https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Crossing the Redline: Colonial Land Zoning and Rural Wealth in Namibia

Osasere V. Amatotsero[1], Javier Miranda[1], Jan Börner[12]

[1]Institute for Food and Resource Economics, University of Bonn, Bonn, 53115, Germany
[2]Centre for Development Research, Bonn, 53113, Germany

Correspondence to: Osasere V. Amatotsero (vanessa.amatotsero@ilr.uni-bonn.de)

Abstract. Colonial land zoning policies have shaped access to land, markets, and public services for large parts of the population on the African continent over decades. Quantitative evidence on whether the impacts of colonial zoning on land use and rural wealth persist until today remains scarce. This paper estimates the long-run association of Namibia's colonial zoning policies with the International Wealth Index, a contemporary wealth proxy derived from satellite data**.** We exploit spatial variation in exposure to and duration of zoning regulations, drawing on 8,639 rural and peri-urban settlements. Using historical analysis, covariate matching with spatially lagged controls, and regression analyses, we find that settlements in regions that were only temporarily disadvantaged by colonial zoning are as well off today as settlements in regions that received preferential treatment during various colonial periods. However, settlements north of Namibia's Redline, an active veterinary zoning policy dating back to the 19th century, exhibit significantly lower average wealth than settlements in the rest of the country. Our analysis of historical documents and reconstructions of agricultural expansion dynamics suggests that forced migration, the expansion of commercial agriculture, and mining are key mechanisms behind our results. As such, our findings are consistent with the idea that colonial institutions can generate persistent economic divides and carry direct implications for spatially targeted land reform and rural development policy in Namibia.

Short summary:

Colonial land zoning policies shaped access to land and economic opportunities in Namibia. Using historical maps and contemporary settlement-level wealth data, this study examines whether historical zoning boundaries are associated with present-day rural wealth. The findings reveal persistent spatial wealth differences across the zones, highlighting the relevance of considering colonial legacies for contemporary land use and rural development policy.

Keywords: Land zoning; Colonial legacy; Historical institutions; Land-use policy; Rural wealth; Spatial differences; Namibia.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.



LAND SYSTEMS Discussions

25

1 Introduction

Understanding the determinants of rural development and related wealth outcomes remains a major research challenge. Colonial rule and related institutions have shaped long-run development outcomes that persist today (Acemoglu et al., 2001; Cogneau and Guénard, 2003; Acemoglu and Robinson, 2012). A common instrument of colonial rule was the discriminatory
30 allocation of fundamental economic resources, such as land (Direito, 2013). This includes land zoning regulations, which divide a country's territory into sub-regions, i.e., zones, with varying levels of access and use restrictions (Grieson and White, 1981; Bengston et al., 2004; Fischel, 2015). Discriminatory land zoning regulations, for example, restricted the free movement of people, market access for agricultural products produced in a given zone, and how and for what purpose land could be used (Direito, 2013; Lens, 2022).

35 While much of the literature has focused on the long-run effects of colonial institutions on development outcomes (Acemoglu et al., 2001; Acemoglu and Robinson, 2012), some studies have examined the implications of colonial land zoning and spatial planning for land use and development (Direito, 2013; Kohima et al., 2023; Kotikot et al., 2025; Makombe and Masakure, 2024). Still, our knowledge about the long-term impacts of colonial land zoning policies on contemporary land use and rural wealth is limited.

40 Here we address this knowledge gap in the context of Namibia, where land has been subject to dynamic colonial zoning regulations (Miescher, 2012). Colonial zoning was also accompanied by a contract labour system that recruited indigenous Namibians from northern Namibia to work in mines and commercial farms in the southern colonial settlement areas. Our research question is whether colonial zoning regulations have left a measurable footprint in contemporary spatial patterns of rural wealth in Namibia. To answer this question, we use historical maps and documents to reconstruct three distinct zones
45 with different exposure to colonial zoning regulations, then use covariate matching and regression analysis with spatially explicit datasets to compare rural wealth outcomes in 8,639 rural settlements across these zones. We substantiate our quantitative analysis with a review of historical events that represent complementary explanations for today's spatial patterns of rural wealth in Namibia.

We find that rural settlements affected by colonial zoning regulations that persist in modified form until today exhibit
50 significantly lower levels of wealth than settlements in zones that received preferential treatment during colonial times. However, small differences in wealth also exist between settlements that differed in exposure to zoning regulations that were abandoned decades ago. Our historical analysis suggests that this may be explained by the land occupation dynamics that unfolded after the partial abandonment of colonial zoning law.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Our main contribution lies in providing quantitative evidence that colonial zoning regulation is associated with measurable path dependencies in rural development outcomes. We also contribute methodologically by showing how quasi-experimental research design can be meaningfully informed through historical analysis by improving the database, contextualising the theory of change, and providing complementary explanations for unexpected results.

The remainder of the paper is organised as follows. Sections 2 and 3 present our theoretical and empirical frameworks. In sections 4, 5, and 6, we report results, discuss our findings, and conclude with implications for future research and policy.

2 Theoretical framework

2.1 Institutional mechanisms of land zoning and rural welfare outcomes

Land zoning is a key element of spatial planning and usually involves the allocation of land and corresponding property rights for a specific purpose or use by a particular group of actors (Cullingworth and Caves, 2004; Hall and Tewdwr-Jones, 2020; Oliveira and Meyfroidt, 2021). Land use in the zones usually entails different rules and regulations, as well as management practices and changes in land-use cover. The objective of zoning is to encourage the sustainable use of land, thereby rationalising land use, reducing environmental degradation, and enabling local communities to use and benefit from land and natural resources (Nolte et al., 2017). However, depending on how it is used, land zoning can have positive or negative effects on rural development and livelihoods (FAO, 2020).

As a planning tool, zoning may provide information on natural resource quality or climatic conditions, thereby informing land-use decisions towards more suitable and potentially productive crop and livestock production (FAO, 1996; Le Page et al., 2017). It may then also guide policy decisions on agricultural support measures or infrastructure investments that change economic opportunities in rural areas (Cullingworth and Caves, 2004, p. 83; Hall and Tewdwr-Jones, 2020).

As a regulatory tool, zoning formalises the access and use rights that govern land for agricultural and non-agricultural uses, such as residential and industrial zones (Sclar et al., 2020). Ideally, this form of zoning enhances social welfare by governing natural resource use to avoid resource overuse and land degradation, as in the 'tragedy of the commons' (Hardin, 1968).

Clearly, both forms of land zoning can be abused by legitimate and illegitimate rulers in favour of specific interest groups (Sclar et al., 2020; Morton, 2017; Shertzer et al., 2016). Discriminatory zoning has been a frequent colonial instrument of oppression in Africa (Jayne et al., 2014; Kenfack Essougong and Teguia, 2019; Shertzer et al., 2016). This kind of zoning excludes marginalised areas and populations from access to natural resources, infrastructure, and economic support policies (Kenfack Essougong and Teguia, 2019; Shertzer et al., 2016). It can thus create and reinforce power asymmetries and economic marginalisation over time (Acemoglu et al., 2001; Parent, 2018; Röhring and Gailing, 2012). Key theoretical mechanisms

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

through which zoning can affect rural welfare outcomes include restrictions on land access, land use, market access, and the mobility of people and assets (see Figure 1).

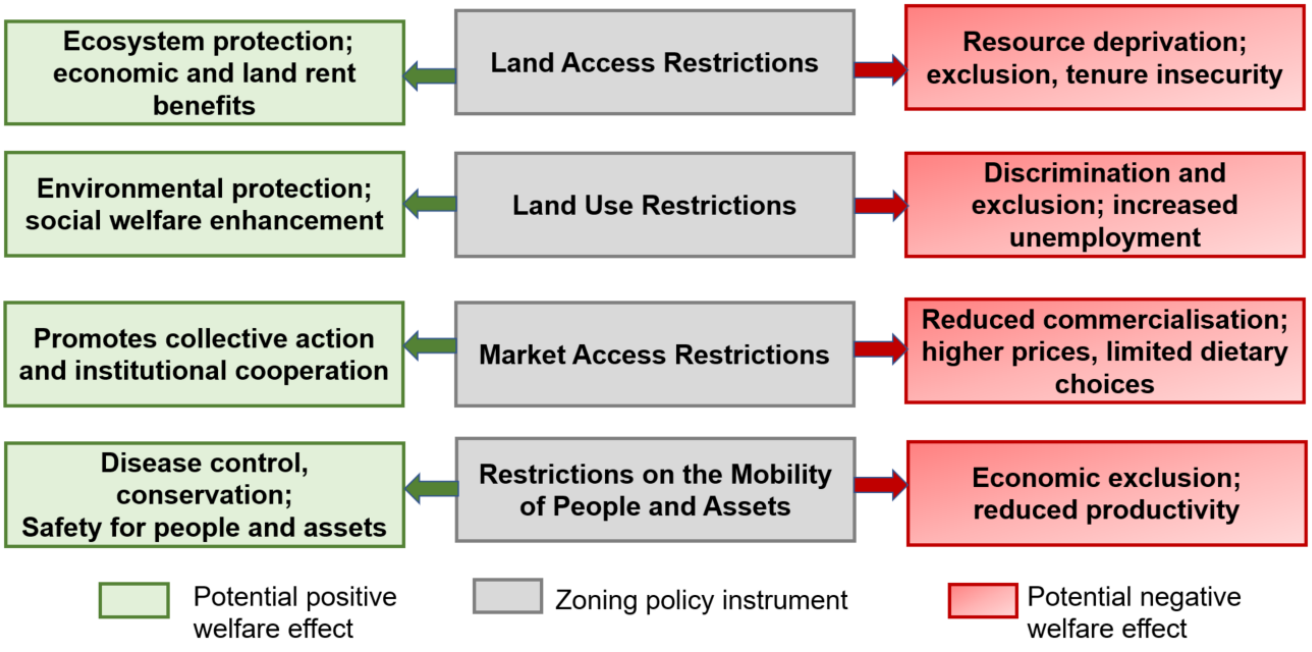


Figure 1: Theoretical mechanisms linking zoning policy instruments to rural welfare: potential positive and negative pathways.

2.1.1 Land access restrictions

Zoning policies may involve the creation of "no-use zones". For instance, strictly protected areas can increase or reduce rural welfare (Naidoo et al., 2019). Welfare may rise where conservation brings economic benefits such as tourism revenue or protects locally valued ecosystem services. It may fall where it cuts local populations off from essential timber and non-timber forest products. Effects can differ across groups. In land-scarce environments, strict protection zones tend to increase land rents, which benefit landowners, but can also limit the economic opportunities of landless rural or marginalised populations (Kalkuhl and Edenhofer, 2017). Land access restrictions can also be discriminatory. Under colonial rule, for example, parts of the population were excluded from formal land ownership and the economic opportunities it brings (Beinart and Delius, 2014; Kenfack Essougong and Teguia, 2019). The resulting tenure insecurity discourages investment, distorts resource allocation, and increases the likelihood of land conflicts (Kenfack Essougong and Teguia, 2019; Bekele et al., 2022; Mkandawire et al., 2025).

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.



LAND SYSTEMS Discussions

2.1.2 Land use restrictions

Often, zoning regulates the intensity or type of eligible land uses (Bruggeman et al., 2018). If aimed at limiting resource overuse, such as in forestry, or ecological damage from agricultural expansion at forest frontiers, this form of zoning can be social welfare-enhancing (Leite-Filho et al., 2021). However, land use restrictions can also be strategically imposed to discriminate against parts of the rural population, for example, by banning or restricting established land uses in parts of a country (Frankema, 2010). They may also positively or negatively affect other socioeconomic outcomes, such as employment, depending on the sector (Emran and Shilpi, 2020).

2.1.3 Market access restrictions

Market access restrictions can result from zoning laws that limit farmers' commercialisation opportunities (Abman and Lundberg, 2024). Affected consumers may also face limited choices and higher prices resulting from reduced competition, with implications for household dietary diversity and food security (Usman and Haile, 2022). Unless market restriction zones serve to limit natural resource overexploitation, as in the case of the Amazon Soy Moratorium (Heilmayr et al., 2020), they may constrain economic growth and impede poverty reduction (Karshenas and van der Geest, 2017). However, reduced commercialisation, for example, in protected areas, can lead to increased income and employment in adjacent and surrounding communities (Gupta et al., 2023). These restrictions can also encourage farmers to engage in collective action or work with institutions to improve market outcomes (Markelova and Mwangi, 2010; Naziri et al., 2015).

