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RESEARCH ARTICLE

Spatial pattern of environmental perception and place attachment in a diverse socio-economic context: the case of Gauteng province, South Africa

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Abstract: There is limited consensus among researchers on whether the spatial distribution of environmental perceptions and place attachment is influenced by socio-economic factors. This study aimed to determine if environmental perceptions and place attachment concepts in our study area (within Gauteng province, South Africa) showed specific spatial patterns. Hot spot, cluster-outlier analysis, and geographically weighted regression (GWR) were used to depict the spatial patterns of environmental perceptions and place attachment. Results showed a pattern where the central, generally affluent wards of the province hold more positive environmental perceptions and place attachment than those in the periphery. This is in line with dependency and other models that associate lower socio-economic status with lower levels of environmental awareness but is incongruent with other findings that have associated lower socio-economic status with pro-environmental behaviour being more prominent. Geographically weighted regression results revealed the combined importance of numbers of people with above-average income, college-level education, age below 50 years, female proportion, formal dwelling residence and African race in explaining the numbers of people with positive views on place attachment and environmental perceptions. Further, the GWR modelling allowed for the spatial dependence of the relationship between place attachment and environmental perceptions on the one hand and socio-economic factors on the other. These results have significant implications for environmental sustainability, planning and policy formulation in the province.

Keywords: environmental perceptions, place attachment, cluster analysis, geographically weighted regression, socio-economic factors

1 Introduction

Owing to the effects of global climate change, there has been growing interest in the past few decades in the way that people perceive and relate to their environment [16, 30]. This interest has also taken on political and social dimensions, with governments and societies expressing strong interest in human–nature relations [5]. As a result, governments are expected to take environmental issues into account in policy and planning, and for communities to implement pro-environmental behaviours involving sustainable environmental use [5]. Two common environmental behaviours that can indicate human–nature interactions include environmental perception and place attachment [46].

Environmental perceptions refer to individuals' understanding of their environment and are built around both their attitudes and understandings reflecting their habitual way of life, as well as people's shared expectations [27,47]. Environmental perceptions are therefore a product of the transactions between individuals and their surroundings [28]. Social, economic, political and cultural settings influence how people perceive their environment and the way they react to it [1, 51]. Environmental perceptions are therefore significant in predicting pro-environmental behaviour, and understanding such perceptions is necessary for characterising this behaviour.

In contrast, place attachment is a branch of psychology that is most likely to situate the individual in an ecological context, by viewing the individual as an active player in the environmental discourse [7, 49]. Place attachment is defined as the feelings we develop towards places that are highly familiar to us, i.e. places we belong to [49]. Place attachment, therefore, represents both an individual's internalised perceptions of the natural area (i.e., identity), as well as the extent to which those areas fulfil motivational goals (i.e., dependence) [49].

Place attachment, in particular, has received considerable attention in the literature because it is seen to have a strong bearing on environmental concern and behaviour [1, 3, 10, 37, 38]. Place attachment has been conceived as a two-dimensional concept: one being a tangible one relating to the attachment to physical features, and the other being a psychological or social component, wherein people get attached to intangible, meaningful elements [39]. Other authors have argued that these two concepts are unidimensional and therefore inseparable because of their symbiotic relationship [37, 49]. However, the literature suggests that most scholars treat these concepts separately, and further, that the social/psychological dimension of place attachment has received more focus than the physical dimension [37].

Several studies have attempted to map environmental perceptions and place attachment spatially to understand their distribution over space and to determine the reasons for their spatial disparities (e.g., [8, 13, 19, 29]). Most of these studies have asserted that people tend on the one hand to stay close to what they like and other people they relate to, and on the other hand to be distant from areas that are hostile or those that do not relate to their worldviews. This is known as the 'geographic discounting theory' [43]. Further evidence for the geographic discounting theory can be found in other more specific works, such as the mapping of individual environmental values (e.g., [11]) and environmental justice (e.g., [48]). Other studies have mapped human–nature relations through the use of public participatory GIS (PPGIS) in informing land-use decision-making (e.g., [11, 50]). Yet others have used the dependency theory [26] to explain the spatial disparities that exist therein. The dependency theory suggests that the extent to which resources are available depends

in part on the shape of the network and the positioning of the inhabitant within a locale. The benefits received from a central place decrease with outward distance, such that the periphery becomes more deprived of resources [26]. The model has been used in several studies, for example in the analysis of networks of scientific collaboration [42], friendship ties [2], and the interaction between corporates [40].

Peberdy et al. [45] used the core-periphery phenomenon to explain the uneven economic development that has occurred in Gauteng province, South Africa. Importantly, the authors note that the concept does not specifically define a location within space, but that "peripheral areas are spaces which may be economically, socially, demographically, politically and/or culturally marginal, in relation to core areas" [45, p. 22]. Borrowing from Wallerstein [52], the authors explain that core areas, regardless of their location within a city, are those where there is an accumulation of capital, and peripheral areas are the suppliers of raw materials and labour. Our use of the core-periphery concept in this research should be understood in this context. Other researchers like Harmse et al. [25] used the core-periphery theory to prove disparities in the spatial patterns of unemployment. Anderson et al. [5] reported on the complex relationship between pro-environmental behaviours including recycling, and how these interrelate with factors such as race and socioeconomic status in Gauteng.

The rapidly growing population of Gauteng, the province of South Africa in which the study was located, presents challenges to the government when trying to reduce inequalities [45]. In light of the characteristics of Gauteng, where there is a distinct variation in socio-economic status between the core, relatively more affluent wards of Johannesburg and Tshwane cities, and peripheral wards comprising poorer communities on the outskirts of the province, the application of the theory presents an opportune area of research. As a result, studies in human–nature relations in the area have assessed the relations between peri-urban and urban-based communities [25,35,45].

However, there have been insufficient studies in the Global South (including South Africa) that have mapped the spatial pattern of environmental perceptions and place attachment and their determinants, especially taking location or localisation into consideration. A cursory search of studies on environmental perceptions and attachment in the Global South showed that such studies have mainly focused on community place attachment [3, 15], place attachment and environmentally responsible behaviour among tourists [14, 46], and on cultural ecosystem services [29]. Most of these studies have considered these concepts in isolation (e.g., [14, 38]), and not holistically. In South Africa, environmental perceptions and place attachment have mainly been studied as part of large-scale surveys (for example, resident satisfaction surveys or attitudes to the quality of life in general) [20]. Some studies have been conducted on rural inhabitants' environmental perceptions and the respective determinants [28]. In others, researchers have investigated place attachment concerning recreational places such as national parks [16]. Yet other researchers have assessed place attachment in a socio-political context, such as Dixon and Durrheim [18] who reviewed attachment based on how people responded to desegregation following years during which space was geopolitically defined along ethnic lines. In contrast, some researchers such as Chigeza et al. [15] have evaluated community attachment. Chigeza et al. in their study on the sense of community in a South African rural setting, noted that community attachment arises as a result of interdependent relationships that community members develop with one another, and is forged in the need for communal survival.

