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Published in:
Journal of Public Health Policy

DOI:
[10.1057/s41271-020-00267-6](https://doi.org/10.1057/s41271-020-00267-6)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Final author's version (accepted by publisher, after peer review)

Publication date:
2021

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Efriandi, T. (2021). Spatial access to health care: a case study on community health centers in Asmat District, Papua, Indonesia. *Journal of Public Health Policy*, 42(1), 113-126. [8].
<https://doi.org/10.1057/s41271-020-00267-6>

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Spatial Access to Health Care: A Case Study on Community Health Centers in Asmat District, Papua, Indonesia*

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Abstract

In recent decades, access to primary health care has become a crucial issue for health policy planners and researchers. One of the fundamental problems is inequitable access to health care due to imbalanced resource distributions between health care providers and population location. Accordingly, this study aims to examine the spatial access to Community Health Centers (CHC) in the Asmat district, one of the most isolated regions in Papua, Indonesia. We conducted the study using a two-step floating catchment area (2SFCA) method to quantify accessibility value to primary health care of each village in the district of Asmat. By taking five distance thresholds ranging from 5 to 25 kilometers with an increment of 5 kilometers, the results indicate that distance has a varying impact on each village. For example, within a 5-kilometer distance threshold, 74% of villages have a zero score or have no access to CHCs, 22% have a score <100, while only 4% of villages have a score >100 or meet the minimum score recommended by World Health Organization (WHO). Two major related factors of these geographic disparities are the unequal distribution of CHCs and the high population dispersion. As an attempt to provide equal access to health care services, these results suggest that spatial access should be conscientiously considered by health planners and policy makers.

Keywords: spatial accessibility, 2SFCA, health care services, Asmat, Papua.

1. Introduction

Equitable access to health care services has emerged as a major policy issue both in high and low resource countries. The United Nation's sustainable development goals (SDGs) also aim to achieve universal health coverage (UHC) by 2030, meaning that all people and communities in the world should have adequate access to the health services they need without suffering financial hardship [1]. In its implementation, UHC is not limited to fiscal affordability but expressly includes the coverage of and the access to health care services [2]. Nevertheless, the majority of research and policy studies on UHC have focused on health financing, whereas studies on availability and access to health care services are limited in numbers and have not drawn much attention [3, 4].

* This article is a post-peer-review, pre-copyedit version of an article published as: Efriandi, T. (2021). Spatial access to health care: A case study on community health centers in Asmat district Papua, Indonesia. *Journal of Public Health Policy*. The final authenticated version is available online at: <http://dx.doi.org/10.1057/s41271-020-00267-6>

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From a planning perspective, inequitable access to health care is related to spatial access, that is, the ease of a population in a given area to reach medical services and facilities [3, 5, 6]. A host of factors, such as the uneven distribution of the population and the health care facilities, or the lack of transportation infrastructure, has contributed to disparity in terms of distance and travel time across the population. Therefore, to mitigate health inequity issues, access variations need to be considered by health planners and policy makers to ensure that health care services are provided adequately and universally [5].

In many countries, the dominant approach of health care facility planning is to distribute the supply of a certain type of health service within an administrative territorial unit, for example, county, province, or city [7, 8]. This approach, however, is flawed due to its inadequacy to take spatial variations in settlement patterns or population distribution into account [8, 9]. In Indonesia, specifically, the national health policy stipulates that distribution of community health centers (*puskesmas*, *Pusat Kesehatan Masyarakat*) should serve the total population within a region and take into account the ease of access to the health care facilities. However, the Indonesian spatial planning system poorly distributes community health centers (hereafter, CHC) at the local level. The distribution of CHC still follows the territorial boundary of sub-districts and as a result, it leads to several problems: (i) the approach does not account for the size of a sub-district area, the population size and the distribution of villages within a sub-district; (ii) the approach does not consider the impact of distance and population mobility. People may cross an administrative boundary to arrive at the nearest health care facilities, but this has not been taken into account in planning [5, 8, 10, 11]. To understand how spatial variations affect access to health care facilities, this study examines the geographical disparities on the distribution of CHCs and their impact on accessibility in the Asmat district, one of the most remote areas in Papua, Indonesia. In early 2018, the news revealed a shocking report on the death of over 65 children due to malnutrition and measles outbreak in this district. A number of factors, such as the difficult geographical conditions and the lack of health care facilities, have been recognized to contribute to this health crisis.

