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Spatial analysis of gender-based high risks of school dropout: A comparative study of urban and rural areas in Sarawak, Malaysia

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Abstract

This study examines gender-based school dropout patterns in Sarawak, Malaysia through spatial analysis, comparing urban and rural regions. Using Getis-Ord Gi* hotspot analysis, statistically significant clusters of high dropout risk for boys and girls are identified. The results reveal distinct spatial disparities: female dropout hotspots are concentrated in specific rural districts, whereas male high-risk clusters emerge primarily in urban neighborhoods. These gender-specific geographic patterns suggest differing socio-economic and cultural drivers of dropout. These findings have important implications for educational policy, highlighting the need for targeted interventions that account for both gender and locality. By mapping dropout risk, the study provides new evidence to inform policies and resource allocation aimed at reducing gender disparities in school retention. The methodology can be applied in other contexts, offering a tool for international education planners to address local dropout challenges.

Keywords: Gender, school dropout, spatial statistics

Introduction

Gender gaps in education remain pronounced worldwide, with dropout patterns often reflecting deep-seated social and economic inequities. UNESCO estimates that some 244 million children and youth (ages 6–18) were out of school in 2021 (Bonfert & Wadhwa, 2024). On the surface, global primary and secondary enrollment is nearly gender-parity, but localized disparities persist. In many low-income countries, adolescent girls disproportionately leave school when faced with poverty, early marriage or caregiving responsibilities (Bonfert & Wadhwa, 2024). For example, UNICEF finds that 10–30% of girls' school dropouts are attributable to early marriage or pregnancy (Bonfert & Wadhwa, 2024). In contrast, boys in similar contexts often exit schooling under economic pressures or restrictive gender norms: financial necessity may pull them into the workforce, and social expectations sometimes devalue boys' engagement in academics (Bonfert & Wadhwa, 2024). A recent World Bank report notes that boys now lag behind girls in basic learning outcomes (they are roughly 3.7 percentage points "learning-poor" on average) (Bonfert & Wadhwa, 2024), highlighting that once in school, girls often outperform boys. These findings underscore that gendered dropout is not a simple story of girls versus boys: it varies by context and reason, and both genders can be disadvantaged by different forces (Bonfert & Wadhwa, 2024).

This complexity is evident in the Southeast Asian region. While most ASEAN countries have achieved near-parity in enrollment, underlying challenges remain gender-specific. In some middle-income countries (e.g. Vietnam, Thailand), girls now complete more schooling than boys, reflecting changing social dynamics. But in many rural and remote communities, traditional norms continue to favor boys, while girls leave school for marriage or domestic duties. Conversely, in urbanizing parts of Southeast Asia, boys are increasingly vulnerable: they are more likely than girls to drop out to take low-skill jobs or because urban schools fail to engage them. In Malaysia, for instance, UNICEF data on Eastern Malaysia (Sabah) show that *rural Malay boys are the group most prone to miss school* (UNICEF, 2019). In short, regional reports echo the global pattern: poverty and labor demands pull boys away, whereas early marriage and gendered household roles push girls out of school (Bonfert & Wadhwa, 2024; UNICEF, 2019).

Malaysia exemplifies these trends. The country invests heavily in education, yet school attrition remains a problem. National statistics have long indicated that male students face higher dropout risk than females at both primary and secondary levels. In the state of Sarawak (Malaysian Borneo), recent studies confirm this gender gap: one survey found that about 54% of dropouts were boys (versus 46% girls), and the vast majority of dropouts occurred at the secondary level (Carlo et al., 2024). At the same time, gender-specific causes are evident. Teenage pregnancy is a key driver of girls' school leaving is overwhelmingly a dropout phenomenon in Sarawak: 97.6% of teenage pregnancies involve girls who had already left school (Lim, 2020). These figures highlight how socio-cultural forces operate differently for each gender. Many Sarawakian girls drop out because of early marriage or family obligations, whereas boys often quit under economic pressure or disillusionment with schooling (Lim, 2020; UNICEF, 2019). Indeed, the persistence of dropouts is seen as undermining Malaysia's education targets: one Malaysian report warns that student attrition threatens the country's goal of universal secondary completion under its Education Blueprint (2013–2025) (Chabo et al., 2022; Ministry of Education, 2012).

Yet despite clear evidence of gendered and geographically uneven dropout patterns, Malaysian policy and research seldom incorporate a spatial perspective. Official plans emphasize universal access but do not map where boys or girls are most at risk. Likewise, most academic studies of school leaving in Malaysia have been descriptive or qualitative, focusing on individual or community factors without geospatial analysis. A recent review notes that virtually *"most studies… only examine the factors of dropout"* and have "neglected the spatial element" (Chabo et al., 2022). This lack of geographic analysis means policymakers cannot identify which districts or schools form high-risk hotspots for dropouts, nor can they target interventions by local context. In short, the spatial dimension of dropout and especially how it intersects with gender is a significant blind spot in both theory and practice (Chabo et al., 2022).

Likewise, while Geographic Information Systems (GIS) have been used to map school locations, access, and outcomes (for example, in studies of school travel or educational resources), they have rarely been applied to dropout data itself. In Malaysia there are "very few" GIS-based studies of student attrition (Chabo et al., 2022). No known research has spatially analyzed male versus female dropout clusters. This is a critical gap: dropouts are inherently local events shaped by place-based factors. For example, ethnographic evidence suggests that interior Sarawak girls often leave school for subsistence farming or caregiving, whereas urban boys may leave for city jobs or because large school class sizes make learning uninspiring. Mapping these patterns could illuminate how transportation barriers, economic demands, and cultural norms vary across space.

This study addresses that gap by applying spatial clustering methods to gendered dropout rates in Sarawak (Figure 1). Using a grid-based Getis–Ord *Gi* hotspot analysis on secondary school data, we will identify and compare areas of high dropout risk for boys and for girls, in both urban and rural settings. In doing so, we can reveal whether male and female dropouts cluster in different districts and what local factors may underlie those clusters. Ultimately, mapping gendered dropout hotspots will allow education planners to link the observed patterns to socio-economic and cultural forces, for example, labor market pull, early marriage norms, school climate, and transport accessibility and to design targeted interventions that account for both gender and geography. In sum, by integrating GIS into gender-focused dropout research, this study aims to provide a nuanced, place-based understanding of why students leave school in Sarawak, advancing theory and informing policy.

