Geospatial Disparities in Elderly Health: A GIS-Based Study of Functional Independence in Tasikmalaya Regency, Indonesia

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Abstract
Population ageing poses significant challenges to healthcare access, particularly in rural areas with varied topography. This study examines geographical health inequalities among single elderly women in Tasikmalaya Regency, West Java, Indonesia a region characterized by rugged terrain and inadequate infrastructure. Using a mixed-methods approach, we assessed the functional health of 383 women aged 60 and above through the Activities of Daily Living (ADL) index and analyzed spatial access to healthcare facilities using Geographic Information System (GIS) based tools, including isochrone mapping and spatial regression. The findings reveal substantial limitations in instrumental activities despite preserved independence in basic self-care. Spatial analysis shows that lower ADL scores are concentrated in highland areas, associated with higher elevations and longer distances to healthcare services. However, proximity to health centers alone does not consistently predict functional status, suggesting that broader social complexities also influence health outcomes. These results underscore the need for geography sensitive healthcare policies such as mobile clinics, improved transportation infrastructure, and community-based support systems to reduce disparities and enhance the well-being of elderly women in remote areas.

Keywords: ADL, Community Health Centre, Elderly Woman, Healthcare Accessibility, Well-Being

1. Introduction

Population aging is a global demographic challenge characterized by a shift toward an older population, driven by declining fertility rates and increased life expectancy. While this trend is more pronounced in developed countries, it is increasingly significant in developing nations like Indonesia, with profound implications for health, welfare, economic, social, and political systems [1][2][3] and [4]. Over time, an aging population can strain healthcare systems, reduce workforce productivity, and exacerbate socio-economic inequalities. In Indonesia, West Java Province is experiencing a notable aging trend, with official statistics projecting a significant increase in the elderly population (aged 60 years and above) in the coming decades [5][6] and [7]. Within West Java, Tasikmalaya Regency, a predominantly rural region, has one of the highest concentrations of elderly individuals, particularly single elderly women, who face unique challenges due to their demographic and socio-economic circumstances.

In Tasikmalaya Regency, which spans 2,719 km², the elderly population constitutes a growing segment, with approximately 4,255 single elderly women aged 60 years and older, based on recent demographic data [8]. This group, which includes widows, divorcees, and single women, is particularly vulnerable because of their greater reliance on public services, low incomes, and lack of social support. The aging trend in Tasikmalaya is driven by a fertility rate decline to 2.3 children per woman in West Java (below the replacement level of 2.1) and a life expectancy increase to approximately 73 years for women [8].

These factors have led to a higher proportion of elderly women living alone or with minimal family support, a situation exacerbated by the outmigration of younger generations to urban areas, leaving rural communities with a disproportionate number of elderly residents. Single elderly women in Tasikmalaya often face economic hardship, with many relying on limited pensions or informal income sources, and physical limitations that hinder their ability to access distant healthcare facilities [6] and [7]. These demographic characteristics, combined with the region's rural and topographically diverse landscape, contribute to significant health disparities, particularly for this vulnerable group.

The terrain of Tasikmalaya Regency, characterized by hills and mountains in the western part and plains in the central and southern areas, presents additional challenges. The region's rural nature, coupled with steep topography, poor road conditions, and a lack of public transportation networks, creates significant barriers to accessing public facilities, particularly healthcare services. These geographical constraints disproportionately affect single elderly women, who may lack the physical capacity or financial means to travel long distances, leading to healthcare disparities and poorer health outcomes [9] and [10]. Studies suggest that geographical location significantly influences the health of elderly populations, particularly in rural settings where remoteness and terrain exacerbate access issues [11]. A geographical perspective is essential for understanding the complex interplay between topography, the distribution of single elderly women, and their health status. Steep terrain and remote locations often limit healthcare accessibility, particularly for elderly women with mobility constraints. This study used Geographic Information System (GIS) analysis to address these challenges, focusing on three primary objectives: (1) to examine how geographical location influences the health status of single elderly women in Tasikmalaya Regency, (2) to assess the relationship between the distribution of healthcare facilities and their health outcomes, and (3) to evaluate how the distance to healthcare facilities affects their health across various districts. Unlike previous studies that primarily explored social determinants of health, this research leverages spatial analysis to identify patterns of health disparities driven by geographical barriers [12]. The findings are expected to inform evidence-based health policy planning, proposing geography-based solutions to improve healthcare accessibility and reduce health inequalities for single elderly women in Tasikmalaya Regency.

2. Method and Data

2.1Study Area

This study was conducted in Tasikmalaya Regency, located in West Java Province, Indonesia. Spanning approximately 2,719 km², the regency features a diverse topography that includes rugged mountains, high plateaus, and lowland areas (see Figure 1).

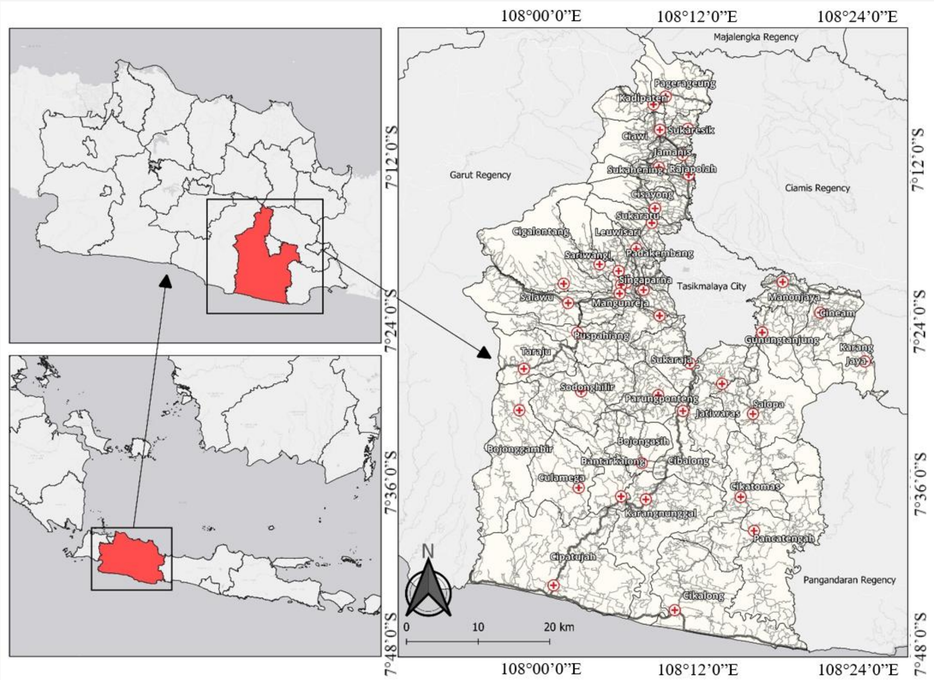

Figure 1: Tasikmalaya Regency, Indonesia

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Administratively, Tasikmalaya Regency is divided into 39 sub-districts and 420 villages, situated between 7° 2′ 22.23″ and 7° 48′ 56.56″ South Latitude and 107° 54′ 25.18″ and 108° 26′ 28.33″ East Longitude. The region's elevation varies significantly, ranging from 800 to 1,500 meters above sea level, contributing to its complex terrain. The hilly and mountainous landscape, coupled with limited infrastructure in remote areas, presents substantial barriers to healthcare access, particularly for vulnerable populations such as elderly women with mobility limitations. These geographical challenges exacerbate disparities in healthcare delivery, often requiring specialized interventions to ensure equitable access to medical services.

2.2 Study Population

The study population consisted of 4,255 elderly women aged 60 years and above in Tasikmalaya Regency, based on official demographic data. A sample of 383 participants was selected using cluster random sampling to ensure representation across the regency's diverse geographical areas. Villages were grouped into clusters based on sub-districts, and a random sample of clusters was selected. Within each cluster, participants were identified based on inclusion criteria: single marital status and age of 60 years or older. The sample size was determined using Slovin's formula (equation 1) with a 95% confidence level and a 5% margin of error, ensuring sufficient statistical power to represent the population while accounting for the study's focus on ADL-based health status assessments:

$$n = \frac{N}{1 + N(e)^2}$$

Equation 1

Where:

n = Sample size
N = Population size
e = Margin of error

2.3 Research Procedure

The study process started with a set of goals to assess the functional health status of elderly women who are single, investigate the effect of topographic and geographic factors, and evaluate healthcare accessibility in Tasikmalaya Regency (see Figure 2). Data were gathered from primary and secondary sources, with the study population defined as older women who were 60 years of age or older and single. Primary data consisted of respondent household coordinates, ADL-based health assessments, and healthcare preferences, whereas secondary data contained health facility locations, road networks, and topography datasets.