The present study aimed to bring a new understanding to human–nature relations through mapping the spatial arrangements of environmental perceptions and place attachment at a small administrative unit for socio-economically heterogenous cities in Gauteng province, South Afirca. Previous studies that have mapped human–nature relations have been at a much coarser spatial levels like national parks [8, 11], and have been applied to specific land use purposes such as tourism [46]. It is hypothesised that higher levels of environmental perceptions and place attachment are positively related to place satisfaction, with greater affluence being perceived to lead to positive environmental perceptions and increased attachment to place. We, therefore, aimed to determine if the socio-economic factors influence environmental perceptions and place attachment in the study area by applying geographically weighted regression technique. The study can determine localised areas where environmental perceptions and attachment levels require intervention to achieve social justice and environmental sustainability. We assert that mapping environmental concepts such as environmental perceptions and attachment could potentially assist in identifying land use conflict and resolution mechanisms [12]. Further, such spatial characterising may also assist in understanding the social acceptability of projects and land uses in the area of study.

2 Study area

The geographical focus area for this study is the Gauteng province (South Africa) which comprises several district municipalities (thereafter districts) (Figure 1) and 529 administrative wards. Gauteng is the economic hub of the country contributing to a third of South Africa's total gross domestic product (GDP) and 10% of the Africa's GDP [24]. The province consists of five districts namely, the City of Johannesburg (hereafter Johannesburg or CoJ), City of Tshwane (hereafter Tshwane), City of Ekurhuleni (hereafter Ekurhuleni), as well as the district municipalities of the West Rand and Sedibeng. Johannesburg and Ekurhuleni contain the largest proportion of Gauteng's population, followed by Tshwane.

Johannesburg comprises several affluent conurbations such as Sandton-Fourways and Midrand, as well as less affluent but more highly populated township settings such as Soweto and Alexandra. Tshwane, the administrative capital of the country, similarly has a mix of affluent suburbs mainly located in the south-eastern region of the city and high density, relatively poorer townships such as Soshanguve and Mamelodi located on the northern urban periphery. The West Rand District Municipality is the poorest in the province, with limited access to basic amenities such as electricity and running water.

3 Theoretical framework

We propose that environmental perceptions and place attachment have a spatial dimension in their distribution in the study area. We develop an integrated structure of environmental perceptions and place attachment to depict how they are distributed, based on the relatively distinct socio-economic and demographic partitioning of the province. The relationship between perceptions and attachment, and their spatial distribution in a socio-demographically heterogeneous environment such as Gauteng, presents new insights and understanding of the spatial spread of such phenomena to a developing area in the Global South. The assumed linear theoretical model of the study is that environmental percep-

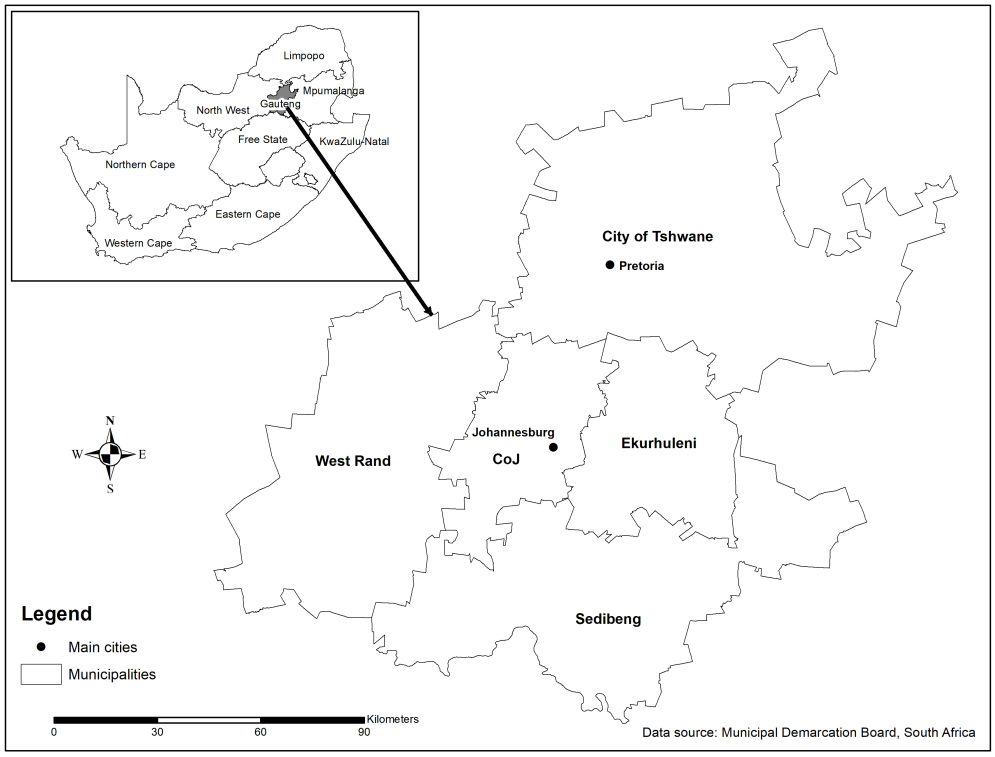

Figure 1: The location of Gauteng province and its metropolitan municipalities, district municipalities and major towns.

tions and place attachment have a distinct spatial character, and are determined by socio-economic factors.

In this study, perspectives on how environmental perceptions and attachment are linked to the socio-economic characteristics of the province in terms of their location (centrality and peripherality) are developed; and how these then translate to spatial distribution of human–nature relations are evaluated. In light of this conceptual framework, we hypothesise that higher levels of environmental perceptions and place attachment are positively related to higher socio-economic status, and that centrality and peripherality have a bearing on perceptions and attachment. This approach is the first of its kind in the Global South and could be generalised to other places with socio-economically and demographically heterogeneous populations whose perceptions of and attachment to their environment could be influenced by their access to resources.

