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Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.6, No.9, 2014

Using a GIS-Based Network Analysis to Determine Urban Greenspace Accessibility for Different Socio-Economic Groups, Specifically Related to Deprivation in Leicester, UK

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Abstract
Accessibility to greenspace by different socio-economic groups specifically related to deprivation in English city of Leicester was done using Geographical Information System (GIS) network analysis. The result was compared with ANGSt standard which provided the benchmark for accessing greenspace in UK. The result shows that greater percentage of socio-economically deprived group in Leicester lack access to greenspace within 300m from home. For distances of 2000m and 5000m, 70% do have access. This work has explored the use of GIS network analysis to assess the accessibility of greenspace among socio-economically deprived groups which will help those saddled with the responsibility of providing greenspace in carrying out their duties to ensure equity. This analysis can be extended to other groups in Leicester e.g. the handicap, elderly etc to assess how accessible greenspace is to them.
Keywords: GreenSpace, GIS Network Analysis, ANGSt Standards, Deprivation

1.0 Introduction

As urban cities around the world continue to loose green space to urbanisation and industrial revolution, the Natural England has developed Accessibility Natural Green Space Standard (ANGTs) to provide a set of benchmarks for ensuring accessibility to urban greenspaces by the people. Smith (2011) defined greenspace as an "***area within an urban environment which is dedicated to nature***". The importance of greenspace cannot be over emphasized as they improve the life of the people, and they provide oxygen and fresh air. Recreation is another important function of greenspace, they provide avenue to people for relaxation, some hiking trails, picnics lawns as well siren environment for human use (Willis and Osman, 2005). It may also provide a psychological benefit that contributes to mental well-being as well as improve the quality of the urban environment for resident apart from contributing to the aesthetics of the environment, providing habitat to some species (City Environmental Induction Encyclopaedia).According to Abubakar and Aina (2008), accessibility is the relative nearness of one place to another which indicates easiness of reaching destination from origin. Since accessibility and facility usage are directly proportional, it should be noted that the more accessible public facilities like parks and open spaces are, the more they improve social cohesion and interaction as more people patronise them ensuring economic efficiency in the use of such facilities because when they service more people, they would be more cost effective.

The following guidelines will be used for this assessment:

- An accessible natural greenspace less than 300m (5minutes walk) from home;
- Statutory Local Natural Reserves at minimum level of one hectare per thousand populations;
- At least one accessible 20 hectares site within two kilometres of home; one accessible 100 hectare site within five kilometres of home; and one accessible 500 hectare site within ten kilometres of home.

Recognising the importance of greenspace on the quality of city life, this project will assess how accessible greenspaces are to socio-economic group in relation to deprivation in Leicester. Accessible greenspace are places that are available for the general public to use free of charge i.e. without paying a fee and without time restrictions, although some sites may be closed to the public overnight and there may be fees for parking a vehicle(Thompson, 2000).

2.0. Literature Review

Public's demand for green space is becoming stronger in order to get aesthetic enjoyment, recreation, and access to clean air or quiet environment (Liu et al., 2011). It has been noted that green space can protect biodiversity, absorb pollutants and mitigate urban heat in term of physical effects therefore keeping the quality of city life. To make green spaces more accessible**,** Natural England has set up a standard and guidance to ensure that everyone has access to good quality natural greenspaces near to where they live, i.e. 'Nature Nearby (Natural England

2010). The Natural England's Accessible Natural Greenspace Standard (ANGSt) provides a set of benchmarks for ensuring access to places near to where people live. This is important because without people gaining access, the benefit of green spaces will not be appreciated by them. Open space is now become part of statutory and community planning processes in UK since our neighbourhood should be somewhere we want to be and be happy to belong to.