After being collected, the data was prepared and analysed systematically. ADL scores were initially processed to determine respondents' functional status, which was then mapped to show spatial dispersion among sub-districts. geographical statistics, such as Global and Local Moran's I, were used to discover health outcome clustering and geographical autocorrelation patterns. Isochrone analysis was used to create accessible maps for health facilities, and further investigation was conducted to explore the link between topography and functional health. Geographically Weighted Regression (GWR) is used to model the spatially variable associations between health outcomes and the explanatory component topography. The results of all steps were synthesised through descriptive interpretation and assessment, yielding empirical findings on geographical health inequalities. These results were then turned into policy suggestions aimed at increasing healthcare accessibility and improving the well-being of single elderly women in the study's region.

2.4 The Activities of Daily Living

Activities of Daily Living (ADLs) are fundamental tasks essential for self-care, survival, and maintaining independence, while *Instrumental Activities of Daily Living (IADLs)* encompass more complex activities required for independent living in a community setting [13] and [14]. These activities are critical for assessing functional status, particularly in populations such as the elderly, individuals with disabilities, or those recovering from medical conditions [15] *ADL* and *IADL* assessments help healthcare providers determine a person's ability to live independently and identify the need for support or interventions, making them vital tools in clinical and caregiving contexts [16].

ADLs include six core tasks requiring basic physical and functional skills: eating (using utensils, chewing, and swallowing safely), dressing (selecting and managing clothing), toileting (using the toilet and maintaining hygiene), bathing (washing the body and safely navigating a shower or bathtub), transferring (moving between surfaces like bed to chair), and continence (managing bladder and bowel functions). *IADLs*, in contrast, require higher cognitive and physical coordination, encompassing tasks such as managing finances (e.g., budgeting or paying bills), shopping (selecting and purchasing necessities), preparing meals (planning and cooking), managing medications, using transportation (driving or navigating public transit), housekeeping (cleaning and laundry), and communication (using phones or handling correspondence).

These tasks are particularly relevant for elderly women, as early difficulties with *IADLs*, such as forgetting to pay bills, may signal functional decline before *ADL* limitations become evident. *ADL* status was classified into three standard categories adapted from the Barthel Index (See Table 1), a widely recognized tool for measuring functional independence in activities such as mobility, self-care, and household tasks [17]: Independent (*ADL* score 21–30), Partially Dependent (*ADL* score 11–20), and Dependent (*ADL* score 0–10).

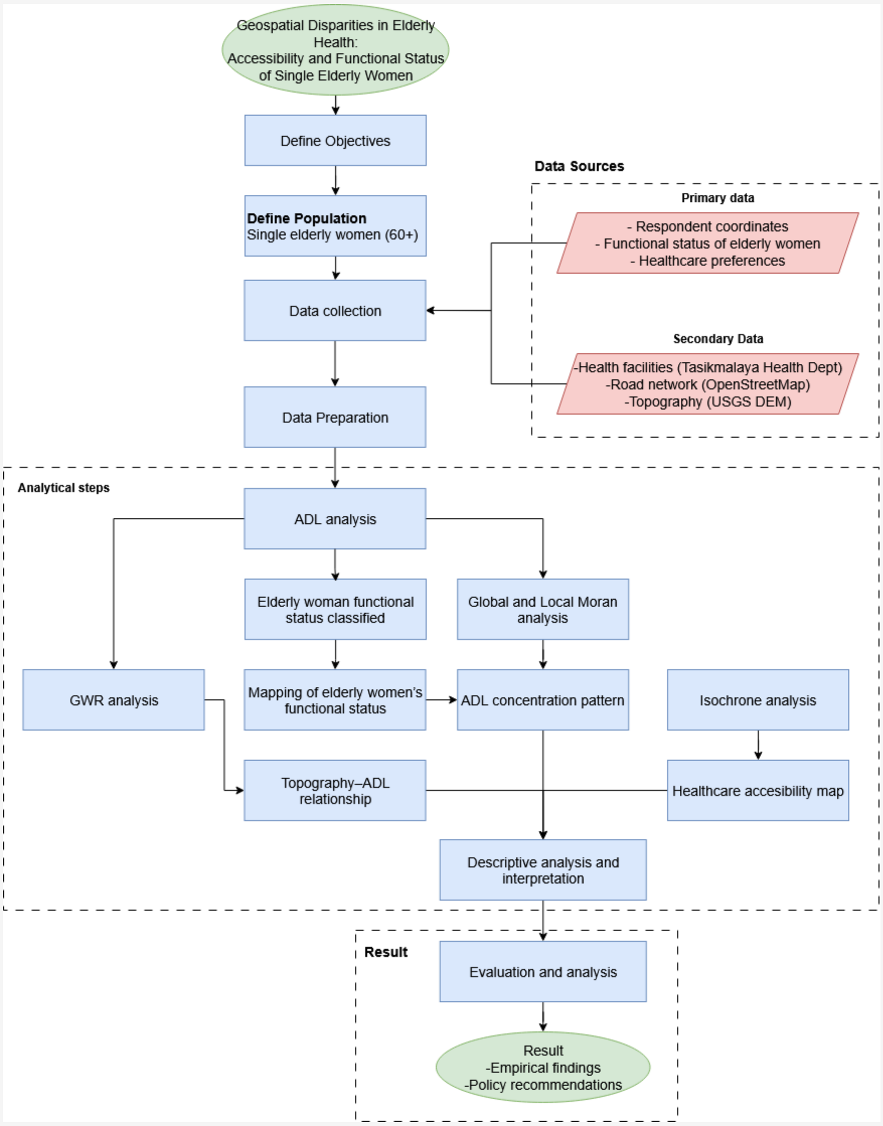

Figure 2: Disparities in elderly health analysis workflow diagram

Table 1: ADL score classification for functional status

ADL Score range	Category	Description
21-30	Independent	Can perform most or all daily activities without assistance; minimal to no functional limitations.
11-20	Partially Dependent	Requires some assistance for certain tasks; mild to moderate functional limitations.
0–10	Dependent	Requires substantial or complete assistance for most activities; severe functional limitations.

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The Barthel Index assigns scores based on an individual's ability to perform ten core activities (e.g., feeding, bathing, mobility, toileting), with higher scores indicating greater independence and lower scores reflecting increased reliance on assistance [17]. In this study, the *ADL* scoring system was adapted to a 0–30 scale to accommodate the specific tasks assessed and the cultural context of elderly women in Tasikmalaya Regency, where activities like telephone use and financial management were included alongside standard *ADL* tasks. The "Independent" category includes individuals who can perform most or all activities without assistance, reflecting minimal to no functional limitations. The "Partially Dependent" category encompasses those who require some assistance for certain tasks but retain significant functional capacity, often corresponding to mild to moderate limitations. The "Dependent" category represents individuals with severe limitations, requiring substantial or complete assistance for most activities, often necessitating medical or caregiver support. This three-tier classification aligns with common practices in *ADL* assessments, which often categorize functional status into levels of independence to guide clinical and caregiving decisions [18].

2.5 Isochrone Analysis

Isochrone analysis is a spatial analysis technique employed to map areas that can be reached from a specific location within a defined time or distance threshold, typically utilizing a road network [19]. In this study, isochrone analysis was conducted to evaluate healthcare accessibility for elderly single women in rural Tasikmalaya Regency, focusing on the distance-based reachability from healthcare facilities. This GIS-based approach generated accessibility metrics to assess how topographic and infrastructural factors influence functional independence, as reflected in *Activities of Daily Living (ADL)* scores.