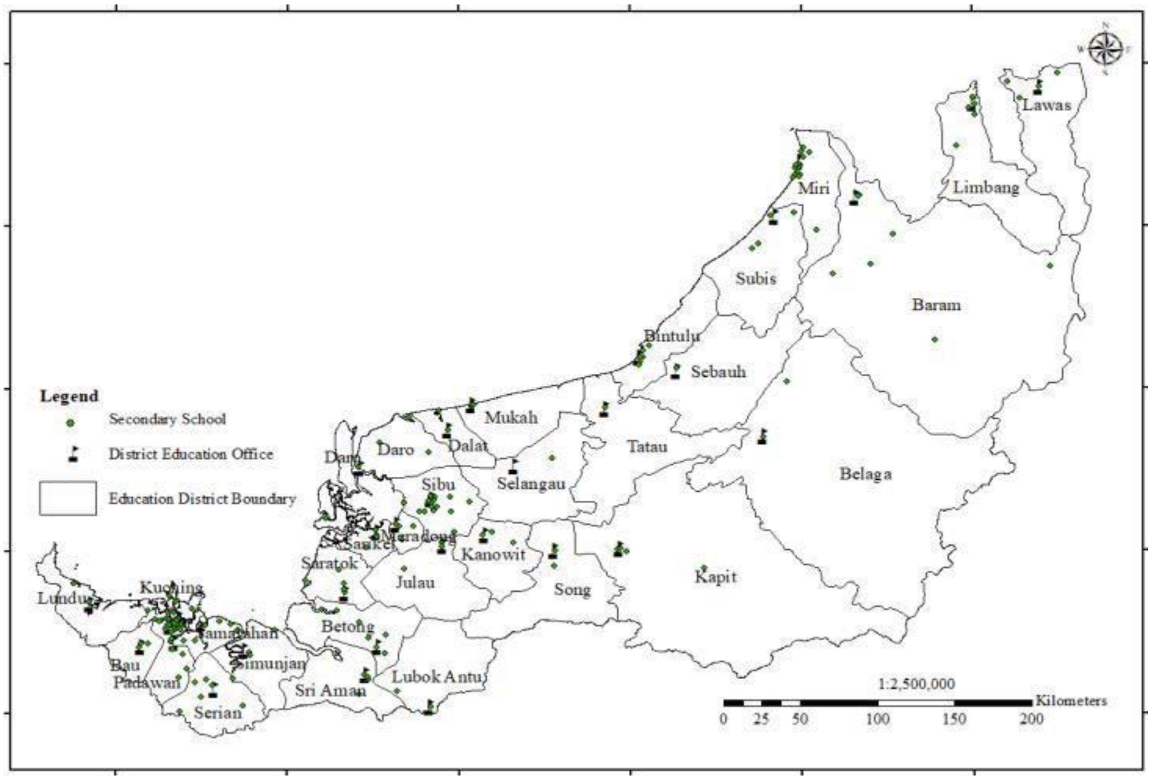

Figure 1. Area study

Methods

The integration of Geographic Information Systems (GIS) and spatial analysis into research (Ariffin et al., 2024; Bismelah et al., 2024; Jamru et al., 2024; Jubit, Masron, Puyok et al., 2023; Mohd Ali et al., 2025; Zakaria et al., 2025; Zakaria et al., 2025) has revolutionized the field of school dropout, providing unprecedented insights into the spatial patterns and dynamics of school dropout. This research, focused on school dropout in Sarawak District Education, utilizes GIS and spatial analysis to achieve several critical objectives (Chabo et al., 2022, 2024; Sepik @ Sipik et al., 2022). A spatial hot spot analysis tool on ArcGIS 10.3 known as Getis-Ord Gi* is used to identify the hotspot areas for secondary school dropouts in Sarawak. The hotspot analysis allows the detection of clusters or concentrations of student dropouts that are difficult to determine with simple visualization. Getis-Ord Gi* can also detect spatial clustering areas with similar values around spatial boundaries (Ahmad et al., 2024, 2025; Jubit et al., 2019; Masron et al., 2024). The dropout data, ethically obtained from the Sarawak State Education Department (JPNS), covers 190 secondary schools under the administration of 31 district education offices. The spatial data and unit of analysis use a grid boundary of 10 square kilometers to divide the school catchment area. High levels of dropout (hot spots) and low levels of dropout (cold spots) were determined by z-score, p-value and confidence levels for each grid on the map. A statistically significant value is when the recorded z-score is positive. The larger the z-score, the higher the clustering density or in other words, hot spots. If the p-value is less than 0.01 and the z-score is more than 2.58, then it indicates a hot spot area with a very high value. Meanwhile, the cold spot area is indicated by a negative z-score value. If the value of the z-score is less than -2.58 with a p-value of less than 0.01, it indicates that the cold spot area has the lowest value (ESRI, 2020). The significant confidence levels of hot spots and cold spots were determined by three levels, namely 90%, 95%and 99%. The table below shows the connection between z-score, p-value and confidence level (Table 1 and Figure 2).

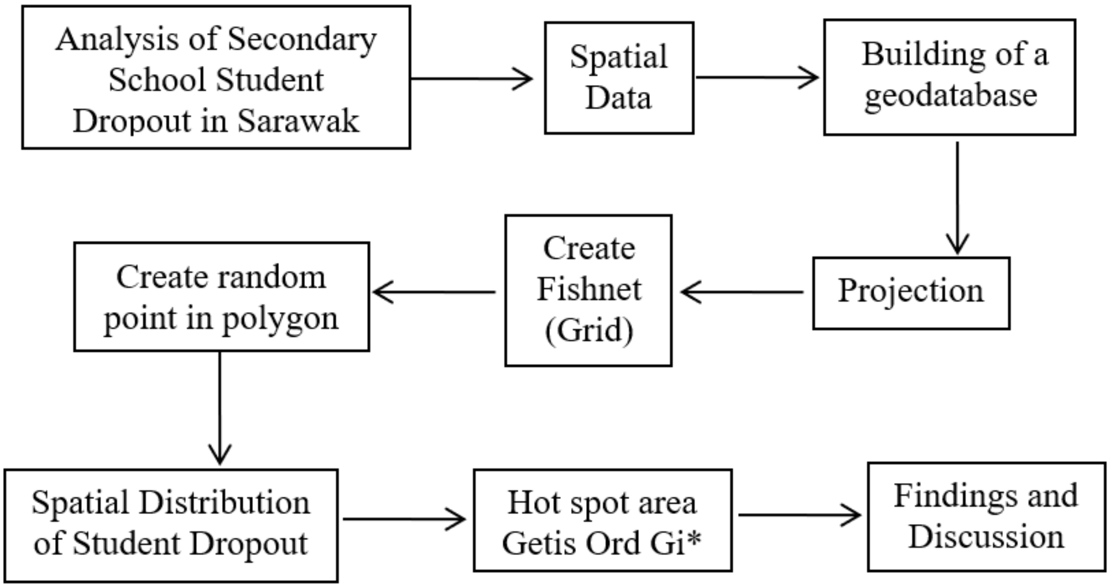

Figure 2. Flowchart of data processing steps

Table 1**.** Relations between z-score, p-value and confidence level

Z-score (Standard deviations)	p-value (Probability)	Confidence level
< -1.65 or > +1.65	< 0.10	90%
< -1.96 or > +1.96	< 0.05	95%
< -2.58 or > +2.58	< 0.01	99%

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Results

Secondary schools' dropouts based on gender

Between 2013 and 2018 male students in Sarawak dropped out in far greater numbers than females. In total, 7,881 male dropouts (61.2%) occurred versus 4,992 female dropouts (38.7%). Yearly data (Figure 3) show male dropouts peaking at 1,754 in 2013, then falling to roughly 1,000 by 2015 (a 42.9% decline), before rebounding to ~1,458 in 2016 (a 31.4% increase) and fluctuating thereafter (decreasing by 19.6% to ~1,171 in 2017, then rising 6.6% to ~1,255 in 2018). Female dropouts, by contrast, were much lower (248 in 2013) and more stable: they fell about 41.5% by 2015, rose 4.8% in 2016, fell 13.4% in 2017, and rose 4.7% in 2018. In other words, boys consistently outnumber girls by roughly 1.6:1 in total dropouts.