4 Data and methods

4.1 Data

Our research drew on Quality of Life Survey data that was acquired in 2015 by the Gauteng City-Region Observatory (GCRO), which conducted interviews with respondents as their primary data collection method. A stratified multistage sample design was used based on a sample of 30,002 residents aged 18 years and older, spread across all 508 wards in the Gauteng province. Respondents had been notified that their participation in the survey was voluntary and that their responses would be anonymised. The data were weighted to ensure that the sample represented the target population as closely as possible. Weighting is a technique that corrects for variations in population across a sampling frame [23]. Sampling was performed at the ward level, using the adult population per ward. Each ward with a weight of 1 was considered to have the ideal sample, while those with weights of less than 1 were oversampled proportionally, and the opposite was true of wards with weights greater than 1 [23]. The weights calculated were proportionally down-scaled to the sample total of 30,002 for all 508 wards in the province.

The outcome or depend variables were environmental perceptions and place attachment. For environmental perceptions, the statement "There has been improvement in the environment over the last 12 months" was used as a proxy for environmental perceptions. The response to this statement is measured on a three-point Likert scale of 1) 'Improved', 2) 'Neutral', and 3) 'No change'. The statement "Gauteng is the best province and I would rather live here than anywhere else" was used as a proxy for place attachment, measured at a 5-point Likert scale of responses ranging from 1) 'Strongly agree', to 5) 'Strongly disagree'. All responses were aggregated using totals per ward, using 1) 'Improved' and 1) 'Strongly agree' for environmental perceptions and place attachment respectively.

For explanatory or independent variables, the socio-economic variables considered to estimate environmental perception and place attachment in the present study included gender, age, ethnicity, settlement type, educational and income levels. Initial screening of the explanatory or independent and dependent or outcome variables resulted in the selection of non-collinear and viable socio-economic factors for estimating the dependent variables. the viability in particular relates to certain variables of factors containing large numbers of zeros (zero inflation) due to the fact that no respondent fell in those variables. A good example in this regard is racial group in which only the African race was recorded in multiple wards. The final factors used in the regression analysis included African race from ethnic group, formal dwelling from settlement type, college graduate from education level, high income level from income group, and people with age below 50 years. The income levels were categorised for the current study using South Africa's average household monthly income of the year 2015 (when the data were collected as a threshold). The age threshold of 50 years also was decided since it was the closest to the retirement age designed in the GCRO's survey [24]. A summary of the explanatory variables is given in Table 1.

Explanatory variable	Minimum	Maximum	Mean / Median	Standard deviation
African ethnic group	3	180	45.7 / 40	24.2
Formal dwelling settlement	2	132	48.5 / 51	21.8
Female	5	106	30.3 / 30	12.9
College education level	0	14	2.1 / 1	2.7
Above average income level	0	57	6.3 / 3	8.0
Age < 50 years	8	161	42.5 / 42	19.6

Table 1: Summary statistics of explanatory variables used to estimate the number of people who expressed agreement with place attachment and who perceived improvement in environmental conditions.

4.2 Assessing the presence of clustering of environmental perceptions and place attachment using spatial autocorrelation analysis

Spatial autocorrelation was tested using the Global Moran's I index [41]. This statistic indicates the degree of association of a standardised value of a variable of interest against its spatial lag and ranges in the interval (-1, 1), with 0 indicating no spatial autocorrelation (complete spatial randomness). On the other hand, -1 shows a perfect clustering of dissimilar values (i.e., perfect dispersion) and +1 indicates a perfect clustering of similar values. Once calculated, the test of statistical significance of spatial effects is given a probability or pseudo-significance level [6]. The test can be visualised using a Moran's scatterplot [6], in which the slope of the regression line corresponds to Moran's I. Formally, the Moran's I is quantified using Equation 1.

$$I = \left(\frac{N}{S_0}\right) \frac{y'W}{y'yI\left(\frac{N}{S_0}\right)y'Wy}/Y'y \tag{1}$$

where N is the number of observations, S_0 is the sum of all elements in the spatial weights matrix, $y'yI$ are the observations from the mean, W is the spatial weights, and Wy is the associated spatial lag.

4.3 Hot spots and cold spots of environmental perceptions and place attachment

In addition to Moran's I autocorrelation, we also performed spatial pattern analysis to identify hot spots and cold spots of environmental perceptions and place attachment. The hot spot was quantified using the Getis-Ord Gi* statistic [44]. The statistic calculates the similarity of neighbouring features, and hot spots are identified by high values surrounded by other cells with high values. Hot spots are spatial clusters of high values while cold spots refer to spatial clusters of low values. However, to be a statistically significant hot spot, a feature will have a high value and be surrounded by other features with high values as well. The Gi* statistic as defined by Ord and Getis [44] is:

$$Gi* = \sum_{j=1}^{n} W_{ij} \ldots \frac{x_j}{n} \sum_{j=1}^{n} X_j \tag{2}$$

where $Gi*$ describes the spatial dependency of a variable i over all n events, X_j = magnitude of variable X at incident location (the ward) j over all n (j may equal i), and W_{ij} = weight value between event i and j that represents their spatial interrelationship.

After the hot spot analysis, we then performed a cluster–outlier analysis. The Gi* statistic tends to treat cluster intensities within a variable homogenously, and thus fails to identify variations (outliers) that may exist within each cluster. These concealments can be identified using cluster–outlier analysis. This cluster–outlier analysis was done in this study using Anselin Local Moran's I statistic, which is computed as:

$$L_i = \frac{y_i - Y}{n - 1 \sum n \left(y_i - Y^2\right)} \sum_{j}^{n} W_{ij} \left(y_j - Y\right) \tag{3}$$

where W_{ij} is the spatial weight between ward i and ward j given by the weight matrix W, y_i is the environmental attitude/place attachment value of the ward of interest while y_j represents the attitude/place attachment index value of the neighbouring ward. Finally, Y represents the average attitude/place attachment value [6].

4.4 Geographically weighted regression for determining socio-economic factors influencing environmental perceptions and place attachment

Geographically weighted regression was used to assess how environmental perceptions and place attachment variables (dependent variables) are can be explained by variations in socio-economic variables (explanatory variables). Unlike global models, the GWR builds Ordinary Least Square (OLS) models at each locality by assuming non-stationarity of relationships across space [22]. Geographically weighted regression has in the past been used in understanding the spatial interplay between socioeconomic variables and disease risk [53] and the equity of public space distribution [36], among others. For brevity, only the number of people who perceived improvement in the environmental category was used as dependent variable. Similarly, only people who agreed to place attachment (strongly agree plus agree) were used as dependent variable for the place attachment group.

