Modelling catchment area of economic activity using GIS-based Huff Gravity Model: A case of Edo State, Nigeria

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Abstract

The need for rapid economic development to match increasing population in Nigeria cannot be overemphasised. For this need to be met, it is pertinent that resources in each state and region of the country are efficiently and effectively utilised to maximise return on investments. Thus, it is necessary to identify the catchment area of the current markets to provide an understanding of the market structure which exists at different scales. This study utilised a Geographic Information System (GIS) -based Huff Gravity model to identify the economic catchment areas of major centres. Results show that 13 out of the 14 centres attracted nearby subregions (SRs). The top 7 centres identified accounted for 86% of the potential economic activities. There is a tendency for limited spatial interaction for some SRs in the south in contrast to northern SRs. In conclusion, there is more competition for economic activities among centres in the northern part with the potential to create some winners and losers. Therefore, place-based policies which can enhance economic development across all regions are necessary.

Keywords: Internal market; GIS, Economic Catchment Area; Huff Gravity Model; Spatial Interaction; Geographic Proximity

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Introduction

In the current economic clime, there is a need for rapid economic development to match the increasing population (Department of Economic and Social Affairs, 2018) of Nigeria and many of its regions (especially the Niger Delta and her States). For this need to be met, it is pertinent that resources in each State and region of the country are efficiently and effectively utilised to maximise return on investments. This brings to the fore questions such as: what is the economic reach of the major towns and cities across a region? Where should investment go to stimulate economic growth and development? Answering these questions could help identify isolated places, as well as potential locations for secondary cities or hubs which could spawn economic activities. Moreover, it is pertinent to model and identify the catchment area of economic activities of major towns and cities within a state or region. As such, this study modelled catchment areas for major towns and cities within Edo State with the purpose of generating a model that represents the internal market area for the identified spheres within Edo State.

The determination of the economic reach or catchment area is very important in supporting effective and efficient allocation of resources. It is also relevant for decisions on policy incentives to achieve a holistic and widespread economic development across a region. This could provide evidence to support the siting of growth or innovation hubs which could drive economic development. Such evidence could help to stimulate growth outside of the traditional and established economic centres while also helping to ease the congestion currently being experienced by many urban agglomerations. This is particularly important in Nigeria as the urban population is set to continue to increase (Department of Economic and Social Affairs, 2018) despite an incongruent increase in infrastructure to handle such a growing population (Ogun, 2010).

Essentially, to understand where economic activity can be stimulated, there is a need to understand potential origins of the current level of activities around the major towns and cities Thus, it is pertinent that a clear understanding of catchment areas of such places is brought to bear in the decision to locate additional growth hubs or centres to better serve any State/region.

Despite its importance, research on economic catchment areas for towns and cities in Nigeria is patchy at best. However, initial attempts at modelling economic potential could be found in the works of Lawal (2017); Lawal and Kalu (2018); and Lawal and Nuga (2015). These initial efforts used Gross Domestic Product (GDP) and age dependencies to group States across the country in order to identify the level of economic activity and the potential for reaping primary and secondary demographic dividends. However, our search shows that there is currently no extant literature clearly identifying the economic reach of major towns and cities across Nigeria.

In analysing the economic reach (market area) of places, the gravity model (GM) (pioneered by Ravenstein (1885)) in its various variations has been employed. This approach is based on the understanding that distance decay is at play in economic activity. As the distance between two places increases, the amount of activity between them is likely to decrease. Trade between places is a good indicator of the potential interaction between place and subsequently area of influence. Unfortunately, such trade data are not available at local or regional level in Nigeria. Fortunately, other predictor variables can be estimated from field data, remotely sensed data and aggregated data for input into the GM. Using the GM and its variants as proxies for identifying market area or reach of places has its foundation in Newton's physical law of gravity. The law can be interpreted in economic terms, as economic flows (spatial interaction) will vary with the size of the economic activity of the origin and destination, and interaction will vary inversely with distance between the source and destination. Conceptually, the value of trade (economic activity) between two places could be likened to the gravitational pull between the two. This pull depends on the totality of economic activity of an area (measured or estimated) within both areas as well as the distance that separates them. This approach has been used extensively across various fields (migration, trade, economic, transport, etc.) and across different parts of the world.

The World Bank and AusAID (2010) used the proximity indicator as a function of the distance between towns and their trading outputs (GDP). Examining the Sub-Saharan Africa region along three dimensions – density, distance and division, the result created a ranking of cities or municipalities (thereby identifying growing and lagging areas) across the region based on indicative output growth between 2000 and 2006.

Battersby (2006), working on the premise that geographic isolation can reduce the labour productivity potential of an economy (highlighting the issue of tyranny of distance as elaborated by Blainey (1966)), used the Gravity Model of Trade (GMT) to test the effect of distance on trade between Australia and USA. Analysis include the test of the effect of internal geographic proximity on labour productivity. The analysis produced a proximity indicator which combined weighted own-state output, weighted other-state output and weighted other-country output (weights were based on distance to the outputs). In conclusion, the author shows that there is evidence of the link between the proximity of State to output and labour productivity, and consequently Australian states may be disadvantaged because of their distance to the global economic centres as well as their distance from one another.

Battersby and Ewing (2005) examined how distance and economic size influence the level of international trade using GMT. They noted that since distance to world economic mass influences the expected level of trade, essentially the distance and size of the economy of Australia have a role in determining the economic outcomes. To explain regional income inequalities across Norway, Midelfart (2004) used level 4 territorial units for statistics in the EU (sub-regional data) for the manufacturing sector to examine the effect of agglomeration and skills on regional variation in income and productivity. The study shows that the effect of agglomeration and location has become more important, contrary to the view that with technology, distance will become less important. Midelfart (2004) concluded that higher incomes across Norway's sub-regions could be attributed to high activity density rather than education and skills.

Brodzicki, Śledziewska, Ciolek, and Uminski (2015), in trying to identify the determinants of intensity of bilateral trade flows of Poland with her trade partners, utilised the GMT for the period between 1999 and 2013. They found that the impact of partners' size (real GDP of trade partner) and distance on level of export is highly significant, while adjacency also has a positive impact on level of exports. Essentially, intensity of export to partners decreases with distance and increases with the size of the partner. Thus, the authors show that geographical proximity is an important factor in spatial interaction (trade flow), potentially due to the cost of transportation and information.

Based on the understanding of the negative effects of isolation from both regional and international markets as results of bad transport infrastructure, Buys, Deichmann, and Wheeler (2010) quantified potential trade expansion as a result of the proposed African Development integrated road network project across Africa. Using cities with a population of over 500,000 and the network of primary roads linking such cities, they estimated overland trade flows with gravity model parameters – road transport quality indicators, road distance and estimates of economic scale of the cities. The result shows that Trans African Highway corridors will expand trade by about $250 billion over 15years.