2.1.4 Restrictions on mobility of people and assets

Some colonial forms of land zoning restrict the movement of people and assets, such as the confinement of people in ethnic reserves or bans on livestock mobility (Werner, 1993; Miescher, 2012). These restrictions can prevent the optimal allocation of land and capital and lower the productivity of individuals and resources. Like market access restrictions, these forms of zoning can deprive affected populations of economic opportunities and lead to persistent marginalisation (Adelaja et al., 1989; Werner, 1993). Exceptions are mobility restrictions that respect human rights and are clearly justified by safety and protection in the case of an epidemic (Sekalala et al., 2020), or by conservation principles and safety measures, such as watershed and flood protection zones (Akasaka et al., 2022; Adams et al., 2023).

2.2 The persistence of zoning effects after removal or reform

The economic effects of discriminatory zoning may persist even after reforms or removal, with lasting impacts on economic outcomes. First, infrastructure investments in response to land zoning create path dependencies (Jedwab and Moradi, 2016), particularly in economically disadvantaged regions. Second, land tenure reforms are often insufficient to overcome historically entrenched patterns of unequal land ownership (Kenfack Essougong and Teguia, 2019). As a result, unequal patterns of asset

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

and wealth accumulation may persist after reforms (Baldomero-Quintana et al., 2025). Third, extended periods of market access restrictions can create persistent local economic structures, including via migration, that moderate rural development outcomes even after removal (Wyrwich, 2020; Valdaliso et al., 2025). This highlights the need to reduce market restrictions in promoting economic growth (Han and Wu, 2024).

3 Empirical approach

3.1 Study area

Namibia is situated in southwestern Africa and covers approximately 824,292 square kilometres, with a population of approximately 2.6 million (Namibia Statistics Agency, n.d.). Agriculture and livestock production constitute the primary livelihood for most of the rural population, with the agricultural industry accounting for approximately 6% of GDP (Namibia Statistics Agency, n.d.). Successive waves of colonial land expropriation and displacement have shaped the agricultural sector. Namibia's semi-arid and ecologically diverse landscape, spanning the Namib and Kalahari Deserts and the Great Escarpment (Goudie and Viles, 2015), varies considerably across our zones of interest (Mulwa and Visser, 2020; Siyambango et al., 2022).

The Veterinary Cordon Fence, which we refer to as the Redline (RL), divides Namibia into zones with different levels of market access for livestock farmers and levels of agricultural integration. Below, we further distinguish between two now-abandoned zones with different historical exposure to colonial zoning regulations: the Blueline (BL) zone and the Temporary Blueline (TBL) zone (Figure 2). More detail on the history of these zones is provided in Section 4.1.

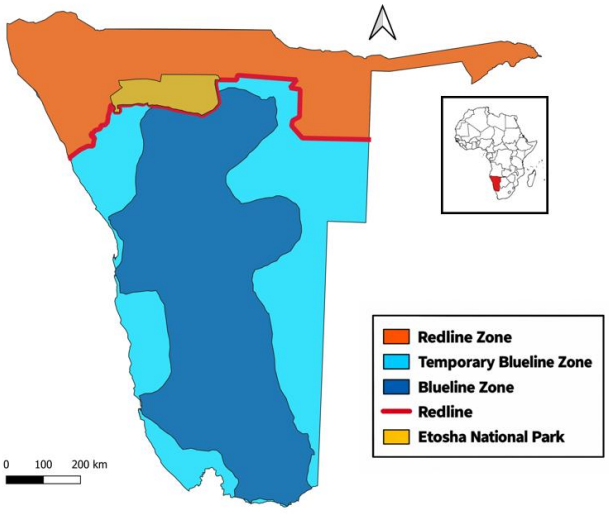


Figure 2: Zoning policies in Namibia. Note: The historical BL zone was reconstructed from the 1907 map of Namibia. The area between the RL and BL zones represents the TBL zone.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.



LAND SYSTEMS Discussions

3.2 Methods

We combine a historical review of Namibia's zoning policy with an empirical strategy linking historical zone classifications to contemporary wealth. Building on the theoretical framework above, our working hypothesis is that settlements in zones subject to discriminatory colonial zoning exhibit lower average wealth today than settlements in zones that were treated preferentially.

To examine the associations between historical zoning and contemporary wealth distribution in Namibia, we employ a multi-step empirical strategy. Spatial endogenous sorting resulting from historical and partially forced migratory movements (Miescher, 2012; Wallace and Kinahan, 2011) implies that the identifying assumptions underlying a spatial regression discontinuity design are violated at zoning boundaries (Imbens and Lemieux, 2008; Lee and Lemieux, 2010). We thus pre-process our data using propensity score matching (PSM) to address selection bias from the non-random spatial sorting of inhabited places across zone boundaries. We incorporate spatial lags of observed biophysical covariates into the PSM to account for spatial dependence in observed characteristics (Anselin, 1988; LeSage and Pace, 2009). Using the matched dataset, we run Ordinary Least Squares (OLS) regression as our main specification and compare results with baseline regressions using the unmatched dataset**,** always controlling for all available covariates and the biophysical spatial lag (Wooldridge et al., 2020).

The treatment variable is derived from historical maps that document major changes in zoning policies (Miescher, 2012, p. 209). We define three zones that differ in terms of zoning regulations and duration: the BL zone, TBL zone, and RL zone, as shown in Figure 2.

The regression model is specified as follows:

$$logIWI_i = \alpha + \beta_1 Z_i + \theta_i X_i + \varepsilon_i \quad (1)$$

where IWI_i is the international wealth index for inhabited place i, Z represents a dummy variable for zone comparison: BL vs. TBL or RL vs. TBL, where TBL is always 1 and RL and BL are always 0. α is the constant term, β_1 is the coefficient of interest measuring the average association between zone classification and localised wealth, and X_i is a vector of the control variables. While θ_i is the coefficient associated with the control variables. The control variables are: topography, rainfall, sand content, accessibility to mines, accessibility to RL gates, accessibility to major cities, and livestock production value. ε_i is the random error term.

We estimate the propensity score as the predicted probability that an inhabited place is classified as a TBL zone, based on pre-treatment biophysical controls, X_i, i.e., rainfall and sand content, and their spatial lags, WX_i, where w is a spatial weights matrix

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

based on a four-nearest neighbours(k) distance algorithm. We implement the PSM in R using the MatchIt package (Ho et al., 2011). Formally, the propensity score is estimated as:

$$\mathrm{P}(Z_i = 1 \mid X_i, WX_i) = F(X_i, WX_i;\, \theta) \quad (2)$$

Where $P(Z_i = 1 \mid X_i, WX_i)$ is the probability of TBL classification given observed covariates and their spatial lags, and $F(\cdot)$ is the estimated regression. We match each inhabited place in TBL to its nearest neighbours in the comparison group (RL or BL). We used a 1:2 matching ratio for the TBL–RL comparison, matching each observation in the TBL zone to two observations in the RL zone, because the number of observations in the RL zone was more than twice that in the TBL zone. We used a 1:1 matching ratio for the TBL–BL comparison, matching each TBL observation to one BL observation. We estimate the average treatment effect on the treated (ATT):

$$ATT = E[IWI(1) - IWI(0) \mid Z = 1] \quad (3)$$

Where $E[IWI\,(1) - IWI(0) \mid Z = 1]$ is the expected difference in wealth between TBL and their matched comparison inhabited places (RL or BL). The identifying assumption is that, conditional on X_i and WX_i, zone classification is independent of potential wealth outcomes, after accounting for observable geographic, economic, and historical characteristics and their spatial lags. Formally:

$$\{IWI(1), IWI(0)\} \perp Z_i \mid X_i, WX_i \quad (4)$$

We also impose the common support condition using a calliper of 0.2 standard deviations, restricting the analysis to TBL localities where the estimated propensity score falls within the range of the comparison group's propensity scores (Rosenbaum and Rubin, 1983; Heckman et al., 1997).

3.3 Robustness checks

To assess the robustness of our main findings, we conducted two robustness checks. First, to ensure our results are not driven purely by how the International Wealth Index (IWI) is constructed, we re-estimate all models using an alternative consumption-based wealth indicator, i.e., the log of the median of annual expenditure per person. The median annual expenditure captures a more immediate consumption flow, enabling us to examine our findings from two dimensions of household economic well-being (Stifel and Christiaensen, 2007). Second, we test whether our hypothesised main mechanism of wealth accumulation in the TBL zone, namely expansion of commercial agriculture, explains the observed spatial patterns of contemporary wealth. To do so, we replace the zone-based treatment variable (Z) in the equations above with a measure of commercial private agricultural land expansion.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

3.4 Data processing

Our main outcome variable is a spatially explicit wealth index at the settlement/village level. This variable is obtained from Lee (2022), who generated a remotely sensed asset-based IWI for inhabited places across Namibia.

Based on historical records, we construct the TBL treatment zone from the 1907 boundary shift, which constitutes a major documented adjustment to the Police Zone boundary**.** First, we scanned, georeferenced, and digitised the 1907 Police Zone boundary (BL) from the German South West Africa map reproduced in Miescher (2012, p. 47) in QGIS. Georeferencing was performed by matching clearly identifiable features, such as road intersections, rivers, and administrative boundaries, to their corresponding locations in OpenStreetMap (OpenStreetMap contributors, n.d.). Once satisfactory positional accuracy was achieved, the historical boundary was manually digitised to produce a vector layer for subsequent spatial analyses and was projected to the WGS 84 / UTM Zone 33S (EPSG:32733) coordinate reference system to ensure consistency across datasets. The TBL zone was then defined as the area between the BL and the current VCF (RL), serving as the treatment group in separate comparisons with the RL and BL zones.

Second, we draw on historical records of large private farms from the Atlas of Namibia Team (2022) to capture the timing of agricultural expansion**.** We classify each location according to the first period in which it became part of a large private farm (existing in 1902, 1902–1921, 1921–1937, 1937–1955, 1955–2001, or 2001–2020), using locations that were never classified as large private farms in 1902 as the reference category (Figure 3)**.**

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

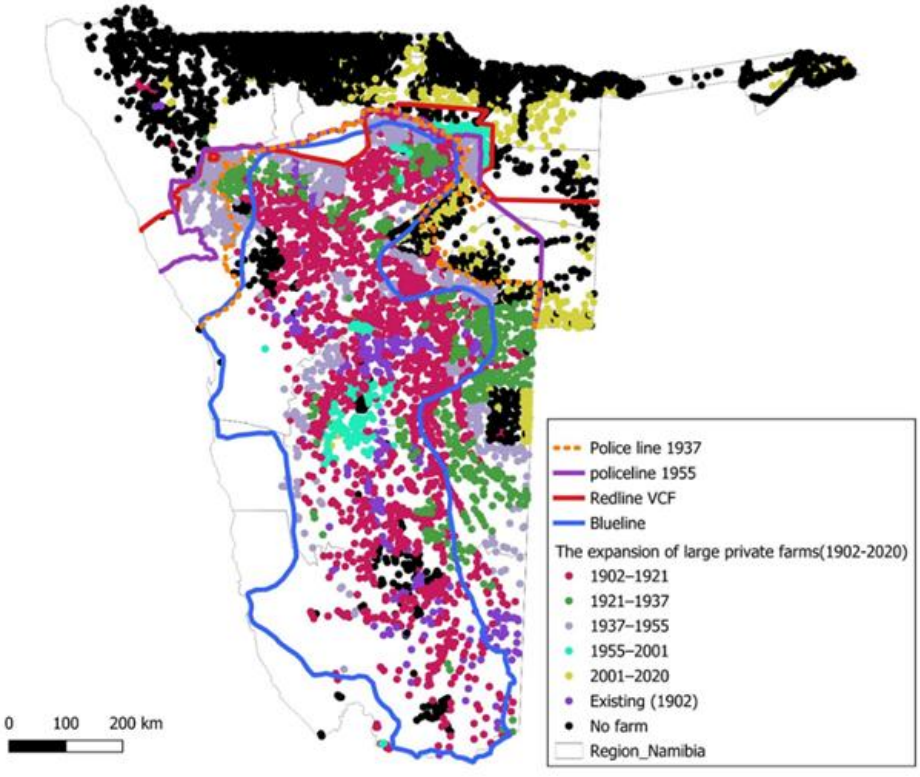


Figure 3: Contemporary settlement locations classified in terms of historical commercial farmland expansion in Namibia (1902–2020). Note: Points represent contemporary settlement locations classified by the period of commercial farmland expansion (1902–2020). The lines indicate historical zoning boundaries, including the Police Lines (1937 and 1955), the historical BL, and the existing RL.

We collected all other covariates from multiple sources (Table 1), including biophysical and socio-economic data from Digital Namibia, WorldClim, ISRIC-World Soil Information, as well as the Atlas of Namibia and the Atlas of Digital Namibia, which we processed to fit the analysis data.