The GWR estimates the weights (coefficients, β) of independent variables as:

$$y_i = \beta_0 + \beta_1 x_1 i + \beta_2 x_2 i + \cdots + \beta_n x_n i + \epsilon i \tag{4}$$

with the estimator:

$$\beta = \left(X^T X\right)^{-1} X^T Y \tag{5}$$

Having identified the independent variables, variations in space are then estimated using GWR, using the regression model with the estimator:

$$\beta'\left(i\right) = \left(X^T W(i) X\right)^{-1} X^T W(i) Y \tag{6}$$

where $W(i)$ is a matrix of weights specific to location i such that observations nearer to i are given greater weight than observations further away [22].

Given that the outcome or dependent variables measure counts of occurrences (total number of people per ward), Poisson regression was applied to build the GWR models. Geographically weighted Poisson regression models (GWPR) is one of the spatial count

regression models that capture the localisation effect on various influencing factors on the dependent variable, using maximum likelihood estimations [4]. Both the spatial pattern analysis and the GWR modelling were implemented in ArcGIS Pro.

5 Results

5.1 Spatial autocorrelation of environmental perceptions and place attachment

Moran's I scatterplots and box plots were constructed to assess clustering in our dataset. Figure 2 shows scatterplots and boxplots of the spatial associations of clusters. Each scatterplot has four quadrants; the lower left and upper right quadrants indicate spatial clustering of similar values. Specifically, the lower-left quadrant shows negative values of the Gi* and the upper-right quadrant represents positive Gi* values. The upper-left and lower-right quadrants indicate spatial association of dissimilar values: low values surrounded by high neighbouring values for the former, and high values surrounded by low values for the latter. Figure 2 also shows that the trends for both environmental perceptions and place attachment are positive, as indicated by the slope of the regression line (Moran's I). The positive trends show the spatial clustering of predominately similar values with fewer spatial clustering of dissimilar values.

Figure 2 also shows box plots associated with environmental perceptions and attitudes. The presence of spatial autocorrelation has a strong influence on the distribution of Moran's I for both the attributes being measured. The mean and standard deviation (s.d.) for both attributes are high, indicating spatial clustering. In effect, therefore, respondents expressed much higher feelings of negative place bonding in the province than they did positive environmental perceptions. It is important to note that the results (observed) of the statistical tests for the Global Moran's I were all significant with a p-value < 0.05, whereas the expected values were -0.013 for environmental perceptions and -0.001 for place attachment.

Having determined the spatial autocorrelation of environmental perception and place attachment variables, we then mapped spatial patterns to identify hot spots and cold spots of these variables. Figure 3 indicates that hot spots for environmental perceptions (a) and place attachment (b) were mostly concentrated in the relatively central wards of Johannesburg, Ekurhuleni and Tshwane, while outlying wards within the West Rand and some parts of Sedibeng were dominated by cold spots.

5.2 Observations of outlying environmental perceptions and place attachment

Cluster–outlier analysis was performed to determine outliers of environmental perceptions and place attachment variables within clusters. Clusters can either be high-high, low-low, high-low, or low-high. High-high and low-low patterns represent target samples belonging to clusters of similar values, whereas high-low and low-high represent samples with values that are an outlier to the clusters surrounding them. Table 2 presents the number of high–high, low–low clusters, high–low and low–high spatial patterns. In support of Moran's I scatterplots plotted for the two attributes, place attachment had a higher number of high–high clusters than did environmental perceptions. This indicates a much higher