Combining economic and geographical attributes of places across the Philippines, Beronilla, Esguerra, and Ocampo (2016) assessed the potential for trading activity to measure economic potential. The study applied GMT in generating trade at town or city level. The result shows that the National Capital Region, neighbouring provinces and the Cebu Region have high economic potential. In addition, peripheral areas such as Cagayan Valley and the Central and Western parts of the Mindanao region area have low trade output.

Huff's gravity model (HGM) (Huff, 1963), another variant of the GM, is also based on the understanding that the interaction between two places will decrease with increasing distance between them. It determines the probabilities of consumers at certain origin locations patronizing various stores. The model considers size and distance of the stores to derive their attractiveness, combined with the population (with certain characteristics) at a geographic boundary, to estimate potential sales and customers for each store. The probabilities are computed using the equation:

$$P_{ij} = \frac{\frac{S_j}{T_{ij}^{\lambda}}}{\sum_i^n \frac{S_j}{T_{ij}^{\lambda}}} \qquad (1)$$

Where P_{ij} is the probability of a consumer at point *i* travelling to a retail location *j*;

S_j is the size of a retail location;

λ is the exponent and

T_{ij} is the travel time (distance) from the consumer at point *i* to travel to location *j*.

From the literature, HGM has been applied widely for different objectives – solving competitive location problems (Drezner & Drezner, 1998, 2004). Conway (2015) applied it in identifying catchment areas of established casinos in relation to places with people's vulnerability to gambling. Wang, Luan, and Du (2001) analysed the relationship between economic indicators of three regions and Port throughput (Dalian and Yingkou) using Huff's Gravity Model and concluded that there is a need for regional cooperation among the ports to foster development. To understand the anomaly in the catchment area of a store in England, Lloyd and Dykes (2006) carried out a catchment area analysis using HGM. Analysing gaming consumer behaviour, James (2007) compared HGM and the regressive approach and concluded that travel time and casino size are the most significant factors influencing casino customer behaviour, with HGM being superior to the regressive approach. To understand retail dominance across regional malls, Mejia and Eppli (1999) developed an index of retail dominance using HGM to test which one of all the characteristics makes a mall more dominant.

From the foregoing, gravity models have been tested and found useful across many areas of economic activity in showing spatial interaction. Thus, this study utilised HGM in modelling the area of influence or catchment of major towns and cities (subsequently referred to as centres) across Edo State. This study adapted the retail trade area techniques implemented in the HGM to model a catchment area for each of the major centres. This is aimed at identifying linked or isolated places across the State and thereby provide insights to guide intervention programmes which are locally relevant, regionally sound and evidence based.

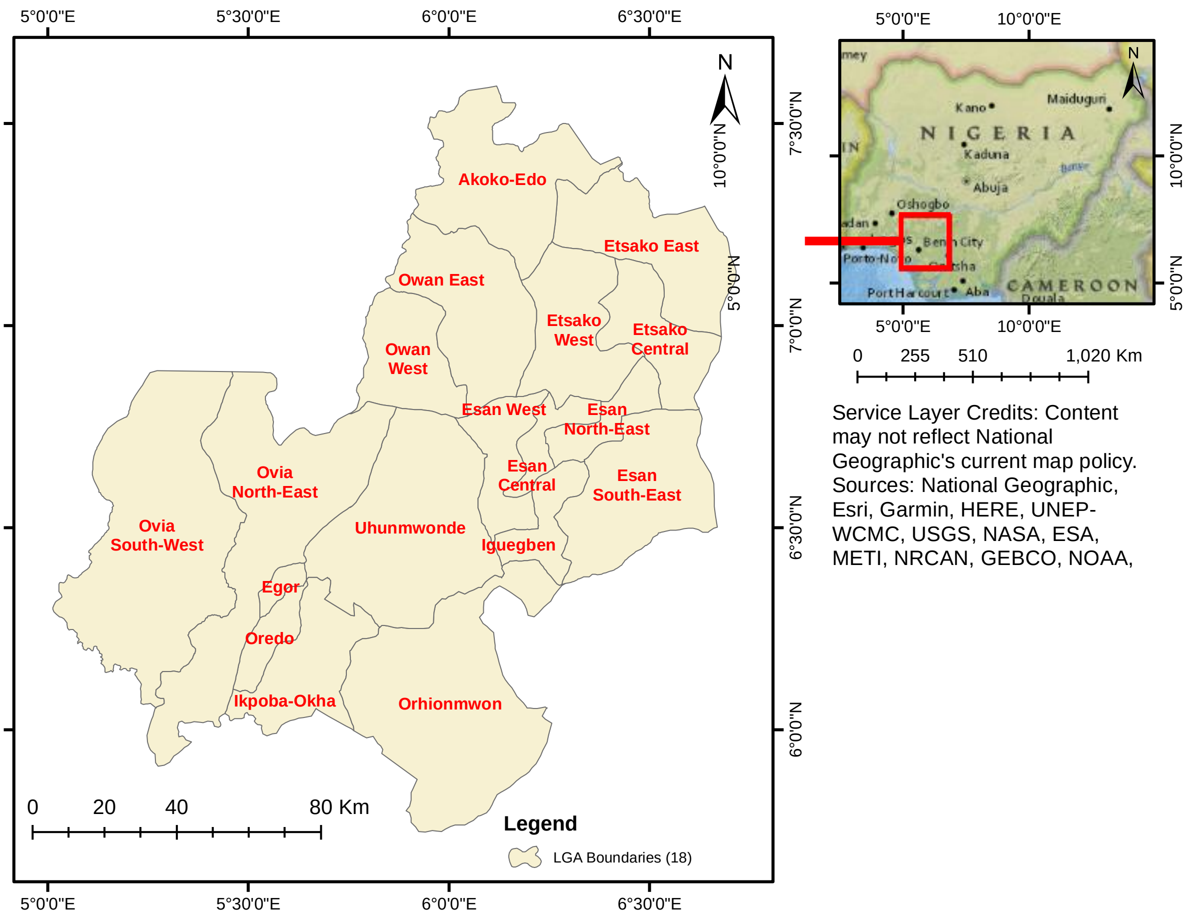

Figure 4: Study area and its Local Government Areas (LGA)

Data and Methods

Study Area

Edo State is located within the Niger Delta Region, and it is divided into three senatorial districts, namely Edo South, Edo North and Edo Central, and into 18 LGAs (Figure 1). The population across these three districts can be described as follows:

Edo South LGAs with Benin communities constitutes 57.54% of the population

Edo Central LGAs with Esan communities are 17.14% of the population, Edo North LGAs have a population of 26.03%, Etsako communities 12.19%, Owan communities 7.43% and Akoko-Edo 5.70% (Edo State, 2006).

However, from the recent estimates by the GeoData Institute (nd), about 55.6% of the population of Edo State can be found in the Southern senatorial district (with 37.1% of these residing in Oredo, Ikpoba-Okha and Egor LGAs). About 17.1% and 27.3% can be found in the Central and Northern senatorial districts of Edo State respectively (Table 1). The three LGAs with the highest population account for only about 6% of the total area of the State; thus population is heavily concentrated around the city while Iguegben has the lowest proportion of the total population.