Additionally, to capture spatial heterogeneity and infrastructural disparities within the study area, we measure accessibility as travel time in minutes rather than Euclidean distance, accounting for variation in road-specific travel speeds and terrain. Specifically, we compute the travel time from each inhabited place to the nearest RL gate, mining site, and major city or town. Major cities and towns include Windhoek, Walvis Bay, Rundu, Oshakati, Swakopmund, Rehoboth, Katima Mulilo, Grootfontein, Ondangwa, Okahandja, Otjiwarongo, Tsumeb, Gobabis, Keetmanshoop, and Lüderitz, all of which are historically and economically important points of interest for land use and wealth distribution in Namibia (Miescher, 2012; Wallace and Kinahan, 2011). We construct a friction surface by integrating transportation infrastructure data with land cover classifications from the European Space Agency's 2015 land cover dataset (Lamarche et al., 2017). The friction surface assigns a travel speed to each grid cell by road category (trunk, main, and district roads) and adjusts for terrain using a 30-meter SRTM

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Digital Elevation Model. We computed accessibility surfaces for each POI in GRASS within QGIS, following the algorithms of Nelson et al. (2019) and Weiss et al. (2018).

The original dataset has 9,336 observations, from which 697 were dropped due to missing values in one or more control variables. The final sample comprises 8,639 observations: 4,276 settlements in the RL zone, 2,696 in the BL zone, and 1,667 in the TBL zone. We standardised all continuous explanatory variables to z-scores (mean = 0, standard deviation = 1) to facilitate comparisons across variables measured on different scales and improve numerical stability. The treatment indicators (RL, BL, and TBL) and the wealth index remain in their original scales.

Table 1: Variable description and data sources.

Variable	Description	Original Resolution	Unit/Range	Source
International wealth index (IWI)	Satellite-predicted, asset-based wealth index estimates for inhabited villages in 2020	1-mi²	0-100	Lee (2022).
Topography	Shuttle Radar Topography Mission (SRTM) 30-metre image for Namibia.	30 m	Metres	Namibia SRTM DEM, 30 metres, in Regional Centre for Mapping of Resources for Development (2017)
Rainfall	Total precipitation (mm) for the year 2020.	2.5 minutes (~21 km² at the equator)	Millimetre	CRU-TS 4.06 (Harris et al., 2020) downscaled with WorldClim 2.1 (Fick and Hijmans, 2017).
Soil	Percentage sand content at a depth of 15-30 cm.	250m	g/100g (w%)	ISRIC soil grid (Poggio and de Sousa, 2020)
Mines	Travel time to the nearest mine, measured in minutes.	Geolocation	Minutes	Original data from Namibia Statistics Agency (n.d.)
Redline (RL)	Georeferenced location of the RL, covering settlements north of the RL	Geolocation	Dummy 1/0	Namibia Statistics Agency (n.d.)
Blueline (BL)	Georeferenced and digitised location of the BL, covering settlements within the BL	Geolocation	Dummy 1/0	Miescher (2012)
Temporary Blueline (TBL)	Settlements located between the RL and BL	Geolocation	Dummy 1/0	Own elaboration from RL (Namibia Statistics Agency (n.d.)) and BL (Miescher, 2012)
Major cities	Travel time to the nearest major city or town in minutes.	Geolocation	Minutes	Original data from Namibia Statistics Agency (n.d.)

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Variable	Description	Original Resolution	Unit/Range	Source
Gates	Travel time to the nearest RL gate in minutes.	Geolocation	Minutes	Original data from Namibia Statistics Agency (n.d.)
Livestock production value	Value of livestock production in 2018. Based on official regional livestock statistics and spatial distribution using 2010 density estimates for cattle.	10-km	N$ / km² / year	Atlas of Namibia Team (2022)
Median expenditure	Median annual expenditure per person (2020). The median represents the 50th percentile of household expenditure within an area.	Geolocation	N$	Atlas of Namibia Team (2022)
Farm dummy	Expansion of large private farms (1902–2020), classified by period (1902, 1902–1921, 1921–1937, 1937–1955, 1955–2001, and 2001–2020). "No farm" refers to settlements outside areas established as large private farms.	A factor of the historical period of the farms	Dummy 1/0 (1= became farm in comparison year, 0= otherwise)	Atlas of Namibia Team (2022)
Herero ancestral land	Digitised from a historical map. See Figure A3.			Gariwo Foundation (n.d.)
Waterberg plateau	Spatial boundary of the Waterberg Plateau, manually digitised and georeferenced using OpenStreetMap as the source of geographic information.	Digitised polygon	Spatial boundary	OpenStreetMap contributors (n.d.)

240

Figure 4 shows the distribution of the IWI across the zones considered in our analysis. The clusters of relatively wealthy inhabited places within and immediately around the BL and additional concentrations between the BL and RL in central Namibia align with our working hypothesis, given that areas north of the RL exhibit relatively lower average levels of wealth.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

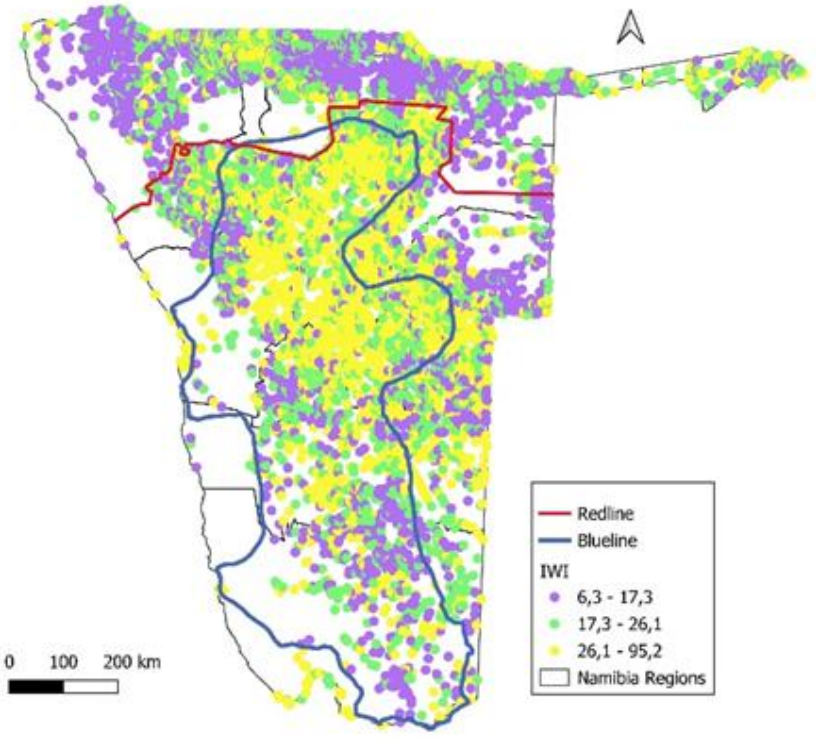


Figure 4: Spatial distribution of settlements by IWI classes across zones. Note: Points represent settlement locations classified into three IWI quantile classes. Purple, green, and yellow indicate low, medium, and high IWI values, respectively. The lines represent the historical BL and existing RL boundaries.

3.5 Summary statistics of variables across zones

Table 2 presents summary statistics for the three zones, suggesting a welfare gradient across them. The BL zone shows the highest wealth index and median annual expenditure per person, followed by the TBL zone. The RL zone shows the lowest values on both measures. Interestingly, settlements in the RL receive higher average rainfall than those in the other zones, despite exhibiting lower wealth levels. This suggests that differences in rainfall alone cannot explain the observed wealth gradient.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Table 2: Summary statistics

Variable	Redline zone (N=4,276)	Temporary Blueline zone (N=1,667)	Blueline zone (N=2,696)
Wealth index	20.46 (9.63)	27.17 (14.80)	33.14 (18.66)
Median expenditure	1,225.11 (719.79)	2,193.00 (1,412.71)	2,997.02 (2,398.99)
Gate (minutes)	11,089.85 (4,921.48)	16,819.63 (10,091.58)	18,284.55 (8,918.90)
Sand content	74.13 (9.08)	73.96 (6.44)	65.94 (7.34)
Rainfall	55.09 (21.78)	34.05 (19.75)	22.32 (13.68)
Topography	1,117.28 (106.80)	1,220.07 (203.27)	1,336.17 (233.55)
Mines (minutes)	11,466.81 (5,016.58)	10,133.69 (5,354.20)	6,336.46 (3,305.65)
Major city (minutes)	6,966.11 (5,606.68)	9,115.75 (4,154.68)	5,381.41 (3,127.63)
Livestock production	7,014.10 (5,910.29)	7,831.54 (4,035.33)	8,991.19 (7,653.84)
Large private farms			
Farms (1902) dummy	0.001 (0.03)	0.02 (0.15)	0.11 (0.32)
Farms (1902–1921) dummy	0.01 (0.07)	0.17 (0.38)	0.54 (0.50)
Farms (1921–1937) dummy	0.001 (0.03)	0.20 (0.40)	0.10 (0.30)
Farms (1937–1955) dummy	0.001 (0.04)	0.22 (0.42)	0.11 (0.31)
Farms (1955–2001) dummy	0.00 (0.00)	0.04 (0.19)	0.05 (0.22)
Farms (2001–2020) dummy	0.06 (0.24)	0.12 (0.32)	0.01 (0.08)
No farm (dummy)	0.93 (0.25)	0.23 (0.42)	0.08 (0.28)

Note: Standard deviations are shown in parentheses.

The historical expansion dynamics of private commercial farms in Namibia further support this notion. In the RL zone, approximately 93% of settlements were never located inside commercial farmland areas, compared to 8% in the BL zone. In the latter, most farms were established between 1902 and 1937, during the colonisation period.

Covariate balance was assessed using absolute standardised mean differences (ASMD), which improved substantially after matching in both the TBL–RL and TBL–BL comparisons (Figure A4).

4 Results

We start by reviewing the historical precedents of Namibia's zoning policy and then present our empirical results focusing on the association between zoning regulations and the IWI, as well as complementary robustness checks.

4.1 Colonial and post-colonial zoning

The colonisation of South-West Africa, now Namibia, began under German colonial rule. German authorities forcibly displaced indigenous settlers, enabling European settlers and companies to claim productive land (Mendelsohn et al., 2002). A defining event during this period was the Herero–Nama War (190–1908), which colonial authorities instigated to extend the eastern border, displace the Herero-Nama people from their ancestral land (see Figure A3), and secure additional land for European settlers (Gewald, 1999; Miescher, 2012; Werner, 1993; Tjirera, 2023). It resulted in a massacre involving the death of 50,000–65,000 Herero and 10,000 Nama. Hereroland is shown to have more fertile soil for agriculture than the areas just

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

above and below it (Figure A3). Additionally, part of the Waterberg region lies within the Hereroland, providing reliable water resources for livestock production. These agricultural and strategic advantages made the area a key target for German colonial expansion and settler occupation. This led to the securing of the area for European settlements and commercial livestock farming (Gewald, 1999; Werner, 1993; Melber, 2019). The German defeat in World War I led to the South African administration in Namibia in 1915, which maintained control until Namibia gained independence in 1990.

The origins of Namibia's zoning policies can be traced to the Rinderpest Cordon of 1896–1897 (see Figure A1), established to control the spread of rinderpest. The first cordon developed into a military outpost border controlling human and animal movements into central and southern Namibia (Miescher, 2012, p. 20; Schneider, 2012). In 1905, the German colonial rulers formalised this boundary by drawing a BL on colonial maps to demarcate a so-called Police Zone border, effectively separating colonial agricultural zones from indigenous communal areas (Miescher, 2012, p. 43; Werner and Odendaal, 2010). This border served as both a veterinary cordon and an administrative frontier, later reinforced by colonial policing structures (Katjavivi, 1988, p. 149; Wallace and Kinahan, 2011; Miescher, 2012, pp. 44–49). The Police Zone essentially institutionalised the German colony, where major commercial activities such as agriculture and mining took place, as well as the communal areas of Namibia (Miescher, 2012, p. 48). On March 15, 1907, colonial authorities issued a decree stating that farmers who settled outside the Police Zone boundary were at their own risk and would receive only limited assistance (Miescher, 2012, p. 47). Regardless, German settlers continued to establish new farms outside the Police Zone (Miescher, 2012, pp. 48–50). By 1907, increased labour recruitment accelerated the movement of indigenous Namibians from northern Namibia to central and southern regions, where they worked on mining sites and European settler farms, which were the country's economic regions (Wallace and Kinahan, 2011; Lyon, 2021).