The analysis relied on road network data were sourced from OpenStreetMap (OSM). The distribution of healthcare facilities was obtained from the official Health Department of Tasikmalaya Regency, compiled as a point dataset representing the geographic coordinates of clinics, health posts (posyandu), and hospitals. This dataset included 42 healthcare facilities, with attributes such as facility type and operational status, validated through field surveys to confirm their accessibility to the elderly population. Demographic data, including the locations of the 383 study participants across sub-districts, were integrated from the survey records, georeferenced using GPS coordinates collected during in-depth interviews.

The isochrone study was carried out utilising a network analytic framework embedded in a Geographic Information System (GIS) environment, especially QGIS software. The approach began with the creation of a network dataset from the OSM road network, with each road segment assigned trip impedance values based on distance and modified for topography and road condition parameters. The network study determined the distance between each healthcare institution and its surroundings using a shortest-path approach tailored for isochrone production. For certain locations within the research region, travel time and distance figures were derived from these computations. Then, using the inverse distance weighting (IDW) approach, these point-based data were interpolated to create a continuous raster surface that represented accessibility, guaranteeing seamless spatial transitions and enabling the visualisation of locations outside of direct road coverage.

2.6 Global and Local Moran's I

We used both Global Moran's I and Local Moran's I (LISA) statistics to explore the geographical patterns of functional health among older women in Tasikmalaya Regency. We can determine if Activities of Daily Living (ADL) ratings are randomly distributed or show clustering throughout the research region using these spatial autocorrelation methodologies. The entire dataset's total spatial autocorrelation is measured by the Global Moran's I (Equation 2). The formal expression is:

$$I = \frac{n}{W} \cdot \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} \left(x_i - \bar{x}\right)\left(x_j - \bar{x}\right)}{\sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2}$$

Equation 2

Where:

n = number of spatial units (sub-districts)

x_i and x_j = ADL scores of locations i and j

w_{ij} = spatial weight between locations i and j

W = is the sum of all spatial weights

Moran's I values close to zero indicate randomness, negative values show regional dispersion (high–low or low–high) [20], while positive values imply grouping of comparable ADL scores (high–high or low–low). The global statistic does not pinpoint the locations of these clusters, but it does provide an overview of the degree of general grouping [21].

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Thus, we used the Local Moran's I, which breaks down the global statistic to the sub-district level and is also referred to as the Local Indicators of Spatial Association (LISA) (Equation 3). The equation is:

$$I_i = \left(x_i - \bar{x}\right)\sum_{j=1}^{n} w_{ij}\left(x_j - \bar{x}\right)^2$$

Equation 3

Where I_i represents the local Moran's I value for observation *i*, and the other parameters are as previously described. A strong positive I_i value shows that a sub-district's ADL score is similar to its neighbours (high-high or low-low clusters), whereas a negative value represents geographic outliers (high-low or low-high).

2.7 Geographically Weighted Regression

We used Geographically Weighted Regression (GWR) to determine if the relationship between daily functioning and elevation factors varied within Tasikmalaya Regency (Equation 4). GWR applies a distinct local regression to each place, resulting in location-specific coefficients that indicate spatial non-stationarity that global OLS models do not capture [22].

$$y_i = \beta_0\left(u_i, v_i\right)\sum_{k=1}^{p} \beta_k\left(u_i, v_i\right)x_{ij} + \varepsilon_i$$

Equation 4

Where:

y_i = dependent variable at location *i* (normalized lagged daily functioning),

x_{ik} = explanatory variable *k* at location *i* (see list below),

$B_k(u_i, v_i)$ = local coefficient for variable *k* at coordinates (u_i, v_i),

$B_0(u_i, v_i)$ = local intercept, and

ε_i = error term.

2.8 Data

The data for this study was collected from both primary and secondary sources. Primary data were collected by surveying respondents and included information on their functional abilities and its geographical plot as latitude and longitude. Primary data collection was assessed with the instrument of Activity of Daily Living (*ADL*) questionnaire to achieve functional capabilities of respondents in performing basic daily activities, such as eating, dressing, bathing, and mobility. In addition, the geographic location of each respondent's household was recorded using GPS camera that capture location of samples with its coordinate.

Meanwhile, Most Secondary data were gained by request from official agencies and open access resources data in the study area of Tasikmalaya (see Table 2). Secondary data that use include the health facility distribution that gained from Official Tasikmalaya Health Agency Department with associate naming attribute and healthcare class. Transportation route were gained from official Tasikmalaya Transportation Department by request to see if healthcare facility were accessible by public transportation. Road Network was gained from openstreetmap dataset that export using Hotosm tools. Finally, topographic data describing the terrain of the study area were derived from a 30-meter resolution Digital Elevation Model (DEM) obtained from NASA’s Shuttle Radar Topography Mission (SRTM) via the USGS EarthExplorer platform.

3. Result

3.1 The Health Index of Elderly Women in Tasikmalaya Regency

This study focusses on elderly women who are single and do not have a companion, a population that frequently suffers distinct social and health risks. Although the actual number of elderly women differs across sub-districts, the sample was carefully balanced so that the number of respondents from each sub-district was relatively equal, thereby ensuring better representativeness of the study area. As illustrated in Figure 3, the majority of respondents are in their 80s, a critical stage where the risk of functional decline accelerates, while the remaining participants are distributed across the 71–81 age range. Prior studies have consistently shown that advancing age, particularly beyond 75 years, is associated with greater limitations in physical functioning and a higher likelihood of disability. Furthermore, older people with a partner tend to keep higher physical functioning than those who are single, suggesting that social support activities serve an important function in maintaining physical ability [23].

Figure 4 provides a dual-map representation of the study area. The left map, titled "Respondents Distribution Map," displays the geographic spread of the 383 respondents as red dots overlaid on a grayscale map of Tasikmalaya Regency, with roads marked in black. The dense clustering of dots, particularly in central and southern subdistricts like Jatiwaras and Cipatujah, reflects higher respondent concentrations, while sparser distributions in northern areas (e.g., Sukabumi) suggest lower participation or accessibility challenges.

Table 2: Secondary dataset references

Data	Source	URL
Health Facility	Official Tasikmalaya Health Department	https://opendata.tasikmalayakab.go.id
Road Network	Openstreetmap	https://www.openstreetmap.org
Transportation route	Official Tasikmalaya Transportation Department	https://opendata.tasikmalayakab.go.id
Topographic/Digital Elevation Model (DEM)	USGS, EarthExplorer	https://earthexplorer.usgs.gov

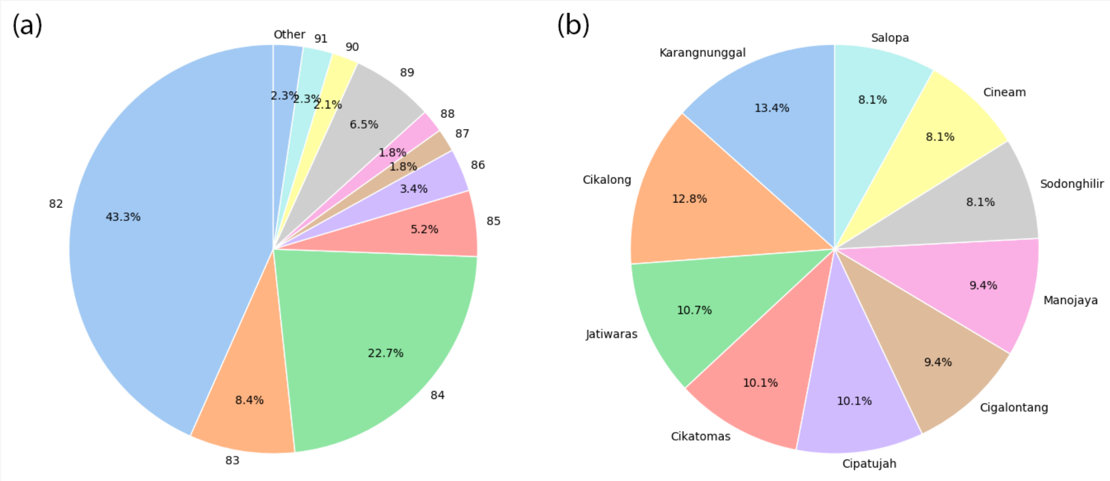

Figure 3: Percentage distribution of respondents by age and subdistrict:
(a) Respondents age (Group <1% as Other) and (b) Respondents based on subdistrict

