SPATIAL DIVERGENCE IN AGEING AND DEPENDENCY BURDEN ACROSS ADMINISTRATIVE DISTRICTS IN SARAWAK (2010–2020)

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ABSTRACT

The demographic megatrend of population ageing presents profound challenges for Malaysia's development agenda, particularly in East Malaysian states like Sarawak, where the pace of demographic transition is regionally uneven. While national-level projections forecast Malaysia becoming an aged nation by 2030, subnational disparities in ageing patterns and dependency burden are rarely analysed in spatially explicit terms. This gap limits the ability of local policymakers to plan for age-related pressures on social infrastructure, healthcare, and economic productivity. This study aims to examine the spatial divergence of ageing and dependency burden across administrative districts in Sarawak between 2010 and 2020. Using demographic data from the Department of Statistics Malaysia, the study calculates two key indicators: the Old-Age Dependency Ratio (OADR) and the Total Dependency Ratio (TDR). To identify spatial clusters of significant demographic burden, Hot spot Analysis (Getis-Ord Gi) was applied to 2020 data. Additionally, K-means Cluster Analysis was employed to classify districts into distinct ageing profiles based on their demographic transition rates and elderly population growth. The findings reveal growing spatial inequality in ageing and dependency trends across the state. Several central and interior districts emerged as ageing hot spots with significantly higher OADR values. The cluster analysis identified five distinct district typologies (Clusters A–E), highlighting regions with rapid demographic ageing and those with persistently youthful structures. These insights demonstrate the heterogeneous nature of demographic ageing and challenge the applicability of one-size-fits-all policies. The study underscores the value of spatial analytical methods for informing decentralised policy design. By pinpointing regional disparities, the results support more targeted and equitable distribution of social services, healthcare infrastructure, and ageing-related interventions, critical for achieving inclusive and resilient demographic outcomes in line with national family and population development goals.*

Keywords: *Population ageing, dependency ratio, spatial analysis, social policy, demographic clustering.*

INTRODUCTION

Population ageing is accelerating across East and Southeast Asia and is reshaping Malaysia's development trajectory. Malaysia crossed the conventional ageing threshold of at least seven per cent of the population aged 65 years and over around 2020 and is widely projected to become an aged society at fourteen per cent by the mid-2040s and a super-aged society at twenty per cent by the mid-2050s (World Bank, 2020; UN DESA, 2023). These shifts carry macro-level implications for labour supply, long-term care, health financing and social protection, and they feature prominently in national reform agendas and international guidance on healthy ageing (Ministry of Health Malaysia, 2023; United Nations, 2021; World Bank, 2020). Global assessments underline the speed of demographic transition in Asia compared with the historic experience of Western Europe, highlighting the need for anticipatory rather than reactive policy responses (Third World Network, 2023; World Bank, 2015).

Beneath national averages, Sarawak exhibits a faster and more uneven ageing trajectory that warrants spatially explicit analysis. State leaders and media reports indicate that Sarawak could attain aged status as early as 2028, with some districts already displaying high shares of older residents; Lubok Antu, for instance, has been reported to have about 15.7 per cent of residents aged 65 years and over (Harian Metro, 2022; UKAS, 2024). District-scale estimates by the Department of Statistics Malaysia further show that Subis crossed the seven per cent threshold in 2025, illustrating how the onset of ageing is not simultaneous across districts (Department of Statistics Malaysia, 2025). In response, Sarawak has intensified policy attention through events such as the Sarawak International Conference on Ageing (SICA) 2025 and through programmes that expand access to primary care and social support for older persons under the Post-Covid-19 Development Strategy 2030 (Bernama/TVS, 2025; UKAS, 2025). These developments underscore an evidence gap that this study addresses: identifying where ageing and dependency burdens concentrate within Sarawak and how those patterns align with service needs and infrastructure readiness.

This paper examines spatial divergence in ageing and dependency across Sarawak's administrative districts from 2010 to 2020 using district-level tabulations from the Department of Statistics Malaysia. Two internationally comparable indicators are employed: the Old-Age Dependency Ratio (OADR), defined as the number of persons aged 65 years and over divided by the number of persons aged 15–64 years, multiplied by 100; and the Total Dependency Ratio (TDR), defined as the number of persons aged 0–14 years together with persons aged 65 years and over divided by the number of persons aged 15–64 years, multiplied by 100 (FAO, 2022; Hayes, 2025; OECD, 2025). To detect locations where the burden of old age is significantly high or low relative to neighbouring districts, we apply Hotspot Analysis (Getis–Ord Gi*) to the 2020 value of the OADR; the procedure yields z-scores, p-values, and Gi_Bin confidence classes that distinguish statistically significant hot and cold spots (Esri, 2025). To support policy segmentation, we then group districts using K-means clustering with a feature set that combines levels and changes: OADR 2010, OADR 2020, the percentage-point change in OADR from 2010 to 2020, the percentage change in the population aged 65 years and over from 2010 to 2020, and the TDR in 2020.