Recent studies in England have shown that the amount of green spaces in an area is generally associated with better health including reduced mortality (Hillsdon *et al*., 2008). They noted that people who perceive easy access to safe green spaces report higher greenspaces use, more regular physical activity and lower risk of obesity. Therefore, access to safe and convenient green space is likely to be an important environmental factor in public health efforts aimed to promote physical activity and reduce obesity. Mitchell & Popham(2008) find out that circulatory disease mortality is lower among populations resident in most green areas. Some of the substantial mental health challenges facing society and physical challenges arising from modern diets and sedentary lifestyles could be addressed by increased forms of activity in natural places (Barton and Pretty, 2011). Living in a clean and healthy environment is everyone's right (Parekh, 2010). Liu et al., (2011) noted that available and attractive greenspace is supposed to be a useful measure to keep the quality of city life using Beijin as example. Ken and Osman (2005) noted that the more accessible and attractive the greenspace, the more likely it is to be used by a wide range of people. Good quality greenspaces encourage people to walk, run, cycled and play (Douglas, 2004). Uncertainty exists regarding the relationship between green space access, the frequency of green space use and physical activity and also, the extent to which relationships between green space and physical activity vary by population sub-group is unknown (Hillsdon et al., 2008). Five main barriers have been identified that deter people from using urban green spaces. In approximate order of importance, and based on all three sources of information, they are: lack of, or the poor condition of, facilities including play for children, other users, including undesirable characters, concerns about dogs and dog mess, Safety and other 'psychological' issues, Environmental quality issues such as litter, graffiti and vandalism (Dunnett et al., 2002)

Liu *et al* (2008) used GIS visually to show the state of accessibility and spatial distribution of greenspaces in Beijing city that supported them with reasonable analysis. Comber *et al* (2008) also use a geographical information system (GIS) to apply a network analysis of greenspace access in Leicester with respect to ethnic and religious groups. Potestio et al.(2009) uses GIS to determine the association between spatial access to parks/green space and childhood overweight/obesity in Calgary, Canada Abubakar and Aina, (2008) carried out geometric (space syntax) and geographic (network analyst) techniques to evaluate the accessibility of urban green areas in Doha district, Saudi Arabia.

3.0 Methodology

3.1 Study Area

Leicester is a Midlands English City which has a large and diverse ethnic minority population and socio-economic groups. Based on 2001 census, Leicester has a low proportion of housing in the owner-occupied categories in comparison with England & Wales as a whole (57% versus 68%). 42.0% live in rented accommodation. The census result also shows that show that 38.32% households in Leicester do not own a car, which is considerably higher than the figure for England and Wales (26.79%).It also has 4.88% unemployment as against England and Wales with 3.35%. The population of Leicester in 2001 census is about 280,000 people occupying an area of 7,309 hectares with perimeter of 51.73 kilometres
Source:http://www.leicester.gov.uk/your-council-services/council-and-democracy/city-statistics/

3.2 Data

The information was gathered from the Leicester City Council website in conjunction with an OS (Ordinance Survey) base map downloaded from Edina and Casweb. Most of the available data was for local parks. Name of fields were added to the cemeteries and local nature reserve attribute tables. As it was important for the analysis to know the area (in hectares) of the greenspaces, the area for each greenspace was computed for each polygon and added to the database. In addition, a gs_type field to identify the type of greenspace associated with each polygon was also added to the database.
Shape files denoting the greenspace were collected online from the council's website. Although, the information contained on the council's website was neither comprehensive nor complete for the entire study area the analysis was carried out based on the available data. The list of the greenspaces considered are:

- Parks and public gardens.
- Green corridors (e.g. adjacent to rivers and canals);
- Local Nature Reserves;
- Surviving Urban Commons;

- Spinneys (or small areas of woodland with undergrowth);
- Sites of Importance for Nature Conservation;
- Washland areas (i.e. regularly flooded areas near to rivers);
- Cemeteries.

3.3 Demographic Data

Demographic data was used to perform spatial analysis with respect to accessibility to greenspace by various socio economic deprived groups in Leicester. This comprises two data types; a digitized boundary dataset and census area statistics. The census area statistics provide a count of people and households for a given area including their socio-demographic characteristics such as their age, occupation and ethnicity, while the digitised boundary dataset tells us where these people live i.e. their locations. The actual data comprised of six census area shape files that were selected out of twenty-three files downloaded from ***Casweb***, including files on Age, Occupation, Heath & Provision, Household Accommodation, Socio-economic class and ethnicity

3.4 Road Data

This is a polyline layer comprising of three distinct road categories (A roads, B roads and Motorways) in Leicester. Rail tracts were not included as they don't provide direct walking or driving distance. The road data is needed in service areas network analysis.