This gender gap aligns with national trends: Ministry of Education Malaysia reports secondary dropout rates of about 7.5% for boys versus 3.7% for girls. The temporal pattern suggests some mid-period gains (2014-15 declines) followed by partial reversals, perhaps reflecting changes in school policy or the economy. Socio-economic and cultural factors likely drive the disparity. Globally, UNICEF notes that poor families often invest first in sons' education (UNICEF, n.d.), yet in Sarawak more boys actually leave school. One reason may be economic necessity: as UNICEF observes, norms of masculinity and the need to earn income lead many boys to quit school (UNICEF, n.d.). By contrast, girls in Sarawak tend to stay in school unless forced out by other factors (such as early pregnancy). Indeed, local data show 97.6% of teenage pregnancies in Sarawak occur in school dropouts (Lim, 2020), indicating that when girls do drop out, it is overwhelmingly due to childbirth or related issues. This reflects broader findings that barriers like child marriage, poverty and lack of sanitation disproportionately block girls' schooling (UNICEF, n.d., 2018, 2020). In sum, the trends indicate that dropout is a strongly gendered problem in Sarawak: most at-risk students are boys, but girls' dropouts often have distinct causes (e.g. maternity).

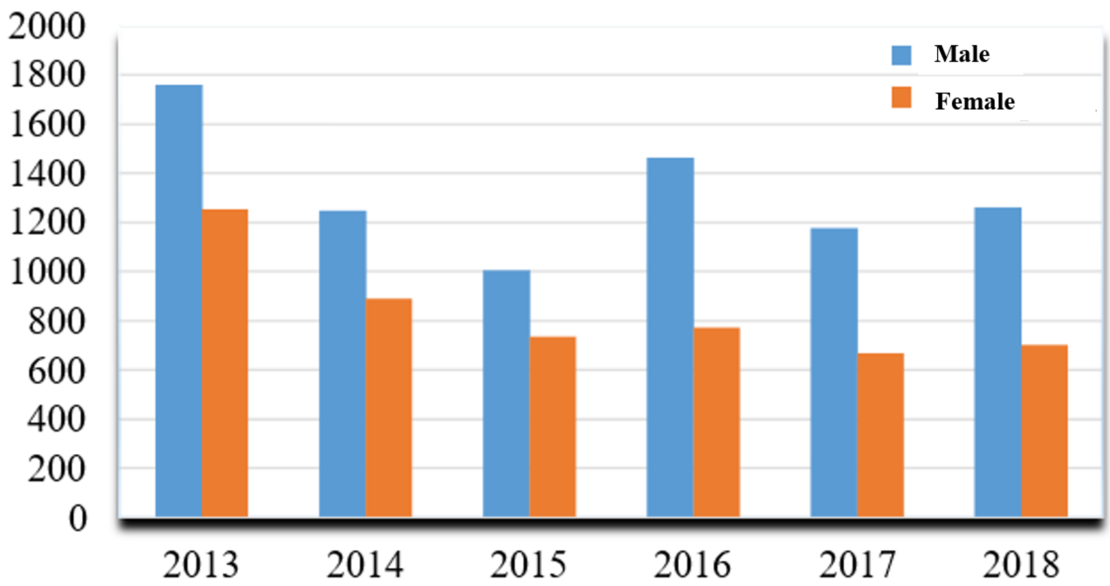

Figure 3. Dropouts among secondary school students in Sarawak according to gender from 2013 to 2018

Hot spots for student dropouts by gender

Spatial Hot Spot analysis (Getis–Ord Gi*) was applied to 10-km grid cells of Sarawak to identify significant clusters of high or low dropout density (Jubit et al., 2019). This technique, widely used in prior studies of Malaysian dropout geography (Ahmad et al., 2024; Jubit, Masron, & Redzuan, 2023; Nordin et al., 2020; Nordin & Masron, 2016), assigns each grid a z-score and p-value to classify "hot" (high) and "cold" (low) clusters. We interpret $z > 2.58$ ($p<0.01$) as an ultra-high hotspot (99% confidence), 1.96–2.58 as high (95%), and 1.65–1.96 as moderate (90%). The results reveal striking urban–rural contrasts that differ by gender.

Male student dropout hot spot area

In every year 2013–2018, male dropout hotspots were statistically significant (99% confidence, $p<0.01$) and almost always centered in urban district centers. For example, in 2013 the highest-risk cluster comprised four schools in the Bintulu District (codes YEA9101, YEA9102, YEA9105, YEE9103 in PPD Bintulu) with GiZ≈16.82 (99% CI). The lowest (coldest) male-dropout area that year was in suburban Padawan (school YRA1302, GiZ≈1.832, $p<0.10$). In 2014 the same Bintulu quartet again formed the dominant cluster (GiZ≈19.15, 99% CI), while the lowest cluster was at YEE3501 (Dalat, 90%). Thus 2013-2014 were dominated by Bintulu (urban) hotspots. In 2015 the peak moved to the rural interior: a single Belaga PPD school (YEA7102, in Kapit Division) had GiZ≈23.28 (99%). In that year the weakest cluster was at YEE6401 (Daro, rural, 90%).

In 2016 the hotspot returned to Bintulu (the same four Bintulu schools, GiZ≈15.53, 99%), with the lowest cluster at Betong (YEA2405, 90%). In 2017 the highest cluster shifted to Kuching (six schools in PPD Kuching, including YEB1202, YEE1201, YEE1204, YEE1205, YEE1301, YFB1201) with GiZ≈15.03 (99%), and the weakest was in Simunjan (YEA8302, rural, 90%). Finally in 2018 the hotspot was again in urban Bintulu (the same four schools, GiZ≈22.14, 99%), and the coldest cluster was in rural Saratok (YEA2201, GiZ≈1.671, 90%). In fact, the 2018 result highlights grid 992 (central Bintulu) as a very-high-risk cell, whereas the rural Saratok grid had one of the lowest z-scores.

Across years, male-dropout clusters were overwhelmingly urban: Kuching and Bintulu districts recur as hotspots, whereas rural districts appear mainly among the low-end clusters. This suggests dropout among boys is concentrated in towns and cities. Possible explanations include urban poverty or labour markets luring boys out of school, as documented elsewhere (UNICEF, n.d.). Methodologically, these findings demonstrate the value of Gi*: high z-scores (>2.58) reliably flagged the densest male-dropout clusters. The spatial analysis thus pinpoints exactly which schools/grids need attention each year. For example, Table 2 (2014) lists Bintulu schools with the highest GiZ, confirming the map view. In summary, urban PPDs (Bintulu, Kuching) consistently emerge as male-dropout "hot spots" at 99% confidence, whereas rural areas only show "cool" spots at 90% confidence (Figure 4).