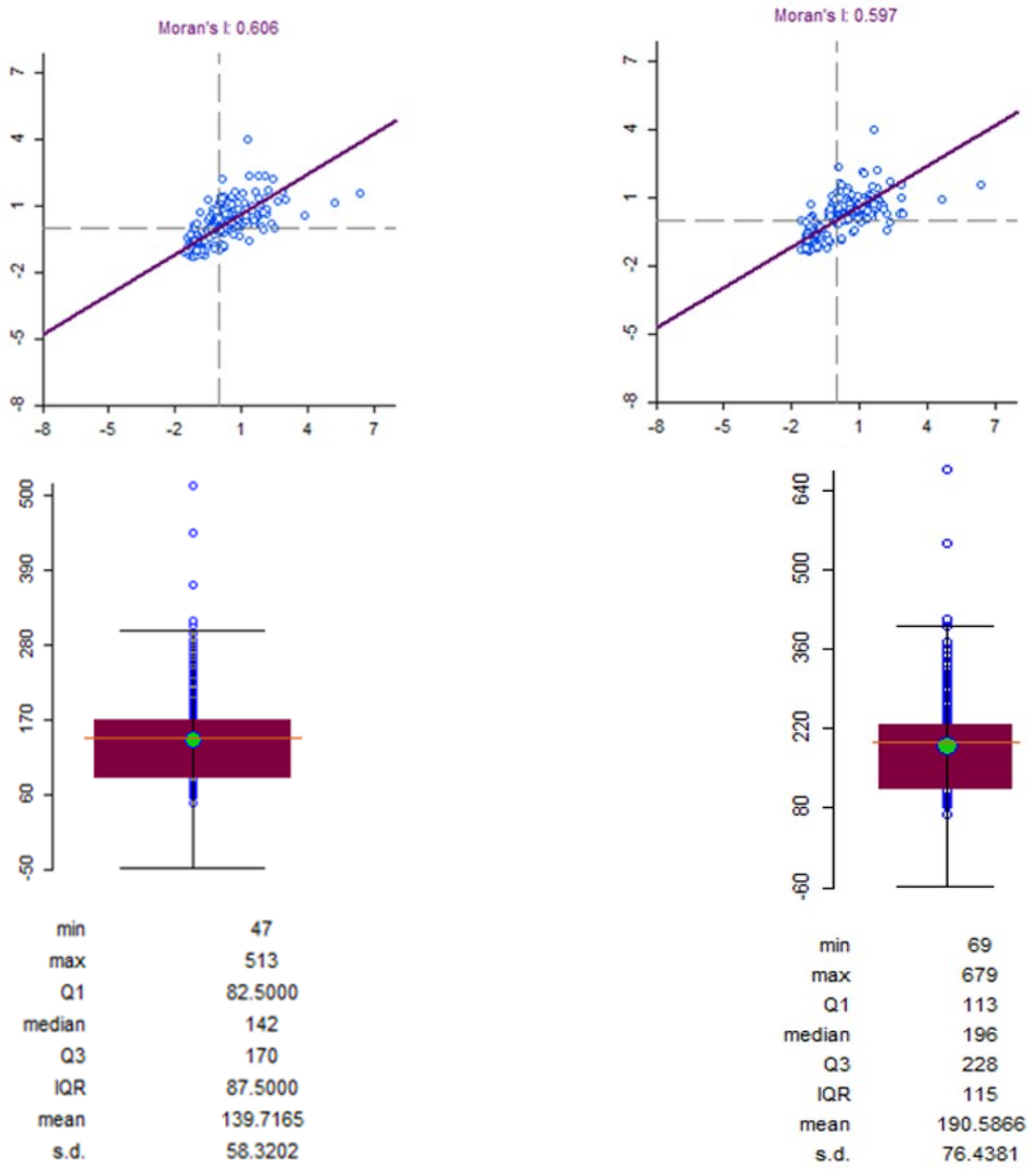

Figure 2: Moran's I scatterplots and box plots for environmental perceptions (a) and place attachment (b).

occurrence of positive place attachment for the province than positive environmental perceptions. However, there was a slightly higher number of wards with low–low values for environmental perceptions than for place attachment. Effectively, cold spots for environ-

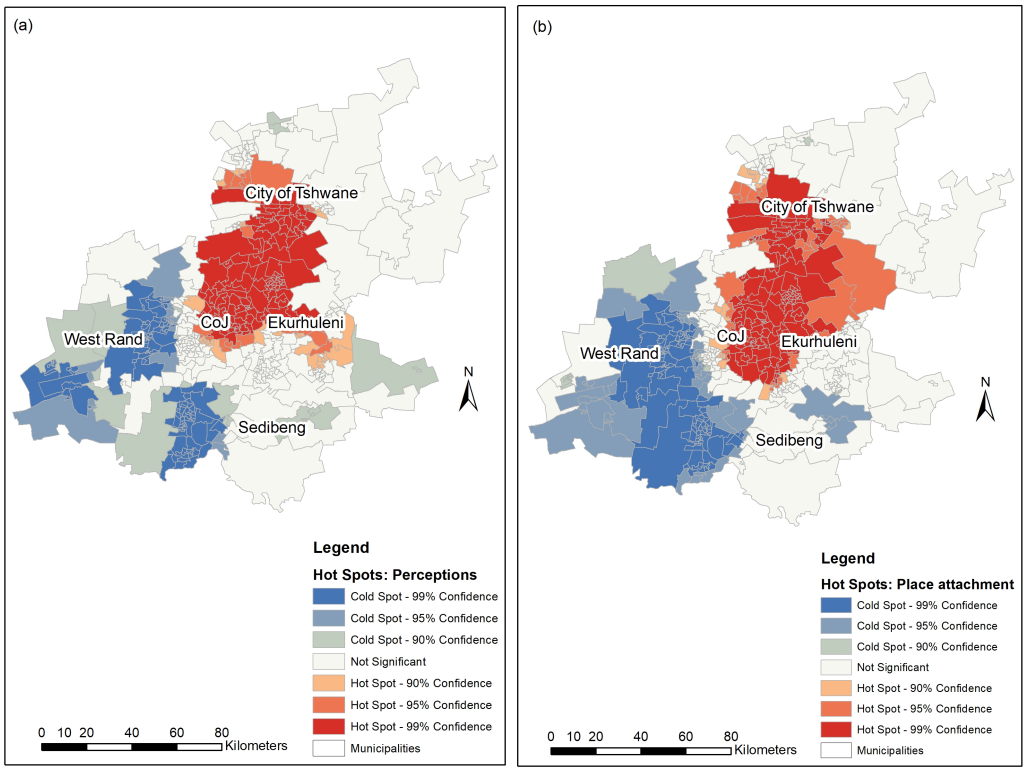

Figure 3: Hot spots and cold spots for (a) environmental perceptions and (b) place attachment.

mental perception were higher than those for negative place attachment. It follows that there were more concentrations of lower positive perceptions about the environment than place attachment.

	Environmental perceptions	Place attachment
High-high	191	205
High-low	16	10
Low-high	36	42
Low-low	164	162

Table 2: Clusters and outliers for environmental perceptions and place attachment (n=529).

5.2.1 Maps of high–high and low–low patterns

The cluster maps, together with their levels of significance, are depicted in Figure 4. The maps show interesting patterns, where wards in or close to the centre of the provinces show more similar values of environmental perceptions and place attachment, while those on the

periphery are dominated by cold clusters (indicating negative environmental perceptions and place attachment). More specifically, there was a dominance of high–high clusters in central wards of Johannesburg, Tshwane, and parts of Ekurhuleni. In contrast, cold spots were dominant in the less affluent, peripheral wards of the West Rand and Sedibeng. It appears, therefore, that central wards held more positive environmental perceptions and place attachment values than peripheral wards.