The study makes three contributions. First, it provides a statistically validated map of hot spots and cold spots for OADR 2020 across Sarawak's districts, moving beyond descriptive cartography to local statistical inference. Second, it develops a policy-oriented district typology that integrates both levels and decade-long change, enabling needs-based prioritisation such as immediate scaling in districts that already shoulder high old-age dependence and early preparation in districts that remain youthful but are ageing quickly. Third, it translates these spatial diagnostics into actionable guidance aligned with national and state frameworks, including healthy ageing programmes, primary care strengthening and the reform pathway set out in the Health White Paper (Ministry of Health Malaysia, 2023; United Nations, 2021; World Bank, 2020). By bringing together standard demographic ratios, local spatial statistics, and unsupervised segmentation, the paper offers decision-ready evidence for targeted allocation of ageing-related services in Sarawak.

LITERATURE REVIEW

Population ageing is commonly framed by demographic transition theory, in which sustained mortality decline followed by fertility decline reconfigures age structures toward older cohorts and slower growth. Contemporary accounts often add a fifth stage, where fertility remains below replacement and the population may contract while ageing accelerates (Roser, 2023; Socio Health, 2025). For policy analysis, two summary indicators are standard: the OADR, the number of persons aged 65+ per 100 persons aged 15–64; and the TDR, the number of persons aged 0–14 together with 65+ per 100 persons aged 15–64 (FAO, 2022; Hayes, 2025; OECD, 2025).

Ageing is advancing rapidly worldwide, with Asia contributing the largest share of the global increase in older persons this century. UN and World Bank syntheses emphasise the pace of transition in East and Southeast Asia, where the share of older persons is doubling within a few decades, far faster than in the historic European experience, implying sharper near-term adjustments in health financing, pensions, and eldercare systems (UN DESA, 2023; World Bank, 2015). Official statistics and

analytical briefs highlight the drivers of this shift: fertility decline, longevity gains, and migration, underscoring the need for anticipatory reforms rather than reactive responses (U.S. Census Bureau, 2022; Socio Health, 2025).

Malaysia crossed the ageing-society threshold in the early 2020s and is on course to reach aged-society status in the 2040s, with super-aged status projected by the mid-2050s (World Bank, 2020; UN DESA, 2023). National policy documents identify four persistent concerns: labour-force headwinds as the working-age share declines, rising demand for long-term and chronic care services, pressure on health financing, and the adequacy of pensions and social protection (Ministry of Health Malaysia, 2023; Bernama, 2025). DOSM's recent communiqués also record the spread of ageing across multiple states and districts, signalling widening subnational disparities that national averages can mask (DOSM, 2025a; DOSM, 2025b). Within this policy context, OADR and TDR have become central metrics for monitoring demographic pressure and guiding allocation decisions.

A growing body of work documents Sarawak's long-run transition toward older age structures and the spatial concentration of senior populations. Over 1980–2020, district-level and GIS-based analyses show intensifying senior-citizen density in urban and peri-urban corridors, while interior districts exhibit distinct ageing profiles shaped by migration and access constraints (Ali et al., 2025a; Ali et al., 2025b). Complementary analyses emphasise how ethnic composition intertwines with ageing patterns in a multi-ethnic state, with implications for equitable provision of services (Ali et al., 2025c). Administrative releases and state communications further underline uneven service capacity across interior–coastal divides, strengthening the case for needs-based programming rather than one-size-fits-all approaches (UKAS, 2024; The Star, 2025). Together, these studies establish the empirical basis for district-scale enquiry and motivate formal spatial inference.

Most Malaysian and Sarawak studies remain descriptive, using choropleths or simple rankings of elderly shares. Recent Sarawak work has advanced the field by integrating multi-decadal census counts with GIS to map shifts in senior density (Ali et al., 2025a), yet the literature still underutilises local spatial statistics that can identify statistically significant clusters where high or low dependence is embedded within neighbouring contexts. The Getis–Ord Gi* statistic evaluates each spatial unit relative to its neighbours and yields z-scores, p-values, and Gi_Bin confidence classes that demarcate hot and cold spots, offering clearer signals for service targeting than visual inspection alone (Esri, 2025). For policy segmentation, K-means clustering groups districts using both levels (OADR 2010, OADR 2020, TDR 2020) and decadal changes (percentage-point change in OADR 2010–2020, percentage change in the 65+ population 2010–2020), producing typologies that are intelligible to decision-makers.