Table 1: Edo State and characteristics of LGAs

Senatorial District	Local Government Area	Headquarters	Area (Km^2)	Percentage of Total Area	Percentage of Total Population (Estimated 2015)
Edo South	Egor	Uselu	92.95	0.5	12.62
	Ikpoba-Okha	Idogbo	810.85	4.1	11.14
	Oredo	Benin City	249.38	1.3	13.32
	Orhionmwon	Abudu	2420.72	12.3	5.35
	Ovia North East	Okada	2302.51	11.7	4.52
	Ovia South West	Iguobazuwa	2805.72	14.3	3.91
	Uhunmwode	Ehor	2054.57	10.5	4.76
Edo Central	Esan Central	Irrua	250.75	1.3	3.41
	Esan West	Ekpoma	946.1	4.8	3.84
	Esan North East	Uromi	338.53	1.7	3.11
	Esan South East	Ubiaja	1306.97	6.7	4.77
	Iguegben	Iguegben	374.78	1.9	1.94
Edo North	Akoko-Edo	Igarra	1371.72	7.0	7.41
	Etsako Central	Fugar	660.38	3.4	2.66
	Etsako East	Agenegbode	1133.42	5.8	4.18
	Etsako West	Auchi	510.34	2.6	5.89
	Owan East	Afuze	1241.13	6.3	4.38
	Owan West	Sabongida-Ora	732.05	3.7	2.80

Source: National Bureau of Statistics (nd) and authors' computation

A wide range of economic activities take place within the State and such undertakings are dominated by agricultural related enterprise (Niger Delta Development Commission, 2006). A wide variety of staple crops, fruit, vegetables and cash crops are widely grown across different regions in the State. These include Cassava, Yam, Pineapple, Rice, Rubber, Cashew, Oil Palm, Groundnut and Cocoa. There is an extensive mining industry in the northern region and across the south there is a host of activities related to aquaculture, poultry and other agricultural processing enterprise. The State is noted as one of the most prominent global sources of irregular migration and human trafficking (Braimah, 2013).

With the economy strongly dependent on oil revenue (like most States in the Niger Delta), and combined with manufacturing and industrial sectors incapable of absorbing the young, the unemployed and the underemployed, the State is likely to continue to be a destination for human traffickers. It is in the light of this problem that the need arises to produce evidence which can support deployment of investment, identification of potential growth areas and sectors to create alternative livelihoods for potential victims of trafficking, and thus reduce drivers of human trafficking and irregular migration in the State.

Data

Within each LGA, subregions were created and population estimates for these were derived from the 2015 population data (GeoData Insitute, 2017). These subregions served as the origin for the economic agents (households and individual) within the HGM. The major attracting locations (centres) were identified by querying the population data for cells with number of persons per pixel ≥12 (equivalent to 1200 person per km^2). This value was selected based on the exploration of the population raster showing that this value is the lowest peak which coincides with known major towns/cities in the State. These locations were subsequently ascribed their respective town and city names. Further to this, the total population within a 1km radius of each of these locations were also computed.

Methods

The Skater algorithm (AssunÇão, Neves, Câmara, & Da Costa Freitas, 2006) was used in creating contiguous subregions (SRs) using the population data (grid). Regionalisation was carried out for each of the LGAs (18) separately. As such, population raster datasets were extracted for each LGA and turned into vector data. The regionalisation operation was set to use the queen case weights, while population within the LGA served as the input and the minimum bound was set as 10% of the total household within the LGA. Initial number of clusters was set to 10, while the Euclidean distance function and inputs were standardised (Z). This regionalisation exercise was solely aimed at creating spatially contiguous areas which can be used as origins for the HGM.

For the HGM (Equation 2) developed, the assumption is that the population of the centres generates the pull of economic activities from the SRs. Thus, the bigger and closer the town and cities are to the origin (subregions) the bigger the pull. Essentially, the attracting locations are defined as the major centres, while the attractiveness of these places is based on their distances to respective origin of economic agents (individuals within each SR) and their populations. Due to the incomplete nature of the road network data and the lack of information on road quality, Euclidean distance was used for the modelling operations.

$$P_{ij} = \frac{\frac{TC_j}{D_{ij}^{\lambda}}}{\sum_i^n \frac{TC_j}{D_{ij}^{\lambda}}} \qquad (2)$$

Where P_{ij} is the probability of a consumer at region *i* travelling to a major centre *j*;

TC_j is a measure of the attractiveness of each major centre;

λ is the exponent applied to distance and

D_{ij} is the distance from region *i* to major centre *j*.

Tests were carried out to examine the impact of different distance friction coefficients (2-5). This was done based on the understanding that the lower the ease of movement, the higher the friction and the less attractive a location is to economic agents. Search radius constraints of between 25, 50, and 100km were also tested. This is based on the understanding that economic agents have a maximum distance they are willing to travel between their origin and the centres for their economic activity. In other words, economic activity decisions are based on limits that people have about how far they are willing to travel, how far they can travel easily and their judgement of potential return for that activity if that distance was covered. Another implementation of HGM test was carried out using the Nearest Neighbour constraint of 2, i.e. imposing a limit on the number of centres to consider in modelling where economic activity will go. This is supported by the understanding that people always have options, albeit their decision or choice is constrained (Zsolnai, 1998).

To identify the most likely catchment area to which each of the SRs belongs, the mode for all the catchment memberships generated across the nine models was computed. The SRs were assigned to the catchment area for which they were assigned most frequently during the modelling exercise. It is expected that this will give a reliable indication of the direction of pull (catchment area) for most of the economic activities across each SR.

Results and Discussion

Subregions by LGA

A total of 129 SRs was created across the 18 LGAs (Table 2). Etsako Central has the highest number of SRs (9) while Esan Central and Etsako East recorded the lowest number of regions (6). For population across the regions, the 3 LGAs making up the capital city (Ikpoba Okha, Oredo, and Egor - Benin City) have an average population per SR ranging between 70,825 (±11,464) and 65,545 (±13,710), with Ikpoba Okha having the highest mean and Oredo the lowest. The lowest mean population per SR was recorded in Iguegben LGA – 11,180 (±2,444) across 7 SRs. For this LGA, the total population ranges between 7,937 and 14,908 individuals. On average, Ovia South West has the largest areas per SR followed by Orhionmwon and Ovia North East (329 – 401Km^2). The smallest average area per SR was recorded for Oredo. Across the 7 SRs created, the smallest covered an area of about 6.4Km^2 and the largest 41.3Km^2. Oredo also has the smallest standard deviation, indicating that the smallest variation in SRs' extent across the State was recorded in Oredo.

Mean population density (individuals per Km^2) for the 129 SRs ranges between 55 (Ovia South West) and 5323 (Egor), clearly showing that there is a very wide variation across the State. Moreover, the highest population density was found around the capital city (Egor, Oredo and Ikpoba-Okha). From these results, it is evident that the population is skewed towards the capital city in the southern part of the State.