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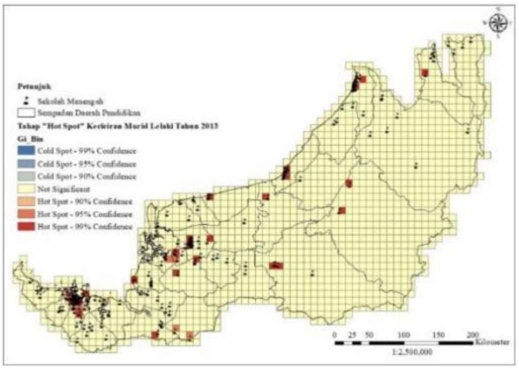

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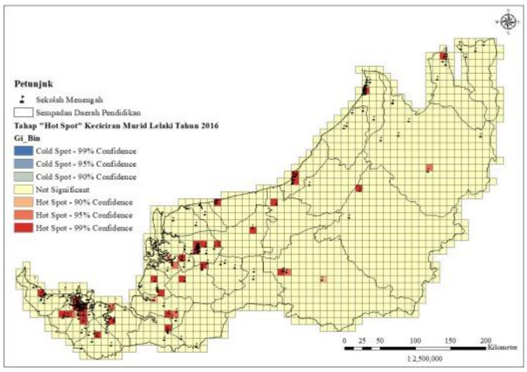

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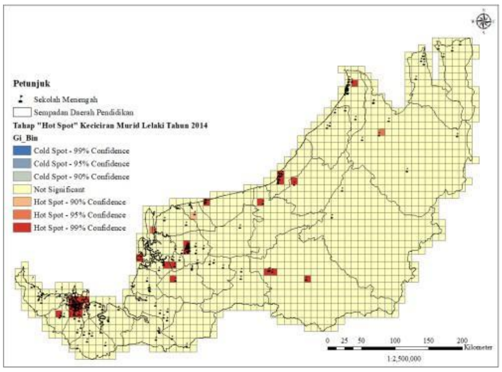

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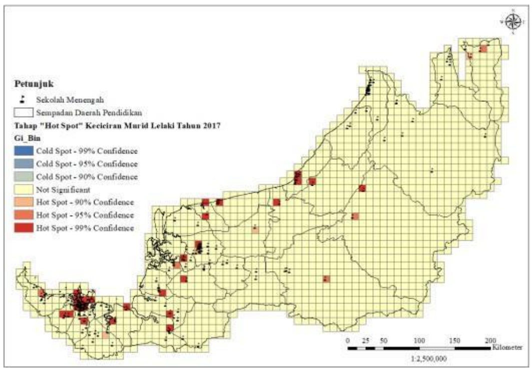

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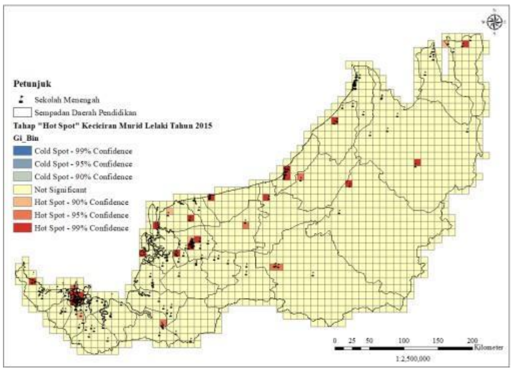

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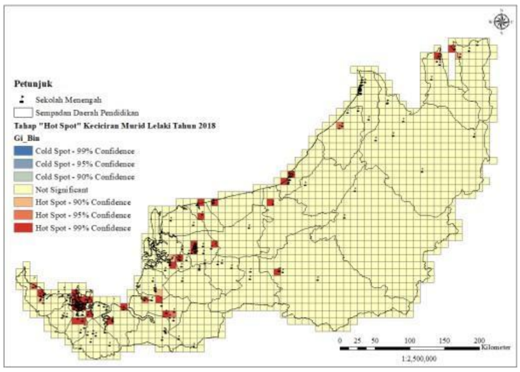

(f)

Figure 4. Hot spot areas for dropout of secondary school boys in Sarawak in (a) 2013, (b) 2014, (c) 2015, (d) 2016, (e) 2017, (f) 2018

Table 2. Hot spots for secondary school male student dropouts in Sarawak in 2014

Grid	District education office	School code	GiZScore	GiPValue	GiBin
141	Samarahan	YEE8101	2.812567	0.004915	3
247	Kuching	YEA1205	3.929569	0.000085	3
404	Julau	YEA6201	6.861758	0.000000	3
424	Kapit	YEA7101	3.230097	0.001237	3
463	Kapit	YEE7102	5.327158	0.000000	3
491	Meradong	YEE6301	2.951073	0.003167	3
528	Daro	YEA6101	4.207864	0.000026	3

Grid	District education office	School code	GiZScore	GiPValue	GiBin
893	Tatau	YEA9201	7.280796	0.000000	3
994	Sebauh	YEB9102	2.811059	0.004938	3
1338	Miri	YEA4107	4.487210	0.000007	3
703	Daro	YEE6402	2.392021	0.016756	2
1197	Baram	YEB4302	2.392021	0.016756	2
191	Samarahan	YEA8103	1.834966	0.066511	1
799	Dalat	YEE3501	1.693624	0.090337	1
138	Bau	YEB1102, YEE1101	2.671379	0.007554	3
140	Samarahan	YEA1302, YEB8101	3.371243	0.000748	3
246	Kuching	YEA1207, YEB1303	8.679656	0.000000	3
462	Kapit	YEA7103, YEE7101	18.595363	0.000000	3
490	Sarikei	YEB6101, YFB6101	3.230404	0.001236	3
1022	Bintulu	YEA9103, YEA9104	4.908176	0.000001	3
885	Mukah	YEA3402, YEE3401, YFB3401	4.207864	0.000026	3
992	Bintulu	YEA9101, YEA9102, YEA9105, YEE9103	19.154039	0.000000	3
190	Kuching	YEB1202, YEE1201, YEE1204, YEE1205, YEE1301, YFB1201	10.495864	0.000000	3
245	Kuching/ Padawan	YEA1209, YRA1303, YEA1309, YEA1211, YEA1208, YRA1301	5.885959	0.000000	3
619	Sibu	YEA3102, YEA3105, YEA3106, YEE3101, YEE3102, YFB3104	4.068633	0.000047	3
576	Sibu	YEA3101, YEA4104, YEA3107, YFB3101, YFB3102,	2.951241	0.003165	3

Grid	District education office	School code	GiZScore	GiPValue	GiBin
189	Kuching/ Padawan	YFB3103, YFB3106, YFB3203 YEA1303, YEB1201, YFB1202, YFB1303, YFB1204, YEA1203, YEA1295, YEA1304, YEA1307	10.635110	0.000000	3

Female student dropout hot spot area

Female dropout hotspots show a more mixed urban–rural pattern (Figure 5). In 2013 the largest cluster was in Kuching/Padawan (grid 189) encompassing nine schools (e.g. YEA1303, YEB1201, YFB1202, etc.), with GiZ≈14.627 (99%). The lowest cluster that year was in Julau (YEA6202, GiZ≈1.783, 90%). In 2014 the highest-z cluster surprisingly lay deep in rural Kapit: two Kapit schools (YEA7103, YEE7101) formed a cluster with GiZ≈17.320 (99%). This "rural" hotspot far outstripped any urban one, consistent with the authors' note that 2014's female hotspot was in a rural area. The weakest cluster that year was at YEA6101 (Daro, 90%). In 2015 the peak shifted to another rural interior location: YEA7102 (Belaga, rural Kapit) with GiZ≈20.460 (99%), while the lowest clusters were in Lawas/Sri Aman (YEE5201, YEE2101, YFB2101 at GiZ≈1.763, 90%).