Regional and Malaysian evidence points to several correlates of district-level ageing: urbanisation and peri-urban expansion; selective youth out-migration from interior regions; differences in education and ethnic composition; and uneven access to health facilities and social care (UN DESA, 2023; U.S. Census Bureau, 2022; UKAS, 2024). These factors shape heterogeneous trajectories across Sarawak, implying that the same OADR level can carry different service implications depending on spatial context, another rationale for combining local clustering with typologies that integrate both levels and change.

District-scale analysis benefits from DOSM's censuses and intercensal estimates but must account for boundary changes, the modifiable areal unit problem, and small-area volatility, each of which can affect cluster detection and the stability of typologies over time. Harmonising boundaries and clearly stating the chosen conceptualisation of spatial relationships in ArcGIS Pro are therefore necessary to support valid longitudinal comparisons and transparent inference (DOSM, 2025a; Ministry of Health Malaysia, 2023; Esri, 2025). The literature establishes the speed of Asia's demographic transition, Malaysia's entry into sustained ageing, and Sarawak's pronounced within-state variation. What remains limited are district-scale statistical identification of hot and cold spots of old-age burden and policy-readable typologies that integrate levels and decadal change. This study addresses those gaps by applying Getis–Ord Gi* to OADR 2020 and K-means clustering on a compact set of level-and-change indicators to derive interpretable district profiles that can inform needs-based allocation in Sarawak.

Conceptual Framework

Figure 1 presents the conceptual framework guiding this study. The framework illustrates how demographic transition processes, particularly declining fertility and increasing life expectancy, contribute to population ageing. This demographic shift is measured through two key indicators, namely the Old-Age Dependency Ratio (OADR) and the Total Dependency Ratio (TDR). These indicators are analysed using spatial analytical techniques, including Getis–Ord Gi* hot spot analysis and K-means clustering, to identify spatial patterns and typologies of ageing across administrative districts. The resulting typologies provide evidence for understanding spatial divergence in ageing and offer insights for policy development related to social welfare, labour markets, and public policy planning.

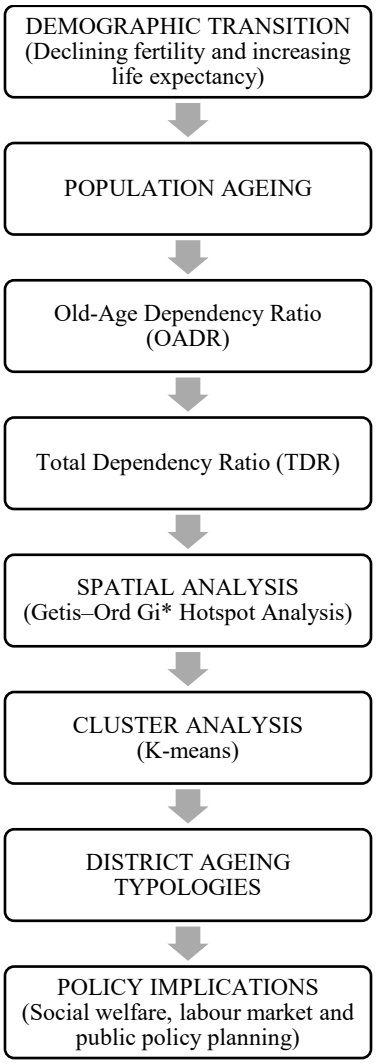

Figure 1: Conceptual framework linking demographic transition, spatial analysis, and district ageing typologies

METHODOLOGY

Data and Study Area

The study covers all 40 administrative districts in Sarawak. District-level demographic statistics for 2010 and 2020 were sourced from the Department of Statistics Malaysia (DOSM), including the population aged 0–14, 15–64, and 65 years and over. From these, the OADR, TDR, and decadal changes (2010–2020) were computed. District boundaries were harmonised to the 2020 administrative geometry to enable consistent temporal comparison. All spatial analysis and mapping were conducted in ArcGIS Pro.

The key indicators were defined as follows (FAO, 2022; Hayes, 2025; OECD, 2025):

i. Old-Age Dependency Ratio (OADR)

$$\text{OADR} = \frac{\text{Population aged } 65+}{\text{Population aged } 15-64} \times 100$$

ii. Total Dependency Ratio (TDR)

$$\text{TDR} = \frac{\text{Population aged } 0-14 + \ 65+}{\text{Population aged } 15-64} \times 100$$

Decadal changes were expressed as: (i) absolute percentage-point change in OADR (OADR 2020 − OADR 2010) and (ii) percentage change in the 65+ population between 2010 and 2020.

These definitions follow international practice and are widely used to benchmark demographic support pressures (FAO, 2022; OECD, 2025; Hayes, 2025).