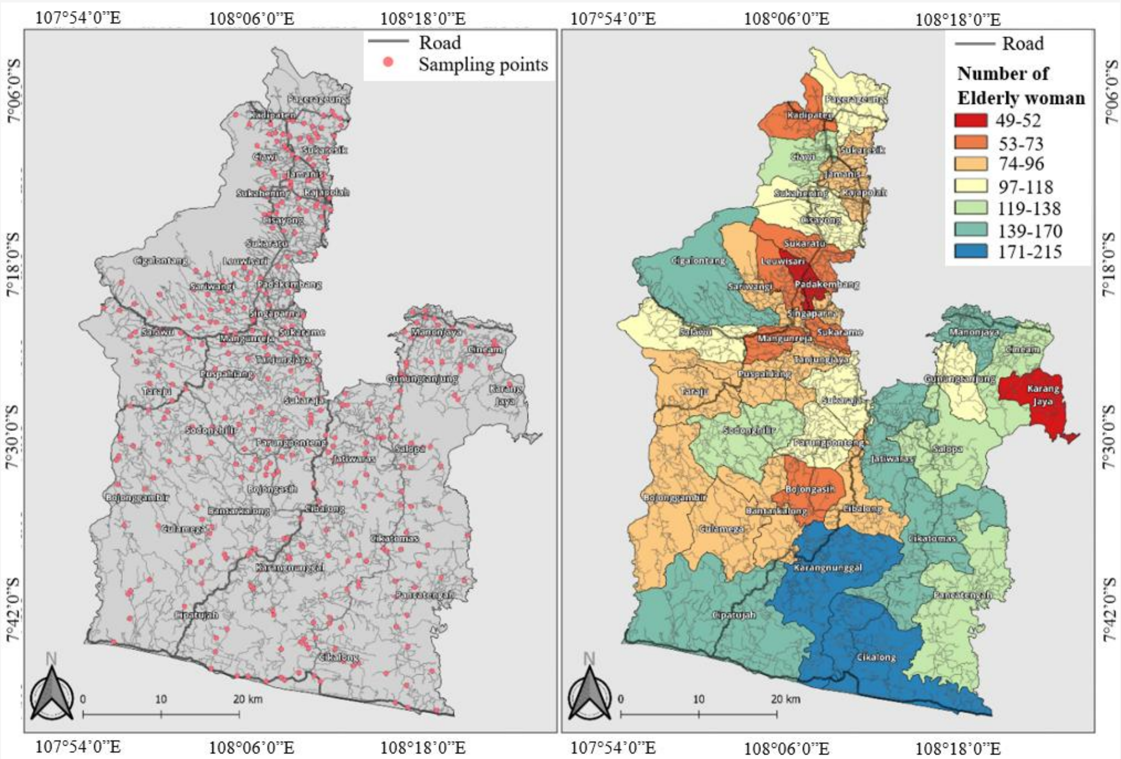

Figure 4: Respondents distribution map (left), elderly woman population by subdistrict map (right)

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The right map, titled "Elderly woman Distribution Map," uses a color gradient to indicate the density of elderly woman populations per 1,300,000 individuals, with a legend ranging from 49–52 (light yellow) to 138–170 (dark red). The darkest red zones, indicating the highest densities (138–170 elderly woman), are concentrated in central subdistricts such as Jatiwaras and Karangnunggal, aligning with the pie chart's subdistrict distribution. Lighter shades (e.g., 73–96) dominate the northern and eastern periphery, suggesting a gradient of elderly population density that may correlate with urban versus rural living conditions. This spatial variation could influence the observed *ADL* score distribution, as urban areas might offer better access to assistive technologies or caregiving support, while rural areas may rely more on family assistance.

In-depth interviews with elderly women in Tasikmalaya Regency revealed a wide range of functional abilities, as reflected in their ADL scores (see Figure 5). The majority of respondents were classified as Independent, indicating they could perform most daily activities without assistance, such as eating, dressing, and bathing, which require basic physical strength. A significant portion were classified as Partially Dependent, reflecting minor limitations in tasks like shopping or cooking, where assistance from relatives was needed but independent function was still possible. No respondents fell into Dependent category, suggesting that even those with lower scores retained some functional capacity and did not require extensive caregiving. The *ADL* score range of 17 to 25 reflects variability in functional status among elderly women, likely influenced by physical health, support access, and familiarity with modern tools like telephones. For example, all 383 respondents showed partial or full dependency in telephone use, likely due to limited exposure to technology, while 154 were Independent and 229 Partially Dependent in mobility, reflecting challenges as many rely on walking rather than driving (See Table 3). Detailed findings indicate that all 383 respondents were Partially Dependent in household chores (e.g., using stairs) and medication management due to physical or cognitive limitations, while tasks like eating and dressing showed universal independence. This spectrum of functional abilities underscores the need for targeted interventions to support complex tasks while preserving independence in basic self-care. Further quantitative or qualitative exploration of the *ADL* score variability could elucidate factors contributing to higher or lower health indices, informing strategies to enhance functional independence among elderly women in Tasikmalaya Regency.

Significant dependencies were observed in telephone use, household chores, and medication management, driven by unfamiliarity with technology, difficulties navigating stairs, and memory or physical limitations. A notable proportion of respondents also reported frequent or occasional bedwetting, indicating substantial challenges with bowel control that impact quality of life. While independence was preserved in basic self-care tasks such as eating, dressing, bed transfer, and bathing, complex or physically demanding activities like shopping and cooking showed greater dependency, particularly in rural or topographically challenging areas. These findings highlight how mobility limitations and environmental barriers exacerbate dependency in instrumental activities, underscoring the need for targeted interventions to enhance functional independence among elderly women (see Table 3 for detailed *ADL* data).

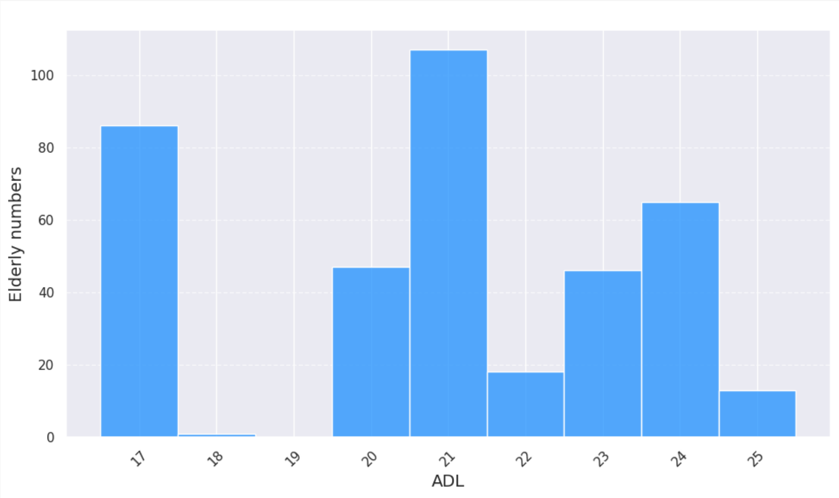

Figure 5: Distribution of elderly respondents by ADL scores

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Table 3: Functional independence and dependency in activities of daily living among elderly woman individuals

Activity	Independent	Partially Dependent	Dependent	Key Insights
Using Telephone	-	27	356	Majority (356) are fully dependent; unfamiliarity with modern technology likely a major barrier.
Mobility (Walking)	154	229	-	Many rely on walking as they do not drive, but mobility challenges are common.
Shopping	78	305	-	High dependence on relatives for transportation and assistance.
Cooking	119	264	-	Physical limitations significantly impact independence in cooking.
Household Chores	-	383	-	All respondents require assistance, indicating severe challenges with stairs.
Taking Medication	-	383	-	Memory or physical issues create dependency.
Managing Finances	71	225	87	Dependency on relatives for financial management is substantial.
Eating	383	-	-	All respondents can eat independently.
Dressing	383	-	-	All respondents can dress independently.
Maintaining Appearance	296	87	-	Most respondents can manage personal appearance, though some need assistance.
Walking	296	87	-	Mobility assistance is needed for 87 respondents.
Bed Transfer	383	-	-	All respondents can transfer in and out of bed independently.
Bathing	383	-	-	All respondents can bathe independently.
Bathroom Access (Timely)	-	383	-	Limited mobility prevents timely access to the bathroom for all respondents.
Bedwetting (Frequency)	-	225	158	225 report frequent issues (≥3 times/week); 158 report occasional issues (1-2/week).