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3.5 Measure of Deprivation

The Townsend Index was used as a measure of deprivation. The Townsend Index was devised by Townsend et al (1988) to provide a material measure of deprivation and disadvantage based on four variables. The data was manipulated in order to establish the index score which determines whether an area can be classified as being deprived. This was used in the analysis to determine whether people who live in deprived areas have adequate access to greenspaces in Leicester City. The four variables used to determine deprivation are:

1. The percentage of economically active residents aged between 16 and 74, excluding students, who are unemployed. The divisionary figure was derived from adding the figures of those who are in full-time employment, part-time employment, self-employed and unemployed. A major flaw associated with collecting census data is that it is a snap shot of the population on one particular day and only relevant for the time that it was collected. For example, a person who at the time of completing the census form was unemployed may have secured a job. Alternatively, a person who stated that they were employed on the census form may have lost their job in the intermediate years, especially in recent times with the onset of the recession.
2. The percentage of private households that do not have a car or a van which were derived directly from census variables.
3. Percentage of private households that are not owner occupied. The number that are not owner occupied is made up of households that rent from the local authority, housing associations or a registered social landlord, private landlords or letting agencies and other sources.
4. The percentage of households that is overcrowded. This was also derived directly from census variables. However, the 2001 census defines overcrowding by using an occupancy rating of -1 or less. According to the comments for Table KS019 (Casweb, 2001) this 'implies that there is one room too few and that there is overcrowding in the household. The occupancy rating assumes that every household, including one person households, requires a minimum of two common rooms (excluding bathrooms).'

Further manipulation was required in order to determine the Townsend index score. The first and fourth variables, those relating to unemployment and overcrowding, were log transformed in order to normalise their distributions. A z-score was then calculated by subtracting the mean of all the output areas in England from each variable and then dividing them by the standard deviation of all the output areas in England, in order to get a comparable figure. The z-score of each variable was then added together to retrieve the Townsend Index score. A score of above zero indicates a high level of deprivation, a score of below zero indicates affluence and a score of exactly zero indicates that the area corresponds to mean levels Townsend et al (1988).

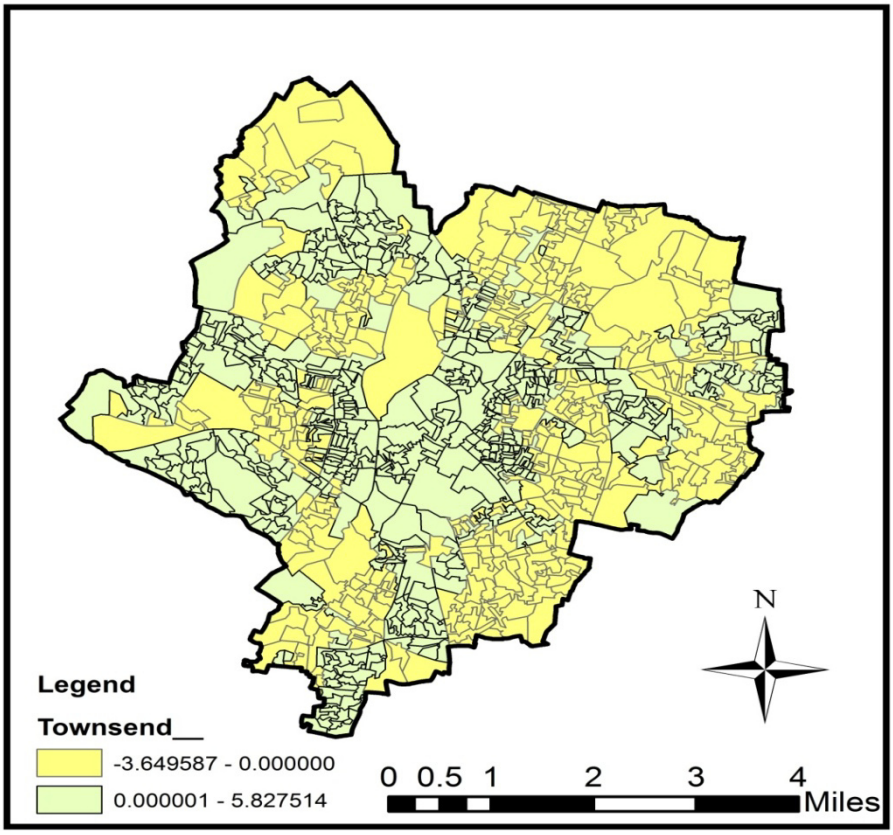


Figure 1a. Spatial distribution of the socio-economic deprived people: above zero indicates deprived while below zero means affluence.