After 2015 the female hotspots migrated back to regional centers. In 2016 five schools in Miri (YEA4103, YEA4105, YEA4106, YEA4108, YFB4103) formed a very high cluster (GiZ≈23.496, 99%); the lowest was at YEE4301 (Subis, 90%). In 2017 the peak cluster was in urban Bintulu (the same four Bintulu schools as the male pattern) with GiZ≈15.467 (99%), and the lowest at Lubok Antu (YEB2301, GiZ≈1.659, 90%). Notably, the authors remark that in 2017 the highest z-scores occurred in urban areas (Bintulu) while the lowest occurred in rural parts. In 2018 the four Bintulu schools again formed the top cluster (GiZ≈18.714, 99%), with Julau (YEA6201, GiZ≈1.649, 90%) as the weakest.

Thus, unlike the male case, female-dropout hotspots began in the Kuching metro (2013), shifted to the rural interior (Kapit, Belaga in 2014–15), and then settled in regional cities (Miri in 2016; Bintulu in 2017–18). Rural districts like Kapit and Belaga accounted for the strongest clusters early on; these areas coincide with poorer, largely indigenous communities where girls face cultural barriers and high teenage birthrates. Indeed, UNICEF highlights that poverty and child marriage especially hamper girls' schooling (UNICEF, n.d.). For example, studies note that in Sarawak many pregnant teens are school dropouts (Lim, 2020). By contrast, the later emergence of urban clusters (Miri, Bintulu) may reflect other factors (e.g. secondary impacts of urban migration or school capacity issues). In all cases the female hotspots were highly significant (GiZ≫2.58) – for instance GiZ≈23.50 in Miri (2016), while the lowest clusters (GiZ≈1.65–1.78) were always at 90% confidence.

Table 3. Hot spots for secondary school male student dropouts in Sarawak in 2018 (36 school)

Grid	District education office	School code	GiZScore	GiPValue	GiBin
102	Padawan	YEE1303	2.826741	0.004702	3
103	Padawan	YEE1302	10.08856	0	3
142	Samarahan	YEA8102	3.816056	0.000136	3
153	Betong	YEA2402	2.990873	0.002782	3
196	Simunjan	YEA8304	3.485792	0.000491	3
246	Kuching	YEA1207	5.138537	0	3
247	Kuching	YEA1205	4.311588	0.000016	3
296	Lundu	YEE1401	4.311241	0.000016	3
301	Kuching	YEA1305	3.816815	0.000135	3
622	Sibu	YEB3201	3.155665	0.001601	3
799	Dalat	YEE3501	2.660496	0.007803	3
883	Dalat	YEA3501	5.301412	0	3
893	Tatau	YEA9201	3.650834	0.000261	3
1398	Lawas	YEA5201	2.660525	0.007802	3
154	Betong	YFB2401	2.495819	0.012567	2
254	Betong	YEA2404	2.330532	0.019778	2
348	Lundu	YEA1401	2.000271	0.045471	2
240	Lundu	YEA1402	1.670604	0.0948	1
308	Saratok	YEA2201	1.670554	0.09481	1
532	Sarikei	YFB6102	1.83599	0.066359	1
1391	Lawas	YEB5202	1.835229	0.066472	1
256	Betong		3.816221	0.000136	3
107	Simunjan	YEA8301, YEE8304	4.476116	0.000008	3
462	Kapit	YEA7103, YEE7101	2.825552	0.00472	3
490	Sarikei	YEB6101, YFB6101	2.990807	0.002782	3
533	Meradong	YEA6301, YFB6301	3.981162	0.000069	3
991	Bintulu		22.13715	0	3
1022	Bintulu	YEA9103, YEA9104	5.136342	0	3
1389	Limbang	YEA5101, YEE5101	3.320722	0.000898	3
1213	Subis	YEA4401, YEB4401	2.000271	0.045471	2
885	Mukah	YEA3402, YEE3401, YFB3401	12.06872	0	3
619	Sibu	YEA3102, YEA3105, YEA3106, YEE3101, YEE3102, YFB3104	5.797013	0	3

Grid	District education office	School code	GiZScore	GiPValue	GiBin
190	Kuching	YEB1202, YEE1201, YEE1204, YEE1205, YEE1301, YFB1201	8.109073	0	3
245	Kuching/ Padawan	YEA1209, YRA1303, YEA1309, YEA1211, YEA1208, YRA1301	9.099642	0	3
576	Sibu	YEA3101, YEA4104, YEA3107, YFB3101, YFB3102, YFB3103, YFB3106, YFB3203	3.321382	0.000896	3
189	Kuching /Padawan	YEA1303, YEB1201, YFB1202, YFB1303, YFB1204, YEA1203, YEA1295, YEA1304, YEA1307	10.08995	0	3

Table 4. Hot Spots for Female Secondary School Dropouts in Sarawak in 2017 (31 School)

Grid	District education office	School code	GiZScore	GiPValue	GiBin
103	Padawan	YEE1302	10.36087	0	3
139	Bau	YEA1101	3.459697	0.000541	3
153	Betong	YEA2402	4.059787	0.000049	3
196	Simunjan	YEA8304	3.159411	0.001581	3
246	Kuching	YEA1207	4.962967	0.000001	3
247	Kuching	YEA1205	7.360746	0	3
296	Lundu	YEE1401	3.159428	0.001581	3
301	Kuching	YEA1305	5.860687	0	3
308	Saratok	YEA2201	3.759517	0.00017	3
404	Julau	YEA6201	5.259817	0	3
494	Julau	YEA6202	2.859338	0.004245	3
893	Tatau	YEA9201	12.76131	0	3
971	Belaga	YEA7102	7.960356	0	3
994	Sebauh	YEB9102	4.659697	0.000003	3
1398	Lawas	YEA5201	4.359665	0.000013	3

Grid	District education office	School code	GiZScore	GiPValue	GiBin
1401	Lawas	YEE5201	3.759517	0.00017	3
40	Lubok Antu	YEB2301	1.659098	0.097096	1
154	Betong	YFB2401	1.959578	0.050045	1
716	Selangau	YEA3401	1.959158	0.050094	1
883	Dalat	YEA3501	1.959172	0.050093	1
107	Simunjan	YEA8301, YEE8304	4.059577	0.000049	3
1022	Bintulu	YEA9103, YEA9104	8.261976	0	3
138	Bau	YEB1102, YEE1101	2.259578	0.023847	2
1389	Limbang	YEA5101, YEE5101	2.259218	0.02387	2
84	Sri Aman	YEE2101, YFB2101	1.959158	0.050094	1
885	Mukah	YEA3402, YEE3401, YFB3401	6.76013	0	3
992	Bintulu	YEA9101, YEA9102, YEA9105, YEE9103	15.46269	0	3
190	Kuching	YEB1202, YEE1201, YEE1204, YEE1205, YEE1301, YFB1201	16.96308	0	3
245	Kuching/ Padawan	YEA1209, YRA1303, YEA1309, YEA1211, YEA1208, YRA1301	7.361766	0	3
619	Sibu	YEA3102, YEA3105, YEA3106, YEE3101, YEE3102, YFB3104	2.859368	0.004245	3
189	Kuching/ Padawan	YEA1303, YEB1201, YFB1202, YFB1303, YFB1204, YEA1203, YEA1295, YEA1304, YEA1307	4.062038	0.000049	3