Table 2: Descriptive Statistics of Regions created across LGAs

LGA	No of Region	Population Mean	Min	Max	SD	Area Distribution (Km^2) Mean	Min	Max	SD
Akoko Edo	7	41613	29213	54767	11020	195.959	81.450	302.187	81.631
Egor	7	70679	50194	86268	12038	13.278	6.389	41.327	12.482
Esan Central	6	22642	13891	31676	7529	42.106	14.056	81.486	27.892
Esan North East	8	15346	12387	18370	2012	42.316	11.903	113.053	34.000
Esan South East	7	26828	18936	38291	6922	186.710	34.315	315.046	102.768
Esan West	7	21094	14774	26438	4779	71.773	19.772	149.737	47.105
Etsako Central	9	11659	10503	13737	1088	73.376	23.785	146.872	40.131
Etsako East	6	27449	21363	32836	4340	188.904	86.052	341.470	116.074
Etsako West	7	33130	23216	52791	11306	135.157	10.833	271.582	104.652
Iguegben	7	11180	7937	14908	2444	54.321	20.873	102.836	32.524
Ikpoba Okha	7	70825	55004	83744	11464	123.279	9.919	640.358	231.675
Oredo	8	65545	52661	89886	13710	31.173	4.892	176.732	59.269
Orhionmwon	7	29271	20591	46165	8213	340.439	206.930	791.068	205.438
Ovia North East	7	25242	17953	41602	8408	328.930	9.491	745.557	289.811
Ovia South West	7	21967	15887	38360	7840	400.815	154.730	945.644	278.266
Owan East	7	24600	17309	34737	6238	177.305	38.542	349.098	111.117
Owan West	7	15759	11070	20943	3626	104.578	35.505	191.046	56.222
Uhunmwonde	8	16964	13778	26796	4278	254.311	68.505	555.642	141.490

Source: Authors' computation

The goal of the regionalisation operation is to create SRs that can be used for subsequent catchment area modelling. Thus, the variation within each LGA and across the State is desirable as it gives a close representation of the pattern of human population distribution across the study area. Based on these regions, it is then assumed that individuals within each SR are likely to display similar characteristics. Essentially, individuals within such regions are expected to be pulled towards certain centres for their economic activities.

Economic Activity Catchment Area Modelling

Catchment Area based on Friction Coefficient

Varying the friction coefficient (FC) from 2 – 5, coupled with the assumption that all economic activities are always attracted to major markets within the State, the gravity modelling was carried out to show which catchment area each SR belongs to (Figure 2a – d).

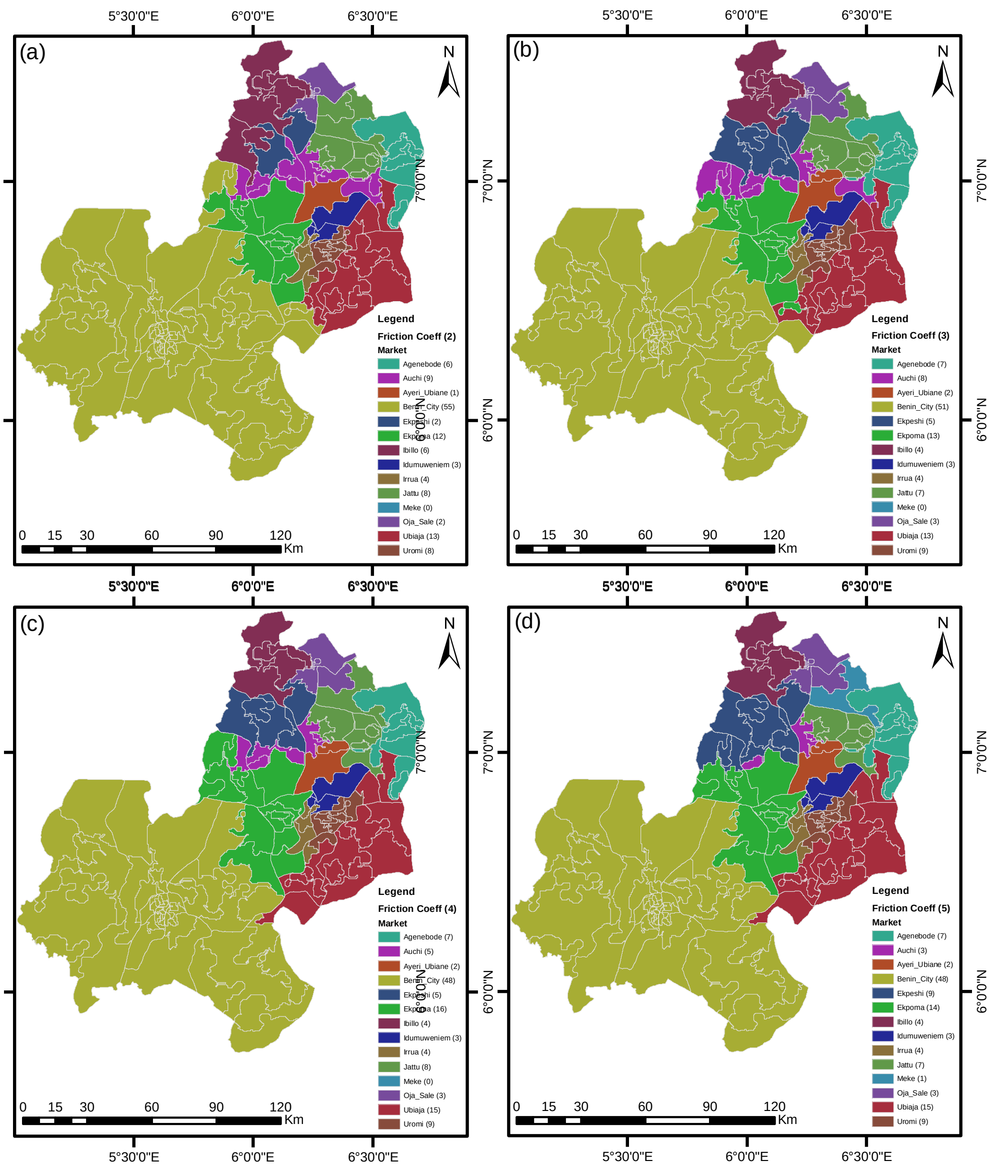

Figure 5: Catchment area for SRs using HGM friction coefficient of 2 – 5

With FC of 2 (Figure 2a), about 43% of the SRs have their economic activities being pulled towards Benin City. Essentially, most of the economic activities in the south are attracted towards Benin City. The SRs attracted to this centre have 56.9% of the population of the State. Ubiaja on the east pulled about 10% of the SRs, while Ekpoma (in the Central region of the State) attracted activities from around 9% of the SRs (both accounting for a total of 13.3% of the population). Auchi, Jattu (both in the North Central part) and Uromi (East) attracted activities from 7%, 6.2% and 6.2% of the SRs respectively (12.2% of the population). Meke is the only centre not able to attract any of the nearby SRs. This could be attributed to the fact that it is surrounded by other major centres with greater pulling power, e.g. Jattu, Auchi and Ekpeshi. Essentially across the State, three major markets (centres) – Benin, Ubiaja and Ekpoma attracted 62% of the SRs (a total of about 70% of the population) for potential economic activities.