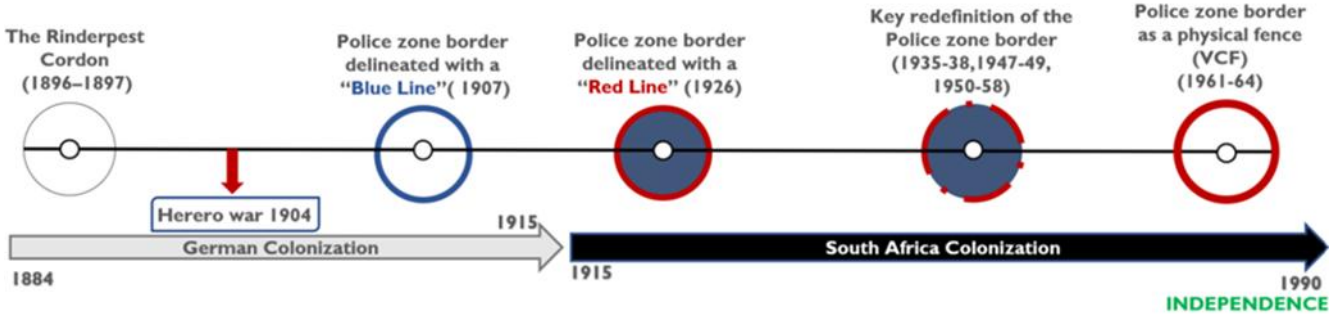


Figure 5: Development of zoning policies and changes in colonial administration in Namibia from 1884 to 1990. Adapted from Miescher (2012).

Figure 5 presents the full trajectory of the zoning policy from 1884 to 1990. After the German defeat, South Africa assumed control in 1915 and prioritised settler mobility and market protection (Miescher, 2012, p. 69). The Prohibited Areas Proclamation (1916) and subsequent regulations redelineated the Police Zone until 1928. Following these adjustments, the

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

adjusted boundary was depicted with a RL on the official map of Namibia, which was used to depict the new evolving boundary that divides the country into veterinary and land-use zones that *de facto* also served as a border for the expansion of formal settlements (Miescher, 2012, p. 129).

An outbreak of foot-and-mouth disease in the Gobabis district in 1934 (Schneider, 2012) reinforced the rationale for the veterinary cordon to protect the Police Zone and restrict the movement of people and animals to curb the spread of disease on commercial farms (Miescher, 2012). The Great Depression of the 1930s encouraged further efforts to protect the economic region of Namibia, which was dominated by white settlers' farms and mining sites, in which the status quo of zoning policies was maintained (Miescher, 2012; Werner, 1993). Successive expansions of the veterinary cordon followed: the Lardner-Burke Commission (1947) recommended enlarging the Police Zone to provide more farmland to settlers (Katjavivi, 1988, p. 14; Miescher, 2012), and the "A Farm for Every Settler" policy (1945–1964) led to extensive land reallocation, further marginalising communal farmers (Katjavivi, 1988; Miescher, 2012, p. 150). In 1961, after several adjustments to the Police Zone border, a physical border with eight access gates, the Veterinary Cordon Fence, known today as the RL, was established for the control of foot-and-mouth disease and finalised by 1964 (Miescher, 2012, p. 101). Until today, this RL restricts access by northern cattle farmers to the southern and central Namibia cattle markets (Miescher, 2012; Naha et al., 2023). Attempts to address the resulting inequalities through initiatives that improve market integration have been constrained by complex regulations, limiting their impact (Naziri et al., 2015; Nehoya et al., 2026).

The BL, imposed by the colonisers to identify the country's economically useful zone (Miescher, 2012, pp. 60-61), was systematically shifted towards today's RL to increase access to productive agricultural land for colonisers, while systematically expelling indigenous communities from customary lands (Werner, 1993; Gewald, 1999; Wallace and Kinahan, 2011; Miescher, 2012, p. 60). The establishment of the BL in the early 20th century and its subsequent reinforcement and extension under South African rule effectively divided the country into a settler-dominated, commercial-agricultural zone and communal indigenous areas (Miescher, 2012, p. 96; Silvester et al., 1998). According to Miescher (2012, p. 100–101), adjustments to the border of the Police Zone constitute political shifts that align with large private farmland expansion as summarised in Table 2. These shifts show a consistent pattern of power asymmetry in which European settler farmers demanded that the Police Zone boundary be pushed further North (Miescher, 2012, pp. 141–143). Subsequently, boundary adjustment was also linked to settler demand for additional grazing land, especially during drought periods (Miescher, 2012, pp. 149–150).

The post-independence land administration differed from that under colonial rule. In the Northern region, land is managed under customary tenure controlled by traditional authorities, whereas in the Southern region, land administration is bureaucratic and based mainly on permanent ownership (Henneberry and Barrows, 1990; Mendelsohn et al., 2002). In particular, Namibia introduced a market-led land reform to redistribute previously colonial commercial farmland to

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

disadvantaged indigenous Namibians (Lahiff, 2007). However, the land reform is limited by the legislative framework and land policies in the country, and has struggled to address unequal historical land ownership (Mundia and Haimbili, 2023).

4.1.1 Commercial farm expansion

The private commercial farm expansion from 1902 to 2020 (Figure 3) mirrors the historical shifts in Namibia's zoning policy. The early period covers the late German colonial era and the early South African colonial era. Importantly, the Herero–Nama War of 1904–1908, which led to the displacement of indigenous Herero from their ancestral land, created an opportunity for large-scale commercial farm expansion in Namibia's colonial period (Werner, 1993; Wilson, 2023). Subsequent periods of expansion in 1921–1937, 1937–1955, and 1955–2001, mostly around the area of adjustment of the BL (Figure 3), are consistent with Miescher's (2012) argument that expansion of the Police Zone took productive land from indigenous Herero-Nama in favour of predominantly non-native commercial farmers. Critically, about half of contemporary settlements in Namibia, mostly in the RL zone, have never been exposed to commercial farmland expansion (Figure 3). Land ownership patterns after independence further highlight this divide. As of 2018, 86% of the land used for commercial farming was privately owned, with 70% in the hands of private landowners, including large private farms (Namibia Statistics Agency, n.d.).

Following Namibia's independence in 1990, the Veterinary Cordon Fence (VCF) was retained primarily for animal disease control and to safeguard export markets for livestock products (Schneider, 2012). While its veterinary function differs from the broader political objectives of earlier colonial boundaries, the fence continues to separate areas characterised by markedly different production systems, market access, and institutional support (Mendelsohn et al., 2002). Although the original colonial border, the Police Zone, no longer exists, the historical spatial trajectory suggests long-term path dependence in land use, infrastructure, and economic investment (Werner, 1993; Wallace and Kinahan, 2011).

4.1.2 Migration under the contract labour system

The contract labour system mobilised indigenous Namibians from northern Namibia outside the Police Zone to work in mines and commercial farms within the Police Zone. The system was operated by the South West Africa Native Labour Association (SWANLA), a semi-governmental agency that administered indigenous workers across the Police Zone. Workers were issued six- to twelve-month contracts, housed in single-sex compounds, prohibited from bringing their families or changing employers, and required to wear a copper or plastic bracelet as identification under coercive working conditions (Werner, 1993; Wallace and Kinahan, 2011; Miescher, 2012). According to Moorsom (1979), as of 1938, about 43% of the total black labour force were contract workers, and this increased to 83% in 1971, reflecting over two-thirds of the male labour from northern Namibia drawn into the contract system. This migration was driven by colonial labour recruitment systems that forcibly extracted indigenous labour, mainly through labour migration routes from northern communal territories such as

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Ovamboland, Okavango, and Caprivi toward central and southern Namibia's white settler farms, mining sites, and municipalities (Silvester et al., 1998; Miescher, 2012, p. 129).

Importantly, while the indigenous workers were integrated into the Police Zone through wage employment (Moorsom, 1977), they were largely excluded from owning their own farms and benefiting from the colonial administrative infrastructure, credit system, and public investment concentrated in the Police Zone (Werner, 1993; Wallace and Kinahan, 2011; Miescher, 2012). Consequently, this suggests labour migration reinforced economic disparities across the border, facilitating accumulation of assets, infrastructure, and institutional capacity in the Police Zone, widening the economic development gap between non-native and systematically excluded native Namibians (Werner, 1993). The contract labour system was abolished in 1977 through the General Law Amendment Proclamation, after the landmark strikes of 1971–1972, when over 25,000 contract labourers in the farm, mining, and municipal sectors protested against a system they characterised as slavery (Wallace and Kinahan, 2011).

These historical patterns suggest that contemporary wealth distribution in Namibia may still reflect colonial land zoning policies implemented under German and South African rule. Forced and voluntary movements between economic zones may help explain the spatial wealth disparities observed in this study.

4.2 Econometric analysis

4.2.1 Baseline regression and propensity score matching

Table 3 presents the regression estimates for three model specifications: OLS (1), OLS with controls (2), and propensity score matching with covariates and their spatial lags (3), separately for the comparison between the RL and TBL zones, and the BL and TBL zones. The full coefficient estimates are presented in Table A1.

Table 3: Association between zoning policy and wealth: OLS and PSM Estimates.

	Redline Comparison			Blueline Comparison		
Variables	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
TBL dummy	0.232***	0.299***	0.206***	-0.180***	0.080***	0.088***
	(0.205, 0.259)	(0.270, 0.328)	(0.163, 0.248)	(-0.212, -0.148)	(0.041, 0.120)	(0.037, 0.140)
Additional controls	No	Yes	Yes	No	Yes	Yes
Spatial lag	No	No	Yes	No	No	Yes
Constant	2.936***	2.966***	3.012***	3.349***	3.127***	3.081***
	(2.925, 2.948)	(2.952, 2.980)	(2.983, 3.040)	(3.328, 3.369)	(3.096, 3.159)	(3.029, 3.133)
Observations	5943	5943	2009	4363	4363	1810

Note. 95% confidence intervals in parentheses. *** p<0.01, ** p<0.05, * p<0.10. (1) Baseline OLS without matching; (2) OLS with controls, without matching; (3) OLS regression on the propensity-score-matched sample, incorporating covariates and their spatial lag in the matching procedure, and subsequent regression. The dependent variable is the log IWI. TBL settlements constitute the treatment group in both comparisons, with RL and BL serving as the respective comparison groups.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Across all specifications for the RL comparison, TBL zone wealth is consistently higher than in the RL zone. Our preferred specification using spatially lagged covariates yields the most conservative estimate, suggesting that settlements in the TBL zone are on average 20% wealthier than settlements in the RL zone.

Estimates for the BL comparison group are smaller and less consistent, with the sign of the TBL coefficient changing between the baseline OLS and matching-based specifications. Our preferred specification in column (3) indicates approximately 9% higher wealth in the TBL zone relative to the BL zone. Historical accounts offer potential explanations for why rural wealth in the TBL zone is similar to or even slightly higher than in the BL zone. Rather than reflecting the economic recovery of settlements that existed before the BL expansion, the result may be linked to the expansion itself. The BL was strategically extended to accommodate commercially oriented settlers who previously lived in the BL zone, seeking better access to indigenous labour, new agricultural land, and water resources for livestock production (Miescher, 2012; Werner, 1993). These opportunities may have facilitated wealth accumulation in the TBL zone, while many of its original inhabitants migrated to the RL zone.

In sum, the results from both comparison groups are consistent with the interpretation that contemporary spatial discontinuities in the distribution of rural wealth in Namibia are linked to past land zoning decisions that restrict market access until today and involved land-use and land-access restrictions during colonial times.

4.3 Robustness checks

4.3.1 Alternative welfare measure

First, we assess the sensitivity of our main finding to the choice of welfare indicator. Table 4 (see the full results in Table A2) repeats the estimates presented in Table 3 using the log of median annual expenditure per person as the dependent variable. We find the results to be broadly consistent across all models for both RL and BL comparisons. In the RL comparison, settlements in the TBL zone exhibit substantially higher expenditure levels than those in the RL zone. The relative difference is larger than in the models using the log of the IWI as the dependent variable. Consumption expenditure differences between the two zones thus seem to be larger than differences in IWI. This suggests that economic differences between the two zones are more pronounced when measured using expenditure than when measured using the IWI.

The models for the BL comparison exhibit the same sign reversal as in the analysis using the IWI, but the coefficient estimates remain small. Hence, although the TBL zone had much shorter exposure to preferential colonial zoning regulations than the original BL zone, contemporary TBL zone settlements compare favourably in wealth and consumption expenditure with settlements in the BL zone.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Table 4: Association between Zoning Policy and Consumption Expenditure; OLS and PSM Estimates. Using two comparison groups (TBL and RL zone comparison, and TBL and BL zone comparison), with TBL as the treatment group. Dependent variable: log median annual expenditure per person

	Redline Comparison			Blueline Comparison		
Variables	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
TBL (dummy)	0.546***	0.583***	0.524***	-0.251***	0.093***	0.083***
	(0.525, 0.567)	(0.562, 0.605)	(0.494, 0.554)	(-0.278, -0.224)	(0.064, 0.121)	(0.049, 0.116)
Additional controls	No	Yes	Yes	No	Yes	Yes
Spatial lag	No	No	Yes	No	No	Yes
Constant	7.052***	7.076***	7.085***	7.848***	7.444***	7.453***
	(7.043, 7.061)	(7.065, 7.087)	(7.062, 7.108)	(7.830, 7.867)	(7.420, 7.468)	(7.415, 7.490)
Observations	5943	5943	2009	4363	4363	1810

Note: 95% confidence intervals are in parentheses. *** p<0.01, ** p<0.05, * p<0.10. (1) Baseline OLS without matching; (2) OLS with controls, without matching; (3) OLS regression on the propensity-score-matched sample, incorporating covariates and their spatial lag in the matching procedure and subsequent regression. TBL settlements constitute the treatment group in both comparisons, with RL and BL serving as the respective comparison groups.