3.6 Methods

Since Network Analysis technique is based on distance measurement between the green areas and the neighbourhoods they serve (Abubakar and Aina, 2008), the Network Analyst geo-processing tool in ArcGIS was used determination of deprived areas. By this geo-processing tool, a network service area was delineated from each greenspace. A network service area is a region that encompasses all accessible streets (that is, streets that are within specified impedance). For instance, the 5-minute service area for a point includes all the streets that can be reached within five minutes from that point of say 300m. Service areas created by Network Analysis also help evaluate accessibility. Concentric service areas show how accessibility varies with impedance. Once built, one can use service areas to identify how many people, land, or anything else is within the neighbourhood. Finding the network-based service area follows the same work flow as other network analysis (ArcGIS9.3 Desktop Help).

3.7 Procedure

The various greenspaces shape files were merged into one shape file using merge tool in ArcGIS 9.3. The green space merged shape file was further sub divided into other groups to represent greenspace areas of at least 20ha and 100ha and also to enable selection by attribute in ArcGIS to be made and new layers created for selected features. The Townsend polygon representing deprived population were converted to points (centrod). The Service Areas were created for various Rules: within 300m, 20ha within 2000m and 100ha within 5000m of greenspace for socio-economically deprived people. The Service Areas were created with the Townsend points serving as the origin while the greenspaces access points which were manually inserted served as the destination using network analysis tool in ArcGiS. Selection by location was done using selection tool in ArcGIS to select deprived areas i.e. areas within 300m, 2000m and 5000m respectively and new layers created for them. Calculating the distances between the access points and output area centres was done; using approximate centre of each area as the source/origin points of the analysis. Distances were calculated for each output area and stored in the data base, analysing the database for access to greenspaces in terms of the deprived socio-economic group of each output area.

