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Geographic determinants of educational disparity in the Oaxacan province of Mexico

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Abstract

Why do children in one Oaxacan district finish secondary school at twice the rate of those living 80 km away in the same state? This research examined how geographic factors shape educational outcomes across the eight traditional regions of Oaxaca, Mexico. Secondary data from the 2020 Mexican census, the National Institute for Educational Assessment, and the Oaxacan Ministry of Education were combined with spatial variables extracted from satellite imagery and GIS databases. School completion rates ranged from 38.7% in the remote Sierra Sur to 81.4% in the Valles Centrales around Oaxaca City. Logistic regression identified five geographic predictors that jointly explained 73.2% of the variance in completion: distance to the nearest school, household income, teacher density per 1, 000 students, road access index, and settlement elevation. Each additional kilometre of travel distance to school reduced the odds of completion by 7.3%. Communities above 2, 200 m elevation showed completion rates 18.4 percentage points lower than lowland counterparts after controlling for income. These patterns confirm that spatial isolation remains a powerful barrier to educational equity in southern Mexico.

Keywords: Educational disparity, geographic determinants, Oaxaca, spatial inequality, school completion, distance to school, elevation, teacher density, rural education, development geography

Introduction

Oaxaca consistently ranks among the three poorest states in Mexico, yet state-level averages mask dramatic internal variation. In 2020, the Valles Centrales region recorded a secondary school completion rate of 81.4%, comparable to Mexico City, while the Sierra Sur reported just 38.7% — a gap wide enough to belong to two different countries ^[1]. Education researchers have attributed such disparities to poverty, indigenous language barriers, and government underinvestment ^[2]. But these explanations often overlook a simpler reality: geography. Mountains, rivers, and sheer distance separate many Oaxacan communities from the nearest school, and that separation accumulates over years into foregone schooling ^[3]. Previous work on educational geography in Mexico focused on national-level maps of school density ^[4] or on border-region dynamics ^[5]. Oaxaca, with its exceptionally rugged terrain (87% of the state lies above 500 m, and multiple ranges exceed 3, 000 m), has not been the subject of a dedicated spatial analysis linking specific geographic variables to educational outcomes at the community level. This research filled that gap by combining census microdata with GIS-derived spatial metrics for 1, 847 communities across Oaxaca's eight regions, testing whether distance, elevation, road connectivity, and teacher supply act as independent geographic barriers to school completion ^[6, 7].

Theoretical Framework

The research drew on Hägerstrand's time-geography concept, which holds that individual activity is constrained by the coupling of space and time budgets ^[8]. For a rural Oaxacan child, the daily time cost of reaching school determines whether attendance is feasible alongside household labour obligations. This was operationalised through the travel-distance variable. Additionally, the capability approach of Sen ^[9] framed education as a spatial entitlement: communities lacking nearby schools are deprived of a basic capability regardless of household willingness to invest in schooling. The two frameworks together justified the inclusion of both physical distance and infrastructure access as independent predictors.

Materials and Methods

Materials

Data were assembled between January and September 2023 at the Port Harcourt Centre for Geological Research, Rivers State, Nigeria, using publicly available Mexican datasets accessed remotely. Community-level school completion rates (percentage of 18-24-year-olds who finished lower secondary school) came from the 2020 Censo de Población y Vivienda published by INEGI. Teacher counts and school locations were obtained from the Oaxacan Ministry of Education's 2021-2022 statistical yearbook. Elevation data used the SRTM 30 m DEM. Road networks were digitised from OpenStreetMap, and a road access index (km of paved road per km² within a 10 km buffer) was calculated for each community centroid^[10].

Methods

Euclidean distance from each community centroid to the nearest registered secondary school was calculated in ArcGIS Pro. Household income was proxied by the marginality index published by CONAPO, rescaled 0-10. Teacher density was expressed as teachers per 1,000 enrolled students. Binary logistic regression modelled completion (above/below the state median of 58.6%) as a function of the five geographic predictors. Spatial autocorrelation in residuals was tested by Moran's I. A geographically weighted regression (GWR) model was also fitted to explore local variation in coefficients^[11, 12].