1.1 Defining access to health care

Abdullah A. Khan [5] defines access as the interplay process between the characteristics of the health care services systems (such as distribution of health care facilities) and the demographic characteristics of the population in a particular area (such as age, ethnic or income status). This interplay results in *potential accessibility* and *revealed accessibility* [5, 11]. *Potential accessibility* refers to the likelihood of potential users of the health services

entering the available health care system. This probability does not automatically ensure the utilization of the offered services by the users because the actual use of the services is dependent on barriers or facilitators both in the health care system and the potential users [5]. The actual entry of potential users into the health care system, or in other words *revealed accessibility*, occurs when all barriers to provision of services are overcome by the facilitators [4, 5].

The barriers and facilitators can be further split into spatial and non-spatial (or aspatial) dimensions [4, 5]. Spatial dimensions, as a barrier or facilitator, emphasize the geographical factors such as distance due to uneven distribution between health care providers and population, while non-spatial dimensions refers to the non-geographical factors such as the demographic and the social-economic status of a particular population that might also become a barrier or facilitator to accessibility [5, 8, 10, 12, 13].

1.2 Assessing potential spatial accessibility

In measuring potential spatial accessibility, Joseph and Phillips [10] differentiate between the regional availability approach and the regional accessibility approach. The former refers to the number of health care providers relative to the total population within a region. It is measured by calculating the ratio of the capacity of health care providers (physicians, clinics or hospital beds), as the numerator, to the population, as the denominator [4, 5]. This approach has a drawback as it does not acknowledge spatial dimensions such as distance between residences and health care centers. In contrast, the regional accessibility approach accommodates spatial elements such as geographical distance, including travel time and transport cost [5, 14]. The utilization of spatial elements, such as distance and time, in the regional accessibility approach takes into account the pattern of interactions between the availability of health care supply and the population's or consumer's demand.

To integrate these two approaches for measuring the potential spatial access to health care services, Luo and Wang [11] modified the spatial decomposition method first developed by Radke and Mu [15]. It originated from a gravity model by Joseph and Bantock [16]. This method, known as two-step floating catchment area, focuses on the provider-to-population ratio as the first step and calculates the accessibility index of a population by summing the provider-to-population ratios in a particular catchment area as the second step. Each step has a catchment area determined by a distance or time threshold from a particular centroid such as a health care center or a population location. As a result, the catchment area from each step creates two catchments that lay or float on top of one another. The spatial accessibility index

is then generated by computing the provider-to-population ratios in this floating catchment area.

Researchers have carried out several extensive studies on utilization of healthcare services by combining both the spatial and non-spatial dimensions of accessibility [12, 14]. There have also been studies on the potential spatial access to health care services; these focus on urban areas of high resource countries [7, 11, 17]. But researchers have conducted few studies on potential spatial accessibility in the rural regions of low resource countries due to the difficulty in obtaining data in such rural and remote areas. For these reasons and as an attempt to contribute to understanding spatial accessibility, this research focuses on the access to primary health care services in one of the rural areas in a developing country.

2. Methods

2.1 The case study of Asmat district

To identify the potential spatial accessibility in a peripheral region, this study focusses on the case of Asmat district, one of the most remote areas in Papua, Indonesia. Geographically, the district is located in the southern part of the Papua province. It has an area of 3,198,369 square kilometers divided into 19 sub-districts and 221 villages (see Fig. 1) with a total population of 126,766 in April 2018 (Minister of Home Affairs Decree No. 137/2017 concerning Code and Data of Government Territorial Administration & Department of Population and Civic Registration of Asmat District, 2018.) Bordered by the Arafuru Sea, the district is surrounded by mangrove forests, rivers, and swamps. Due to its lowland characteristics and lack of infrastructure, many of the sub-districts and villages are accessible only by traditional canoes or ferry speedboats. Traditional construction of houses are traditionally places them above swampy ground because of frequent occurrence of flashfloods. Villages often build boardwalks to connect houses within a village. Currently, there is only one hospital in the district capital and it serves the entire population of the sub-districts and villages. Also, from the 19 sub-districts, 17 CHCs are available only in 14 sub-districts (see Table 1 for an overview).