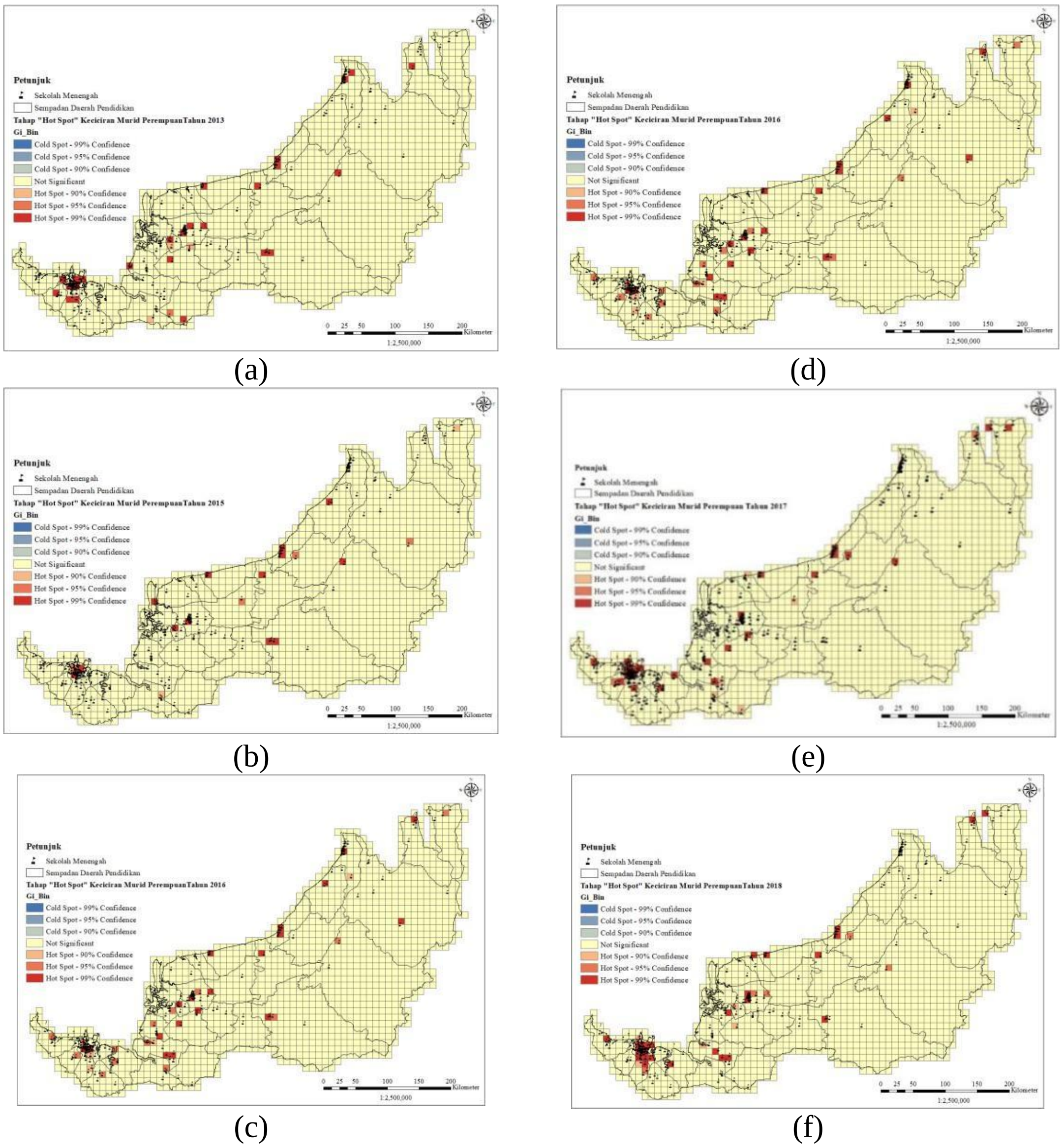

Figure 5. The hot spot area for the dropout of secondary school girls in Sarawak in (a) 2013, (b) 2014, (c) 2015, (d) 2016, (e) 2017, (f) 2018

Urban–Rural comparison:

Overall, male dropout clusters are concentrated in cities (Bintulu, Kuching), whereas female dropout clusters are split between some rural divisions (Kapit, Belaga) and urban centers. The grid analysis underscores this: e.g. grid 992 (central Bintulu) repeatedly appears as a male hotspot, while female grid 992 is also high in 2017–18. In 2014–15, however, the female hot grids were in interior Sarawak (Kapit/Belaga). These patterns reflect gendered social contexts: rural girls may leave school for early marriage or work (consistent with global UNICEF findings on girls' dropout) (UNICEF, n.d.), whereas urban boys leave perhaps for labour or because urban schooling is undervalued. Such insights supported by this hotspot mapping are critical for policy. As Chabo et al. (2022) argue, identifying local dropout hot spots enables targeted interventions by district. For example, resources can be prioritized to the specific schools/grids with GiZ>2.58 (seen in Tables 2-4) rather than to whole districts. In short, spatial analysis adds precision to our understanding of who drops out and where, so that policymakers and educators can focus support (e.g. counselling, scholarships, school access) on the most vulnerable gender–location groups.

Discussion

Our spatial analysis reveals a striking gendered geography of dropout risk: male students concentrate in urban hotspots (notably Bintulu and Kuching), whereas female risk clusters oscillate between cities and Sarawak's remote interior (Belaga, Kapit, Julau). These patterns align with broader evidence that urban–rural context drives gendered school leaving. Rural girls often face pressures such as early marriage, domestic chores or agricultural labor, consistent with UNICEF observations that girls' dropouts worldwide are linked to household responsibilities and early childbearing. By contrast, urban boys may enter the labor market early or disengage when schooling is undervalued (UNICEF Malaysia, 2023). Indeed, Malaysian data show widening secondary-level gender gaps disadvantaged boys (GPI of ≈0.8 in math and reading) (UNICEF Malaysia, 2023), suggesting systemic barriers to male engagement. These diverging social contexts urban male youth seeking economic opportunities vs. rural female youth constrained by tradition or access likely underlie the spatial divergence we observe.

Dropout "reasons" logged by schools (e.g. expulsion, "lack of interest", or absences "untraceable") appear insufficient to explain these patterns. For example, our field informants simply recorded that Bintulu boys "lost interest" without further detail (Chalkwall, 2017; Febriana & Suparman, 2020; Kamal & Bener, 2009; Khotmi et al., 2024). However, educational research shows that "disengagement" typically masks deeper issues. Students labeled as unmotivated may in fact be reacting to an uninspiring curriculum, poor school climate, or low self-efficacy (Wali & Khadim, 2025). Khotmi et al. (2024) similarly found that Afghan children drop out from boredom or a lack of stimulating instruction. Likewise, expulsion often recorded as a dropout cause may reflect negative school discipline practices that disproportionately affect certain communities (e.g. Indigenous or minority youth) (Wali & Khadim, 2025). "Untraceable" absences, common in remote schools, likely signal migrant or transient families, pregnancy, or lack of documentation, rather than mere truancy. In short, narrow administrative categories hide multi-layered socio-economic factors.