Hotspot Analysis and District Typologies

Hotspot Analysis (Getis–Ord Gi*) was applied to district-level OADR values for 2020 to identify statistically significant spatial clusters of high and low ageing burden across all 40 Sarawak districts. The analysis used the Timbalai 1948 / RSO Borneo projected coordinate system, with a k-nearest-neighbour spatial conceptualisation (k = 8) and row standardisation. False Discovery Rate (FDR) correction was enabled to control for multiple testing effects. Statistical significance was assessed using GiZScore and GiPValue outputs at 99%, 95% and 90% confidence levels, producing discrete hot spots (higher-than-expected ageing burden) and cold spots (lower-than-expected ageing burden) (Esri, 2025)

This analytical strategy aligns with recent Malaysian applications in criminology, where Global Moran's I and local Getis–Ord Gi* have been combined to quantify spatial autocorrelation and detect statistically significant hot and cold spots of property crime across police station jurisdictions in major urban centres (Ahmad et al., 2024). Their work demonstrates how Gi*-based hot spot maps, interpreted through z-scores, p-values and Gi_Bin classes, can yield decision-ready evidence for targeting resources in high-burden locations, a logic that is adapted here to the context of demographic ageing rather than crime.

K-means clustering was then applied to five standardised indicators: OADR 2010, OADR 2020, absolute change in OADR (percentage points), percentage change in the 65+ population, and TDR 2020, to derive district typologies. The optimal number of clusters was selected using the elbow and silhouette criteria, resulting in k = 5. The algorithm was initialised with a fixed random seed to ensure reproducibility. Cluster outputs were visualised using radar plots to profile relative indicator magnitudes across ageing dimensions and mapped to show the spatial distribution of cluster types.

RESULTS AND DISCUSSION

District-Level Clustering of Old-Age Burden (Gi* on OADR 2020)

Seven districts form a statistically significant hot-spot belt: Lubok Antu and Kanowit (99% confidence; GiZ = 3.690 and 3.242), Sri Aman, Betong, Song and Julau (95%; GiZ = 2.674, 2.527, 2.331, 2.633), and Pakan (90%; GiZ = 2.085). A broad northern/interior cold zone comprises six 99% cold spots: Subis (GiZ = −4.206), Beluru (−4.091), Belaga (−3.581), Sebauh (−3.573), Telang Usan (−3.504) and Miri (−3.147), and four 95% cold spots: Limbang (−2.744), Lawas (−2.769), Marudi (−2.744) and Bintulu (−2.489). The remaining 23 districts show no significant clustering ($p > 0.10$).

These patterns indicate a central–southern corridor of elevated old-age dependence contrasted with a pronounced northern/interior cold belt, sharpening signals beyond descriptive choropleths and pointing to differentiated service needs. Districts in the hot spot belt are likely to face tighter constraints on working-age carers and greater demand for geriatric-friendly services, while cold-spot districts still enjoy relatively youthful structures but may experience rapid change in the coming decades (UN DESA, 2023; World Bank, 2015).

Table 1: Descriptive statistics for district-level indicators, Sarawak, 2010 and 2020 (n = 40)

	Mean	Min	Max	SD
OADR 2010 (per 100)	10.55	3.68	17.95	3.28
OADR 2020 (per 100)	11.91	3.72	19.93	3.87
Change in OADR 2010–2020 (percentage points)	14.71	−52.82	56.30	24.40
Change in population aged 65+ 2010–2020 (%)	19.96	−62.68	88.93	30.74
Total Dependency Ratio (TDR) 2020 (per 100)	44.88	27.04	78.23	8.47