Fig.1 Map of the Asmat district with CHC and village location

Table 1 An overview of the Asmat district^{a,b}

Sub-district	Number of			
	Population (April 2018)	Village	CHC	Physician
Agats	29026	12	1	1
Akat	5296	11	1	-
Atsj	8559	9	1	1
Ayip	4901	6	1	-
Betcbamu	2547	7	-	-
Der Koumur	2583	9	-	-
Fayit	10582	23	1	-
Jetsy	1643	8	-	-
Joerat	3208	6	-	-
Kolf Braza	4587	11	1	-
Kopay	2333	10	-	-
Pantai Kasuari	4302	9	1	1
Pulau Tiga	3501	11	1	-
Safan	7762	12	2	-
Sawa Erma	7143	10	2	-
Sirets	4704	8	1	-
Suator	3732	27	1	1
Suru-suru	2928	23	2	2
Unir Sirau	3848	9	1	1
Total	113185	221	17	7

^a Data are sorted in alphabetical order of sub-district's name^b Source: Department of Population and Civil Registration of Asmat district, 2018; Minister of Home Affairs Decree No. 137/2017; Department of Health of Asmat district, 2019.

2.2 Data sources

We collected data for this study from the central government agencies and the local government of the Asmat district during a fieldwork trip between December 2018 and February 2019. Subsequently, we augmented these datasets using Geographic Information Systems software to calculate accessibility scores to CHCs of each village in the Asmat district. For the GIS analysis, we used spatial and attribute datasets from the Asmat district in this analysis (see Table 2).

Table 2 Data sources for GIS analysis

Dataset name	Type of data	Sources	Year
Asmat district & sub-district digital map	Spatial	Geospatial Information Agency	2016
Village centroid points	Spatial	Ministry of Home Affairs	2016
CHC centroid points	Spatial	Ministry of Home Affairs	2016
Village & sub-district name	Attribute	Ministry of Home Affairs	2017
CHC address	Attribute	Department of Health of Asmat district	2019
Population data per village	Attribute	Department of Demography and Civil Registration of Asmat district	2018

2.3 Applying the 2SFCA method

To examine the inequitable geographical distribution of CHCs in the Asmat district, this study applies the 2SFCA method. We chose this method for two interrelated reasons. First, this method not only assesses the availability of health care facilities in a particular area, but also measures accessibility in terms of how the locations of health care facilities are reachable from where inhabitants reside [11]. The distribution of health care facilities in Indonesia is defined by administrative boundaries without considering the dispersion of settlements and population density. Hence, this method helps to identify the impact of the existing distribution of health care facilities on the inequality of access to health care. Second, the 2SFCA method recognizes the possibility of cross border interactions between health care facilities and population locations by using distance thresholds instead of administrative boundaries in measuring the service area of health care facilities. Thus, this method identifies, given a certain distance threshold, whether a population location is served by more than one health care facility or has no access to health care facilities at all. The following paragraphs characterize the formulation of 2SFCA as developed by Luo and Wang [11].

Step 1: health care center (provider) to population ratio

For each health care provider at location “ j ”, step 1 traces all population locations (k) that are within the threshold distance (d_0) from location “ j ” (the coverage of this threshold distance is the catchment area of “ j ”) and calculates the number of health care providers as the numerator and the total population within the catchment area as the denominator. The calculation from this first step will generate the provider to population ratio (R_j):

$$R_j = \frac{HC_j}{\sum_{k \in \{d_{kj} \leq d_0\}} P_k}$$

R_j	: health care centers to population ratio at location “j”.
HC_j	: the number of health care centers at location “j”.
P_k	: the number of inhabitants at location “k” whose centroid falls within the catchment area $\{d_{kj} \leq d_0\}$.
d_{kj}	: the distance between “k” and “j”.
d_0	: distance threshold from health care centers to resident location