The universal need for assistance in medication management and widespread dependency in financial management point to critical vulnerabilities in cognitive and physical capabilities, potentially exacerbated by socioeconomic constraints or limited healthcare access. Frequent bowel control issues further signal a pressing need for specialized healthcare interventions, especially for women in remote areas with limited access to medical facilities [24]. Despite preserved independence in basic self-care, reliance on assistance for mobility-related tasks and timely bathroom access reflects the impact of Tasikmalaya's rugged topography and limited transportation options. The lack of correlation between *ADL* scores and proximity to health centers (see Figures 6 and 11) suggests that non-geographic factors, such as economic barriers or cultural preferences, might influence functional outcomes. These patterns call for a holistic approach to policy design, integrating solutions like community-based care to address both environmental and social barriers to elderly women's health and independence (see Table 2 for detailed *ADL* dependency data).

3.2 Spatial Pattern and Topographic Association

The functional status of elderly single women in Tasikmalaya Regency was evaluated *ADL* scores, with sample sizes ranging from three to eight individuals per sub-district. *ADL* statuses ranged from 'partially dependent' to 'independent,' indicating considerable variation across the region. These spatial patterns are illustrated in Figure 6, which maps the average *ADL* score per sub-district alongside the distribution of individual sample points. Comparing across sub-districts and identifying broad geographical trends are made possible by the use of the average ADL score as a measure of central tendency. However, this does not imply that all elderly individuals in a sub-district are in the same functional group. For example, some people may still be partially dependent even if the average for a subdistrict is inside the independent range. To address this limitation, Figure 6 shows individual respondent ratings, which enable for visual assessment of variance within each sub-district.

Sub-districts in the western and northern side of study area tend to exhibit lower average ADL scores (17–20), indicating a partial dependence in the region (See Figure 6). In contrast, eastern and southern region of study having higher ADL scores (22–25) that associate that people live there are more independent. This result shows that the ADL score pattern might be associated with region characteristics but also could be result from individual complexities in quality of life. The northwestern region is more developed in terms of road networks, as it is crossed by primary roads, while the eastern to southern areas are less developed. This leads to the assumption that elderly women living in less developed regions may have better functional status, which could be associated with a calmer and cleaner environment. From another perspective, healthcare accessibility advantages are determined by the availability of sufficient road networks and proximity to healthcare facilities, with studies suggesting that better access increases functional independence [25] and [26]. However, the relationship between regional development and health outcomes in this section remains unclear, as other studies suggest [27]. As shown in Figure 7, which presents the topographic map of Tasikmalaya Regency overlaid with observed functional status, elderly women in the southern lowland sub-districts such as Cipatujah, Karangnunggal, and Pancatengah tend to have a higher "independent" ADL status.

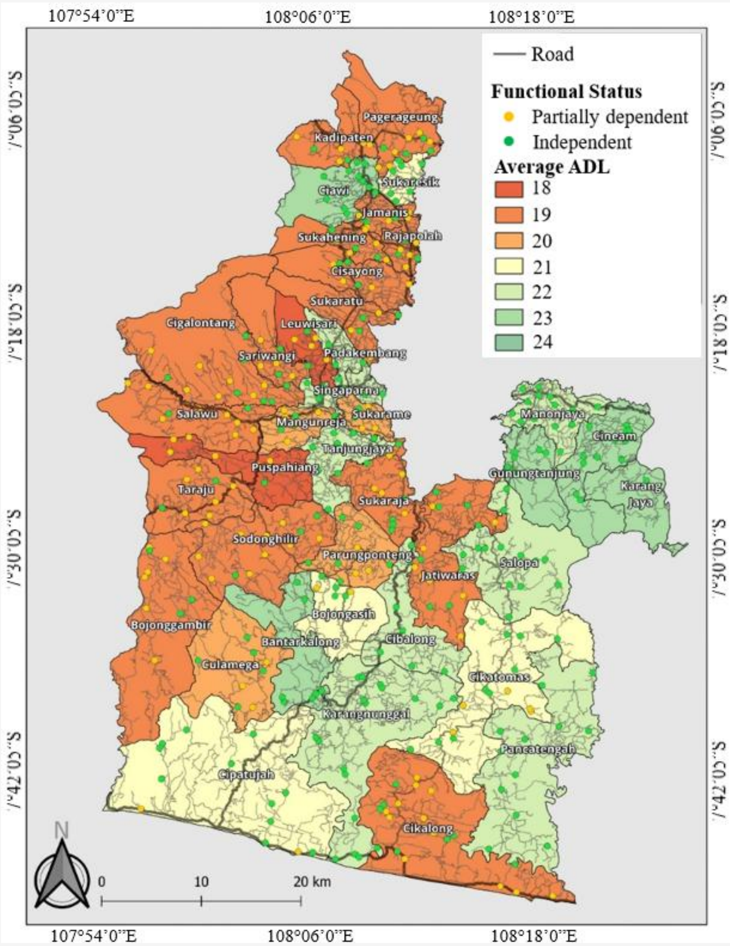

Figure 6: Spatial distribution of ADL scores among elderly woman in Tasikmalaya Regency

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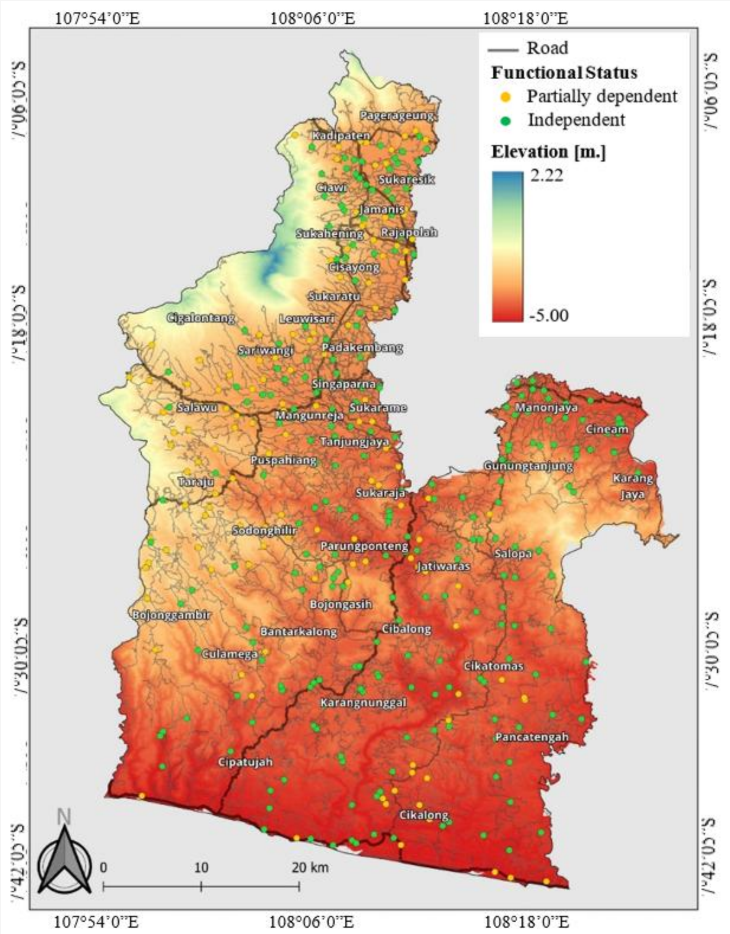

Figure 1: Topographic map of Tasikmalaya Regency

In contrast, Cikalong appears as an outlier with notably lower ADL scores, which may be attributed to specific social complexities in that area. Highland sub-districts in the western part of the study area, such as Puspahiang, Taraju, and Salawu, exhibit lower average ADL scores, with most participants classified as partially dependent. The highlands in this western region are associated with Mount Galunggung, which has rugged terrain that makes daily activities more challenging. This finding also aligns with a study in Colombia, which suggested that higher altitude is associated with lower quality of life [28]. However, this study implies that it is not guaranteed that elderly women living at higher altitudes have lower functional status, as some observations still show individuals in the independence category. Higher elevations were linked to greater dependency, according to the analysis, which showed a relationship between topographic elevation and ADL scores, especially among older women (See Figure 8). This implies that difficult topographic characteristics, like steep terrain and restricted accessibility, may make it more difficult to go about daily tasks in highland regions. Lowland subdistricts, on the other hand, showed higher *ADL* scores, most likely as a result of better mobility assistance and infrastructure, which promote greater independence in day-to-day activities.