Using an FC of 3 (Figure 2b), three major centres (Benin, Ubiaja and Ekpoma) attracted about 60% of the SRs (for a total of 68.8% of the population). This is almost the same as an FC of 2; however, there were slight differences. The total population within these centres was slightly lower - 68.8% compared to 70% in the previous scenario (FC = 2). After these three centres, Uromi is the next (instead of Auchi), attracting 9 SRs with 3.4% of the population. Put together, these four accounted for 66.7% of the SRs and 72.2% of the population. This gave the indication that the majority of the economic activities are potentially attracted towards very few centres across the State.

In the case of an FC of 4 (Figure 2c), the four major centres remained the same. However, the order (Benin > Ekpoma > Ubiaja > Uromi) and the population across the region attracted to them changed. For example, the first three attracted 61% of the SRs with 69.6% of the population. Uromi has 9 SRs with a total of 3.4% of the State's population; this is similar to the observation for an FC of 3. Across the 3 FCs considered so far (2 - 4), Meke has very little pull for economic activities from any of the SRs surrounding it due to its size as well as the economic power of its neighbours.

The last scenario for FC considered a value of 5, and the result (Figure 2d) shows that Benin remained the most dominant attractor of economic activities in the State, attracting 48 SRs across the southern parts (54.3% of the population). Ubiaja and Ekpoma served 22.5% of the SRs with 14.4% of the population. Ekpeshi is the fourth, serving 7% of the SRs with 5.6% of the population within these SRs. Meke was able to serve one of the nearby SRs with 0.6% of the total population. One of the SRs within Auchi's catchment area displayed an odd behaviour – non-contiguous with other SRs within the catchment area. This can be expected since modelling was implemented using Euclidean distance and the closest centre with adequate pull power to this SR is Auchi. However, while it is very plausible that some of the economic activities within this SR might go towards Auchi, but it is very unlikely that the entire activity will gravitate towards Auchi.

Frequency analysis of the catchment area membership for each of the SRs under different FC values (Figure 3) shows that there is a high level of consistency in the membership irrespective of the coefficient. This is evident, as 86% of the SR belonged to just one catchment area irrespective of the value of FC, while only about 1.6% changed every time FC value changed. The consistency is an indication that there is a high probability that catchment areas identified for these SRs are closer to the real catchment area of economic activities. SRs changing with changes in FC were found only in Owan West at the northern extreme of the LGA bordering Owan East.

Generally, as the friction increases, economic activities get more localised, since effort to travel through the landscape becomes more expensive. Moreover, there are indications that in the northern part of the State there are variations in the catchment membership. This could be attributed to the high number of small centres (weak gravitational pull) competing for economic activities. In the south, there is only one economic centre attracting all the economic activities.

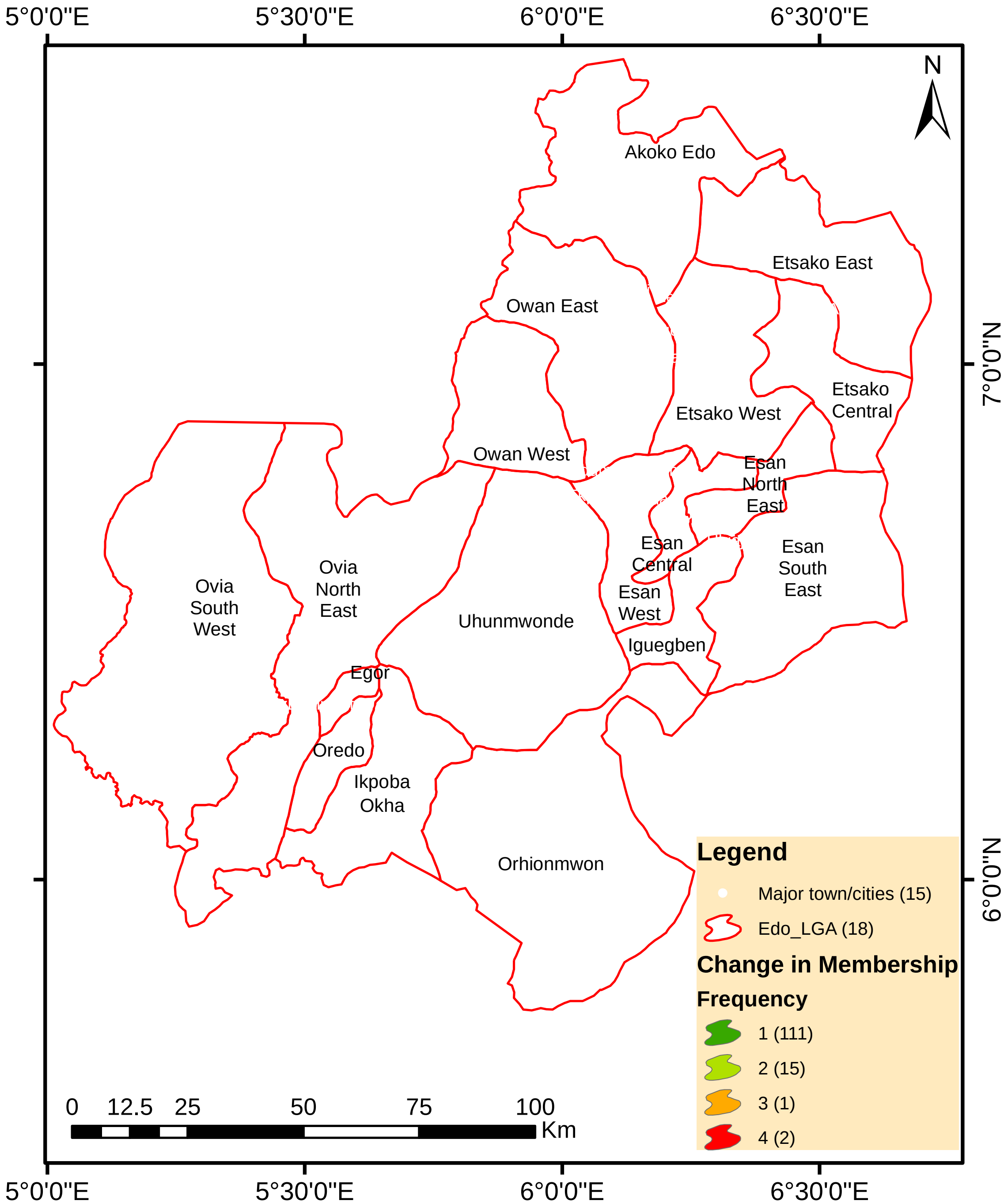

Figure 6: Frequency of change in membership to catchment area (Friction Coefficient)

Catchment Area based on Search Radius Constraint

The potential catchment area was modelled using the search radius of 25, 50 and 100km and the HGM results are presented in Figure 4a – c. Using a search radius of 25km (Figure 4a), for about 27% of the SRs there is the potential for their economic activities to be localised within their extent, i.e. not attracted towards any of the major centres. These SRs represented about 18% of the population.