Step 2: measuring accessibility index

If the catchment area in the first step is centered at the location of a health care center, the catchment area in the second step is centered at each inhabitant’s location. Consequently, because the catchment area is based on the acceptable distance threshold to where population may be willing to travel to the health care center, there is a possibility that it will cross the territorial administrative borders. It is also possible that an inhabitant’s location will be served by more than one health care centers. Hence, the score of spatial accessibility index in the second step is formulated by computing the provider-to-population ratios of one or more health care center within the catchment area of a particular habitation. The formula in this second step is operationalized below:

$$A_i^F = \sum_{j \in \{d_{ij} \leq d_0\}} R_j$$

A_i^F	: the accessibility of population at resident location “i”.
R_j	: health care centers to population ratio at location “j” (the result from the first step).
d_{ij}	: the distance between “i” and “j”.
d_0	: distance threshold from resident location to health care centers

The accessibility score (A_i^F) from this second step represents the accessibility level of each inhabitant’s location. The higher the accessibility score of a habitation the better access to health care. Thus, in this 2SFCA method, the number of health care facilities, the population, and the distance or time threshold are the three major components that will determine the potential spatial accessibility score. We can further hypothesize that a smaller population, a greater number of health care facilities, and reduced distance threshold between population residences and health care facilities will generate a higher accessibility score.

For the 2SFCA method in this study we use the ArcGIS Desktop 10.5.1 software and the following steps:

- (1) A circle has been created with its center on each CHC location. The radius of the circle is drawn based on the chosen distance threshold (see Fig. 2A). This study uses five distance thresholds ranging from 5 to 25 kilometers with an increment of 5 kilometers as the catchment area.

- (2) Before calculating the provider to population ratio as the first step, we count the number of CHCs that lie within each catchment area. There is a probability that the radius of a circle will cross the administrative boundary and as a result, creates a possibility that more than one or multiple CHCs fall within a catchment area. In Fig. 2A, for example, by taking CHC *a* as the centroid, there is another CHC (CHC *b*) from a different sub-district that falls within the catchment area and therefore, there are two CHCs (*a* and *b*) within the radius of the catchment of CHC *a*.
- (3) After counting the number of CHCs that lie within the circle, the first step of 2SFCA formula is executed by dividing the number of CHCs and the total population of all villages within each distance threshold, which will generate the provider-to-population ratio (R). As an illustration, in Fig. 2B it is assumed that only one person inhabits each village. By taking CHC *a* as the centroid, there are two CHCs (*a* and *b*) and seven inhabitants within the catchment area. Therefore, the provider-to-population ratio of CHC *a* is $2/7$.
- (4) The second step involves drawing a circle with its center on each village location. The radius of the circle, based on the distance threshold, defines the catchment area where people have potential access to travel to CHC (Luo, 2004). The accessibility score of each village (A^F) is generated by summing the provider-to-population ratios (from step 1) of all the CHCs within the catchment area of each village. In this step, the five distance thresholds to measure provider to population ratio from step one will be used again to measure the accessibility score in step two. The calculation at this step produces final accessibility scores. These represent opportunities for the population in each village to access a CHC given a particular distance threshold. The higher the scores of a village, the greater the opportunity for the population to access a CHC compared to a population who lives in a village with a lower accessibility score. Fig. 2C provides an illustration of this step. By taking village 1, 5, 9, and 13 as the centroids, the A^F score of village 1 is zero since there is no CHC available within its catchment area, whereas village 5, 9, and 13 have the A^F score of $31/35$, $44/35$, and $2/5$, respectively.

2A Spatial join of CHC

2B Step 1 (CHC per population)

2C Step 2 (accessibility score per village)

- : Sub-district boundary
- Ha : CHC location
- 1 : Village location and ID

Fig. 2 Operationalization of the 2SFCA method

3. Results

As explained in the methodology section, the analysis begins by calculating the distribution of CHCs, using five different distance thresholds (d_0). In this stage, each CHC location becomes the centroid of a particular catchment area (see Fig. 3). The results of this spatial join analysis are presented in Table A1 in the appendix.

