (Kaski) in province 4 is shown (Figure 2). The nearest wards of Morang, Sarlahi, Kathmandu, Kaski, Rupendehi, Surkhet and Kailali district from the densest were found to be Biratnagar-3, Malangawa-3, Tokha-5, Lekhnath-3, Butwal-8, Birendranagar-8 and Tikapur-9, respectively; with the furthest being Miklajung-8, Lalbandi-14, Shankarapur-1, Annapurna-11, Siddharthanagar-5, Chaukune-1 and Chure-6, respectively.

Building a predictive model

To build a predictive model, a slope was plotted between cumulative distance and population of each selected district, within 10 km from its densest ward of each selected district. The slope represents how packed the population are in each district and showed gradients ranging from 10537 to 169214 (Figure 3). The slope was below or equal to (≤) 20,000 for Province 2, 6 and 7, meaning the area had fewer dentists with respect to population clusters. In Provinces 1, 4, and 5, there was a medium number of dentists present (slope was between >20,000 to ≤50,000). The slope was above 50,000 for Province 3 because the population are highly concentrated near its densest ward and almost half of the total nationwide dentists were in the Kathmandu district.

To measure dentists in relation to slope, the slope (M) indicating the rate of population increase per kilometer outward obtained from the scatter plot, was plotted against the number of dentists available (Figure 4a). Kathmandu district was excluded from this analysis because the population size and number of dentists were much higher than the remaining districts and might offer a false high R^2 value. The cluster of plotted values rising from left to right indicates a directly proportional relationship between population cluster and the number of dentists ($R^2 = 0.80$[17]). More dentists are located where population is clustered (Figure 4b(i)), than where the exact same size population is more widely distributed (Figure 4b(ii)) within a district. This indicate that dentist numbers are not just a reflection of population size, but also of the "clustering" of the population.

Discussion

The study aimed to build a predictive model to determine if the distribution pattern of the population could predict the availability of dentists in a district. There was a direct correlation between population clusters and dentist numbers. This implies that in an area with an evenly distributed population the number of dentists