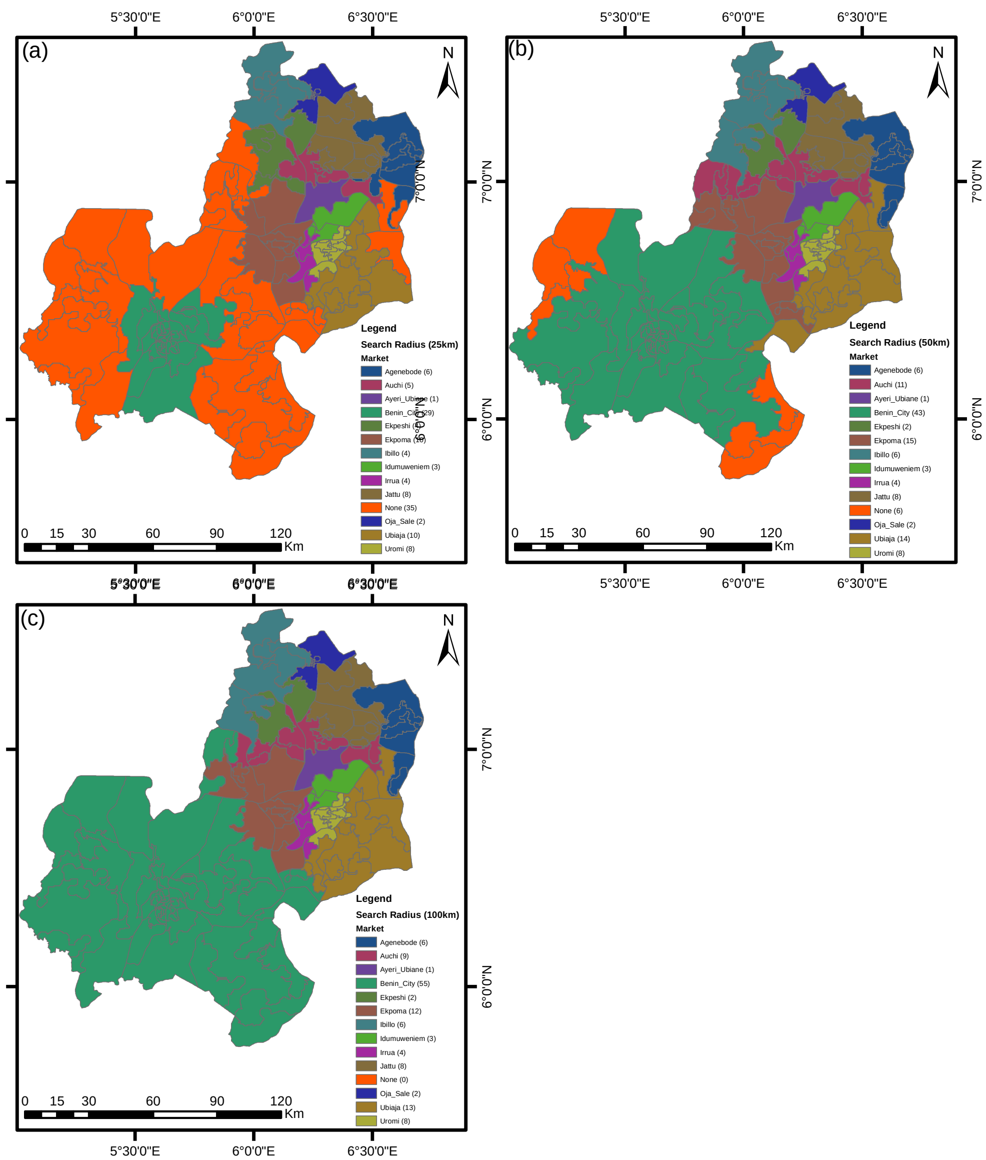

Figure 7: Catchment area for SRs using HGM search distance radius of 25, 50, 100km

These SRs are mostly in the southern and the central (west and east) parts of the State. However, Benin city captured about 22.5% of the SRs with 42% of the population. This is followed by Ekpoma, Ubiaja, Jattu and Uromi (7.7%, 7.7%, 6.2% & 6.2% respectively) in terms of total SRs in these catchments. These five served a total of 61% of the population in the State. Under this scenario, Meke was still not able to attract any of the nearby SRs. This indicates that its pull is too small, and the strength of its neighbours, coupled with their distance to SRs, confers on them an advantage over Meke as attractive centres of economic activities.

For a search radius of 50km (Figure 4b), 33% of the SRs were attracted towards Benin, followed by Ekpoma (11.6%), Ubiaja (10.9%), Jattu (6.2%) and Uromi (6.2%), with Benin serving about 51% of the population while 7.1%, 7.3%, 4.8% and 3.0% were served by Ekpoma, Ubiaja, Jattu and Uromi respectively. Essentially, more than 70% of the population are potentially being served when the distance constraint of 50km is considered. Furthermore, 6 SRs were not served by any of the major centres identified for this simulation and they accounted for about 3.4% of the population. These SRs are likely to have very localised economies, or their activities will flow out to neighbouring states as they are all on borders with other states (Figure 4b).

Considering a search radius of 100km for potential market for each SR (Figure 4c), the result shows that all SRs were attracted to one centre or the other. Under this scenario, Benin served more than 50% of the population by attracting 43% of the SRs across the southern and central parts of the State. There are 5 other major attractive centres (Ubiaja > Ekpoma > Auchi > Jattu = Uromi) in terms of number of SRs attracted. These accounted for a total of 25% of the population of the State; thus these, including Benin, potentially served 82% of the population for economic activities.

The frequency analysis of the catchment area membership for each of the SRs under different search radius distance values (Figure 5) shows that there is a high level of consistency in the membership irrespective of the search radius. This is like what was observed for friction coefficient. There are about 70% of the SRs which have the same membership across the different parameters specified (search radius), while only about 5% of the SRs changed membership once every time the search radius changed. Around 25% changed twice (out of three) when the search radius changed. Potentially, the models generated capture another aspect of the potential catchment areas across the State. Most of the regions with varying catchment membership are at the edges of the study area, with a significant majority in the southern part of the State.

From the foregoing, it is evident that when the search radius for a centre is constrained, many areas are likely to remain isolated in their economic interaction (limited spatial interaction). As the possibility of covering longer distances increases, the level of economic isolation is likely to reduce. Few centres dominate across the State and will potentially stifle the development of other centres if appropriate planning is not done for decentralisation to stimulate growth of the other centres. In another view, the spread of the benefit of the economic activities is also likely to remain localised around these major centres, thus creating/entrenching inequality which is likely to further exacerbate poverty and income inequality.