Table A1 shows that with a larger value of d_0 more CHCs fall within the catchment area. For example, within a 15-kilometer distance threshold and taking CHC Unir Sirau as the centroid, there are two other CHCs from two different sub-districts that fall within the catchment area (see Fig. 3). This indicates that populations in villages within the catchment area of CHC Unir Sirau have a better supply of health care resources compared to other villages outside of the catchment area that have one CHC.

Fig. 3 CHC to Population Ratio in three CHCs ($d_0 = 15$ km)

After joining the number of CHCs, the first step of 2SFCA is executed by dividing the number of CHCs with the total village population, again using five different distance thresholds (d_0). The result of this step generates the CHC to population ratio (R). Figure 4 below shows the result of R of each CHC with five different d_0 . For easy comparison the values have been multiplied by 10^5 . A cap of 100 is used based on the minimum ratio recommended by World Health Organization (WHO), that is, 1 physician per 1000 population or 0.001. This escalates to 100 when multiplied by 10^5 to compare it with the R score of each CHC. Because WHO defines the ratio on the number of physicians, we assume here that each CHC has 1 physician. Note that in the Asmat district this is not the case in some CHCs.

Fig. 4 CHC to Population Ratio (R)

Figure 4, shows the various R -scores for the sub-districts and demonstrates several trends:

- (1) For $d_0=5$ km, 7 centroids (CHC Kolf Brasa, Mumugu, Pulau Tiga, Suator, Suru-Suru, Tomor and Yaosakor) have a score over 100, which indicates that these CHCs exceed the WHO minimum ratio. Note, however, that this result is based on capturing a small number of villages with a small population size using the distance threshold of 5 kilometers. For instance, with only one CHC available in the centroid of CHC Kolf Brasa, it presents the highest score because it captures only one village with 545 inhabitants. However, because the sub-district of Kolf Brasa has 11 villages and only one CHC, with the distance threshold of 5 kilometers, the other 10 villages in this sub-district are not covered by a CHC.
- (2) The R scores are lower using $d_0=15$ km in most centroids, although in 3 centroids (CHC Ayam, Fayit and Sawa Erma) the R score is slightly higher. In general, the lower R score is caused by an increase in the number of villages that captured by the larger catchment area. However, a larger area also includes a larger number of village inhabitants, while not more CHCs become available within this area. In contrast, the higher R score in the 3 centroids is due to an increase in the number of CHCs available when using the 15-kilometer distance threshold.
- (3) The variation in the value of R also emerges when using the 20 km and 25 km thresholds, depending on the number of CHCs available, the number of villages and the size of the population in those villages that fall within a catchment area of 20 or 25 kilometers.
- (4) The lowest R score across the five distance thresholds is for the centroid of CHC Agats, which is located in the capital of the Asmat district. Because it is the capital city, most of the population is concentrated in the Agats sub-district. The large population size, however, is not facilitated by a sufficient number of CHCs, there is only one CHC available within the radius of 25 kilometers.

In the second step, each village, that represents the population location, becomes a centroid for a particular catchment area. However, obtaining complete data on Indonesia's peripheral regions is a problem, because most of the data are not available. In this study, from a total of 221 villages, there are only 180 village centroids identified and drawn on the digital map of Asmat. Population data for each village were only available in 174 of 180 village centroids.

The spatial accessibility score of each village (A^F) is obtained by summing up the R score from step 1 of all CHCs that lie within the catchment area of the villages. In Komor village, for example, there are three CHCs available within the distance threshold of 15

kilometers. The accessibility score of this village is calculated by sum of the R scores of those three different CHCs (see Fig. 5). For easy comparison, the A^F scores have also been multiplied by 10^5 . In Table A2, the mean and standard deviation of the A^F scores of all 180 villages in the Asmat district are calculated per distance threshold. Figure 6 shows the number of villages in each distance threshold classified into six categories of A^F scores (i.e. 0, 1-25, 51-75, 76-100, 100+). Figure 7 shows the percentage of population captured with each distance threshold and distributed into these six categories of A^F scores.