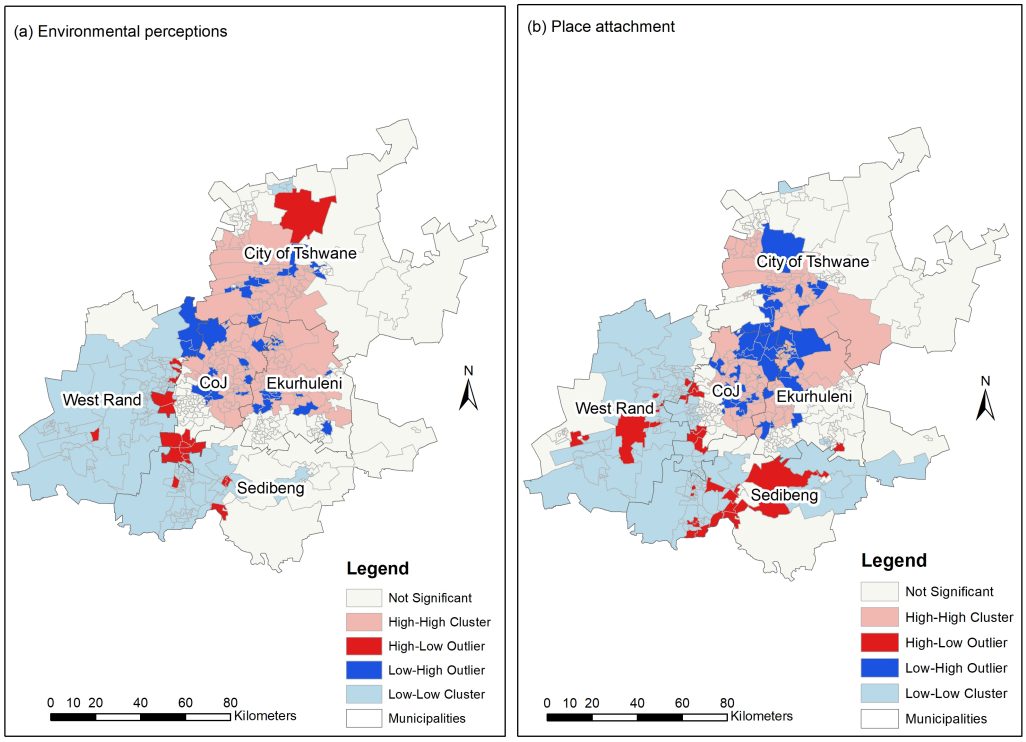

Figure 4: Cluster maps for (a) environmental perceptions and (b) place attachment.

5.2.2 Maps of low–high and high–low patterns

Low–high and high–low outliers were also identified. These values represent outliers of the variables being measured.. This means some wards would have high positive environmental perceptions being surrounded by outliers of low values for place attachment. High–low outliers are wards with high values of the mapped measure surrounding a ward with a low outlier value of the measured variable. For environmental perceptions, high–low clusters were found on the outskirts of Johannesburg, and the periphery of the Sedibeng District Municipality. They followed a similar pattern for place attachment. The low–high outliers, in contrast, were located on the immediate outskirts of the core wards of Tshwane and Johannesburg. Notably, these are the centres where areas with different socio-economic and

demographic characteristics are juxtaposed, e.g. where informal settlements have grown around more affluent areas. These juxtaposed areas may express differences in environmental sentiments. In Tshwane, these areas consisted of peri-urban areas and informal settlements on the outskirts and similarly in the south-eastern parts of the province. For example, these juxtapositions are also concentrated in the central band of informal and high-density settlements in the Johannesburg. Notably, however, large parts of the province displayed non-significant values for environmental sentiments being tested.

5.3 Geographically weighted regression for determining socio-economic factors that influence environmental perception and place attachment

Geographically weighted regression was conducted to assess the spatial relations between selected socio-economic variables with environmental perception and place attachment variables. The socio-economic variables selected in the study explained the variation in the number of people who agreed with place attachment quite well (Figure 5a) with the multiple coefficient of determination (R^2) of 0.68. The explanatory power of the same socio-economic factors on the variation who perceived improvement in environmental conditions was even more impressive at R^2 of 0.81. It is important to look into the contributions of each socio-economic factor in explaining the numbers of positive responses to place attachment and environmental perceptions. All factors had positive and linear overall contributions to both depend variables (result not included in this paper). The number of people below the age of 50 years was the most important factor in explaining place attachment followed by the number of females while high income levels and holding college-level qualification contributed the least in the estimation (Figure 5c). In contrast, multiple socio-economic factors made significant contributions to the estimation of environmental perception with people living in formal dwelling type being the greatest contributors while five of the six factors making a contribution of R^2 of 0.27 or more each (Figure 5c). Such difference in the importance of explanatory factors agrees with the overall R^2 that was better for environmental perceptions than for place attachment.

Accuracy of estimation of environmental perception and place attachment are shown using residual deviance in Figure 6. The residual in place attachment estimation was the lowest (-0.5 to 0.5) mostly in the north- eastern and south-eastern parts of the province. Although overestimation and underestimation (negative and positive residuals, respectively) existed, most were relatively low falling between -1.5 to -0.5 distributed evenly across the province. The best estimation accuracy (residual of -0.5 to 0.5) for environmental perception were prevalent in the central followed by north-eastern and western parts of the province. Similar to place attachment, the over- and under-estimations were not severe for environmental perception.

6 Discussion

The results point to a pattern where the central wards of the province hold more positive environmental perceptions and place attachment than those in the periphery. There was also a pattern where the low–high outliers are distinctly located in the immediate outskirts of the central wards of the cities of Tshwane and Johannesburg. Notably, these are the

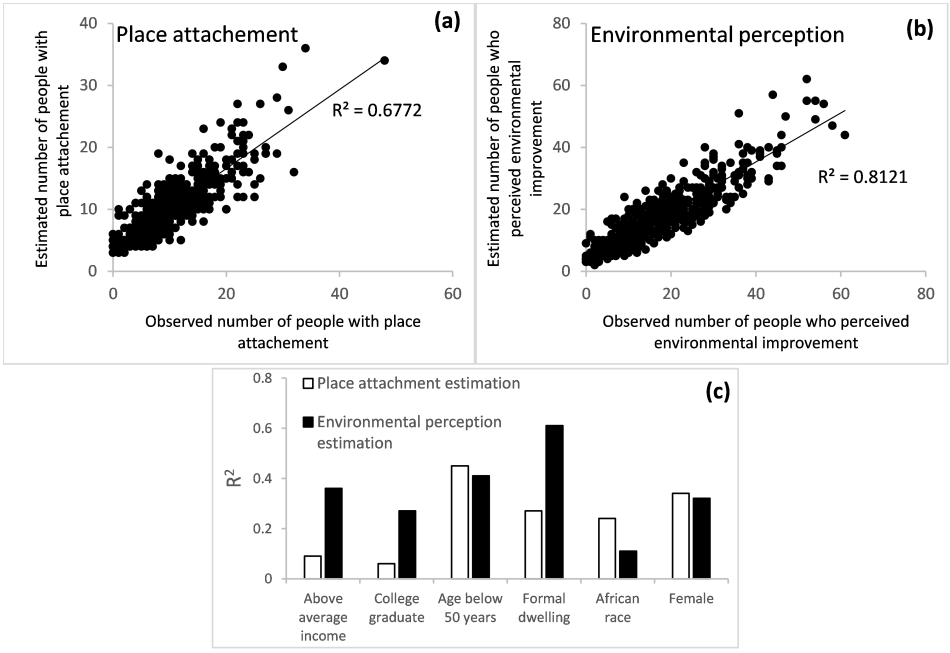

Figure 5: Goodness-of-fit between estimated and observed number of people who agreed with (a) place attachment and (b) improvement in the environment. The contributions of individual factors to the estimations of both dependent variables are shown in (c).

centres where areas with different socio-economic and demographic characteristics are juxtaposed, e.g. where informal settlements have grown around more affluent areas, or high-density inner-city areas that are surrounded by affluent suburbs. Respondents in these spatial areas expressed differences in environmental sentiments. Geographically weighted regression results indicated that gender was a more significant predictor of environmental perceptions than it was of place attachment. The model also showed overprediction in less affluent districts of the province.