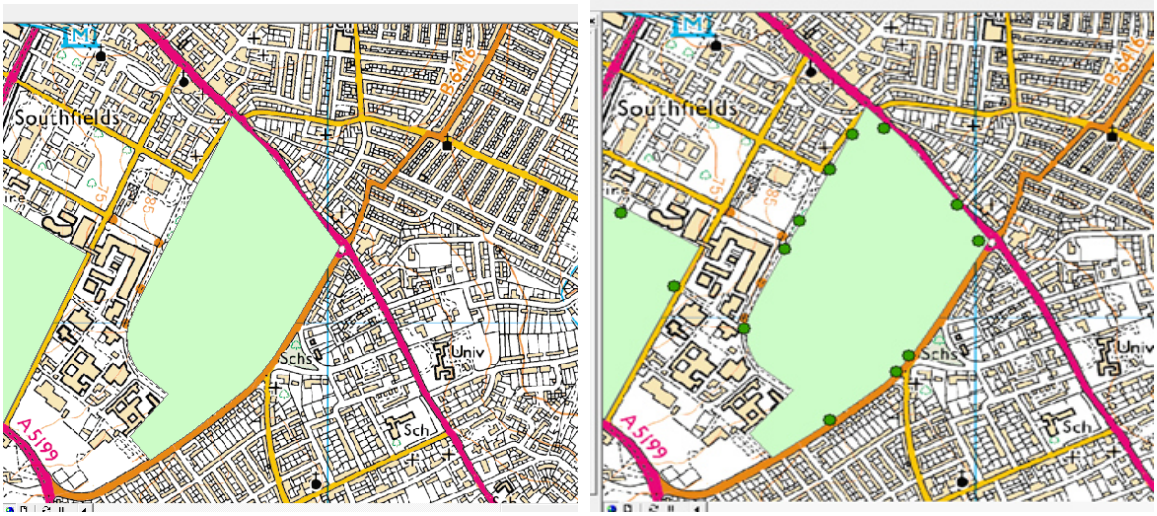


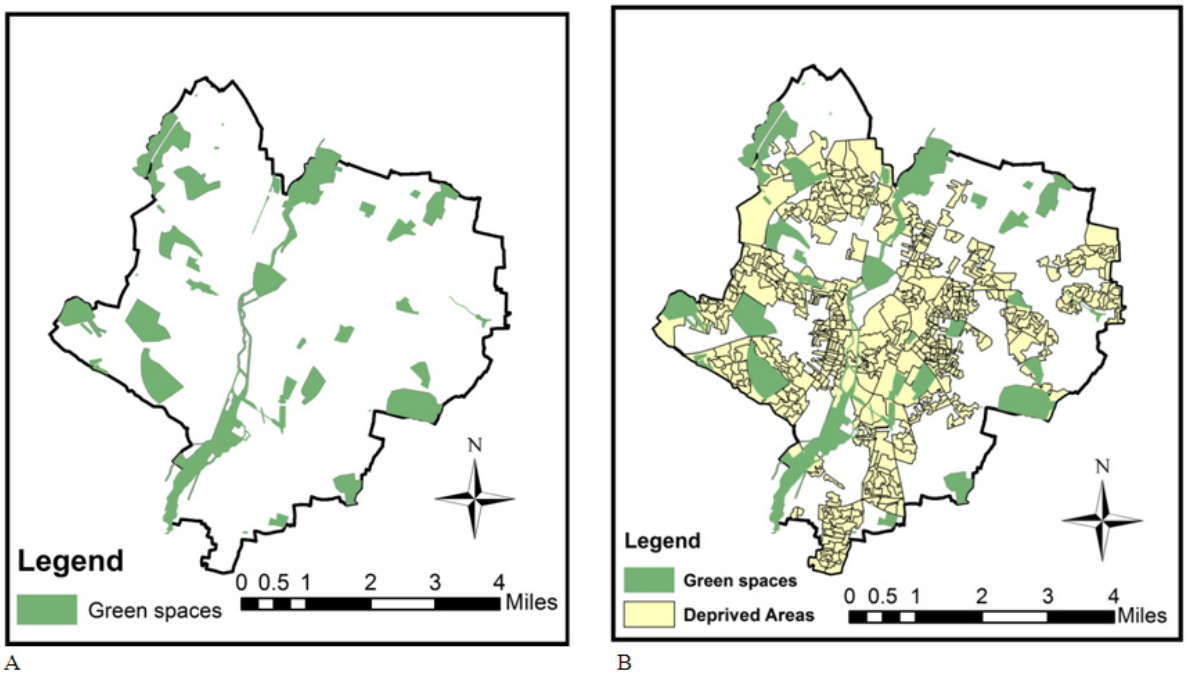
Figure 1. Greenspace left and right manually inserted access points for Victoria Park Leicester. Ordinance survey base map 2007

4.0 Results

The result of these studies shows the accessibility to greenspaces for socio-economic deprived people. The classes of unemployed people considered being: unemployed, household without a car, people living in overcrowded and those who do not live in their own house.

4.1 Distribution of Greespaces and Socio-Economically Deprived People

Fig 2 shows the spatial distributions and green spaces (a) use as well as the distribution of the socio-economically deprived areas in Leicester (b). From the maps, It could be observed that greespaces are relative evenly distributed (a) while the socio-economically deprived people are more cluster at the city centre.



A B

Figure 2. Distribution of greenspaces in Leicester A); distributions of Greenspaces in leicester in relation to socio-economically deprived people.

4.2 Service Areas

Fig 3(a) shows the service areas efficiently covered within 300m from home; Fig 3(b) shows service areas within 2000m from an accessible greenspace of 20 hectares, while Fig 3(c) shows service areas of not more than 5000m from an accessible greenspace of 100 hectares in dark. The white is the areas not accessible by the deprived.