Institutional and geographic barriers compound these gendered effects. Rural interior schools (Sarawak Level 2/3) suffer from severe access issues. For example, the PPD Belaga school YEA7102 – one of our rural female hotspots – is designated "Level 2" (moderate accessibility) and struggles to even contact absent students. Studies confirm interior communities lack roads, reliable transport, or communication networks; students often travel by boat or foot for hours, and teachers may live off-site (Carlo et al., 2024; Sarawak Tribune, 2025). Weak infrastructure was repeatedly cited as hindering continuation: a recent Sarawak study noted that limited roads, classrooms and boarding facilities prevent interior children (especially girls) from remaining in school (Carlo et al., 2024). Conversely, urban students may attend nearby schools easily, but face large class sizes, overcrowding, and disruptive peer environments. Interviews elsewhere link unfavourable school climate – bullying, strict discipline, or disengaged teachers to dropout risk (Wali & Khadim, 2025). In Malaysia's schools, it is plausible that disciplinary expulsion in crowded urban schools shifts some students into the dropout category.

Importantly, these spatial–gender dynamics intersect with socio-economic and cultural factors. Indigenous and rural communities in Kapit or Belaga have different norms than Kuching urbanites. For example, Sarawak's interior girls may leave school for subsistence work or to help at home; UNICEF has documented that girls in marginal communities shoulder household duties that compete with schooling. Indeed, the Sarawak Women's Ministry reported that among 623 teenage pregnancies in early 2020, a staggering 97.6% were among school dropouts, highlighting a reproductive dimension to rural female dropout. By contrast, Bintulu's economy (oil, gas, industry) may create job pull factors for urban boys, encouraging early workforce entry. Boys in cities might also perceive less value in formal education, especially if local industries hire before graduation.

Malaysia has recognized some of these challenges with policy initiatives in 2020–25. The Education Ministry's Digital Education Policy (2021–2025) aims to narrow urban–rural divides via "smart classrooms" and ICT integration (Hassanuddin, 2025). Efforts include retraining 100,000 teachers in digital pedagogy and deploying AI-driven learning tools to identify at-risk students (BERNAMA, 2025). Such technology promises to engage remote learners by bringing virtual resources to under-staffed rural schools. Similarly, the government has launched Zero Student Dropout programs: pilot "K9/K11 model schools" in remote areas and an electronic system (SiPKPM) for early warning of at-risk youth (BERNAMA, 2025; Zahiid, 2025). Minister Fadhlina Sidek has emphasized needs-based, context-specific interventions, for example, counseling or scholarships targeted to girls in interior Kapit vs. boys in Bintulu (Zahiid, 2025). Non-governmental efforts also contribute; for instance, PINTAR Foundation's school adoption initiatives bring resources to struggling rural schools. These policies reflect an understanding that generic solutions are insufficient: our findings support a gender-sensitive, place-based strategy.

The gendered spatial patterns suggest different strategies: in urban Bintulu and Kuching the focus should be on keeping boys engaged, perhaps by linking education to job skills (as recommended by UNICEF) (UNICEF, n.d.). In rural Kapit and Belaga, community outreach and addressing early marriage or motherhood might retain girls in school. The Getis–Ord Gi* method itself has proven valuable in several Malaysian education studies (Chabo et al., 2022), demonstrating that geospatial techniques can reveal critical dropout "hot spots" that aggregate data would miss. In line with educational spatial-analysis literature, this study underscores that mapping dropout risk is a powerful tool for designing targeted retention programs and ultimately reducing gender gaps in schooling (Ahmad et al., 2024; Chabo et al., 2022; Jubit et al., 2019; Jubit, Masron, & Redzuan, 2023; Masron et al., 2024; Nordin et al., 2020; Nordin & Masron, 2016).

In sum, the spatial analysis confirms that dropout is not a uniform issue in Sarawak. Urban Bintulu and Kuching contain male-dominated hotspots, likely reflecting labour-market pulls and urban school climates, whereas female hotspots shift between cities and isolated interiors, reflecting cultural norms and access constraints. The simplistic dropout categories (expulsion, disinterest, unknown) fail to capture this complexity. We argue for richer, mixed-methods investigation: following up "untraceable" cases to learn why girls in Belaga disappear from class, or why boys in Kota Samarahan disengage. Equally, policies must recognize these socio-spatial mechanisms. Efforts like digital classrooms and zero-dropout schemes are promising, but must be matched with on-the-ground supports, reliable transport, safe boarding, community outreach and gender-responsive curricula especially in remote districts (How AI Can Transform Malaysia's Education, 2025; Sarawak Tribune, 2025). Only by aligning resource allocation with the geospatial patterns and gender realities revealed here can Malaysia hope to close both the rural–urban gap and the male–female dropout gap.

Implications

The study reveals stark geospatial gender disparities in Sarawak's school dropout rates. Male dropout hotspots cluster in urban centers (e.g. Bintulu, Kuching), whereas female hotspots concentrate in certain rural and semi-urban districts. This suggests different underlying drivers: rural girls may leave school for subsistence work, household duties or early marriage, while urban boys may exit schooling due to local labor opportunities or disengagement. These findings have direct educational and social implications. National planning must account for these patterns by allocating resources to specific high-risk areas. For example, Malaysia's Education Ministry already aims to narrow urban–rural gaps and ensure all children (regardless of location or gender) complete at least primary school (Rickie & Alias, 2024). The observed clusters indicate where such policies must be tailored locally – e.g. investment in rural transport, safe boarding, and community outreach for girls in interior districts, versus vocational or engagement programs for boys in cities.

The results also highlight spatial inequality and demand gender-sensitive policies. The fact that dropout "hot spots" are concentrated by gender and location underscores that generic, one-size-fits-all interventions are insufficient. Indeed, SDG4 (Quality Education) explicitly calls for eliminating gender disparities (Target 4.5) and ensuring equal access to all levels of education (UNESCO, 2024). UNESCO's profile for Malaysia notes that gender parity widens in favour of girls at higher levels (e.g. GPIs >1.25 in reading by lower secondary) (UNICEF Malaysia, 2023), reflecting that boys increasingly lag behind in progression. Our findings confirm this: with boys disproportionately dropping out in urban areas, and girls disproportionately in some rural areas. Thus, achieving Malaysia's SDG4 commitments and its Education Blueprint (2013–2025), which envisions "education for all" regardless of background (Rickie & Alias, 2024) requires interventions informed by these spatial patterns.

Practically, spatial hotspot mapping provides a tool for targeted intervention. As Chabo et al. note, mapping dropout risk "provides new evidence to inform policies and resource allocation aimed at reducing gender disparities in school retention". For instance, education authorities could use the Getis–Ord Gi* hotspots to identify specific schools or grids where dropout risk is highest and deploy support there. This aligns with recent policy moves: Malaysia's 2021–25 digital education strategy and Zero-Dropout initiatives recognize that urban and rural areas have distinct needs. In sum, the gendered spatial trends call for place-based, gender-responsive policies such as scholarships or mentoring for girls in Kapit/Belaga, and skills-linked learning for boys in Kuching/Bintulu to fulfil both national education equity goals and the broader SDG4 agenda.

Recommendations for future research

Building on these insights, future studies should employ mixed-methods and longitudinal designs. The current spatial analysis identifies "where" dropout risk is high, but deeper understanding requires following *why* students leave. Qualitative fieldwork – interviews with dropouts, families, and teachers would unpack the socio-cultural and economic factors hidden by coarse administrative labels (e.g. “untraceable” or “lost interest”). For example, tracing address lists of dropouts and surveying them could reveal causes such as illness, migration, or school climate issues. Longitudinal tracking of student cohorts over time would also allow assessment of when and why disengagement begins, and how interventions (e.g. scholarships or ICT programs) affect trajectories. As other studies suggest, multi-dimensional data can improve analysis combining spatial, demographic, and school-level variables to model dropout pathways (Psyridou et al., 2024).