Based on the *GWR* model's coefficient for elevation (-0.003), which was statistically significant ($p = 0.006$), a 100-meter elevation increase was quantitatively linked to an estimated 0.3-point drop in ADL scores (See Table 4). The geographically weighted model captured more variation in *ADL* outcomes than the global linear regression model (R2 = 0.396 vs. 0.168), highlighting the significance of spatial variation in comprehending functional health among older populations. Nevertheless, the impact of elevation on dependency varied. Elevation alone does not always predict functional outcomes in this area, as evidenced by the fact that some people in the mid-level elevation Jatiwaras sub-district had lower *ADL* scores while others had higher scores.

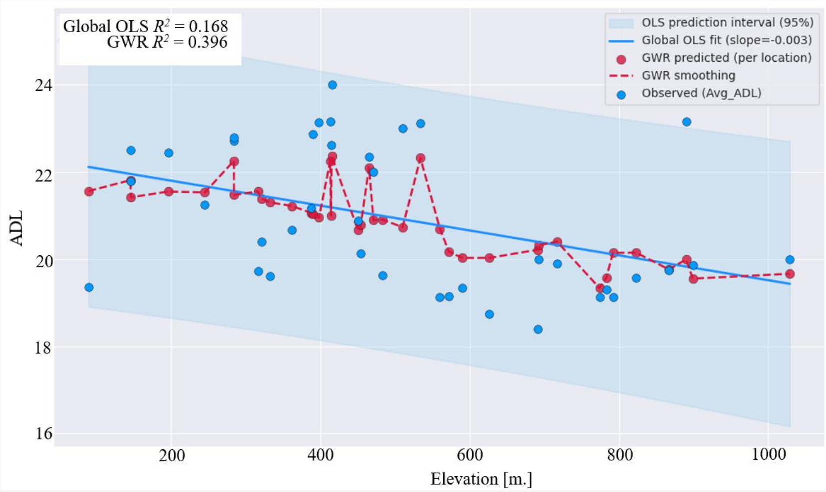

Figure 8: Relationship between ADL and elevation with OLS and GWR fits

Table 4: Summary of Ordinary Least Squares (OLS) and Geographically Weighted Regression (GWR)

Component	Metric/variable	Value
model Fit	Global R² (OLS)	0.168
	Adjusted Global R² (OLS)	0.146
	GWR R²	0.396
	Adjusted GWR R²	0.288
	Effective Number of Parameters (ENP)	5.747
	AIC (Global)	144.359
	AICc (Global)	147.044
	AIC (GWR)	141.379
	AICc (GWR)	144.724
coefficient estimates	Intercept (X0)	22.371
	Elevation (X1)	-0.003
SE	Intercept (X0)	0.582
	Elevation (X1)	0.001
t-value	Intercept (X0)	38.429
	Elevation (X1)	-2.735
p-value	Intercept (X0)	<0.001
	Elevation (X1)	0.006

Table 5: Global Moran's I test for spatial autocorrelation of ADL scores

Statistic	Value
Moran's I	0.226
Expected I	-0.026
Variance	0.011
Z-score	2.356
P-value	0.018

The northeastern cluster showed exceptionally high *ADL* scores, which may have been caused by unrecognised sociocultural or infrastructure factors. This underscores the role of non-physical determinants in the independence and health of the elderly. The fact that none of the participants were categorised as completely dependent might indicate that the *ADL* scale was not sensitive enough to identify extreme dependency or that the sample was biassed towards healthier people. Access to healthcare was identified as a potential confounding factor. In lowland areas, road networks probably lessened the impact of remoteness, but in highland areas, geographic isolation made matters worse. The statistical robustness of these results is, however, limited by the small sample size per sub-district (ranging from 3 to 8 respondents), which calls for careful interpretation and emphasises the necessity of more thorough data collection in subsequent research. The *Global Moran's I* test, summarized in Table 5, indicates a positive spatial autocorrelation of *ADL* scores across Tasikmalaya Regency's sub-districts, with a Moran's I value of 0.226, suggesting that areas with similar functional independence levels tend to cluster spatially. This finding, supported by a Z-score of 2.356 and a p-value of 0.018, is statistically significant at the 5% level, rejecting the null hypothesis of no spatial autocorrelation (Expected I = -0.026). The result aligns with the observed patterns in Figure 7, where western highland sub-districts like Puspahiang and Taraju show lower *ADL* scores, forming a cluster of reduced independence, while northeastern lowlands like Cikalong and Cipatujah exhibit higher scores, indicating a cluster of greater independence. The variance of 0.011 further supports the consistency of this spatial relationship, suggesting that elevation factors, as discussed earlier, likely contribute to these concentration patterns, with further analysis needed to disentangle additional socioeconomic influences.

As shown in Table 6, the Local Moran's I (LISA) analysis (clusters significant at $p < 0.05$) identifies several spatial clusters of ADL scores across sub-districts in Tasikmalaya Regency.

Table 6: Local Moran's I (LISA) cluster of ADL scores

Cluster type	Number of sub-districts
High-High	3
Low-Low	2
High-Low	1
Low-High	0
Not significant	33

Three sub-districts in the eastern part of the region Manonjaya, Cineam, and Karangjaya form a High–High cluster, indicating a spatial concentration of elderly women with higher functional independence surrounded by neighbouring areas with similarly favorable outcomes. In contrast, Low–Low clusters are observed in Taraju and Rajapolah in the western region, which is characterized by higher elevation, reflecting localized vulnerabilities in mountainous areas where elderly women exhibit lower ADL scores alongside neighbouring sub-districts with similarly poor functional status. Tanjungjaya in the central region appears as a High–Low outlier, suggesting relatively better ADL status compared with its surrounding sub-districts with lower scores. These spatial patterns, significant at the 0.05 level, show concentrated areas of both higher and lower ADL scores. This suggests the need for further study into potential structural determinants that may underlie the observed clustering, such as socioeconomic conditions [29] and environmental features [30].

3.3 Respondent Preference of Healthcare

Most elderly woman in Tasikmalaya Regency prefer Community Health Centers for healthcare due to their regional accessibility, non-commercial nature, and affordability, particularly for those registered in the Integrated Social Welfare Data (DTKS). These centers provide cost-effective treatments and examinations, unlike commercial hospitals or clinics, which often charge higher fees [31]. Some elderly woman choose traditional medicine because of their cultural beliefs and faith in its effectiveness [32]. Others choose pharmacies for convenience when they already have prescriptions, while a smaller group seeks hospitals for their advanced facilities. Despite the widespread distribution of clinics and commercial health facilities across Tasikmalaya's sub-districts, their high costs deter many elderly women from utilizing them. Over half of the respondents find Community Health Centers "quite helpful" in meeting their healthcare needs (see Figure 9), reflecting their critical role in the community. Accessibility remains a significant challenge. Many elderly woman respondents face difficulties reaching healthcare facilities due to long distances, underdeveloped rural infrastructure, and extreme geographical conditions in some areas. Public transportation is often limited, with routes not extending to respondents' homes, and for some, the cost of travel is prohibitive. These barriers particularly affect the 89 respondents who highlighted transportation challenges. However, in densely populated economic hubs of Tasikmalaya Regency, healthcare facilities are more accessible. Improved access to healthcare facilities would significantly enhance the well-being of 113 respondents, who see proximity as key to better health outcomes. Yet, many respondents remain neutral about the impact of proximity, possibly due to infrequent healthcare-seeking behavior influenced by cultural or personal factors.