Fig. 5 Accessibility Score (A^F) of Komor Village ($d_0 = 15$ km)

Fig. 6 Number of villages in each of the six categories of A^F score.

Fig. 7 Percentage of population in each of the six categories of A^F score.

Taken together, Table A2, Fig. 6 and Fig. 7 reveal the following results:

- (1) For each distance threshold, several villages have a score of zero. This indicates that inhabitants in these villages have no access to a CHC. The largest number of villages with a zero score emerges using the distance threshold of 5 kilometer (132 villages or 51% of population) and 10 kilometers (104 villages or 41% of population). Though the number of villages with no access to CHCs decreases when the distance threshold increases, it implies that a patient has further to travel.
- (2) The standard deviation (SD) in Table A2 shows that a greater distance threshold does not lead to a smaller variance in accessibility score. The SD is lower using the distance thresholds 5 to 15 kilometer. However, the SD is higher again with the distance threshold of 20 kilometer. This is due to the increasing number of CHCs that fall within the catchment area of 20 kilometers.
- (3) When the distance increases, the A^F score of most villages also increases. This is indicated by mean accessibility score, the lower number of villages with a zero score and the higher number of villages that fall into the other categories. Note, however, that the higher number of villages is not always followed by a commensurate increase in the percentage of the population in the same category. In the category of 51-75, for example, the number of villages increases from 22 villages ($d_0=20$ km) to 30 villages ($d_0=25$ km). Meanwhile, for the same distance thresholds, the percentage of population declines from 12% to 10% respectively. Similarly, in the category of 76-100, whereby the higher number of villages in the 25 kilometers versus the 20 kilometers threshold is not accompanied with a similar change in the percentage of population covered in these distance thresholds. This indicates the diversity of villages' population density in the Asmat district and suggests the importance of considering the population density in distributing CHCs in remote areas like the Asmat district.
- (4) Overall, the A^F score of most villages and their population in the Asmat district falls within the categories of 0, 1-25 and 51-75 for all distance thresholds. The accessibility score is low as it falls below the standardized minimum ratio of the WHO. However, a few villages have a score of over 100. This means that the supply of CHCs in these villages exceeds the WHO's minimum ratio. Note that villages with such high accessibility scores are villages located in remote areas, while villages in the district capital have low accessibility scores. This shows that the accessibility score does not only

depend on the distribution of CHCs within a region, but also, and more importantly, on the density and/or the distribution of the population within a particular catchment area.

4. Discussion

Delivering equitable access to health care services is essential for improving the population's health. It is also one of the global development goals to make health care universally accessible by 2030. In Indonesia, however, inequalities in access to health care persist due to geographical imbalances between the spatial allocation of health resources and the distribution of the population. By applying the 2SFCA method to the Asmat district in the province of Papua, Indonesia, this research shows that CHC's are distributed unequally across regions in this district. The societal impact is that, given certain distance thresholds, some villages have a better accessibility as they are served by more than one CHC, or have a low population density. In contrast, a number of villages have an accessibility score of zero, which indicates that those villages have no CHCs available in their region.

The disparity of access to CHCs in the Asmat district is caused by two interrelated factors. First, the shortage and unequal distribution of CHCs due to the health planning policy to establish CHCs according to administrative boundaries. CHCs are most often established in sub-district regions and services are determined by predefined administrative boundaries without taking into account the distribution of population locations and the density of the population in each location. The second factor is the uneven distribution of the population within a region, with the district capital having high population density, and villages in remote areas having low population densities. Using the 2SFCA method, the analysis reveals that villages with smaller populations have a higher accessibility score than villages with a larger population. This indicates that inhabitants in sparsely populated regions have lower competition for access to CHCs (low demand) than inhabitants in densely populated regions (high demand).

For improving the access to health care services, this research has a number of policy implications for health care planning. First, analyzing spatial accessibility value would help regulatory planning authorities to allocate health care resources more precisely by redesigning the supply of CHCs particularly in regions that are underserved. Policy responses can be made, for example, not only locating CHCs within an acceptable travel distance, but also by recognizing the importance of population density of certain regions in the Asmat district. Second, by measuring the coverage of services based on a particular distance threshold of CHCs instead of using administrative boundaries, health planners and policy makers may increase access to patients from outside of the sub-district boundaries. Thus, the coverage of CHCs in providing health services is not limited by the administrative boundaries but is instead determined by the acceptable distance people in need of health services have to travel.