The central wards in Johannesburg, Tshwane, and Ekurhuleni displayed positive environmental perceptions and place attachment. Conversely, the peripheral wards expressed negative environmental perceptions and place attachment during this period. Notably, the core wards of the province are dominated by more affluent areas around the cities of Johannesburg, Tshwane, and Ekurhuleni. The peripheral wards, in contrast, are dominated by less affluent wards mainly in the Sedibeng and West Rand DMs. Researchers have in the past pointed to a link between economic deprivation and environmental concern. The link is complex, and the results have not been conclusive [10, 31]. Some researchers have used the deprivation theory to indicate that central places within an urban area are more likely to express positive sentiments because they have more economic power and access to resources [26,35]. In addition, the geographic discounting theory [43] proposes that people prefer to stay close to what makes their lives more bearable, such as access to resources, places of work, or people with similar values. This has implications for the aggregation and disaggregation of people of different socioeconomic statuses in space.

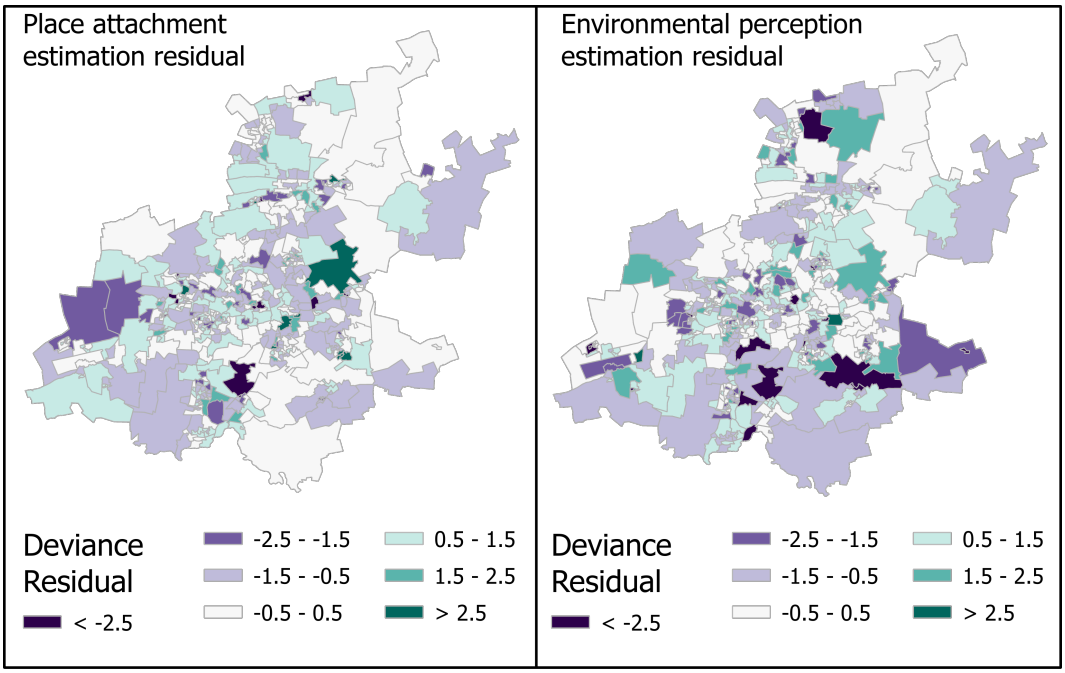

Figure 6: GWR estimation residuals of place attachment and environmental perceptions across the Gauteng province.

In addition, in light of the dependency theory, the peripheral areas are more deprived, with power and decision-making processes that are not in their favour [45]. Despite such levels of deprivation, these areas are likely to reflect community bonds that are built over social and emotional ties to place and community (unlike in the more urbanised centre, where such bonding may be minimal) [34]. Socio-demographically, Peberdy et al. [45] have noted that peripheral areas are likely to be dominated by challenges including insufficient schooling facilities and migrants who may not have the capacity or necessary documentation to readily take their children to school. Areas with a less educated population then become dominated by unskilled workers, low-paid employment, less investment and uneven development. Peberdy et al. also showed congruity in many areas with regard to employment for individuals living in core and peripheral areas.

Peberdy et al. [45] also noted that peripheral areas in the province are largely characterised by high rates of unemployment. Second, people resident in the periphery may be employed in core areas, where a cheap labour force is used for capital accumulation, yet the periphery does not benefit from this development. Our study also showed a link between socio-economic disadvantage, marginality, and peripherality, with the less affluent expressing more negative environmental sentiments. The spatial distribution of people according to socio-economic status could be a result of South Africa's past policies of apartheid (separate development) which established core-periphery disparities [45]. In response, the post-apartheid policy of the government has attempted to redress these disparities through the provision of low-cost housing, mostly in peripheral areas and on the edges of the province, where land is cheap. These houses are, however, still devoid of proper services such as

water, sanitation, and refuse removal, although strides have been made in the provision of electricity in disadvantaged communities.

However, other research findings have found a more complex link between ethnicity, socio-economic status and pro-environmental sentiments. A study by Anderson et al. [5], for example, found that less affluent African households held more positive environmental sentiments through waste recycling than Indian, Coloured, or White households. This is despite the other finding of the same study, that found that the higher the level of educational attainment of the head of household, the more likely it was that a household recycled—with African households more prone to recycle even though the head of the household had no education at all.