3.4 Healthcare Accessibility

The spatial distribution of community health centers across Tasikmalaya Regency is relatively well-balanced, with each sub-district having at least one health center, except for Singaparna, which has two to accommodate its larger population (See Figure 10). The capacity of these health centers varies based on the number of healthcare workers, availability of medical equipment, and accessibility for people with disabilities and the elderly. The 383 sample points, representing the residential locations of elderly women across Tasikmalaya Regency, illustrate a proportional allocation of health centers in densely populated areas. Access to fair healthcare is severely limited in remote, rural, and difficult to reach regions. New health centres are anticipated to be built nearer to isolated communities as population growth pushes the expansion of administrative areas. The placing should be accessible to as many people as possible, particularly in underserved areas [33].

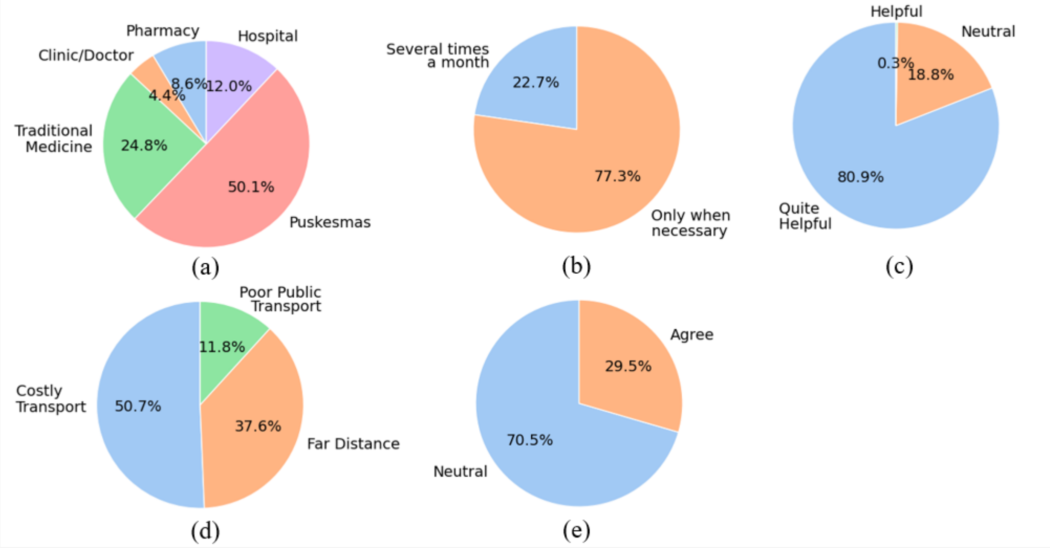

Figure 2: Respondent preferences and challenges in accessing healthcare services: (a) Medical Treatment Preferences (b) Visit Frequency per Month (c) Perceived Support from Nearby Facilities (d) Types of Access Difficulties (e) Would Closer Facilities Help?

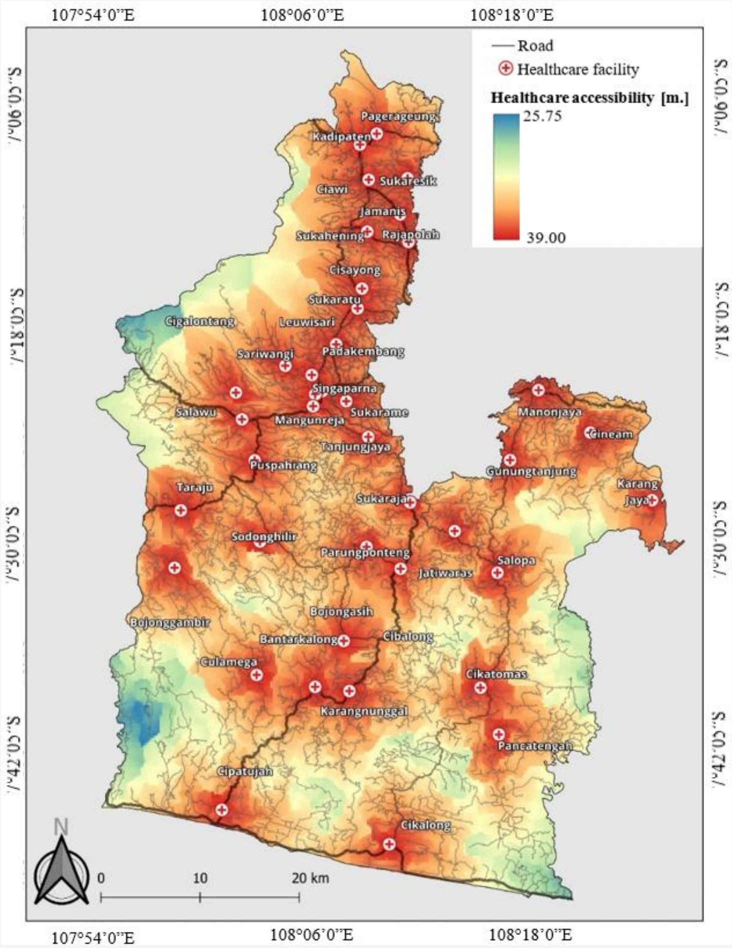

Figure 10: Accessibility map of community health center

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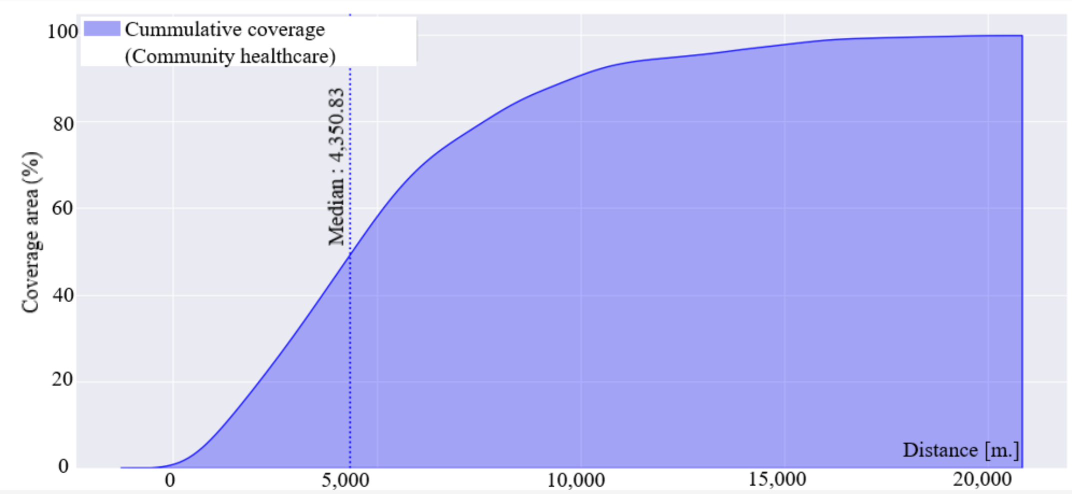

Figure 11: Cumulative community health centre coverage of Tasikmalaya Regency

This study evaluates the distance between elderly women and their nearest community health center to identify potential mobility challenges and inform strategies for improving healthcare accessibility. While proximity is a key factor, accessibility encompasses more than distance alone, as road conditions, transit availability, and travel time also play critical roles. Using the isochrone method, which maps areas reachable within specific time or distance thresholds, the study provides a nuanced assessment of accessibility beyond simple Euclidean distances. Additionally, raster data, representing continuous distance surfaces to health centers, was extracted at sample points, accounting for variations in terrain and road networks to offer a spatially accurate depiction of healthcare access.

The distribution of travel distances for elderly woman in Tasikmalaya Regency to reach the closest Community Health Center is depicted in Figure 11, which presents the cumulative Community Health Center coverage. The cumulative proportion of people covered within each distance range is displayed on the y-axis, while the x-axis indicates the distance in meters. The curve shows a consistent rise in coverage, indicating that a greater percentage of older women are within the accessible range as the distance from healthcare facilities increases. Half of the older women must travel at least 4,350.83 meters (4.35 km) to reach the nearest Community Health Center, while the other half must travel further. This is known as the median travel distance. Distance is a key metric in evaluating healthcare accessibility from a public health perspective, especially for older populations who may face limited mobility, financial constraints, or a lack of transportation options [34] and [35]. While the majority of elderly woman live within 10 km of a health facility, Figure 11 shows that complete coverage (nearly 100%) is only attained at around 20 km, indicating that some individuals face significant geographic obstacles to care. Long commutes to medical facilities have been linked in studies to poorer health outcomes, delayed treatment, and reduced healthcare utilization in older populations [36] and [24].