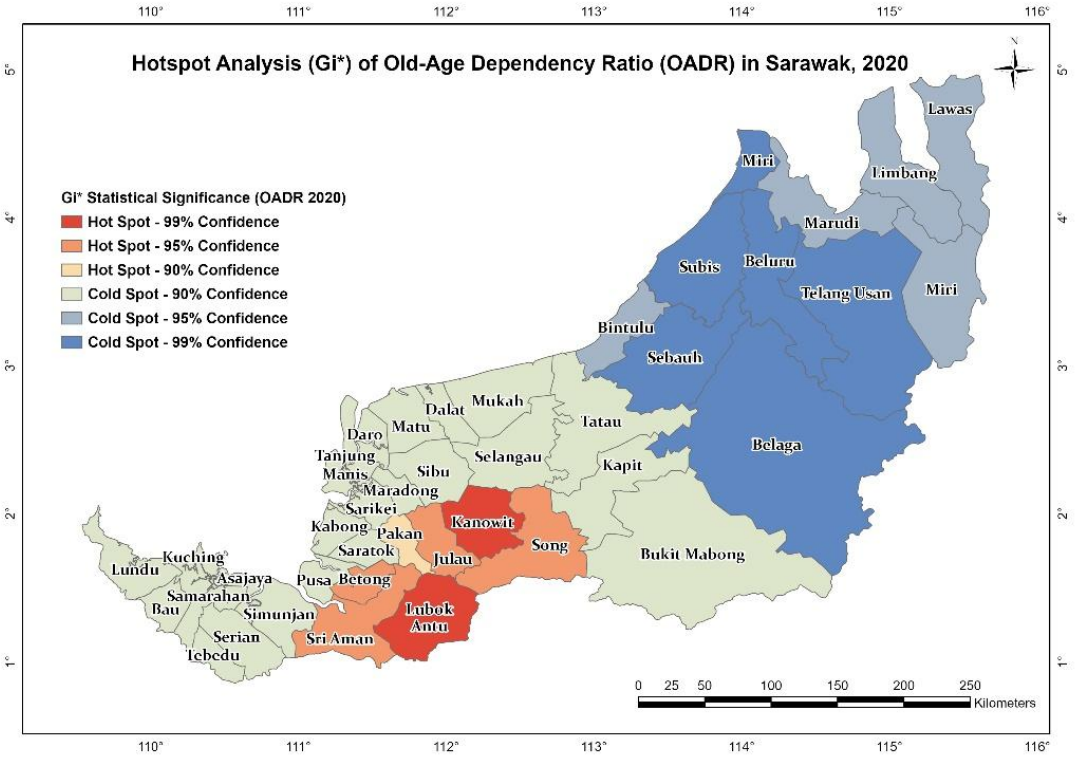

Figure 2. Hot spot Analysis (Getis–Ord Gi*) of OADR, 2020, by district

Typologies of ageing levels and trajectories (K-means profiles, 2010–2020)

Unsupervised clustering on the five indicators (OADR 2010, OADR 2020, change in OADR between 2010 and 2020, percentage change in the 65+ population, and TDR 2020) yields five interpretable district types, labelled A–E. Figure 3 presents the standardised radar profiles for each cluster, while Figure 3 maps their spatial distribution across Sarawak. Table 2 lists the specific districts belonging to each cluster, providing a direct link between statistical profiles and territorial units relevant for planning.

i. Cluster A (n = 14): Mature-ageing districts.

These districts exhibit high OADR in both 2010 and 2020 with moderate growth in the 65+ population. They are already carrying a substantial old-age burden and should be prioritised for scaling geriatric-friendly primary care, rehabilitation outreach, and community-based support services.

ii. Cluster B (n = 14): Fast-ageing districts.

Medium OADR combined with strong growth in both the 65+ population and the change in OADR. These fast-ageing places require proactive planning for workforce participation, transport, and long-term care (LTC) before burdens peak (World Bank, 2015; Ministry of Health Malaysia, 2023).

iii. Cluster C (n = 1): Mixed-burden district.

Pusa stands alone with a very high TDR but only moderate OADR, indicating simultaneous youth and old-age pressures on the working-age population. Policy responses here must balance investments in childcare, schooling, and eldercare infrastructure to avoid overloading local systems.

iv. Cluster D (n = 8): Emerging-ageing districts.

These districts remain relatively low on OADR in both years but show very rapid growth in the 65+ population between 2010 and 2020. They represent "emerging-ageing" contexts where early, prevention-oriented interventions, such as age-friendly public spaces and primary care focused on chronic disease management, can be implemented while dependency levels are still comparatively low.

v. Cluster E (n = 3): Relatively youthful districts.

Cluster E comprises districts with persistently low OADR and limited change, consistent with relatively youthful age structures. For these areas, routine monitoring and integration of demographic indicators into development planning are adequate for now, although continued migration and fertility shifts could alter trajectories in the longer term.

These typologies convert raw ratios into actionable policy segments for needs-based allocation, consistent with calls in Malaysia's Health White Paper and international guidance to move beyond one-size-fits-all responses (Ministry of Health Malaysia, 2023; UN DESA, 2023; World Bank, 2015).