The link between economic well-being or deprivation to environmental behaviour has, however, been inconclusive [3, 32]. Some researchers have linked economic deprivation to negative environmental sentiments, like having lower environmental concern, negative environmental attitudes, and negative place bonding [17]. Others, however, have found that increased levels of well-being lead to a decrease in environmental concern [38]. Following the dependency theory, it would mean that people centrally located in urban areas express more positive environmental values, pro-environmental behaviour and higher levels of place attachment. This notion has been disputed in several circles, with some researchers suggesting a more complex interplay between socio-demographic characteristics and that people who are more economically deprived also exhibit pro-environmental behaviours [5, 7]. In contrast to Anderson et al.'s findings, others such as Theodori and Luloff [51] in their study in America found that respondents with higher incomes were significantly more likely than those with lower incomes to exhibit pro-environmental behaviours like recycling. Theodori and Luloff [51] also found that politically liberal respondents were significantly more likely than their politically conservative counterparts to contribute money or time to an environmental or wildlife conservation group, read a conservation or environmental magazine, and watch a television special on the environment. These results, however, are also in contrast to those reported by Brechin and Kempton [9], who concluded that research within industrialised nations does not support the idea that higher incomes are associated with higher levels of environmental concern, and that other factors like education, religion and political orientation interplay with economic factors to determine pro-environmental behaviours. Theodori and Luloff's [51] findings, however, were in agreement with the notion that education was a positive and significant predictor of pro-environmental behaviour, with highly educated respondents significantly more likely than those with lower education to contribute money or time to an environmental or wildlife conservation efforts.

In essence, therefore, the more educated and politically liberal residents in core areas are likely to hold more pro-environmental behaviours than their peripheral counterparts. However, the literature is not conclusive on whether economic status is responsible for the lower levels of environmental perceptions of people dwelling on the city periphery; hence our assertion that social community ties are more characteristic of communities living towards the periphery of the city. These ties can strongly contribute to explaining environmental perceptions and place bonding in our study area. This assertion is supported by studies by Brehm et al. [10] who found that longer-term residents who had a high level of social attachment held higher and more positive levels of environmental concern than those who were more focused on the protection of their local environment and surrounding landscapes. Such social attachment appears to be an important predictor of local environ-

mental concern, especially when the indicators reflect aspects of the environment that are particularly relevant to community culture or identity. This is characteristic of areas where place bonding is linked to communal ties, as is the case in the peripheral wards in our study area.

Geographically weighted results showed that age and gender were key factors influencing place attachment. The number of people below the age of 50 years was the most important factor in explaining place attachment followed by the number of females. Geographically weighted regression has been used to predict how gender predicts obesity [33], and commuting habits [21], whilst no studies were identified on how it predicted environmental perceptions and attitudes. Essentially, therefore, being either male or female is an important predictor on whether one will have positive or negative feelings about the environment, particularly in the relatively more affluent metros of Tshwane and Johannesburg. This has implications of taking gender into account for environmental planning in these areas of the province. Dwelling type and age were key factors influencing environmental perceptions in Gauteng, South Africa. Living in formal dwelling type was the greatest contributor in determining people's environmental perceptions followed the number of people below the age of 50 years.

7 Conclusion

Exploratory spatial data analysis results and GWR have indicated distinct patterns in the distribution of environmental perceptions and place attachment within Gauteng. In support of the research hypothesis, higher levels of environmental awareness and place attachment are positively related to positive perceptions and place attachment, and vice versa. Results indicate a concentration of negative environmental perceptions and place attachment in the southern, peripheral wards of the province, with simultaneous indications of positive values of these sentiments in central, more affluent wards. In explaining this pattern, we used the dependency theory in an attempt to explain it, indicating that environmental sentiments may be linked to the geography of the province, where central wards are more affluent than the peripheral wards, and linked this to pro-environmental behaviour, based on the literature that has found a link between socio-economic status and certain environmental behaviours. We have also asserted that, based on the literature, peripheral areas are more likely to display community attachment because of community ties built around close-knit communities in urban peripheries, while central areas are likely to exhibit a sense of place arising from their relationship with their physical environment. This is because the link between socio-economic status and pro-environmental behaviours is complex. Consequently, even though there is a distinct geo-location of wards based on race and socioeconomic status within the province, various research has found conflicting results on the relationship between these aspects and environmental behaviour. Numerous factors like political affiliation, education level and employment status interplay to determine environmental behaviour, as asserted by various researchers (e.g., [3, 51]) who have noted the complexity between place, demographic and socio-economic status in determining environmental behaviour.

Geographically weighted regression results showed that the socio-economic variables explored in this paper explained the variation in the number of people who agreed with place attachment and improvement of environmental conditions sufficiently with high

multiple coefficient of determination with $R^2 = 0.68$ and $R^2 = 0.81$ respectively. The number of people below the age of 50 years was the most important factor in explaining place attachment followed by the number of females. For the estimation of environmental perceptions, living in formal dwelling type was the greatest contributor followed by the number of people below the age of 50 years. In addition, geolocation was a significant factor in predicting the influence of gender on perceptions and attachment. Furthermore, GWR results indicated that gender was more of a predictor of perceptions than attachment, particularly in the relatively more affluent districts of Tshwane and Johannesburg in the Gauteng province.

However, despite the significance of our findings, some limitations of these data must be considered. First, our environmental perception and place attachment variables were based on questions not that had not been designed to accurately measure perceptions or attachment; this may have influenced the responses in that they may be a reflection of people's sentiments not related to the environment. Framing the questions to directly determine environmental perceptions and, in particular place attachment, may have yielded more specific results. Second, there were no follow up questions to measure specific environmental behaviours such as engaging in recycling activities, or reactions to perceived environmental pollution. However, the study findings are useful in identifying that environmental planners need to direct environmental resources towards improving community attachment in peripheral areas, for example by setting up or supporting environmental community groups, or physical environmental amenities in core areas to improve the levels of positive environmental perceptions and place attachment.

Also, the analysis was done at the ward level which has shortcomings because perceptions are not bound by administrative boundaries. Furthermore, wards are political delineations and might not illustrate socio-economic characteristics clearly. However, in the absence of other data of this nature at a detailed spatial level, we believe the analysis adds significant value to understanding the spatial distribution of environmental perceptions and place attachment. In addition, a variety of factors may have prompted responses to the two selected survey questions, and this presents another limitation to our study. The human–nature phenomenon being analysed (i.e., environmental perceptions and place attachment) cannot be confined to arbitrary administrative boundaries such as wards. The approach adopted therefore focused on a particular ward in relation to its neighbouring wards, giving rise to spatial autocorrelation (i.e., clustering of wards with near similar levels of environmental perceptions and place attachment). Furthermore, the study did not set out to compare two societies (i.e., rich and poor) but rather focused on the spatial distribution of perceptions about the environment and place attachment.

Despite the limitations, the study findings can assist environmental planners and policymakers in identifying risks associated with potential land-use changes that may diminish peoples' identification with their places. They can also aid in resolving land-use conflicts where changes in land use are proposed or planned. Future work should directly investigate the link between long-term residence, community cohesion and positive environmental concerns.

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