An equally important point is that the equitable allocation of health resources should also be supported by development of transportation infrastructures, distribution of physicians, and quality of health services.

There are some limitations of this research. First, because this research primarily focuses on measuring potential spatial accessibility, the measurement results are only based on the spatial distribution of CHCs (supply) relative to the geographical distribution of population (demand) in a particular service area. It does not necessarily represent and account for the actual mobility experiences or travel behavior of the population to be able to access health services. For instance, due to the difficult terrain and limited transport options, patients may experience difficulties and may not be able to access the CHCs even though proportionally their area may have a better supply of health services. Second, this research considers the distribution of primary health care facilities without taking into account the number of physicians or health services in each CHC. Despite the inequitable geographical distribution of CHCs in the Asmat district, the shortage of physicians and lack of services also limits the delivery of these health care services. Physicians are only available in some CHCs and in many cases physicians are absent from their posts [18].

Hence, further research is needed in order to provide a better analysis of accessibility both on the supply and demand side. On the supply side, the availability of CHCs should also recognize the availability of physicians and health care personnel, including facilities and the type of services offered at CHCs to reflect the real capacity of CHCs in meeting the needs of the population. On the demand side, the measurement of utilization of CHCs might be improved by incorporating non-geographical factors such as demographic, socioeconomic status, or ethnicities to provide a comprehensive understanding of how these factors could hinder or facilitate access to CHCs. Third, due to limitations in data availability, this study uses the Euclidean distance by drawing a circle to measure distance between two points within a certain threshold. The application of Euclidean distance, however, has a limitation. Regardless of the existing river network, this study assumed that all villages within the same catchment area have an equal spatial access to CHCs, whereby the spatial accessibility score between villages at the periphery of the catchment area is equal to villages close to the centroid. In practice, however, the scores may vary due to differences in the river network distances. Thus, the results may not reflect the actual or experienced spatial distance between villages and CHCs. Better measures of accessibility can be made in the future research by applying different types of distances such as network distance and by collecting data at the individual level to track the river network used for transportation.

APPENDIX

Table A1. Spatial distribution of CHC within five distance thresholds (d_0).

No	CHC (centroid)	Sub-District	Joint Count CHC				
			$d_0 = 5$	$d_0 = 10$	$d_0 = 15$	$d_0 = 20$	$d_0 = 25$
1	CHC Agats	Agats	1	1	1	1	1
2	CHC Atsj	Atsj	1	1	1	2	2
3	CHC Awuy	Ayip	1	1	1	1	1
4	CHC Ayam	Akat	1	1	2	2	3
5	CHC Bayun	Safan	1	1	2	3	3
6	CHC Fayit	Fayit	1	1	2	2	2
7	CHC Kolf Brasa	Kolf Brasa	1	1	1	2	2
8	CHC Mumugu	Sawa Erma	1	1	1	1	2
9	CHC Pantai Kasuari	Pantai Kasuari	1	1	1	1	1
10	CHC Primapun	Safan	1	1	1	2	2
11	CHC Pulau Tiga	Pulau Tiga	1	1	1	1	1
12	CHC Sawa Erma	Sawa Erma	1	1	2	2	3
13	CHC Suator	Suator	1	1	1	2	2
14	CHC Suru-Suru	Suru-Suru	1	1	1	1	1
15	CHC Tomor	Suru-Suru	1	1	1	1	2
16	CHC Unir Sirau	Unir Sirau	1	1	3	3	3
17	CHC Yaosakor	Sirets	1	1	1	2	2

Note: Data are sorted in alphabetical order of CHC's name.

Table A2. Mean and standard deviation of A^F score of 180 villages

Distance threshold (d_0)	Mean	Standard deviation
5	13.9	33.8
10	16.6	32
15	22.7	28.3
20	30.2	30.9
25	36.8	29.6

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