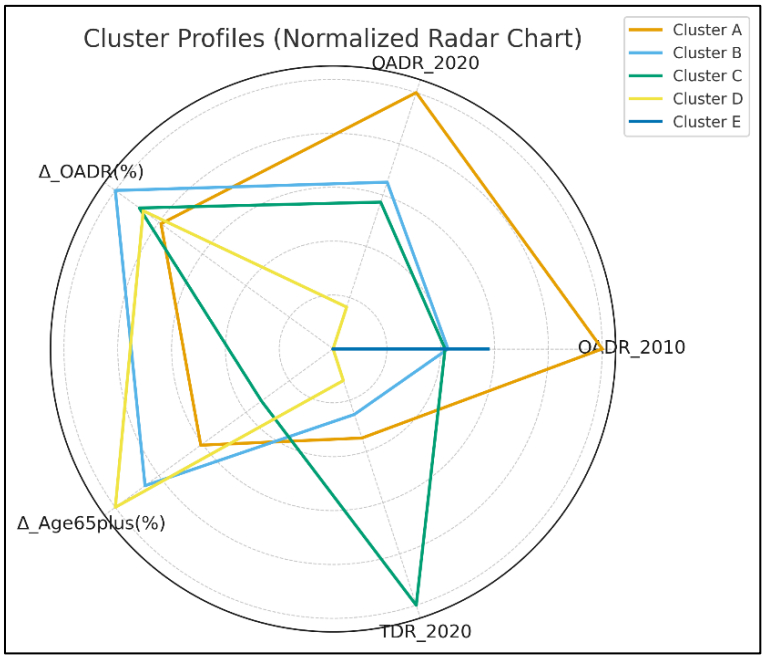

Figure 3. Cluster Profiles (Radar)

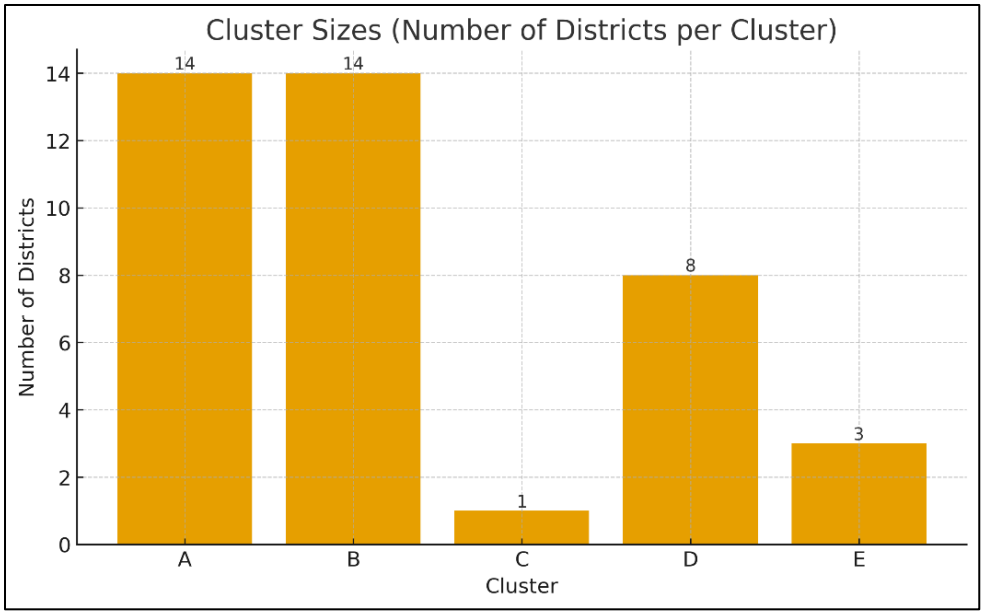

Figure 4. Cluster Sizes

Table 2. District membership by cluster (A–E) from K-means results (based on OADR 2010, OADR 2020, change in OADR 2010–2020, percentage change in population aged 65+, and TDR 2020), Sarawak, 2010–2020

Cluster	No. of districts	Districts
A	14	Asajaya, Betong, Bukit Mabong, Dalat, Julau, Kanowit, Lubok Antu, Maradong, Matu, Pakan, Selangau, Simunjan, Song, Sri Aman
B	14	Bau, Daro, Kabong, Kapit, Kuching, Lawas, Limbang, Lundu, Saratok, Sarikei, Serian, Sibu, Tanjung Manis, Tebedu
C	1	Pusa
D	8	Beluru, Bintulu, Miri, Mukah, Samarahan, Subis, Tatau, Telang Usan
E	3	Belaga, Marudi, Sebauh

Districts Leading the Transition (Ranked Changes, 2010–2020)

Ranking statistics highlight where trajectories are steepest:

i. OADR (2010–2020). The largest percentage-point increases appear in Miri, Sarikei, Sibu, Tanjung Manis, Kuching, Serian, Lubok Antu, Sri Aman, Limbang, and Lawas (Figure 5). These districts are ascending quickly toward older structures, even when current OADR is not yet extreme, an early warning signal for labour markets and LTC capacity (World Bank, 2015).

ii. Population aged 65+ (2010–2020). The fastest proportional growth in older persons occurs in Samarahan, Miri, Kuching, Sibu, Beluru, Lundu, Bintulu, Sri Aman, Lawas, and Limbang (Figure 6). This reinforces the urban–peri-urban expansion of senior cohorts along growth corridors, echoing prior work that links urbanisation and migration to subnational ageing (Ali et al., 2025a; U.S. Census Bureau, 2022).