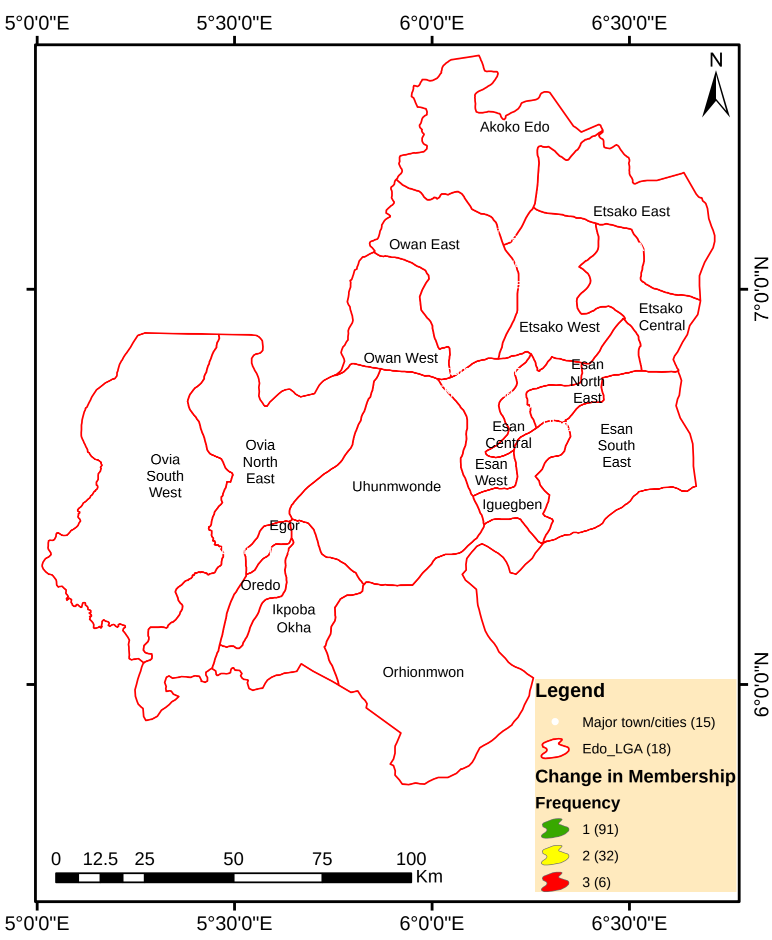

Figure 8: Frequency of change in membership to catchment area (Search radius)

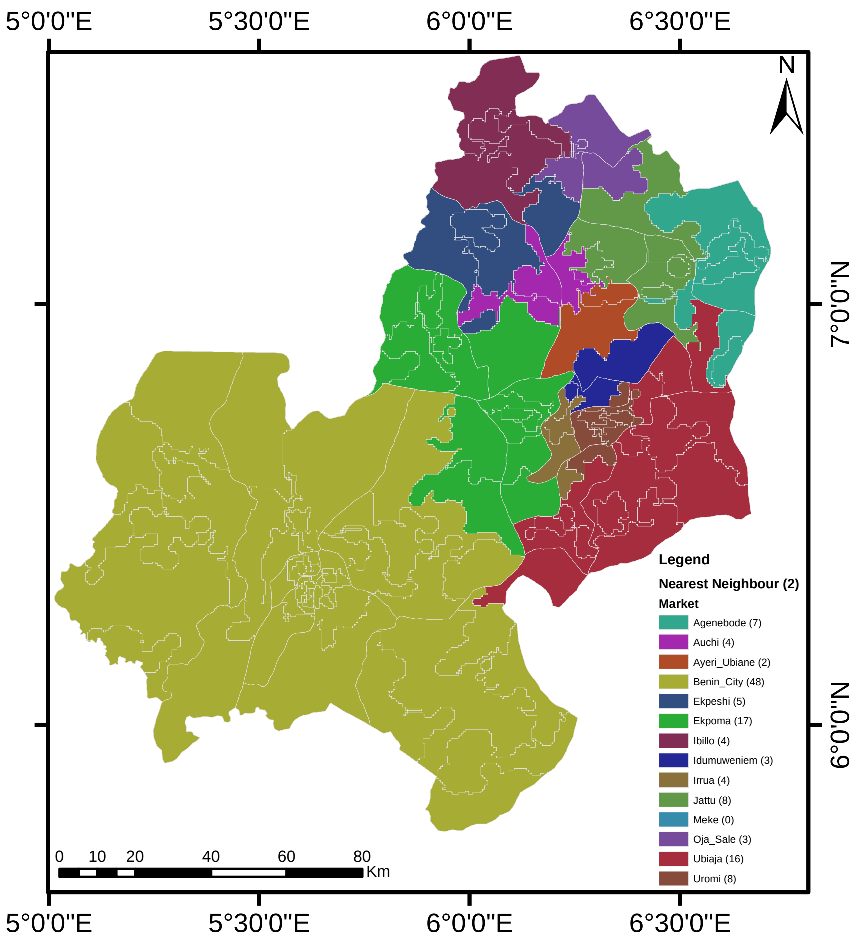

Figure 9: Catchment area for regions using HGM with Nearest neighbour constraints

Catchment Area based on Nearest Neighbour Constraint

The HGM was also implemented using the nearest neighbour constraints (2 nearest neighbours) and the results are presented in figure 6. These results give an indication of what the catchment area would be if the choice for spatial interaction for economic activities were constrained to two options for each of the SRs. Two were selected based on the distribution of the major centres (towns/cities) across the State (clustered in the northern part and just one in the southern part), as most of the SRs potentially have access to only a minimum of one or two major centres.

Benin captured about 37% of the SRs, especially all those in the southern part of the State, which accounted for about 54% of the State's population. Following Benin is Ekpoma > Ubiaja > Jattu/Uromi; these four accounted for 38% of the SRs (23.2% of the population). Thus, about 75% of the population potentially have their economic activities attracted to 5 out of the 14 centres. What is more, Meke as an economic centre remained too weak to attract any SR for economic activity across the State, even under this condition.

With more centres around the north and central parts of the State, there are consequently more catchment areas in these parts. From this pattern, economic activities are relatively closer to rural SRs in the north and central parts than the southern part.

Overall Potential Catchment Area

The simulation of different scenarios was carried out because not everyone within the SR makes decisions the same way. There are likely to be a multitude of criteria for undertaking economic activities towards a centre. However, if an SR shows membership to a centre's catchment area often (over different scenarios), there is a high probability that the majority of the economic agents in that SR will be pulled towards that centre.