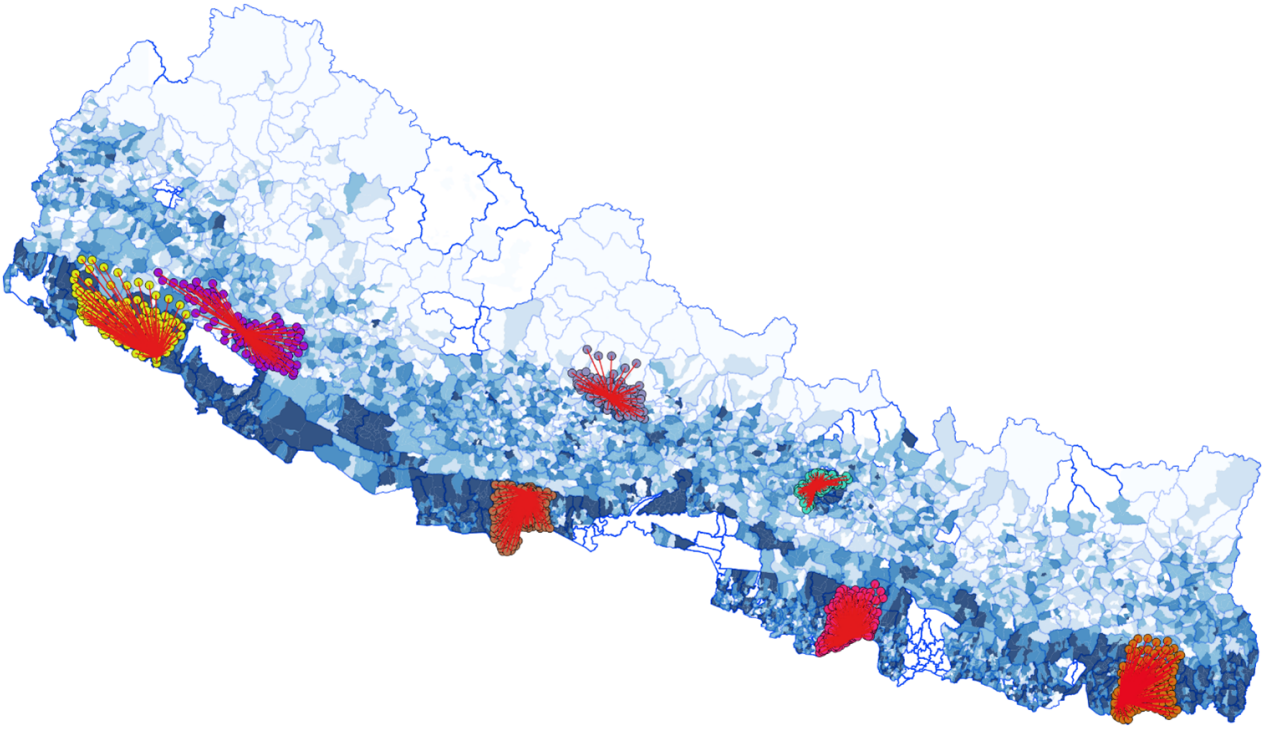

Figure 1. The most densely populated wards of selected districts of each province. The small circles represent population clusters. Province is indicated as Prov in this figure.