By focusing on top increases, the paper avoids redundancy with the hot spot map while flagging districts that deserve anticipatory investments despite not being 2020 hotspots.

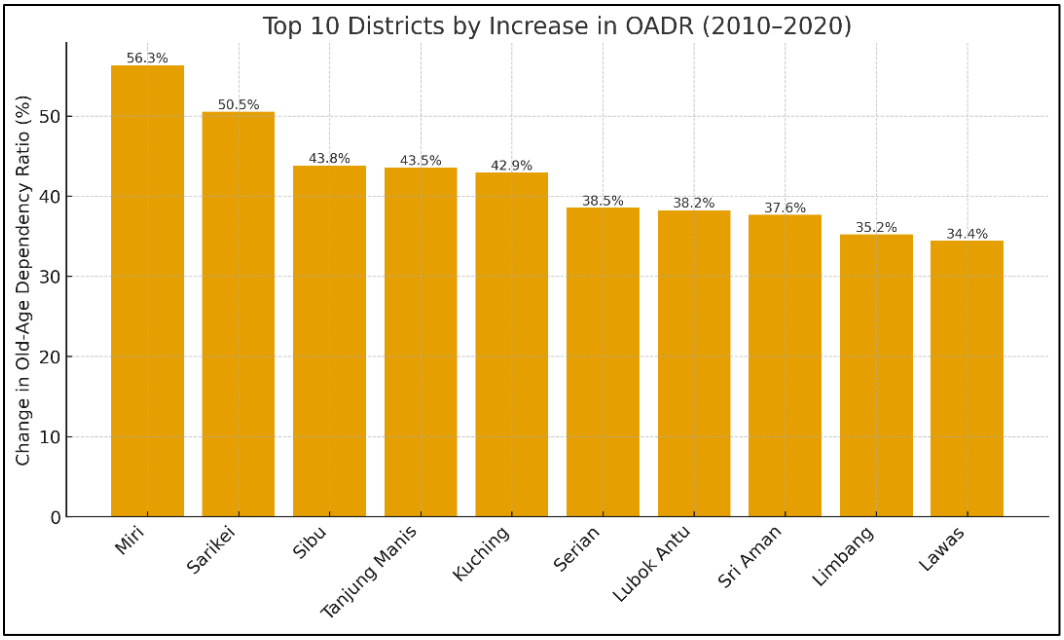

Figure 5. Top 10 Districts by Increase in OADR (2010–2020)

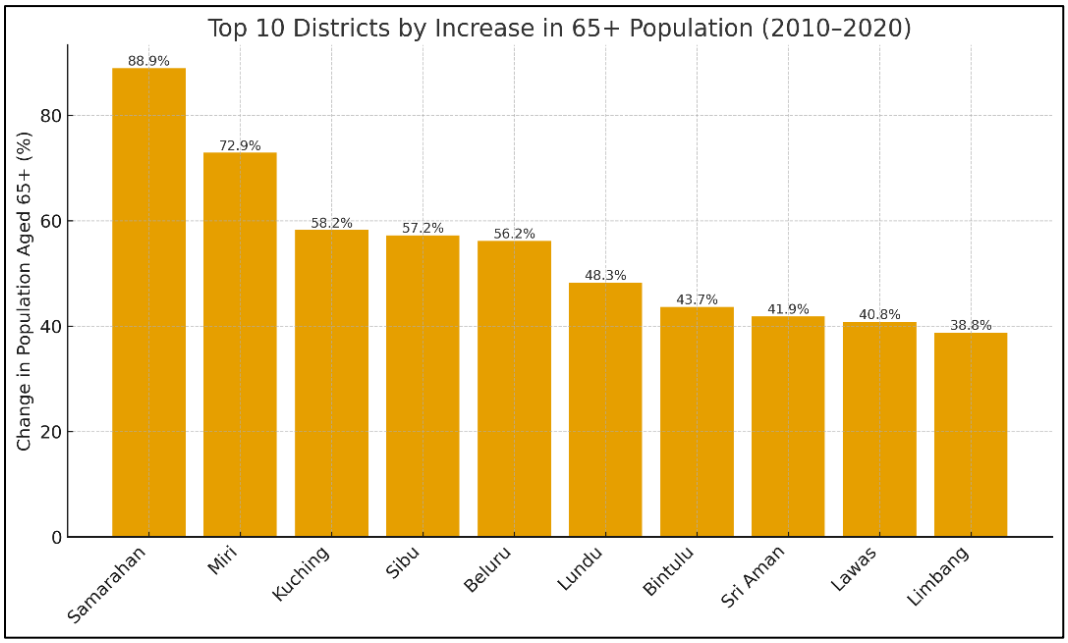

Figure 6. Top 10 Districts by Increase in Population Aged 65+ (2010–2020)

Policy implications

The central–southern hot spot belt, the rapidly ageing Cluster B districts, and the urban–peri-urban rise in the 65+ population motivate three immediate policy directions:

i. Targeted primary care and long-term care.