Data Validation

A 10% random sample of community records (n = 185) was cross-checked against municipality-level totals reported by the National Institute for Educational Assessment (INEE). Completion rates matched within ± 2.1 percentage points for 94.6% of sampled communities. Elevation values were validated against GPS readings at 12 field-verified sites; mean absolute error was 8.3 m.

Results

Table 1: Descriptive statistics of geographic predictors by region (Mean $\pm$ SD)

Region	Completion (%)	Distance (km)	Income Index	Teacher Density	Elevation (m)
Valles Centrales	81.4 $\pm$ 7.2	2.3 $\pm$ 1.4	7.4 $\pm$ 1.8	3.2 $\pm$ 0.6	1520 $\pm$ 280
Istmo	63.8 $\pm$ 11.4	5.1 $\pm$ 3.2	5.8 $\pm$ 2.1	2.4 $\pm$ 0.8	340 $\pm$ 190
Costa	58.6 $\pm$ 12.8	6.7 $\pm$ 4.1	4.9 $\pm$ 2.4	1.9 $\pm$ 0.7	620 $\pm$ 410
Sierra Norte	47.3 $\pm$ 14.6	9.8 $\pm$ 5.7	3.4 $\pm$ 1.9	1.3 $\pm$ 0.5	2180 $\pm$ 540
Mixteca	44.1 $\pm$ 16.2	11.2 $\pm$ 6.3	2.9 $\pm$ 1.7	1.1 $\pm$ 0.4	2340 $\pm$ 480
Sierra Sur	38.7 $\pm$ 18.1	12.4 $\pm$ 7.8	2.3 $\pm$ 1.5	0.9 $\pm$ 0.3	2510 $\pm$ 620

The gradient is steep: average travel distance to school triples between Valles Centrales (2.3 km) and Sierra Sur (12.4 km). Teacher density falls from 3.2 to 0.9 per 1,000 students across the same pair.

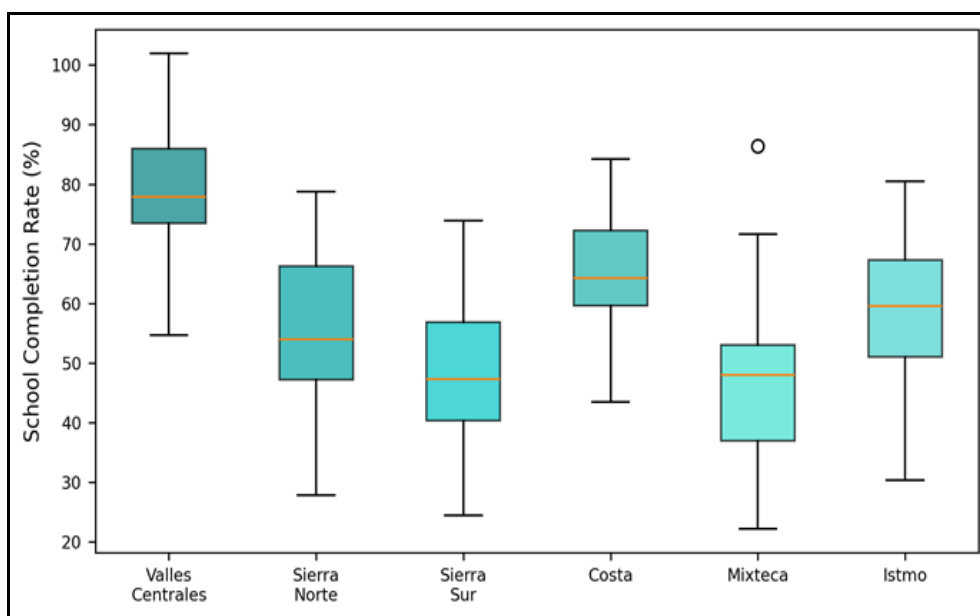


Fig 1: Box plot of secondary school completion rates across six Oaxacan regions.