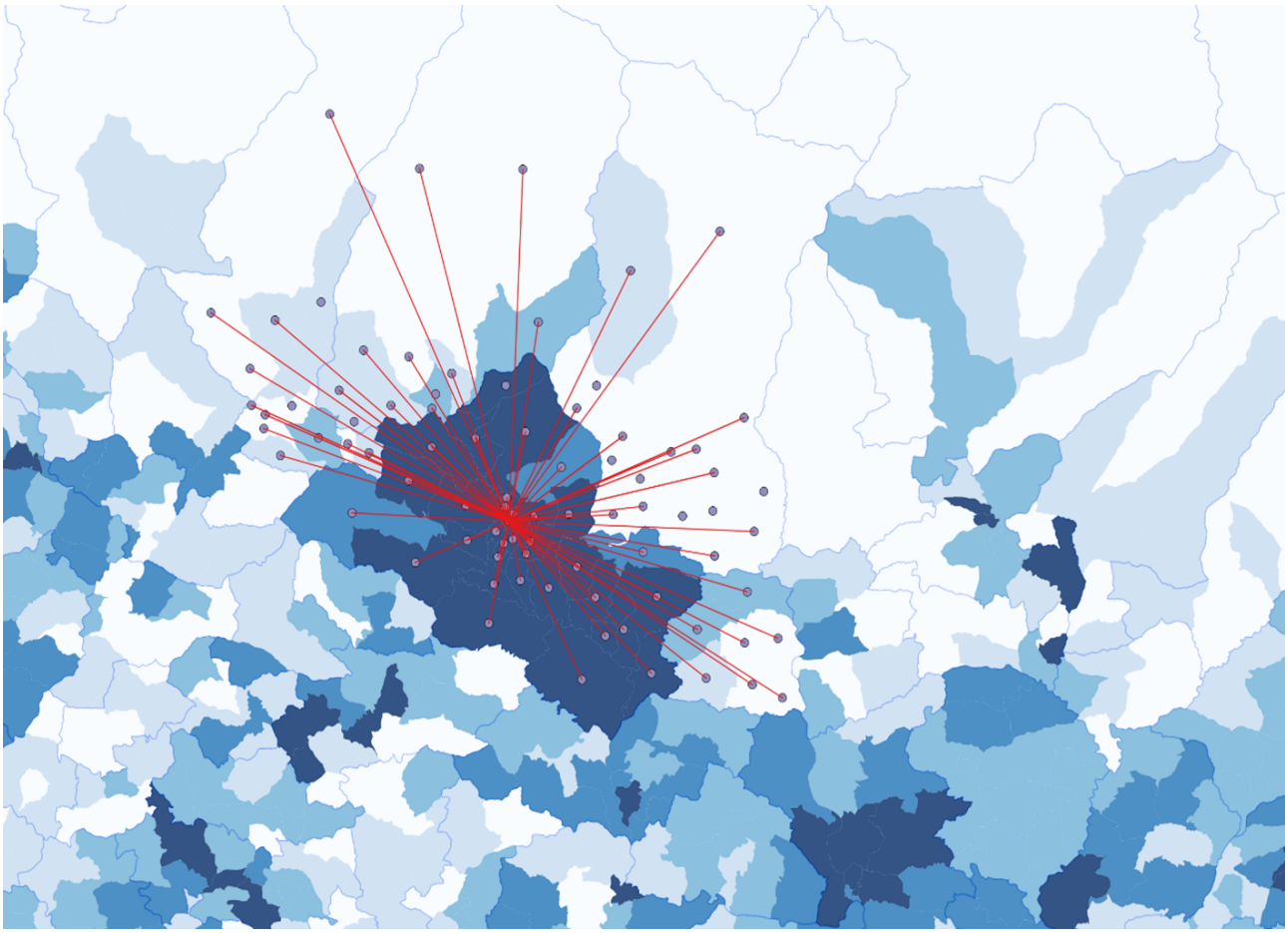

Figure 2. Position of centroid of the highest density ward and remaining wards in Kaski district. Centroids of wards are indicated by purple dots. Distance from the centroid of Lekhnath to the remaining wards of Province 4 indicated by red lines.

is less than in an unevenly distributed population, even though the population might be the same size in the two areas. Therefore, the higher the clusters of the population within an area, the higher the number of dentists.

The predictive model was constructed to predict the number of dentists based on the population of clustering patterns across the country. A similar predictive model was used in previous studies (Wijewardena *et al*., 2018;