Concentrate geriatric-friendly primary care, rehabilitation outreach, and transport assistance in Cluster A hotspot districts, and stage additional capacity in Cluster B districts before thresholds are crossed (Ministry of Health Malaysia, 2023).

ii. Needs-based social protection and labour measures.

Use OADR, TDR, and cluster class to calibrate locality-specific subsidies, caregiver support, re-skilling for older workers, and age-friendly public transport, especially where fast ageing coincides with socio-economic vulnerability (UN DESA, 2023; World Bank, 2015, 2020).

iii. Monitoring and boundary-aware planning.

Maintain district dashboards with harmonised administrative boundaries to track annual changes in OADR and the 65+ share, explicitly acknowledging modifiable areal unit and intercensal estimation limitations (DOSM, 2025a; Esri, 2025).

These actions translate the study's spatial diagnostics into differentiated, evidence-based pathways for Sarawak's districts and provide a reproducible template for subnational ageing policy.

Limitations

Findings should be read with four caveats. First, district harmonisation and intercensal estimation can introduce small-area volatility, particularly where population counts are low. Second, Gi* outcomes are sensitive to the specification of spatial weights; this analysis used k-nearest neighbours (k = 8) with row standardisation, and alternative conceptualisations may yield slightly different local clusters, a point that has also been highlighted in Malaysian applications of hotspot analysis to crime data (Ahmad et al., 2024). Third, multiple testing in local statistics can inflate significance; False Discovery Rate (FDR) correction was applied but cannot fully eliminate this risk, mirroring concerns raised in other spatial hotspot studies. Finally, structural ratios (OADR, TDR) do not capture morbidity, disability, or effective care need; future work should integrate service utilisation and health-state measures to move from structural burden to actual demand (Ministry of Health Malaysia, 2023; UN DESA, 2023).

CONCLUSION

This study examined how population ageing and dependency burdens diverge across Sarawak's administrative districts between 2010 and 2020 using district-level indicators, OADR, TDR, and changes in the population aged 65 years and over, combined with local spatial statistics (Getis–Ord Gi*) and K-means clustering. The analysis identified a central–southern belt of statistically significant old-age burden hot spots in 2020 and a contrasting northern corridor of cold spots, alongside districts that have experienced the steepest increases in OADR and growth of older residents over the decade.

Three results stand out. First, ageing is spatially clustered rather than uniformly distributed: neighbouring districts share similar burdens, implying shared service constraints and opportunities for regional coordination. Second, trajectories differ from levels: several districts with moderate 2020 values are ageing fast and will cross pressure thresholds soon if unaddressed. Third, typologies are actionable: five cluster profiles translate heterogeneous indicators into policy-relevant groups that distinguish mature-ageing districts from fast-transition districts and mixed-burden contexts.

The implications are direct. Districts in the hot spot belt should be prioritised for geriatric-friendly primary care, rehabilitation outreach, and mobility support; fast-transition districts should stage capacity early (workforce retention, prevention, and community-based care) before dependency peaks; and mixed-burden districts require calibrated social protection that balances youth and elder needs. Using OADR and TDR with the cluster labels provides a transparent, reproducible basis for needs-based allocation and monitoring at the district scale, in line with Malaysia's healthy-ageing and social-protection agendas (Ministry of Health Malaysia, 2023; UN DESA, 2023; World Bank, 2020).

This work has limitations. District harmonisation and intercensal estimation can introduce small-area volatility; local hotspot results depend on the chosen spatial-weights specification; FDR adjustment mitigates but does not remove multiple-testing concerns; and structural ratios do not capture morbidity, disability, or effective care need. Future research should integrate morbidity and functional limitation measures, migration flows, and facility utilisation to move from structural burden to service demand; test alternative spatial conceptualisations and robustness to boundary changes; and extend the panel beyond 2020 to track post-pandemic dynamics.

In sum, the study demonstrates that ageing and dependency in Sarawak are heterogeneous and spatially organised. By pinpointing where burdens are concentrated and where they are accelerating, the findings offer a concrete template for targeted, district-level planning in health, long-term care, and social protection, while providing a replicable framework for other subnational settings undergoing rapid demographic transition. These spatially differentiated ageing patterns highlight concrete entry points for improving social welfare, strengthening labour market resilience, and refining public policies in line with the national agenda on productive and inclusive ageing.

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