Overall, these findings suggest that our main results are robust to the choice of welfare indicator, with both asset wealth and consumption expenditure showing similar patterns of spatial differences across zones.

4.3.2 Historical farm establishment and contemporary wealth

In Table 5, we re-estimate our models by replacing the TBL zone dummies with the historical farmland expansion dummies to corroborate the conjecture that wealth accumulation in the TBL zone occurred predominantly through commercial farmland expansion. The coefficient estimates can be interpreted as showing the difference between settlements in locations that were exposed to expanding commercial farmland in the various historical periods compared to settlements in locations that experienced no such exposure. In both comparison groups, historical farmland expansion is mostly associated with higher contemporary wealth than in locations without such expansion. Consistent with the results using zone dummies in Table 3, however, coefficient magnitudes are smaller in the BL comparison than in the RL comparison.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Table 5: Contemporary wealth differences by period of historical large private farm establishment in Namibia

	Redline Comparison		Blueline Comparison	
Variables	**(1)**	**(2)**	**(1)**	**(2)**
Farm (1902) dummy	0.077	0.111	0.372***	0.140**
	(-0.049, 0.203)	(-0.115, 0.337)	(0.295, 0.449)	(0.017, 0.262)
Farm (1902–1921) dummy	0.365***	0.428***	0.256***	0.215***
	(0.305, 0.425)	(0.329, 0.526)	(0.204, 0.307)	(0.140, 0.290)
Farm (1921–1937) dummy	0.218***	0.308***	0.149***	0.101**
	(0.166, 0.269)	(0.212, 0.404)	(0.089, 0.209)	(0.019, 0.183)
Farm (1937–1955) dummy	0.229***	0.235***	0.117***	0.008
	(0.182, 0.276)	(0.165, 0.305)	(0.060, 0.173)	(-0.069, 0.086)
Farm (1955–2001) dummy	0.352***	0.291***	0.193***	0.176
	(0.236, 0.467)	(0.158, 0.425)	(0.113, 0.273)	(-0.036, 0.389)
Farm (2001–2020) dummy	-0.099***	-0.052	-0.070	-0.059
	(-0.144, -0.053)	(-0.122, 0.018)	(-0.162, 0.022)	(-0.204, 0.086)
Constant	2.959***	2.904***	3.105***	3.120***
	(2.947, 2.971)	(2.882, 2.927)	(3.060, 3.150)	(3.057, 3.183)
Observations	5943	2009	4363	1810

Note: 95% confidence intervals in parentheses. *** p<0.01, ** p<0.05, * p<0.10. (1) OLS with large private farms established as an independent variable (farm dummy), (2) OLS regression on the propensity-score-matched sample, incorporating covariates and their spatial lag in the matching procedure. The dependent variable is the log IWI.

Importantly, estimates are close to zero for farmland expansion that occurred after independence, suggesting negligible impacts of recent farmland expansion on contemporary wealth patterns in settlements. Estimates using our alternative dependent variable (log median annual expenditure per person) are presented in Table A3 and are largely consistent with the results in Table 5. Taken together, our quantitative analysis is consistent with historical accounts that highlight the path dependence of wealth and historical farms. Crucially, the interlocking nature of market access restrictions, land use restrictions, land access restrictions, and the controlled mobility of people and assets reinforces that zoning policy and large private farm establishment cannot be treated as separable institutions; each reinforced the other, especially due to the historical trajectory from the BL to the RL zones, which has spatially determined the distribution of farms in Namibia, leading to systematic wealth accumulation in the Police Zone (Werner, 1993; Miescher, 2012, p. 203), as shown in Figure 3 above. This is consistent with Acemoglu et al. (2001), who argue that colonial institutions form interlocking systems, making the land policy and agricultural development of colonial Namibia inherently difficult to disentangle (Werner, 1993).

5 Discussion

In this section, we discuss our results and contextualise them within the historical trajectory of Namibia and the land zoning mechanisms. Our findings indicate persistent spatial differences in contemporary wealth across Namibia's historical zoning areas. While settlements north of the Redline remain considerably less wealthy than those in the Temporary Blueline zone, wealth differences between the Temporary Blueline and the original Blueline zones are much smaller. This contrast suggests

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

that the relationship between colonial zoning and contemporary wealth depends not only on historical exposure to zoning regulations but also on the economic transformations that accompanied changes in these boundaries.

First, settlements in the TBL zone are consistently associated with higher contemporary wealth than those in the RL zone across specifications, including after incorporating spatially lagged covariates. The smaller and less consistent differences between the TBL and BL zones suggest that contemporary wealth patterns may reflect not only historical zoning boundaries but also subsequent changes in land use and economic opportunities. Historically, commercial agriculture and economic activity were concentrated in the Police Zone, while communities outside faced restrictions on land access, livestock commercialisation, and mobility (Werner, 1993; Miescher, 2012). Our findings are therefore consistent with wider evidence that colonial institutions can generate persistent spatial differences through geographically differentiated access to land and economic opportunities (Acemoglu et al., 2001; Frankema, 2010). They are also consistent with Jedwab and Moradi (2016), who show that historically determined market access patterns can create persistent spatial differences in development outcomes. Our findings also align with research showing that zoning can reproduce spatial differences by shaping access to land and economic opportunities (Shertzer et al., 2016; Lens, 2022). We contribute to this literature by showing that historical veterinary zoning is associated with contemporary rural wealth differences.

Second, evidence suggests path dependence in the association between the historical large private farm establishment and contemporary wealth. Settlements in areas incorporated into large private farm establishments in earlier historical periods are generally associated with higher contemporary wealth than those without such historical farm establishments. This pattern is consistent with historical accounts showing that colonial land dispossession and commercial farm expansion were intertwined with the spatial patterns of Namibia's colonial economy (Werner, 1993; Miescher, 2012). It also corresponds with broader evidence linking colonial land policies to persistent inequalities in access to land and productive resources (Frankema, 2010; Lawrence and Sajid, 2025). Our findings suggest that, rather than treating zoning and large private farm establishments as separate historical institutions, their development was interconnected: boundary changes facilitated private large-farm expansion, while commercial agricultural activities reinforced the economic significance of the spatial divisions created by colonial zoning policy. The different patterns of farm establishment after independence, however, suggest that the historical association between commercial farm establishment and wealth has not simply been reproduced in the post-colonial period. Areas associated with farms established during 2001–2020 do not exhibit the same pattern of asset-based wealth as those associated with earlier farm establishment. This is consistent with Southern African research showing the difficulty of overcoming historically unequal land distributions through post-colonial land reform and that changes in formal land allocation do not necessarily eliminate inherited spatial differences in productive resource endowments and economic opportunities (Lahiff, 2007; Cousins, 2016; Tjirera, 2023). It is also in line with Kotikot et al. (2025), who highlight that historical land policies can be associated with contemporary spatial and land-use patterns in agropastoral landscapes.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Historical labour migration across zoning boundaries represents another potential mechanism through which spatial wealth differences may have persisted. The contract labour system directed indigenous workers from northern communal areas to farms, mines, and other economic activities within the Police Zone, while maintaining restrictions on settlements, land ownership, and mobility, with no similar patterns of migration of white settlers to the north (Moorsom, 1977; Silvester et al., 1998; Lyon, 2021). Access to wage employment, therefore, did not necessarily imply equivalent access to land and productive assets through which longer-term wealth could accumulate or reproduce in the RL zone.

The alternative welfare measure reinforces our main findings. Notably, the TBL–RL difference is larger for median annual expenditure per person than for the IWI, suggesting that spatial disparities are more pronounced in consumption expenditure than in asset-based wealth. This finding is consistent with broader evidence that market accessibility is associated with household economic well-being, as Usman and Haile (2022) find that households located closer to markets have higher consumption expenditure, more diverse diets, and lower food insecurity in Ethiopia and Tanzania.

Additionally, the TBL–BL comparison provides further insight into the historical implications of colonial land zoning. The significant positive associations between the TBL zone and both IWI and median annual expenditure, after controlling for observed characteristics, may be understood in the context of the expansion of the BL, which extended opportunities for commercial farming into the TBL zone for farmers and settlers initially located within the BL zone (Katjavivi, 1988, p. 14; Miescher, 2012, p. 43). This historical expansion of commercial farming, alongside the unequal access to land and economic opportunities discussed above, may be linked to why settlements in the TBL zone exhibit relatively higher wealth and expenditure levels than those in the BL zone after accounting for observed characteristics.

Taken together, our findings are consistent with the path dependence of colonial institutions in which zoning, land access, commercial farm establishment, market integration, and labour mobility were interconnected and mutually reinforcing elements of colonial spatial organisation rather than independent historical processes. Our findings extend those of Kohima et al. (2023) and Melber et al. (2025) on the persistence of colonial spatial planning in Namibia by showing that historical agricultural and veterinary zoning policy is also associated with contemporary rural wealth differences.

Several limitations qualify these findings. We primarily rely on cross-sectional IWI data, and missing outcome and control data reduce the available sample size. Although PSM and spatial covariates improve comparability, unobserved differences may remain. Furthermore, some contemporary controls, such as market accessibility, may themselves have been influenced by historical zoning. Present-day settlements and populations may also differ from those originally affected by colonial policies**.** The estimates therefore identify associations rather than causal effects. Historical boundaries are reconstructed in the literature with archival evidence, while variation in their local implementation cannot be fully observed. Finally, following the colonial history of the zoning policy, zoning, farm expansion, market access, and migration evolved jointly; their individual contributions to contemporary wealth cannot be separately identified.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

6 Conclusion

This study examines whether Namibia's historical colonial zoning is associated with contemporary spatial differences in wealth. Combining historical evidence with spatial econometric analysis, we find persistent differences in contemporary wealth across the historical zoning regions. Settlements in the TBL zone are consistently associated with higher wealth than those in the RL zone. At the same time, differences between the TBL and BL zones are smaller and more sensitive to observable characteristics, suggesting that the historical zoning boundaries may have persisted beyond the colonial institutions that originally established these boundaries. Likewise, historical large private farm establishments are generally associated with contemporary wealth, particularly in areas incorporated into commercial farming earlier.

Linking the evolution of the RL from the BL, our findings suggest that contemporary spatial wealth differences reflect not only historical zoning boundaries but also the broader spatial organisation of Namibia's colonial economy, which interconnected zoning, commercial farm expansion, unequal land access, market integration, and controlled labour mobility.

Our findings provide useful context for contemporary spatial development planning in Namibia. The persistence of lower wealth in historically marginalised areas implies that current policy efforts in the areas of land reform, agricultural commercialisation, market integration, and rural development could benefit from accounting explicitly for inherited spatial differences in access to productive resources and economic opportunities.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Appendix A

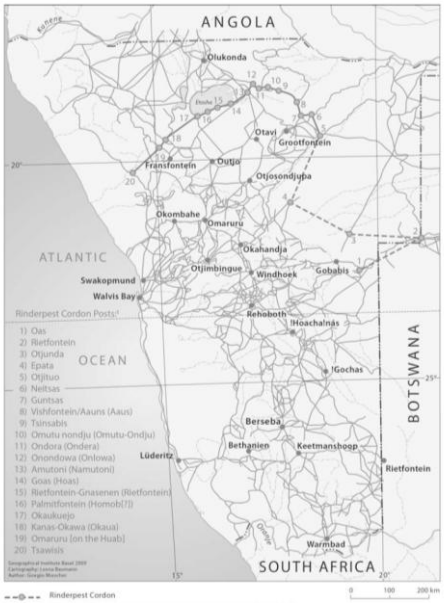


Figure A1: Roads of Namibia (1894) and Rinderpest cordon (1896/97). Source: Map adapted from Miescher (2012, p. 24).