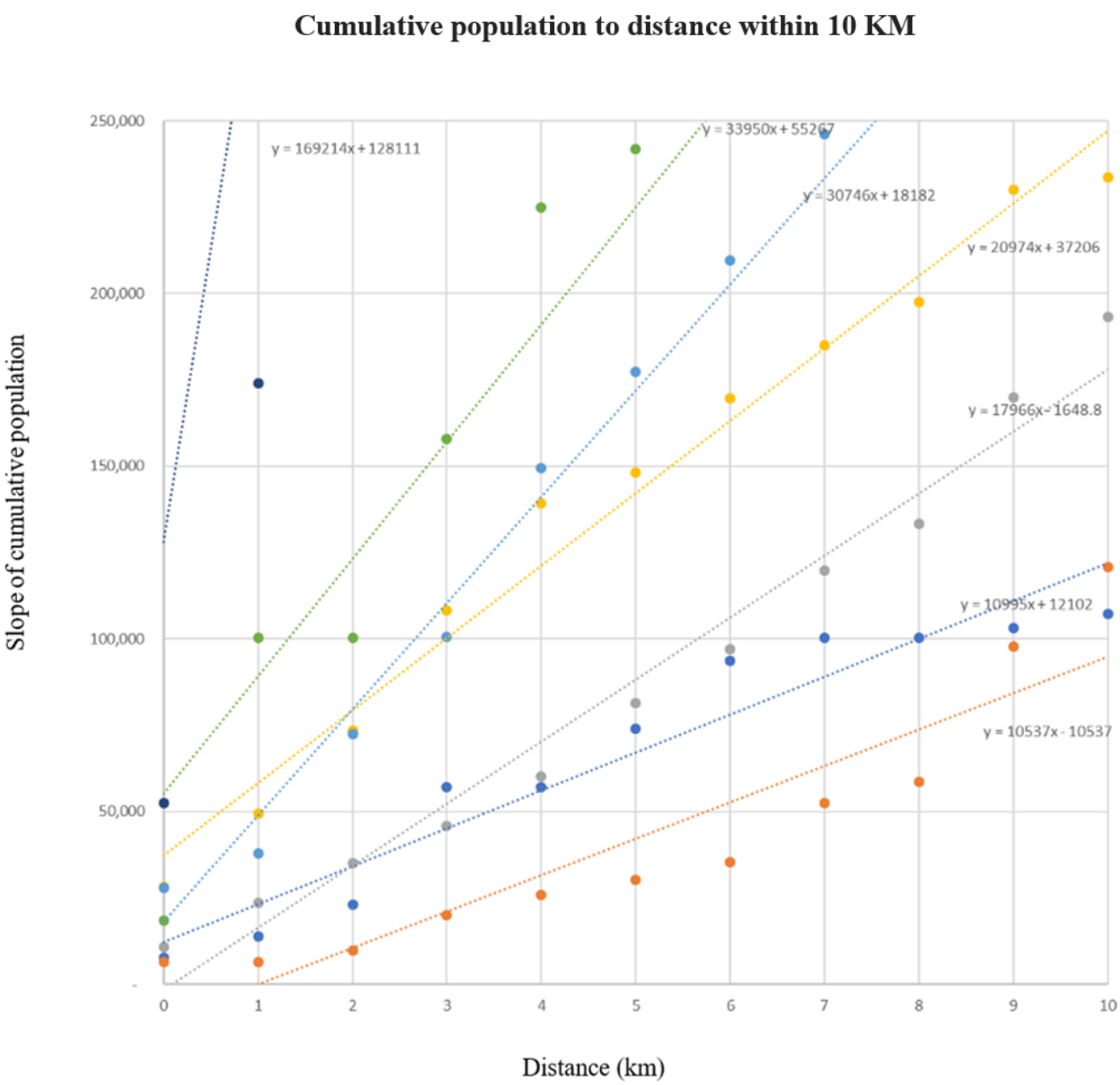

Figure 3. The relation of distance and population number. Orange, blue, grey, light blue, yellow, green and purple trend lines represent provinces 7, 6, 2, 1, 5, 4 and 3 respectively.

Md Bohari *et al*., 2018; Jean *et al*., 2020) to enhance the accessibility of dental health services nationally (including in Australia, Sri-Lanka, and Malaysia) by optimising the dental workforce distribution and location and establishment of dental clinics and/or dental schools. This method could be used elsewhere, as the required data are available for most countries.

The latest Nepal population census, conducted in 2011, was made publicly available (Central Bureau of Statistics, 2012). We selected seven out of seventy-seven districts based on the largest population. The population data from the most densely populated ward within a distance of 10 km were selected as urban wards and to reflect the feasibility of the distance to travel to a dentist, as established by Karki et al. (2018).

Information on the status and distribution of Nepal's dental workforce is scarce (Shrestha *et al*., 2017). Although the Nepal Medical Council should provide an Annual Register of doctors, it has not been able to do so (Knevel *et al*., 2015). In addition, little information on the health workforce in Nepal are available, restricting studies of the health workforce.

Previous national surveys have identified high dental treatment needs in rural areas of Nepal, as well as among the low socio-economic population. (Thapa *et al*., 2016; Karki *et al*., 2018). However, current policies do not advocate the establishment of health services (public or private) as per needs assessment. Health services could focus on the areas where the needs are greater to ensure the availability and accessibility of services (Penchansky and Thomas, 1981).

Nepal is facing a critical health workforce shortage relative to its population. The Human Resources for Health (HRH) profile of the Ministry of Health and Population (2013) showed there were only 1.05 health workers per 1000 population, compared to an indicative threshold of 4.45 per 1000 to achieve the Sustainable Developmental Goals (Ministry of Health and Population, 2013). The spatial analysis here identified an uneven distribution of dentist locations with population clusters.