With the farthest sample site located more than 35 km from the nearest transit station and approximately 20 km from the closest Community Health Center, elderly women living in the most remote regions of the study area face significant accessibility challenges. Most of the older women in this study reside farther than the recommended 2 km threshold, which is considered the optimal distance for accessing healthcare services. Some literature suggests that travel time to a health facility should not exceed 30 minutes [37]. In this study, most elderly women must travel between 4 and 20 kilometers to reach a health center, and fewer than 20% of the sample population live within the ideal coverage area. However, this distance standard may primarily apply to urban administrative areas, while rural regions may accommodate longer travel distances [38].

Access to primary healthcare services, medical check-ups, and geriatric care remain important to elderly woman, as being close to healthcare centres is frequently linked to higher health index ratings, which indicate greater independence in daily activities (see Figure 10 for accessibility map). Similar study in China showed that improved geographical access to community health centres has a significant positive influence on older individuals' physical ability to perform Activities of Daily Living (ADL), with greater advantages seen in urban areas compared to rural settings [23].

However, there is no apparent connection between *ADL* scores or health index ratings and the distance to medical facilities in this study. Figure 6's *ADL* scores show a random pattern that is inconsistent with Figure 10's accessibility map of the community health centre. Healthcare utilisation may be influenced by factors other than physical distance, such as transportation difficulties, economical restraints, or cultural preferences, since respondents reported infrequent or non-routine visits to healthcare facilities, even when they were reasonably close.

4. Discussion

Highland regions, such as the sub-districts of Taraju, Salawu, Puspahiang, and Cigalontang in Tasikmalaya Regency, tend to have reduced Activities of Daily Living (ADL) scores compared to regions at lower elevations. This disparity is primarily due to the lower quality of life, as suggested by studies showing that higher-altitude environments have lower oxygen availability [28]. The lower functional status in higher regions could also be caused by challenges in accessing health facilities, driven by steep terrain, poor road quality, and limited transportation infrastructure. Studies in China have shown that elderly populations in mountainous regions face a higher risk of functional health decline due to restricted access to health services [10]. In contrast, lower-elevation areas in southern region like Karangnunggal, Cipatujah, and Cikalong, demonstrate higher *ADL* scores, indicating greater functional independence among the elderly. Although this part of the region is dominated by the independence category, some observations show outliers, and there is a partial concentration of dependence in Cikalong. These findings imply that elevation alone cannot explain the functional status of elderly women, as it may also be influenced by the complexity of health behaviors in the region, such as local residents' health literacy [39] or the poor quality of health facility services. The GWR model explains 28–39% of the variation in the outcome, with the adjusted value (28%) providing the more reliable estimate. This indicates that the model has some explanatory power, as evidenced by a statistically significant p-value (0.006), although it does not fully predict the outcome. In other side, the observed variance in ADL scores between sub-districts, ranging from partially independent to dependent, emphasises that distance to healthcare does not have significant effects on the functional status of the elderly. While it is commonly assumed that being closer to healthcare results in better outcomes, research found that accessibility to health services impacts the quality of life of the elderly [40]. Transportation difficulties and long distances to health facilities are commonly reported barriers to healthcare access among older adults living in rural areas [41]. A systematic review of quantitative studies concluded that these geographic and transport barriers significantly reduce use of modern healthcare services by rural elderly women, and that the problem is especially Striking in low- and middle-income settings [42]. However, many studies focus on linking elderly health outcomes to socioeconomic parameters while overlooking physical environmental factors such as slope, elevation, and terrain ruggedness, which are highly relevant in regions like Tasikmalaya Regency. This study fills this gap by directly connecting topographic variation to the accessibility of health services, lending credence to [9] findings that topography has a major influence on access to medical facilities. The focus on Tasikmalaya Regency, with its diverse topographical conditions, adds novelty by demonstrating how elevation has a proportional influence on the health status of the elderly.

The results show that there needs to be targeted policies to make health facilities easier to get to in hilly and remote areas, especially for vulnerable groups like elderly single women. Effective interventions should not only set up health centres but also look at the broader context of rural elderly women, including their healthcare needs, socioeconomic factors, and cultural issues [42]. For instance, improving road infrastructure, establishing health centers in mountainous regions, and providing affordable transportation services are critical steps. Additionally, deploying *community health workers (CHWs)* for home-based care, utilizing mobile teams for regular health check-ups in remote areas, and engaging communities to raise awareness about elderly health needs can enhance ADL scores and functional health [43]. These efforts could be integrated into frameworks like the Healthy Indonesia Program with a Family Approach (PIS-PK), which should prioritize equitable health access while addressing socioeconomic and cultural barriers faced by elderly women in challenging terrains. Furthermore, the Long-Term Regional Development Plan (RPJMD) should incorporate topographical conditions and the unique needs of elderly populations to ensure equitable distribution of health facilities, aligning with *Sustainable Development Goal (SDG)* 3 for universal access to quality health services.

A key strength of this study is its mixed-methods approach, combining quantitative and qualitative methods to provide a richer context for understanding environmental and social factors affecting health facility accessibility. This contrasts with earlier studies, such as [40] and [44], which relied solely on quantitative methods. This study gives an improved understanding by combining both approaches. This is especially useful for formulating policies in areas with challenging landscapes, such as Tasikmalaya Regency. The focus on older single women, who face greater challenges due to transportation barriers, geographic isolation, and economic constraints, highlights that this group requires targeted assistance [42]. Despite these contributions, the study has limitations. The spatial data on health facilities may not fully reflect actual conditions, potentially affecting the accuracy of accessibility assessments. Health facilities from different regions might have disparities in equipment readiness or service quality. Additionally, the *ADL* measurement, based on questionnaires, may introduce subjective bias due to reliance on elderly participants' self-reported abilities. The complex topography of Tasikmalaya Regency also demands more sophisticated geospatial analysis, which this study's analytical model may not fully address. Future research should incorporate more comprehensive spatial data and advanced analytical methods to further elucidate the interplay between topography, socioeconomic factors, and elderly health outcomes.

5. Conclusion

This study shows that elderly single women in highland sub-districts tend to have lower ADL scores than those in lowland areas. A spatially explicit model (GWR) detected a small but statistically significant negative association between elevation and ADL. The adjusted GWR R^2 was approximately 0.28 and the p-value was 0.006, indicating that elevation contributes to variance in functional status but is not the sole determinant. The spatial distribution of health facilities in this study cannot be used to explain ADL variation, as no significant relationship was found. Many respondents did not use community health centres regularly, partly because distance and transport difficulties in remote regions reduce service use. To address these barriers, interventions should be multi-pronged and geographically sensitive. These include improving roads and transport infrastructure in remote areas, locating or upgrading services to reduce travel burdens, deploying mobile clinics and community health workers for home-based care, and incorporating elderly-targeted measures into local planning such as PIS-PK and RPJMD.

6. Limitation

It should be noted that this study has several limitations. Subjective bias is a risk linked with using self-reported *Activities of Daily Living (ADL)* questionnaires because older participants may over-report or underreport their functional abilities due to memory problems, social desirability, or misinterpretation, which may bias *ADL* scores. Concerns are raised regarding possible sampling bias towards healthier individuals or the limited sensitivity of the adapted *ADL* scale to detect severe dependency, given the lack of respondents in the "Dependent" *ADL* category (scores 0–10). In addition, the study lacks the thorough qualitative analysis required for fully understanding these dynamics and only briefly discusses socio and cultural factors, despite their acknowledged impact on healthcare utilisation. The cross-sectional design, based on data from a single time point, restricts the ability to evaluate changes in functional health or healthcare access over time. Future research must make use of more extensive spatial datasets, longitudinal approaches, and strong qualitative analyses.

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