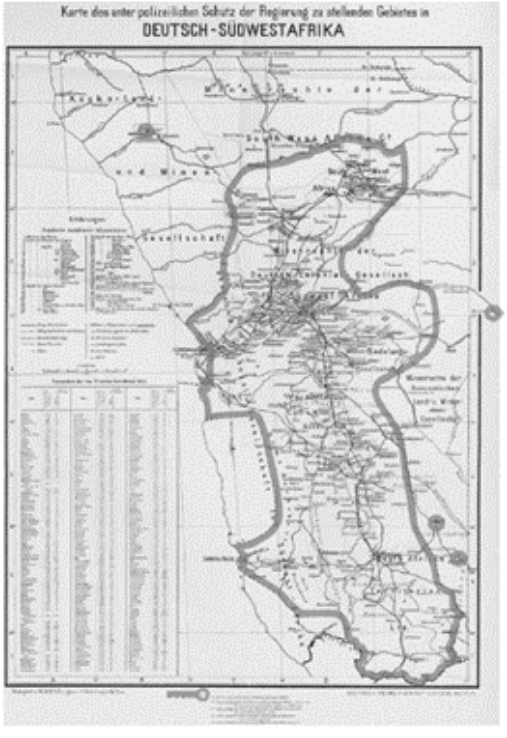


Figure A2: Police Zone boundary in Namibia, 1907. Source: Map adapted from Miescher (2012, p. 45).

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

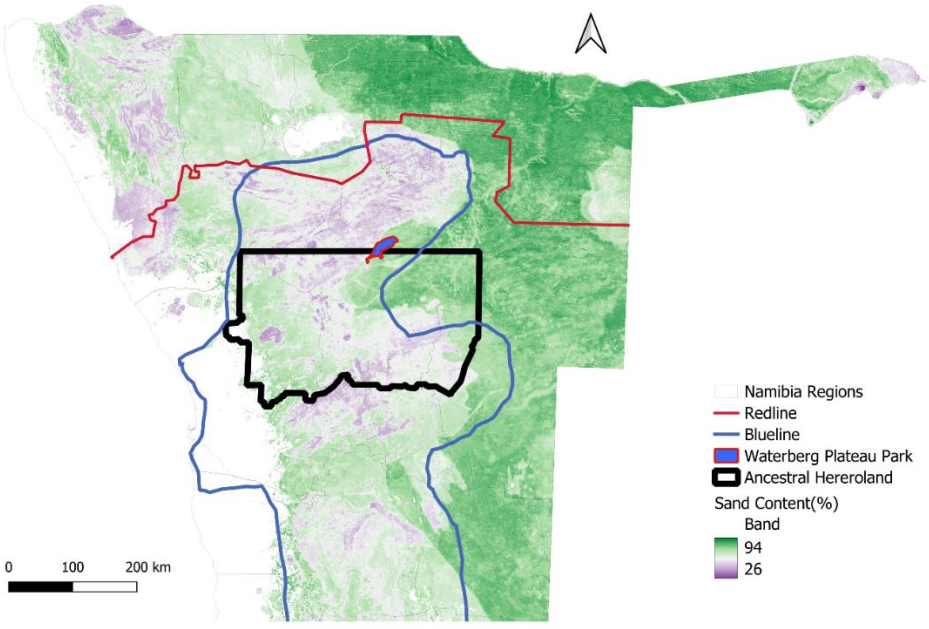


Figure A3: Sand-content distribution across the historical zoning regions and the Herero ancestral territory. Source: Herero ancestral land, adapted from Gariwo Foundation (n.d.).

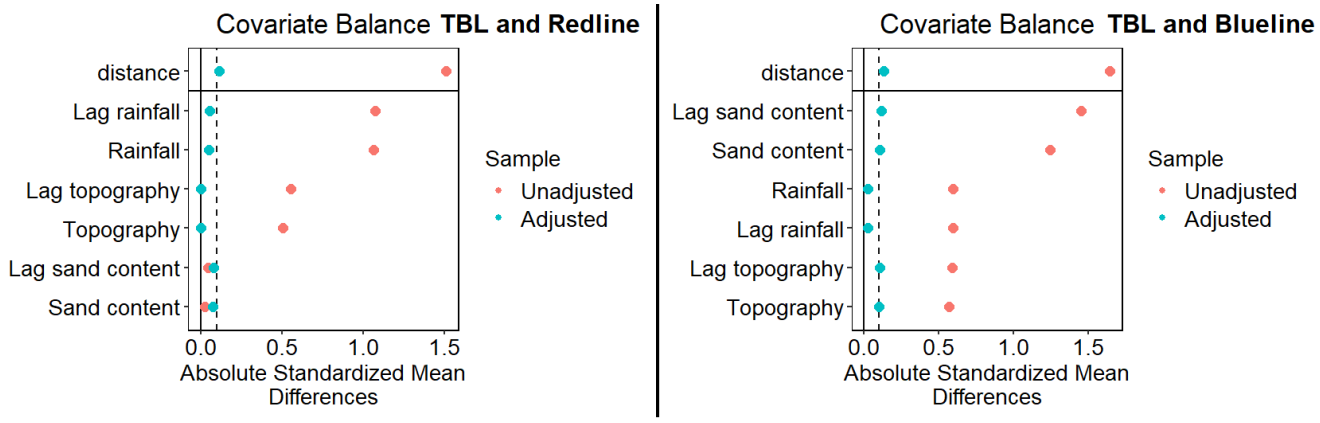


Figure A4: Covariate balance before (red dots) and after (blue dots) matching for the TBL–RL and TBL–BL comparisons. Note: Figure A4 presents covariate balance plots for the TBL zone against the RL and BL zones, using the absolute standardised mean differences (ASMD) and a calliper of 0.2. Balance improves substantially after matching for distance, rainfall, and topography in both comparisons. Sand content was already well-balanced before matching. Overall, matching improves comparisons between treatment and control.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Table A1: Association between zoning policy and wealth: OLS and PSM estimates using log IWI

	Redline Comparison			Blueline Comparison		
Variables	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
TBL (dummy)	0.232***	0.299***	0.206***	-0.180***	0.080***	0.088***
	(0.205, 0.259)	(0.270, 0.328)	(0.163, 0.248)	(-0.212, -0.148)	(0.041, 0.120)	(0.037, 0.140)
Gate		0.021**	0.036***		0.015	0.037***
		(0.003, 0.039)	(0.010, 0.062)		(-0.003, 0.034)	(0.010, 0.063)
Major City		-0.126***	-0.136***		-0.100***	-0.115***
		(-0.139, -0.113)	(-0.158, -0.113)		(-0.126, -0.075)	(-0.154, -0.075)
Mines		-0.047***	-0.063***		-0.093***	-0.131***
		(-0.062, -0.032)	(-0.089, -0.037)		(-0.119, -0.066)	(-0.166, -0.095)
Livestock Value		0.027***	-0.011		0.139***	0.124***
		(0.012, 0.042)	(-0.042, 0.020)		(0.121, 0.157)	(0.088, 0.160)
Rainfall		0.031***	-0.124		-0.060***	0.448
		(0.012, 0.050)	(-0.502, 0.254)		(-0.091, -0.029)	(-0.251, 1.147)
Sand Content		-0.106***	-0.071***		-0.033***	-0.014
		(-0.119, -0.093)	(-0.110, -0.032)		(-0.053, -0.013)	(-0.058, 0.030)
Topography		-0.031***	-0.131***		0.047***	-0.100**
		(-0.048, -0.014)	(-0.216, -0.046)		(0.029, 0.064)	(-0.195, -0.005)
Lag Rainfall			0.147			-0.506
			(-0.231, 0.525)			(-1.208, 0.196)
Lag Sand Content			-0.062***			0.019
			(-0.105, -0.019)			(-0.030, 0.068)
Lag Topography			0.099**			0.168***
			(0.011, 0.186)			(0.070, 0.267)
Constant	2.936***	2.966***	3.012***	3.349***	3.127***	3.081***
	(2.925, 2.948)	(2.952, 2.980)	(2.983, 3.040)	(3.328, 3.369)	(3.096, 3.159)	(3.029, 3.133)
Observations	5943	5943	2009	4363	4363	1810

Note: 95% confidence intervals in parentheses. *** p<0.01, ** p<0.05, * p<0.10. (1) Baseline OLS without matching; (2) OLS with geographic controls, without matching; (3) OLS regression on the propensity-score-matched sample, incorporating covariates and their spatial lag in the matching procedure and subsequent regression. The dependent variable is the log IWI. TBL settlements constitute the treatment group in both comparisons, with RL and BL serving as the respective comparison groups.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Table A2: Association between zoning policy and consumption expenditure; OLS and PSM estimates of log median annual expenditure per person

	Redline Comparison			Blueline Comparison		
Variables	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
TBL (dummy)	0.546***	0.583***	0.524***	-0.251***	0.093***	0.083***
	(0.525, 0.567)	(0.562, 0.605)	(0.494, 0.554)	(-0.278, -0.224)	(0.064, 0.121)	(0.049, 0.116)
Gate		0.170***	0.195***		0.237***	0.246***
		(0.155, 0.186)	(0.172, 0.219)		(0.222, 0.253)	(0.225, 0.266)
Major City		-0.192***	-0.171***		-0.035***	-0.042***
		(-0.201, -0.183)	(-0.188, -0.154)		(-0.055, -0.016)	(-0.065, -0.018)
Mines		0.023***	-0.006		-0.081***	-0.120***
		(0.009, 0.036)	(-0.029, 0.018)		(-0.101, -0.062)	(-0.143, -0.097)
Livestock Value		0.026***	0.042***		0.182***	0.120***
		(0.015, 0.037)	(0.018, 0.066)		(0.157, 0.206)	(0.082, 0.157)
Rainfall		0.025***	-0.026		-0.128***	0.056
		(0.009, 0.041)	(-0.311, 0.260)		(-0.153, -0.104)	(-0.405, 0.518)
Sand Content		-0.043***	-0.061***		-0.092***	-0.032*
		(-0.053, -0.034)	(-0.092, -0.031)		(-0.110, -0.075)	(-0.066, 0.003)
Topography		-0.093***	-0.156***		0.061***	-0.167***
		(-0.111, -0.074)	(-0.267, -0.045)		(0.044, 0.078)	(-0.283, -0.051)
Lag Rainfall			0.043			-0.119
			(-0.245, 0.330)			(-0.581, 0.343)
Lag Sand Content			0.014			-0.012
			(-0.021, 0.049)			(-0.052, 0.028)
Lag Topography			0.065			0.232***
			(-0.047, 0.176)			(0.114, 0.350)
Constant	7.052***	7.076***	7.085***	7.848***	7.444***	7.453***
	(7.043, 7.061)	(7.065, 7.087)	(7.062, 7.108)	(7.830, 7.867)	(7.420, 7.468)	(7.415, 7.490)
Observations	5943	5943	2009	4363	4363	1810

Note: 95% confidence intervals in parentheses. *** p<0.01, ** p<0.05, * p<0.10. (1) Baseline OLS without matching; (2) OLS with geographic controls, without matching; (3) OLS regression on the propensity-score-matched sample, incorporating covariates and their spatial lag in the matching procedure and subsequent regression. TBL settlements constitute the treatment group in both comparisons, with RL and BL serving as the respective comparison groups.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Table A3: Association between historical large private farm establishment and median annual expenditure per person in Namibia: OLS (1) and PSM (2) estimates

	Redline Comparison		Blueline Comparison	
Variables	**(1)**	**(2)**	**(1)**	**(2)**
Farm (1902) dummy	0.820***	0.904***	0.528***	0.308***
	(0.690, 0.949)	(0.666, 1.142)	(0.445, 0.610)	(0.218, 0.398)
Farm (1902–1921) dummy	0.683***	0.774***	0.358***	0.255***
	(0.630, 0.737)	(0.661, 0.887)	(0.312, 0.405)	(0.202, 0.309)
Farm (1921–1937) dummy	0.626***	0.704***	0.207***	0.144***
	(0.598, 0.655)	(0.654, 0.753)	(0.158, 0.257)	(0.092, 0.196)
Farm (1937–1955) dummy	0.428***	0.465***	0.129***	0.045
	(0.390, 0.466)	(0.405, 0.524)	(0.074, 0.183)	(-0.016, 0.107)
Farm (1955–2001) dummy	0.175***	0.341***	0.039	0.154
	(0.099, 0.251)	(0.236, 0.446)	(-0.024, 0.103)	(-0.052, 0.359)
Farm (2001–2020) dummy	0.113***	0.268***	0.039	0.047
	(0.078, 0.147)	(0.216, 0.320)	(-0.017, 0.094)	(-0.029, 0.122)
Constant	7.090***	6.981***	7.516***	7.550***
	(7.080, 7.100)	(6.959, 7.003)	(7.474, 7.558)	(7.506, 7.593)
Observations	5943	2009	4363	1810

Note: 95% confidence intervals in parentheses. *** p<0.01, ** p<0.05, * p<0.10. (1) OLS with large private farms established as an independent variable (farm dummy), (2) OLS regression on the propensity-score-matched sample, incorporating covariates and their spatial lag in the matching procedure. The dependent variable is the log median annual expenditure per person.