There are underlying causes for the uneven distribution of dentists. Their provincial concentration correlates with the concentration of dental schools. Most of the twelve dental schools (2014) are in one province, along with

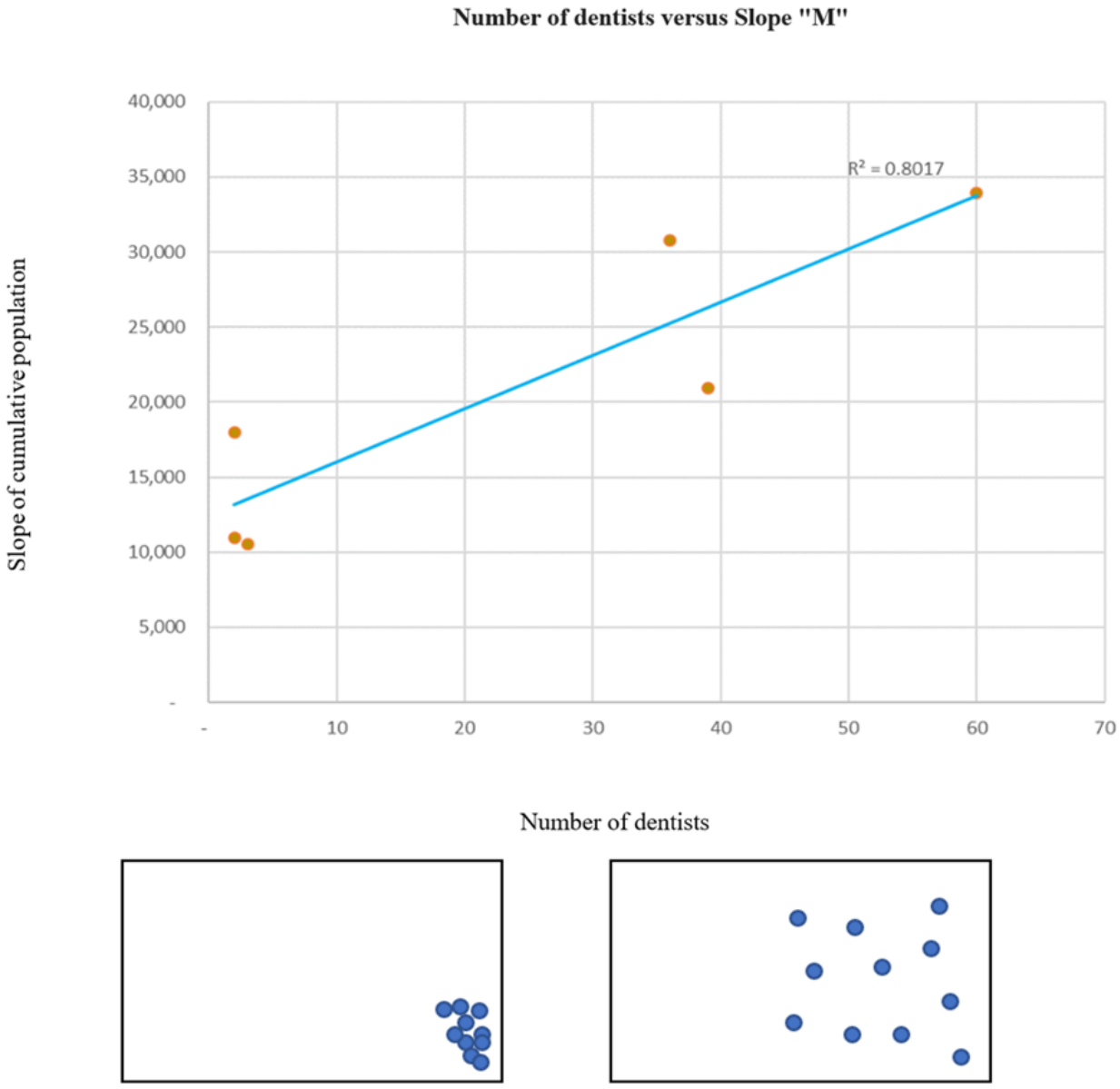

Figure 4. Scatter plot showing the relation between the number of dentists and the slope (4a). More dentists are found where the population is clustered (4b-i), than where the population are spread out(4b-ii), even though the population is the exact same size in two districts.