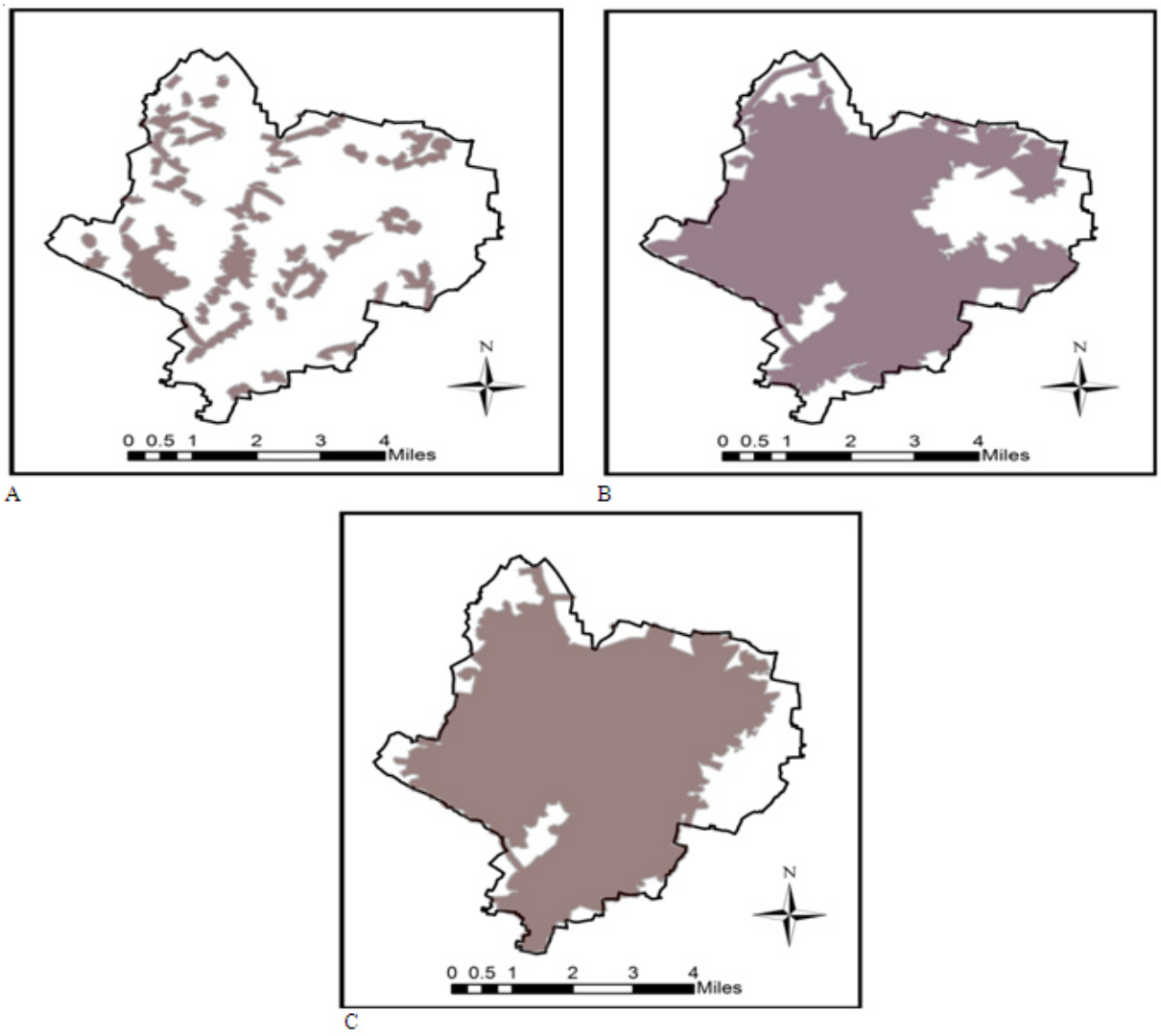


Figure 3. Service areas of not more than 300m from home A); service areas within 2000m from an accessible greenspace of 20 hectares B), service areas of not more than 5000m from an accessible greenspace of 100 hectares C) in dark. The white is the areas not accessible by the deprived.

4.3 Deprived Areas Accessibility to Greenspaces

Fig. 4 shows the spatial distribution of the deprived areas having access to greenspaces base on the ANGSt standard in green. Fig. 4(a), are the areas that are within 300m to greenspaces, Fig. 4(b) presents the areas having access to greenspaces within 200m while Fig. 4(c), areas having access to greenspaces within 500m. From the maps shown in the figures, it could be observed that access to green spaces within 300m is very low (only at the city centre) while there are more access to greenspaces within 2000m and 500m respectively.