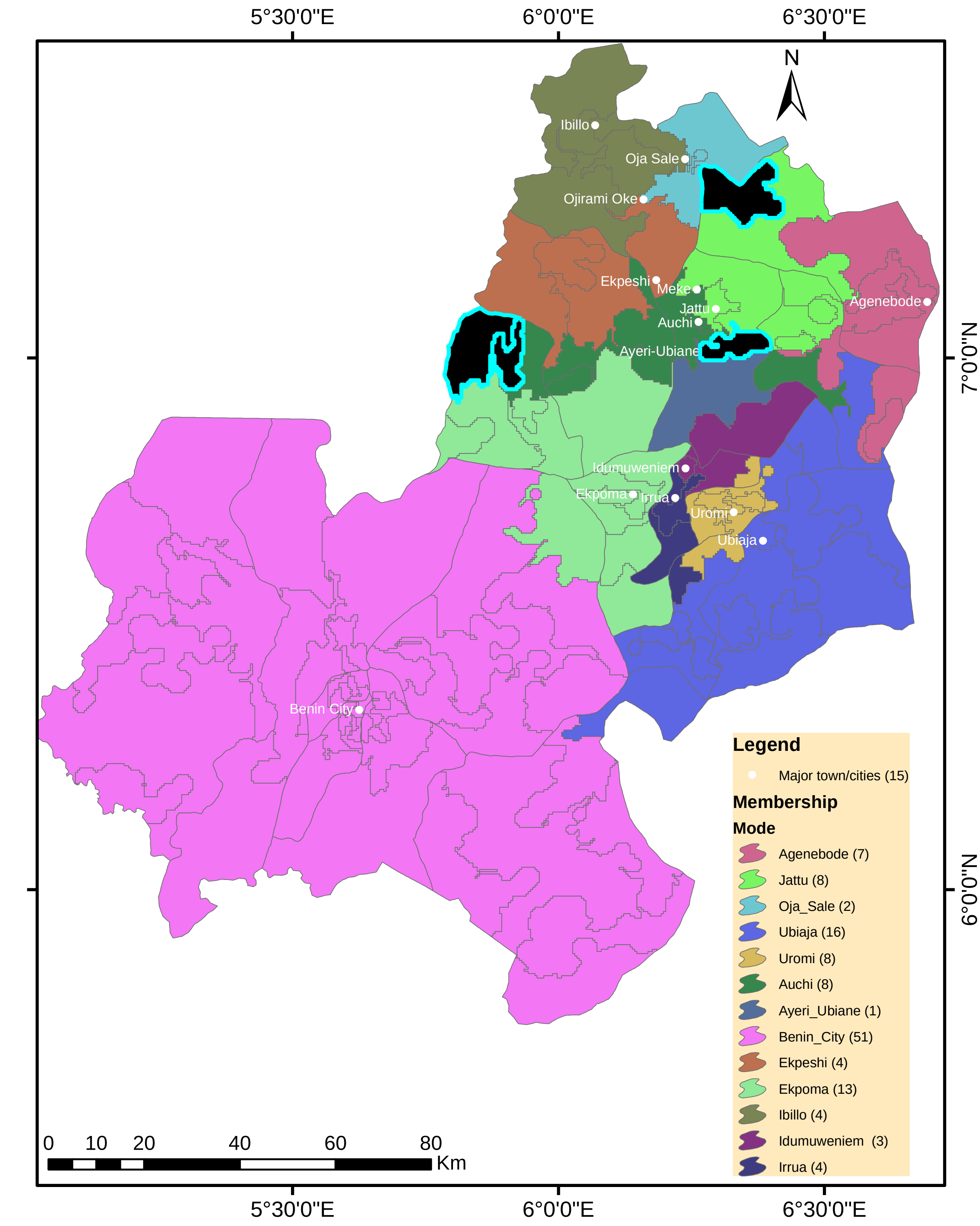

Figure 10: Mode of membership for SRs from all HGMs

Mode was computed for each SR to ascertain the most likely catchment area they belong to from all the scenarios. The results (Figure 7) show the catchment areas to which each SR belongs most of the time. Benin has the highest mode membership (39.5%) followed by Ubiaja > Ekpoma > Uromi/Jattu/Auchi/ >Agenebode. All the other 6 centres accounted for a total of 14% (ranges 0.8% - 3.1%) of the SRs within the State.

In Owan West, there are 2 SRs on its northern border with Owan East with a modal membership which indicates that they belong to the Benin City catchment area. This is a curious case, since they are not contiguous with other SRs in this catchment area. However, a closer look revealed that these two also have a modal membership for two other centres – Auchi and Ekpoma. Essentially, there are better odds (as this will constitute a contiguous catchment area) for the economic activities from these SRs to flow towards these centres (Auchi or Ekpoma) than towards Benin City.

Overall, the SRs in the northern part of the State have relatively better access to major market centres – with twelve of the centres occurring in this area and serving more than 60% of the population. However, incentivising the development of other smaller towns along the western end of this part of the State could boost economic activities and create new centres, thus increasing economic development. This will surely require further investigation to ascertain the validity of such measures.

Across the south, the capital city is the only major centre, and because of its pull it is able to attract SRs far beyond its immediate neighbours. However, the questions remain, even if these SRs fall within its catchment area, how effective is the access to this centre? Considering the argument presented by Blainey (1966) and tested by Battersby (2006), even when the economic catchment area of the centres is defined or identified, there is still the challenge of "tyranny of distance" (the farther away a place is from the other, the lesser their interaction). It could be argued that productivity and efficiency are likely to be decreasing as the distance between the centres and the SRs increases. From this viewpoint, with Benin having a larger economic reach, regions farther away from this centre are not likely to be as efficient and productive as those closer. Compared to SRs in the northern and central parts where catchment areas are relatively more compact (Figure

7), these are likely to have much better efficiency and productivity (several smaller centres could bring about better access with shorter distance), albeit with a smaller market size.

Conclusions

The internal market area of the State was modelled using various scenarios for decision making by potential economic agents. From the results, one could conclude that the size of the market (centres) and distance influence catchment membership, i.e. geographical proximity is important for spatial interaction. In addition, there is more competition for economic activities among centres in the northern part of the State compared to the southern part. Such intense competition is likely to create some winners and losers. Therefore, place-based policies for development (stimulating private sector investments and consequently economic growth) which can enhance economic development across all regions need to be developed and implemented. Benin city shows economic dominance across the southern part of the State. While the agglomeration is good for productivity and efficiency, the spread of the benefits is likely to decay as one moves away from the city. Thus, there is a need to consider how to spread the benefit conferred by these attributes of the city to other LGAs south of the State. Some of the potential place-based policies that could be considered to enhance the internal market structure of the State include:

- creation of corridors and long-distance transport infrastructure;
- special economic zones;
- identification and incentivising of lagging regions; and
- enhancement of urban transport and housing.

Moreover, there might be the need for the establishment of new centres (optimised locations) to ensure increased spread of economic activities across the south. These make the case for proper consideration of the spatial context in development policies in the country

Finally, taking spatial equilibrium into consideration – access to various activities, potential for higher wages— balances out the negative attributes of pollution, overcrowding, long commute, high housing rent, smaller house size etc. Thus, to properly guide policy towards developing regions, enhancing internal market structure and stimulating growth centres, understanding the spatial equilibrium of each catchment area is vital.

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