many dentists (Knevel *et al.*, 2015). A similar pattern occurs in Malaysia (Md Bohari e*t al*., 2018). Another reason may be the ten years (1996-2006) of civil war that affected Nepal, impacting on both the population's health and the health care system (Devkota and van Teijlingen, 2010). The conflict mainly affected rural areas, which may account for the lack of overall health workforce in those areas. More than 1000 health posts were destroyed (Mukhida, 2006). A similar loss was also observed in rural areas after the Sri-Lankan civil war (Wijewardena *et al.*, 2018). Although, amidst the civil war, Nepal appeared to have improved its human development index and life expectancy (Tsai, 2009), dental services and oral health status are still lacking in rural areas (Pokhrel and Pokhrel, 2019). The 'brain drain' of health professionals, including dentists, may also be another significant problem for Nepal. The brain drain of medical practitioners, inevitably contributed to their uneven distribution (Tamang *et al.*, 2020). More than 500 doctors emigrate annually, making it difficult for the government to deliver universal health coverage (International Labour Organization, 2017). The prime reason for the brain drain of Nepalese doctors is the low salary and lack of professional growth opportunities and support from the senior colleagues (Tamang *et al.*, 2020; International Labour Organization, 2017).

We found that the distribution of dentist's is highly related to population distribution. Thus, perceived over-supplies of dentists are limited to specific areas, with shortages in rural areas comprising a lower number of evenly distributed populations. There is a substantial geographic maldistribution of dentists', similar to the situations in other countries, with dental services being more saturated in the major cities (Md Bohari *et al.,* 2018; Wijewardena *et al.*, 2018). Shrestha and colleagues' (2017) found that approximately half of dentists in Nepal live in the capital, Kathmandu, to serve 1 million population, leaving 34 districts devoid of them.

Along with the saturation of dentists, many private clinics are concentrated in bigger cities, especially in Kathmandu

(Dolma Development Fund, 2014). This reflects the situation in other countries, where private clinics, which are driven by market forces, are not sustainable in rural areas due to low population density (Md Bohari *et al.*, 2018).

The reason underlying the inverse care law, which limits dental services for poor and marginalised people are complex (Fiscella and Shin, 2014). Although lower socioeconomic status populations have greater need, urban dwellers with high socioeconomic status are more inclined to use services (Jean *et al*., 2020). The Organisation for Economic Co-operation and Development (2015) have identified multiple factors for the reluctance of dentists to work in rural areas, such as high workload, lack of infrastructure, medicine, cultural differences, lack of basic amenities, gender bias and security issues. These reasons are relevant to Nepalese health workers (Tamang *et al.*, 2020). Therefore the high cost for dental treatment in private dental facilities, and their locations, concentrated around the major cities, are both physically and economically inaccessible for rural people.

This is the first study to use population census data and qGIS tools to predict the number of dentists in a district, providing valuable information for policymakers to develop the dental workforce. These data also inform policy that could be implemented by establishing clinics and dental schools in rural areas. This method could be used to construct a national map of the distribution of the dental health workforce in each of the districts. Geospatial information of dentist availability on a national level is important to identify areas with low supply and to formulate policies that close these gaps. Policy-oriented health service data should be conducted routinely to monitor the status of the dental workforce for health service planning.

This analysis should be interpreted with some limitations. The study only considers seven districts; hence, the results may not be generalised to other areas. Second, we developed predictive models using a spatial context. Other variables such as socioeconomic determinants, service utilisation, and transport access should also be considered, although they might be more challenging to consider. Future studies may attempt to integrate these variables.

In conclusion, we demonstrated substantial disparities in the distribution of dentists in Nepal. Dentists were distributed relative to higher population clusters and were unevenly distributed across Nepal. Most people with the highest accessibility to a dentist resided in Kathmandu district, located in Province 3. This study also provides a foundation for a detailed study of available dentists as per the population need across the country, to enable sustainable dental workforce planning.