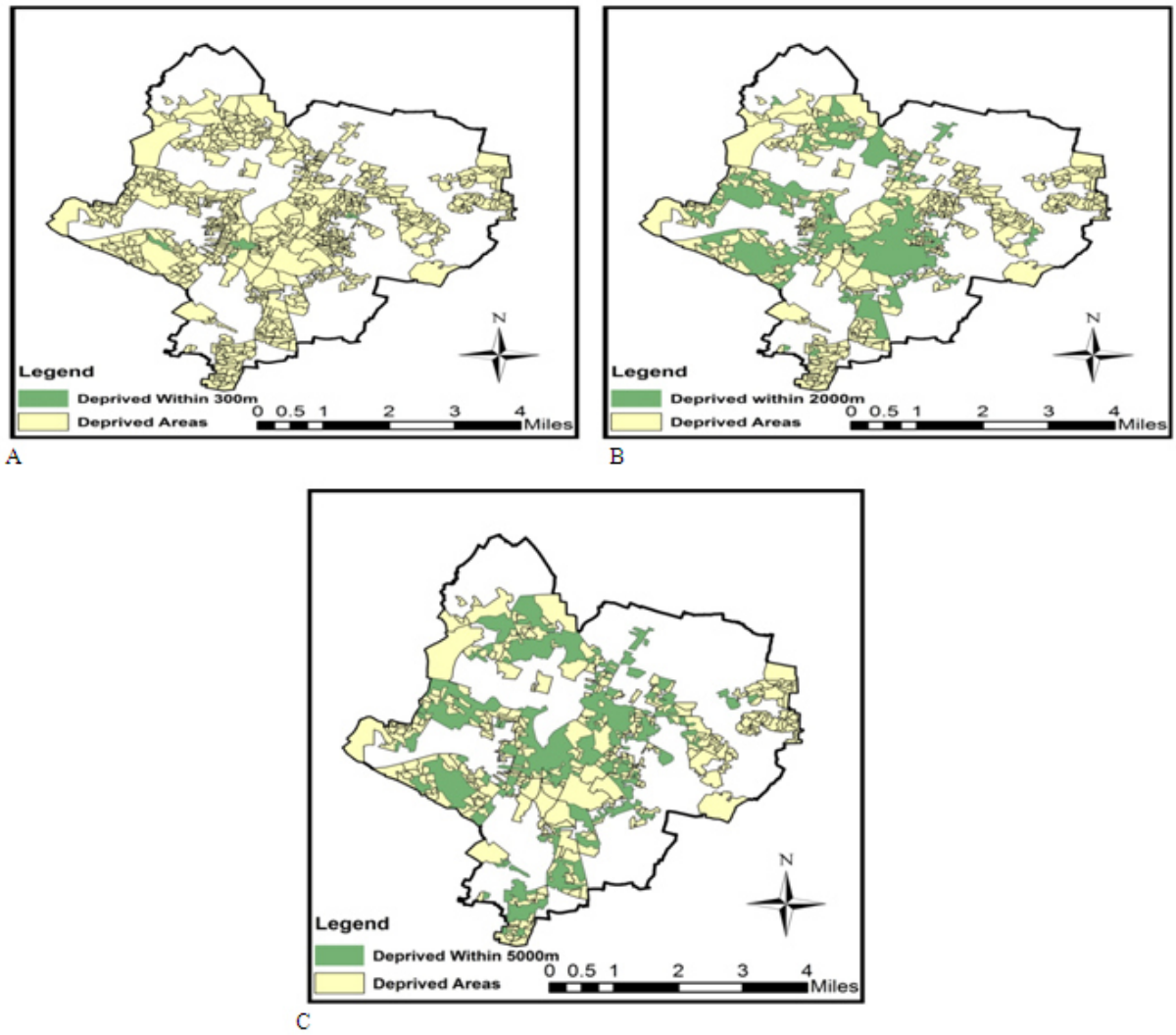


Figure 4. (a) Deprived areas having access to greenspace within 300m, (b) deprived areas having access to greenspace within 2000m of 20ha, (c) deprived areas having access to greenspace within 5000m of 100ha in green.

4.7 Summary of Accessibility to Greenspaces Based on ANGST Standard

From Table 1, it is obvious that Leicester satisfied some of the rules, while some are not yet to be met. The rules are:

Rule1: Nobody should live 300m away from accessible greenspace of at least 2ha base on ANGSt standard but this analysis was done base on 300m (5 minutes work) from all greenspaces. The implication of this will be discourse latter. Leicester did not satisfied rule 1 as 98.3% of socio-economically deprived people do not have access to greenspace in Leicester within 300m

Rule2: At least one accessible 20ha site within 2km of home. 70.70% of socio-economically deprived people have access to at least 20ha site within 2km of home while 27.3% lack access.

Rule3: One accessible 100ha site within 5km of home. 84.06% of socio-economically deprived people in Leicester have access to at least 100ha within 5km of home while 15.6% do not have access

Rule4: No 500 hectares in Leicester

Rule5: One hectare of statutory Local Nature Reserves per thousand populations. This rule was analysed using two factors; the total population of Leicester and the total population of the deprived socio-economic group. Leicester has a population of about 280,000 people base on 2001 census while the population of the socio-economically deprived is 64520. We have 159.67 hectares of Local Natural Reserves in Leicester. Using the total population, Leicester did not fulfil this requirement because it has just 0.57 hectares per 1000 population. For the deprived, it fulfils the requirement by having 2.47 hectares per 1000 socio-economically deprived population.

Table 1. The percentage access to greenspace by socio-economically deprived people.