Methodologically, researchers should refine the spatial approach. The 10-km grid used here is a pragmatic choice, but future work could use finer geographic units or actual school catchment boundaries to reduce the Modifiable Areal Unit Problem. Integrating population or household data could weight risk by density. Moreover, advanced analytics such as machine learning can enhance early prediction: recent longitudinal studies (e.g. Psyridou et al., 2024) have shown that ML models using rich educational and socio-emotional data can classify later dropouts (AUC ~0.65) and flag at-risk students years in advance (Psyridou et al., 2024). Adapting such models to Malaysia, perhaps incorporating GIS features or mobility data could supplement hotspot mapping.

Finally, these methods should be replicated and scaled. The approach taken in Sarawak could be applied in other Malaysian states or ASEAN countries with similar rural–urban divides. Chabo et al. point out that their spatial methodology “can be applied in other contexts, offering a tool for international education planners”. Conducting comparative studies would reveal whether observed gender-patterns (urban-boy vs. rural-girl hotspots) are unique to Sarawak’s economy and culture or part of a wider trend. Such comparative research could inform national and regional policies on closing dropout gaps.

Limitations

This study’s findings must be interpreted in light of several data and methodological constraints. First, the administrative data quality is limited. School records often use vague categories (e.g. “untraceable”, “lost interest”, or “expulsion”) without detailed reasons. As a result, we cannot fully explain the causes behind each dropout cluster. Many socio-economic drivers (e.g. poverty, health, or migration) are simply not captured. The study also cannot track students after dropout; no follow-up data exist to know whether a student migrated, re-enrolled elsewhere, or left for work. Second, the spatial resolution is coarse. Dropout counts were aggregated to 10-km fishnet grids (commonly used in Malaysian studies), which may blur local variation. Smaller clusters or inequities at the village level could be missed, and the choice of grid size can influence hotspot detection (a manifestation of the Modifiable Areal Unit Problem). Future analysis might use finer units or weighted kernels to mitigate this bias.

Third, the analysis is descriptive and correlational. The Getis-Ord Gi* method identifies where dropouts concentrate but cannot establish causality. For example, a hotspot in a town could correlate with industry presence or school policy, but this spatial correlation alone does not prove these factors cause dropouts. Unobserved confounders (like parental education or community norms) may underlie the patterns. Without experimental or quasi-experimental designs, caution is needed before inferring cause-and-effect from the mapped clusters. In summary, while the spatial findings are robust, they depend on the limitations of administrative dropout data and spatial aggregation.

These constraints highlight the need for richer data and methodologies in future research precisely the points noted by the authors and by related studies (Psyridou et al., 2024).

Conclusion

The spatially-disaggregated analysis in this study reveals that dropout risk in Sarawak is not a uniform phenomenon but one deeply entwined with both place and gender. In our maps, male hotspots cluster in urban centers (e.g. Bintulu, Kuching) while female hotspots are concentrated in remote rural and semi-urban districts. These divergent patterns signal entrenched structural inequities: for example, girls in interior Sarawak often leave school to help with subsistence farming or early marriage, whereas boys in cities drop out under economic pressure or disengagement. In other words, geography and gender jointly shape educational trajectories. Such findings move us beyond listing dropout counts to interpreting why education access is systematically unequal. They suggest that the drivers of attrition, whether poverty, transport barriers or gender norms are place-specific. In rural areas, a girl's schooling is often limited by infrastructure and patriarchal expectations, while in urban schools large class sizes or lack of vocational paths push boys out. These patterns lay bare the fault lines of Sarawak's education system: they reflect not individual failures but social structures that leave certain communities and genders behind.

These insights carry clear policy and theoretical implications aligned with global equity goals. Quality Education (SDG4) demands universal completion and the elimination of gender gaps, yet our results show that Malaysia's SDG4 targets cannot be met without place-sensitive strategies. UNESCO's data confirm widening gender parity in favor of girls at higher levels in Malaysia, reflecting boys' lagging progression. Our maps echo this: boys in urban Sarawak lag behind, and girls in rural Sarawak do the same. Addressing this dual disparity also advances SDG5 (Gender Equality) and SDG10 (Reduced Inequalities). Gendered dropout hotspots are, in effect, manifestations of social exclusion; reducing them would directly empower girls (and disadvantaged boys) by securing equal educational opportunities. Likewise, SDG10's call to reduce sub-national inequality finds a clear target here: the spatial clusters of high dropout risk flag exactly where education outcomes are most unequal. Crucially, the fact that dropout "hot spots" align along geographic lines means that one-size-fits-all policies are insufficient. Mitigating educational inequity will require interventions tailored by both gender and place for example, investing in rural transport or safe boarding for girls in interior Kapit and Belaga, and introducing skills-based programs to keep urban boys engaged in Kuching and Bintulu. In this way, our findings directly inform the 2030 Agenda: they show that empowering girls (SDG5) and narrowing regional disadvantages (SDG10) hinge on overcoming precisely the local barriers we have identified.

Importantly, the methodological approach itself has direct policy value. Spatial hotspot mapping here implemented with the Getis-Ord Gi* statistics transforms raw dropout data into actionable intelligence. Rather than treating dropout as a uniform problem, education planners can use our maps to see where risk is highest and which gender is most affected. For instance, policymakers could overlay our hotspot grids with demographic and infrastructure data to prioritize scholarships or community outreach in the most deprived districts. Such GIS-informed targeting is already gaining traction in Malaysia; for example, the national Zero-Dropout initiative and Digital Education Strategy acknowledge the distinct needs of urban versus rural students. Our study provides a concrete template for these efforts. It demonstrates that routinely incorporating spatial analysis into Ministry planning would ensure resources (like tutoring programs, school buses, or conditional cash transfers) are sent to the right places. In short, mapping dropout risk makes the abstract goal of "equity for all" operational: by showing how urban–rural and gender disparities play out on the ground, it enables place-based, gender-responsive interventions rather than generic reforms.

Finally, this research fills a critical gap in both Malaysian and global education policy literature. Prior Malaysian studies have largely treated dropouts as isolated incidents or focused on individual factors without spatial context. By contrast, our analysis explicitly links school leaving to location and gender, providing empirical depth that was previously missing. In doing so, it aligns local schooling data with international equity agendas: for example, it offers a quantifiable basis for Malaysia's Education Blueprint commitment to universal schooling by highlighting which communities require extra support. More broadly, our findings suggest a template for other countries with rural–urban divides. If applied elsewhere, similar GIS-based approaches could reveal whether the rural-girl versus urban-boy pattern holds in other settings or if new gendered geographies emerge. Such comparative research would inform national and regional policies on closing dropout gaps.

In summary, our study's spatial gender analysis produces actionable, forward-looking conclusions. It shows that the fight for quality education must be fought in specific places as well as across genders. By linking Sarawak's dropout clusters to SDG4, SDG5, and SDG10, we highlight that achieving global education equity depends on resolving the very spatial and cultural inequities our maps expose. These conclusions suggest that embedding GIS in routine educational monitoring and designing interventions that are both place and gender-aware can turn the Sustainable Development Goals from aspirations into targeted policies. In this way, the research not only enhances theoretical understanding of schooling inequity but also provides a practical roadmap for ensuring no child is left behind, regardless of their gender or where they live.

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