Code and data availability

The data used in this study are derived from publicly available sources. The processed analytical dataset and replication code necessary to reproduce the results will be made publicly available in an open repository upon acceptance of the manuscript.

Author contributions

- Osasere Vanessa Amatotsero: Conceptualisation, Methodology, Data Curation, Formal Analysis, Writing – Original Draft, Revision and Editing, Visualisation.
- Javier Miranda: Methodology, Data Curation, Writing – Review and Editing
- Jan Börner: Conceptualisation, Writing- Review and Editing, Funding Acquisition, Supervision.

Competing interests

The authors declare no competing interests.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Acknowledgements

The authors are grateful to everyone who contributed to the paper, including colleagues who contributed to the discussion of the paper at conferences and seminars. We also acknowledge the individuals, institutions and organisations that made available the historical materials, maps, and geospatial datasets.

Financial support

This study was conducted at the University of Bonn. Funded by the German Research Foundation (DFG) through the Collaborative Research Centre (CRC/TRR 228) Future Rural Africa project, subproject A01– Future Carbon Storage.

Declaration of generative AI use

During the preparation of this manuscript, the authors used generative AI (ChatGPT) to assist with language editing, grammar correction, and some R coding. All assisted output was reviewed and verified by the authors. The authors take full responsibility for the integrity, accuracy, and originality of the final manuscript.

References

Abman, R. and Lundberg, C.: Contracting, market access, and deforestation, J. Dev. Econ., 168, 103269, https://doi.org/10.1016/j.jdeveco.2024.103269, 2024.

Acemoglu, D., Johnson, S., and Robinson, J. A.: The colonial origins of comparative development: An empirical investigation, Am. Econ. Rev., 91, 1369–1401, https://doi.org/10.1257/aer.91.5.1369, 2001.

Acemoglu, D. and Robinson, J. A.: Why Nations Fail: The Origins of Power, Prosperity, and Poverty, Crown Publishers, New York, USA, ISBN 978-0-307-71923-2, 2012.

Adams, V. M., Chauvenet, A. L. M., Stoudmann, N., Gurney, G. G., Brockington, D., and Kuempel, C. D.: Multiple-use protected areas are critical to equitable and effective conservation, One Earth, 6, 1173–1189, https://doi.org/10.1016/j.oneear.2023.08.011, 2023.

Adelaja, A., Derr, D., and Rose-Tank, K.: Economic and equity implications of land-use zoning in suburban agriculture, J. Agric. Ethics, 2, 97–112, https://doi.org/10.1007/BF01826926, 1989.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Akasaka, T., Mori, T., Ishiyama, N., Takekawa, Y., Kawamoto, T., Inoue, M., Mitsuhashi, H., Kawaguchi, Y., Ichiyanagi, H., Onikura, N., Miyake, Y., Katano, I., Akasaka, M., and Nakamura, F.: Reconciling biodiversity conservation and flood risk reduction: The new strategy for freshwater protected areas, Divers. Distrib., 28, 1191–1201, https://doi.org/10.1111/ddi.13517, 2022.

Anselin, L.: Spatial Econometrics: Methods and Models, Kluwer Academic Publishers, Dordrecht, the Netherlands, https://doi.org/10.1007/978-94-015-7799-1, 1988.

Atlas of Namibia Team: Atlas of Namibia: Its Land, Water and Life, Namibia Nature Foundation, Windhoek, Namibia, https://atlasofnamibia.online/, 2022.

Baldomero-Quintana, L., Woo-Mora, L. G., and De la Rosa-Ramos, E.: Infrastructures of race? Colonial indigenous segregation and contemporary land values, Reg. Sci. Urban Econ., 110, 104065, https://doi.org/10.1016/j.regsciurbeco.2024.104065, 2025.

Beinart, W. and Delius, P.: The historical context and legacy of the Natives Land Act of 1913, J. South. Afr. Stud., 40, 667–688, https://doi.org/10.1080/03057070.2014.930623, 2014.

Bekele, A. E., Drabik, D., Dries, L., and Heijman, W.: Large-scale land investments and land-use conflicts in the agro-pastoral areas of Ethiopia, Land Use Policy, 119, 106166, https://doi.org/10.1016/j.landusepol.2022.106166, 2022.

Bengston, D. N., Fletcher, J. O., and Nelson, K. C.: Public policies for managing urban growth and protecting open space: Policy instruments and lessons learned in the United States, Landsc. Urban Plan., 69, 271–286, https://doi.org/10.1016/j.landurbplan.2003.08.007, 2004.

Bruggeman, D., Meyfroidt, P., and Lambin, E. F.: Impact of land-use zoning for forest protection and production on forest cover changes in Bhutan, Appl. Geogr., 96, 153–165, https://doi.org/10.1016/j.apgeog.2018.04.011, 2018.

Cogneau, D. and Guénard, C.: Colonisation, institutions, and inequality: A note on some suggestive evidence, IAI Discussion Papers, No. 107, Ibero-America Institute for Economic Research, University of Göttingen, Göttingen, Germany, https://hdl.handle.net/10419/27398, 2003.

Cousins, B.: Land reform in South Africa is failing. Can it be saved? Transformation: Critical Perspectives on Southern Africa, 92, 135–157, https://doi.org/10.1353/trn.2016.0030, 2016.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Cullingworth, B. and Caves, R. W.: Planning in the USA: Policies, Issues and Processes, 2nd edn., Routledge, London, UK, https://doi.org/10.4324/9780203380444, 2004.

Direito, B.: Land and Colonialism in Mozambique–Policies and Practice in Inhambane, c. 1900–c. 1940, J. South. Afr. Stud., 39, 353–369, https://doi.org/10.1080/03057070.2013.795812, 2013.

Emran, M. S. and Shilpi, F.: Do land market restrictions hinder structural change in a rural economy? Evidence from Sri Lanka, Bangladesh Dev. Stud., 43, 1–35, https://www.jstor.org/stable/27116972, 2020.

FAO: Agro-ecological zoning: Guidelines, FAO Soils Bulletin 73, Food and Agriculture Organisation of the United Nations, Rome, ISBN 92-5-103890-2, https://www.fao.org/4/w2962e/w2962e00.htm, 1996.

FAO: Strengthening civic spaces in spatial planning processes: A technical guide on regulated spatial planning and tenure to balance societal priorities in the use of land, fisheries and forests, Governance of Tenure Technical Guide No. 12, Food and Agriculture Organisation of the United Nations, Rome, https://doi.org/10.4060/cb0422en, 2020.

Fick, S. E. and Hijmans, R. J.: WorldClim 2: New 1-km spatial resolution climate surfaces for global land areas, Int. J. Climatol., 37, 4302–4315, https://doi.org/10.1002/joc.5086, 2017.

Fischel, W. A.: Zoning Rules! The Economics of Land Use Regulation, Lincoln Institute of Land Policy, Cambridge, Massachusetts, USA, https://www.lincolninst.edu/app/uploads/legacy-files/pubfiles/zoning-rules-chp.pdf, 2015.

Frankema, E.: The colonial roots of land inequality: Geography, factor endowments, or institutions? Econ. Hist. Rev., 63, 418–451, https://doi.org/10.1111/j.1468-0289.2009.00479.x, 2010.

Gariwo Foundation: Herero and Nama genocide, Gariwo Foundation, https://en.gariwo.net/education/insights/herero-and-nama-genocide-21602.html (last accessed: 21 October 2026), n.d.

Gewald, J.-B.: Herero Heroes: A Socio-Political History of the Herero of Namibia, 1890–1923, James Currey, Oxford, UK, https://sahistory.org.za/sites/default/files/archive-files3/jan-bart_gewald_herero_heroes_a_socio-politicalbook4you.pdf, 1999.

Goudie, A. and Viles, H.: Landscapes and Landforms of Namibia, World Geomorphological Landscapes, Springer, Dordrecht, the Netherlands, https://doi.org/10.1007/978-94-017-8020-9, 2015.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Grieson, R. E. and White, J. R.: The effects of zoning on structure and land markets, J. Urban Econ., 10, 271–285, https://doi.org/10.1016/0094-1190(81)90001-2, 1981.

Gupta, A., Zhu, H., Bhammar, H., Earley, E., Filipski, M., Narain, U., and Taylor, J. E.: Economic impact of nature-based tourism, PLOS ONE, 18, e0282912, https://doi.org/10.1371/journal.pone.0282912, 2023.

Hall, P. and Tewdwr-Jones, M.: Urban and Regional Planning, 6th edn., Routledge, London, UK, https://doi.org/10.4324/9781351261883, 2020.

Han, Y. and Wu, M.: Inter-regional barriers and economic growth: Evidence from China, J. Dev. Econ., 167, 103197, https://doi.org/10.1016/j.jdeveco.2023.103197, 2024.

Hardin, G.: The tragedy of the commons, Science, 162, 1243–1248, https://doi.org/10.1126/science.162.3859.1243, 1968.

Harris, I., Osborn, T. J., Jones, P., and Lister, D. H.: Version 4 of the CRU TS monthly high-resolution gridded multivariate climate dataset, Sci. Data, 7, 109, https://doi.org/10.1038/s41597-020-0453-3, 2020.

Heckman, J. J., Ichimura, H., and Todd, P. E.: Matching as an econometric evaluation estimator: Evidence from evaluating a job training programme, Rev. Econ. Stud., 64, 605–654, https://doi.org/10.2307/2971733, 1997.

Heilmayr, R., Rausch, L. L., Munger, J., and Gibbs, H. K.: Brazil's Amazon Soy Moratorium reduced deforestation, Nat. Food, 1, 801–810, https://doi.org/10.1038/s43016-020-00194-5, 2020.

Henneberry, D. M. and Barrows, R. L.: Capitalisation of exclusive agricultural zoning into farmland prices, Land Econ., 66, 249–258, https://doi.org/10.2307/3146727, 1990.

Ho, D. E., Imai, K., King, G., and Stuart, E. A.: MatchIt: Nonparametric preprocessing for parametric causal inference, J. Stat. Softw., 42, 1–28, https://ideas.repec.org/a/jss/jstsof/v042i08.html, 2011.

Imbens, G. W. and Lemieux, T.: Regression discontinuity designs: A guide to practice, J. Econom., 142, 615–635, https://doi.org/10.1016/j.jeconom.2007.05.001, 2008.

Jayne, T. S., Chamberlin, J., and Headey, D. D.: Land pressures, the evolution of farming systems, and development strategies in Africa: A synthesis, Food Policy, 48, 1–17, https://doi.org/10.1016/j.foodpol.2014.05.014, 2014.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Jedwab, R. and Moradi, A.: The permanent effects of transportation revolutions in poor countries: Evidence from Africa, Rev. Econ. Stat., 98, 268–284, https://doi.org/10.1162/REST_a_00540, 2016.

Kalkuhl, M. and Edenhofer, O.: Ramsey meets Thünen: The impact of land taxes on economic development and land conservation, Int. Tax Public Finance, 24, 350–380, https://doi.org/10.1007/s10797-016-9403-6, 2017.

Karshenas, M. and van der Geest, W.: Market access, growth, and poverty reduction in a Kaldorian framework, J. Income Distrib., 24, 54–80, https://doi.org/10.25071/1874-6322.40365, 2017.

Katjavivi, P. H.: A History of Resistance in Namibia, James Currey, London, UK, https://sahistory.org.za/sites/default/files/archive-files3/peter_h._katjavivi_history_of_resistance_in_namibook4you.pdf, 1988.

Kenfack Essougong, U. P. and Teguia, S. J. M.: How secure are land rights in Cameroon? A review of the evolution of land-tenure systems and their implications for tenure security and rural livelihoods, GeoJournal, 84, 1645–1656, https://doi.org/10.1007/s10708-018-9935-7, 2019.

Kohima, J. M., Chigbu, U. E., Mazambani, M. L., and Mabakeng, M. R.: (Neo-)segregation, (neo-)racism, and one-city two-system planning in Windhoek, Namibia: What can a new national urban policy do?, Land Use Policy, 125, 106480, https://doi.org/10.1016/j.landusepol.2022.106480, 2023.

Kotikot, S. M., Smithwick, E. A. H., Gergel, S., Nankaya, J., Abila, R., and Mabwoga, S.: Historical land policies influence contemporary landscape patterns in agropastoral landscapes, Landsc. Ecol., 40, 163, https://doi.org/10.1007/s10980-025-02178-x, 2025.

Lahiff, E.: "Willing buyer, willing seller": South Africa's failed experiment in market-led agrarian reform, Third World Q., 28, 1577–1597, https://doi.org/10.1080/01436590701637417, 2007.

Lawrence, A. K. and Sajid, F. M.: The political origins of colonial land policy: Evidence from British India and French Algeria, Comp. Polit. Stud., 58, 963–995, https://doi.org/10.1177/00104140241252093, 2025.