References

Bakrania S. (2015): *Urbanisation and urban growth in Nepal.* From http://www.gsdrc.org/wp-content/uploads/2015/11/HDQ1294.pdf

Central Bureau of Statistics (2012): *National Population and Housing Census 2011*. From https://unstats.un.org/unsd/demographic-social/census/documents/Nepal/Nepal-Census-2011-Vol1.pdf

Devkota, B. and van Teijlingen, E. (2010): Understanding effects of armed conflict on health outcomes: the case of Nepal. *Conflict and Health* **4**

Dolma Development Fund (2014): *Market Data for Private Sector Investments in Nepal Healthcare Sector*. From http://www.dolmaimpact.com/pdf/DIF%20I-%20Healthcare%20Market%20Report_Final_1-10-2014.pdf

Fiscella, K. and Shin, P. (2005): The Inverse Care Law. *Journal of Ambulatory Care Management* **28**, 304-312.

International Labour Organization (2017): *Migration of health workers from Nepal*. From https://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/---ilo-kathmandu/documents/publication/wcms_546805.pdf

Jean, G., Kruger, E. and Tennant, M. (2020): The distribution of dentists in Australia Socioeconomic profile as an indicator of access to services. *Community Dental Health* **37**, 5-11.

Karki, S., Laitala, M., Humagain, M., Seppänen, M., Päkkila, J. and Anttonen, V. (2018): Oral health status associated with sociodemographic factors of Nepalese schoolchildren: a population-based study. *International Dental Journal* **68**, 348-358.

Knevel, R., Gussy, M. and Farmer, J. (2017): Exploratory scoping of the literature on factors that influence oral health workforce planning and management in developing countries. *International Journal of Dental Hygiene* **15**, 95–105.

Knevel, R., Gussy, M., Farmer, J. and Karimi, L. (2015): Nepalese dental hygiene and dental students' career choice motivation and plans after graduation: a descriptive cross-sectional comparison. *BMC Medical Education* **15**, 219.

Md Bohari, N., Kruger, E., John, J. and Tennant, M. (2018): Analysis of dental services distribution in Malaysia: a geographic information system – based approach. *International Dental Journal* **69**, 223-229.

Ministry of Health and Population (2013): *Human resource for health Nepal country profile*. From: http://www.nhssp.org.np/NHSSP_Archives/human_resources/HRH_Nepal_profile_august2013.pdf

Mukhida, K. (2006): Political crisis and access to health care: a Nepalese neurosurgical experience. *Bulletin of the American College of Surgeons* **91**, 19–24.

Organisation for Economic Co-operation and Development (2015): *Health at a glance 2011*. From https://www.oecd.org/els/health-systems/49105858.pdf

Pokhrel, P. and Pokhrel, K. (2019): Rural Health Awareness and Incidence of Oral Diseases in Rural Communities of Nepal. *Acta Scientific Nutritional Health* **3**, 34–40.

Penchansky, R. and Thomas, J.W. (1981). The concept of access: definition and relationship to consumer satisfaction. *Medical care* **19**, 127–140.

Shrestha, R., Shrestha, S. and Kunwar, N. (2017): Dentists in Nepal: A Situation Analysis. *Journal of Nepal Health Research Council* **15**,187-192.

Szabo, S., Nove, A., Matthews, Z., Bajracharya, A., Dhillon, I., Singh, D., Saares, A. and Campbell, J. (2020): Health workforce demography: a framework to improve understanding of the health workforce and support achievement of the Sustainable Development Goals. *Human Resources for Health* **18**, 1-10.

Tamang, B., Poudel, P., Karki, S. and Gautam, R. (2020): A mandatory bonding service program and its effects on the perspectives of young doctors in Nepal. *Rural and Remote Health* **20**, 5457.

United Nations Population Fund (2017): *Population situation analysis of Nepal*. From https://nepal.unfpa.org/sites/default/files/pub-pdf/Nepal%20Population%20Situation%20Analysis.pdf

Wijewardena, B., Ranasinghe, N., Kruger, E. and Tennant, M. (2018): The Distribution of Dental Health Specialist Locations in Sri Lanka. *Community Dental Health* **35**, 241–246.

World Health Organization: *Oral health services*. From: https://www.who.int/oral_health/action/services/en/

Yee, R. and Mishra, P. (2004): Nepal National Oral Health 'Pathfinder' Survey 2004. Kathmandu, Nepal: Oral Health Focal Point, Ministry of Health, HMG Nepal.