Deprived Socio-Economic Group		Population	Deprived %	Access%	Rule
	Total	64570			
	300Meters	1116	98.3	1.7	Rule 1
	2000meters	45665	27.3	70.7	Rule2
	5000Meters	54277	15.9	84.06	Rule3

5.0 Discussion

Based on the results shown in Table 1 and Figure.4, the greenspaces available for the socio-economically deprived groups in Leicester within 300m is grossly inadequate. About 98% do not have access within 300m from their homes. This result would have been worse if ANGSt rule of 2ha were followed because greenspaces above 20ha would not have been considered since the guideline is for 2ha within 300m. There is a greater accessibility of 20ha within 2000m for 70.7% of the deprived population and 100ha within 5000m for 84.06% of the population as shown in Table 1. Figure. 4 again shows that smaller greenspaces within 300m are in short supply to this group of people, this people thus need more access to greenspaces within the shortest distance possible due to the fact that they are deprived socio-economically: they do not have car, live in overcrowded accommodation, unemployed and live in rented apartment. To many of them, parks would have been their second home where they could hang around in the daytime since they live in overcrowded accommodation and access to greenspace is free. Taking a taxi or public transport to greenspace far away from home will not be convenient for them since they are mostly unemployed and immobile. This lack of accessible greenspace within 300m has denied them of the economic benefits of better health (Hillsdon *et al*., 2008) thereby increasing the government spending on health.

Considering the ANGSt rules, Rules 2 and 3 yielded more acceptable result of over 70% of accessibility based on the analysis within a distances of 2000m (20ha.) and 5000 (1000ha). The analysis could be run for 2000m within 20ha and above to include 100ha just as it was done for 300m which included every greenspace from 2ha above, this will give a better representation as some could actually have access to 100ha within 2000m from home. The proportional distribution could be affected but it will give an idea of the places that need more greenspaces urgently considering the scarce resources at the disposal of the government.

The result for rule 1 of access to greenspaces within 300m is the most affected as shown in Figure.8 as it shows a lot of variation when GIS analysis was done, the authority concerned need to take urgent steps to address this issues especially the town planner. GIS base network analysis attempts to give the actual distance base on the access to the greenspaces unlike buffer which give an offset (straight) distance from a particular point without taking into consideration the road to the place. The implication is that someone may live adjacent to a greenspaces of 10m, but the real distance base on road could be 500m away, buffer will consider him to be within 300m while network analysis will not. One of the weakness of this network analysis is that foot paths were not considered as some people could use other routes other than the one used in this analysis. Buffer would have taking care of this. Another method which can be used for analysis is Space syntax which models the spatial configurations of urban spaces by using a connectivity graph representation but does not considering metric distance (Abubakar and Aina, 2008). Urban and Regional Planners are therefore enjoined to consider GIS base network analysis to enable them meet ANGSt standard and as well enable them to identifying places that need improvements in the provision of smaller greenspaces.

The provision of 2ha Local Natural Reserved for a 1000 population within Leicester do satisfied Rule 4 in respect to socio-economically deprived people with 2.47ha per 1000 deprived population against 0.57 per 1000 for total population in Leicester which did not meet the requirement. The total population of Leicester is 280,000 according to 2001 census while the population of the deprived people is 64520 people, the LNRs is Leicester is 159.67ha. There is therefore the need to have more LNRs for the entire population. Also, another analysis could be done to assess how accessible these LNRs is to the deprived i.e. the range, it is not enough to have them without the people having access to them with ease within accessibly distance. They should be fairly distributed spatially to avoid a situation where they will all be located in one place.

Finally, the authorities have to provide more numbers smaller greenspaces to enable the deprived people access to them as this will reduce government spending on health related issues since research has shown that there exists great correlation between human health and accessibility to greenspaces.

6.0 Conclusion and Recommendation

This analysis has shown how GIS base network analysis is used with census data to determine the accessibility

among the socio-economically deprived people in Leicester. Both the locations of the greenspaces and that of the deprived people are shown spatially to enable the policy maker in achieving ANGSt specification. This work will serve as a base map to the planners which will aid them as they seek to provide more greenspaces to the people in Leicester. This studies could be extended to cover other groups in the society e.g. handicap, elderly people, etc. Comber et al. (2008) carried out a similar GIS base network analysis to determine urban greenspace accessibility for different ethnic and religious groups. He shows the spatial distribution of greenspaces among different groups of society in Leicester and also shows how GIS and spatial analyses was used to quantify the provision of and access to a range of community goods and services amongst different socio-economic groups. It is therefore important to cover other groups.

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