Le Page, Y., Vasconcelos, M., Palminha, A., Melo, I. Q., and Pereira, J. M. C.: An operational approach to high-resolution agro-ecological zoning in West Africa, PLOS ONE, 12, e0183737, https://doi.org/10.1371/journal.pone.0183737, 2017.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Lee, D. S. and Lemieux, T.: Regression discontinuity designs in economics, J. Econ. Lit., 48, 281–355, https://doi.org/10.1257/jel.48.2.281, 2010.

Lee, K.: High-resolution poverty maps in Sub-Saharan Africa, Harvard Dataverse [data set], Version 1, https://doi.org/10.7910/DVN/5OGWYM, 2022.

Leite-Filho, A. T., Soares-Filho, B. S., Davis, J. L., Abrahão, G. M., and Börner, J.: Deforestation reduces rainfall and agricultural revenues in the Brazilian Amazon, Nat. Commun., 12, 2591, https://doi.org/10.1038/s41467-021-22840-7, 2021.

Lens, M. C.: Zoning, land use, and the reproduction of urban inequality, Annu. Rev. Sociol., 48, 421–439, https://doi.org/10.1146/annurev-soc-030420-122027, 2022.

LeSage, J. and Pace, R. K.: Introduction to Spatial Econometrics, 1st edn., Chapman and Hall/CRC, New York, USA, https://doi.org/10.1201/9781420064254, 2009.

Lyon, W. B.: From labour elites to Garveyites: West African migrant labour in Namibia, 1892–1925, J. South. Afr. Stud., 47, 37–55, https://doi.org/10.1080/03057070.2021.1851972, 2021.

Makombe, E. K. and Masakure, C.: The colonial state, land-use policy and local responses in Seke Reserve, Rhodesia: 1935 to 1958, New Contree, 91, 249, https://doi.org/10.4102/nc.v91.249, 2024.

Markelova, H. and Mwangi, E.: Collective action for smallholder market access: Evidence and implications for Africa, Rev. Policy Res., 27, 621–640, https://doi.org/10.1111/j.1541-1338.2010.00462.x, 2010.

Melber, H.: Colonialism, land, ethnicity, and class: Namibia after the Second National Land Conference, Afr. Spectr., 54, 73–86, https://doi.org/10.1177/0002039719848506, 2019.

Melber, H., Camfield, L., and Kothari, U.: Development as (In)Justice: The Case of Namibia, Progress in Development Studies, 25(3–4), 211–230, https://doi.org/10.1177/14649934251388766, 2025.

Mendelsohn, J., Jarvis, A., Roberts, C., and Robertson, T.: Atlas of Namibia: A Portrait of the Land and Its People, David Philip Publishers, Cape Town, South Africa, https://www.researchgate.net/publication/263546846_Atlas_of_Namibia_A_Portrait_of_the_Land_and_its_People, 2002.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Miescher, G.: Namibia's Red Line: The History of a Veterinary and Settlement Border, Palgrave Macmillan, New York, USA, https://doi.org/10.1057/9781137118318, 2012.

Mkandawire, N. D., Mangisoni, J., Pangapanga, I., and Machila, K.: Assessing the impact of land-tenure security on farm-level investment in soil and water conservation practices: Evidence from smallholder farmers in Malawi, Land Use Policy, 159, 107803, https://doi.org/10.1016/j.landusepol.2025.107803, 2025.

Moorsom, R.: Underdevelopment, contract labour and worker consciousness in Namibia, 1915–72, J. South. Afr. Stud., 4, 52–87, https://doi.org/10.1080/03057077708707979, 1977.

Moorsom, R.: Labour consciousness and the 1971–72 contract workers strike in Namibia, Dev. Change, 10, 205–231, https://doi.org/10.1111/j.1467-7660.1979.tb00041.x, 1979.

Morton, A. D.: Spatial political economy, J. Aust. Polit. Econ., 79, 21–38, https://www.ppesydney.net/content/uploads/2020/05/Spatial-political-economy.pdf, 2017.

Mulwa, C. K. and Visser, M.: Farm diversification as an adaptation strategy to climatic shocks and implications for food security in northern Namibia, World Dev., 129, 104906, https://doi.org/10.1016/j.worlddev.2020.104906, 2020.

Mundia, K., and Haimbili, R.: The intricacies of land reform in Namibia: An overview of the land question in Namibia 33 years after independence, Potchefstroom Electronic Law Journal, 26, 1–26, https://doi.org/10.17159/1727-3781/2023/v26i0a14715, 2023.

Naha, D., Périquet, S., Kilian, J. W., Kupferman, C. A., Hoth-Hanssen, T., and Beasley, J. C.: Fencing affects movement patterns of two large carnivores in Southern Africa, Front. Ecol. Evol., 11, 1031321, https://doi.org/10.3389/fevo.2023.1031321, 2023.

Naidoo, R., Gerkey, D., Hole, D., Pfaff, A., Ellis, A. M., Golden, C. D., and Fisher, B.: Evaluating the impacts of protected areas on human well-being across the developing world, Sci. Adv., 5, eaav3006, https://doi.org/10.1126/sciadv.aav3006, 2019.

Namibia Statistics Agency: Digital Namibia [data set], https://digitalnamibia.nsa.org.na/ (last accessed: November 2023), n.d.

Naziri, D., Rich, K. M., and Bennett, B.: Would a commodity-based trade approach improve market access for Africa? A case study of the potential of beef exports from communal areas of Namibia, Dev. Policy Rev., 33, 195–219, https://doi.org/10.1111/dpr.12098, 2015.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Nehoya, L. T., Kalundu, S. K., and Muzanima, J.: Investigating the cattle supply chain in the northern communal areas of Namibia: A case study paper of the Oshikoto and Zambezi regions, International Journal of Research and Innovation in Applied Science, 11(6), 343–358, https://doi.org/10.51584/IJRIAS.2026.11060035, 2026.

Nelson, A., Weiss, D. J., van Etten, J., Cattaneo, A., McMenomy, T. S., and Koo, J.: A suite of global accessibility indicators, Sci. Data, 6, 266, https://doi.org/10.1038/s41597-019-0265-5, 2019.

Nolte, C., Gobbi, B., le Polain de Waroux, Y., Piquer-Rodríguez, M., Butsic, V., and Lambin, E. F.: Decentralised land-use zoning reduces large-scale deforestation in a major agricultural frontier, Ecol. Econ., 136, 30–40, https://doi.org/10.1016/j.ecolecon.2017.02.009, 2017.

Oliveira, E. and Meyfroidt, P.: Strategic land-use planning instruments in tropical regions: State of the art and future research, J. Land Use Sci., 16, 479–497, https://doi.org/10.1080/1747423X.2021.2015471, 2021.

OpenStreetMap contributors: OpenStreetMap [data set], https://www.openstreetmap.org/ (last accessed: November 2023), n.d.

Parent, A.: Introduction to the special issue on colonial institutions and African development, J. Inst. Econ., 14, 197–205, https://doi.org/10.1017/S1744137417000510, 2018.

Poggio, L. and de Sousa, L. M.: SoilGrids250m 2.0 – Sand content [data set], ISRIC – World Soil Information, https://doi.org/10.17027/isric-soilgrids.713396fa-1687-11ea-a7c0-a0481ca9e724, 2020.

Regional Centre for Mapping of Resources for Development (RCMRD): Namibia SRTM DEM 30 meters [data set], Africa GeoPortal, https://rcmrd.africageoportal.com/datasets/ed3e881f0fd74b639e0d7d4cfa5c823f/about (last accessed: November 2023), 2017.

Rosenbaum, P. R. and Rubin, D. B.: The central role of the propensity score in observational studies for causal effects, Biometrika, 70, 41–55, https://doi.org/10.1093/biomet/70.1.41, 1983.

Röhring, A. and Gailing, L.: Linking path dependency and resilience for the analysis of landscape development, in: Resilience and the Cultural Landscape: Understanding and Managing Change in Human-Shaped Environments, edited by: Plieninger, T. and Bieling, C., Cambridge University Press, Cambridge, UK, 146–163, https://doi.org/10.1017/CBO9781139107778.012, 2012.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Schneider, H. P.: The history of veterinary medicine in Namibia, J. S. Afr. Vet. Assoc., 83, 4, https://doi.org/10.4102/jsava.v83i1.4, 2012.

Sclar, E., Baird-Zars, B., Fischer, L. A., and Stahl, V. E. (Eds.): Zoning: A Guide for 21st-Century Planning, Routledge, New York, USA, https://doi.org/10.4324/9780429489228, 2020.

Sekalala, S., Forman, L., Habibi, R., and Meier, B. M.: Health and human rights are inextricably linked in the COVID-19 response, BMJ Glob. Health, 5, e003359, https://doi.org/10.1136/bmjgh-2020-003359, 2020.

Shertzer, A., Twinam, T., and Walsh, R. P.: Race, ethnicity, and discriminatory zoning, Am. Econ. J. Appl. Econ., 8, 217–246, https://doi.org/10.1257/app.20140430, 2016.

Silvester, J., Wallace, M., and Hayes, P.: "Trees Never Meet": Mobility and Containment: An Overview, 1915–1946, in: Namibia under South African Rule: Mobility and Containment, 1915–1946, edited by: Hayes, P., Silvester, J., Wallace, M., and Hartmann, W., James Currey, Oxford, UK, 3–50, https://sahistory.org.za/ref/R-0150437, 1998.

Siyambango, N., Togarepi, C., Mudamburi, B., Mupambwa, H. A., and Awala, S.: Climate-smart agriculture: Perspectives for subsistence crop farming in Namibia, in: Food Security for African Smallholder Farmers, edited by: Mupambwa, H. A., Nciizah, A. D., Nyambo, P., Muchara, B., and Gabriel, N. N., Springer, Singapore, 251–266, https://doi.org/10.1007/978-981-16-6771-8_15, 2022.

Stifel, D. and Christiaensen, L.: Tracking poverty over time in the absence of comparable consumption data, World Bank Econ. Rev., 21, 317–341, https://doi.org/10.1093/wber/lhm010, 2007.

Tjirera, E.: Namibia's intractable land question, Curr. Hist., 122, 167–171, https://doi.org/10.1525/curh.2023.122.844.167, 2023.

Usman, M. A. and Haile, M. G.: Market access, household dietary diversity and food security: Evidence from Eastern Africa, Food Policy, 113, 102374, https://doi.org/10.1016/j.foodpol.2022.102374, 2022.

Valdaliso, J. M., Suárez, P., Mayor, M., and Magro, E.: Lock-in, resilience and path development in old industrial regions: An agency-based explanation, Camb. J. Reg. Econ. Soc., 19, 109–127, https://doi.org/10.1093/cjres/rsaf043, 2025.

https://doi.org/10.5194/ls-2026-13
Preprint. Discussion started: 13 November 2026
© Author(s) 2026. CC BY 4.0 License.

Wallace, M. and Kinahan, J.: A History of Namibia: From the Beginning to 1990, Oxford University Press, New York, USA, https://sahistory.org.za/sites/default/files/archive-files3/marion_wallace_a_history_of_namibia_from_the_bebook4you.pdf, 2011.

Weiss, D. J., Nelson, A., Gibson, H. S., Temperley, W., Peedell, S., Lieber, A., Hancher, M., Poyart, E., Belchior, S., Fullman, N., Mappin, B., Dalrymple, U., Rozier, J., Lucas, T. C. D., Howes, R. E., Tusting, L. S., Kang, S. Y., Cameron, E., Bisanzio, D., et al.: A global map of travel time to cities to assess inequalities in accessibility in 2015, Nature, 553, 333–336, https://doi.org/10.1038/nature25181, 2018.

Werner, W.: A brief history of land dispossession in Namibia, J. South. Afr. Stud., 19, 135–146, https://doi.org/10.1080/03057079308708351, 1993.

Werner, W. and Odendaal, W.: Livelihoods after Land Reform: Namibia Country Report, Land, Environment and Development Project, Legal Assistance Centre, Windhoek, Namibia, https://www.lac.org.na/projects/lead/Pdf/livelihoods.pdf, 2010.

Wilson, P.: Remembering the Herero-Nama genocide in Namibia, Afr. Arts, 56, 62–81, https://doi.org/10.1162/afar_a_00698, 2023.

Wooldridge, J. M., Wadud, M., Lye, J., and Joyeux, R.: Introductory Econometrics: Asia-Pacific Edition, 2nd edn., Cengage AU, https://l1nq.com/aspp5ky, 2020.

Wyrwich, M.: Migration restrictions and long-term regional development: Evidence from large-scale expulsions of Germans after World War II, J. Econ. Geogr., 20, 481–507, https://doi.org/10.1093/jeg/lbz024, 2020.