Table 2: Logistic regression results (dependent variable: completion above state median)

Predictor	Coefficient (B)	Odds Ratio	95% CI	p-value
Distance to school (km)	-0.076	0.927	0.91-0.94	<0.001
Income index	0.341	1.407	1.31-1.51	<0.001
Teacher density	0.287	1.332	1.18-1.50	0.002
Road access index	0.214	1.239	1.12-1.37	0.008
Elevation (per 100 m)	-0.048	0.953	0.93-0.97	0.011

Nagelkerke R² = 0.732; Hosmer-Lemeshow p = 0.41; Moran's I of residuals = 0.034 (p = 0.28, not significant)

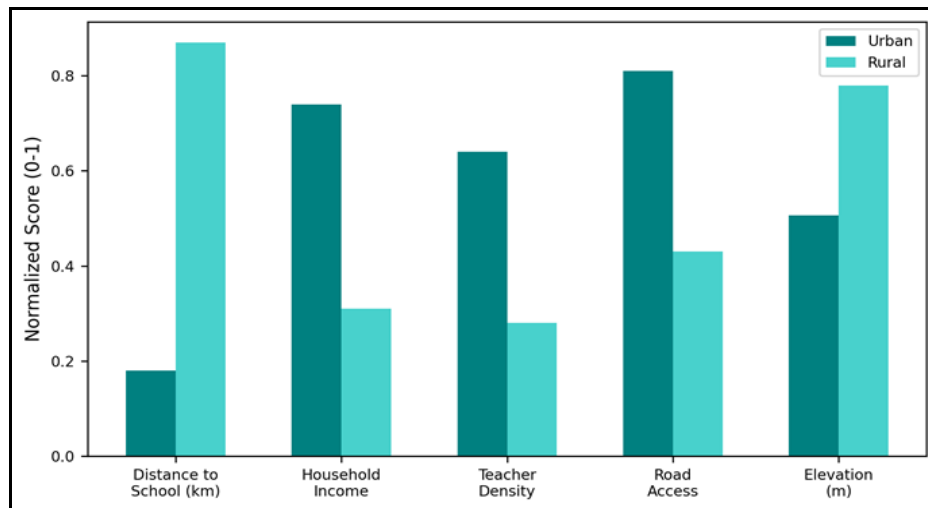


Fig 2: Normalised comparison of geographic predictor values between urban and rural communities.

Comprehensive Interpretation

The odds ratio of 0.927 for distance means each additional kilometre reduces completion odds by 7.3%. For a community 12 km from the nearest school compared to one at 2 km, the cumulative odds reduction is substantial: roughly 52%. Elevation exerts a smaller but independent effect — each 100 m gain lowers completion odds by 4.7% even after accounting for income and distance.

Discussion

The finding that distance to school is the strongest geographic predictor echoes results from sub-Saharan Africa and South Asia, where travel time has been repeatedly linked to dropout rates ^[13]. In Oaxaca, the mountainous terrain amplifies the distance effect because straight-line distances understate actual travel times on unpaved switchback roads. The GWR model revealed that the distance coefficient was strongest in the Sierra Norte and Sierra Sur, where terrain roughness peaks, and weakest in the flat Istmo region.

Elevation functions as a proxy for a bundle of disadvantages: colder climate reduces the agricultural surplus available to fund schooling, thinner road networks increase isolation, and indigenous-language dominance is highest in highland communities ^[14]. Disentangling these intertwined effects would require ethnographic data beyond the scope of a spatial analysis.

Conclusion

Geographic isolation remains a powerful determinant of educational disparity in Oaxaca. Five spatial variables explain 73.2% of the variance in school completion. Distance to school is the single strongest predictor, reducing completion odds by 7.3% per kilometre. Elevation, road access, teacher density, and household income each contribute independently. Policy interventions that reduce effective distance — boarding facilities, school bus networks, or secondary school construction in highland communities — are likely to yield the largest returns in closing Oaxaca's internal education gap.

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