Effects of Land Cover resolution on spatially distributed demand surfaces: the binary dasymetric approach

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Abstract:

It is a common practice to disaggregate population totals and to compare the results with actual small area counts for validation. This is difficult where there are no published census figures, such as in Nigeria. This study evaluates dasymetric surfaces generated using different satellite data with differing resolutions and scales of analysis in a location where small area census data is available, in order to infer the most appropriate methods for areas where it is not. Initial results show that land cover derived from high-resolution satellite data and dis-aggregations over fine scale target grids provides better population dis-aggregations for use as demand surfaces in siting service facilities. This research addresses problems in population estimation in locations where validation data is not available.

1. Introduction

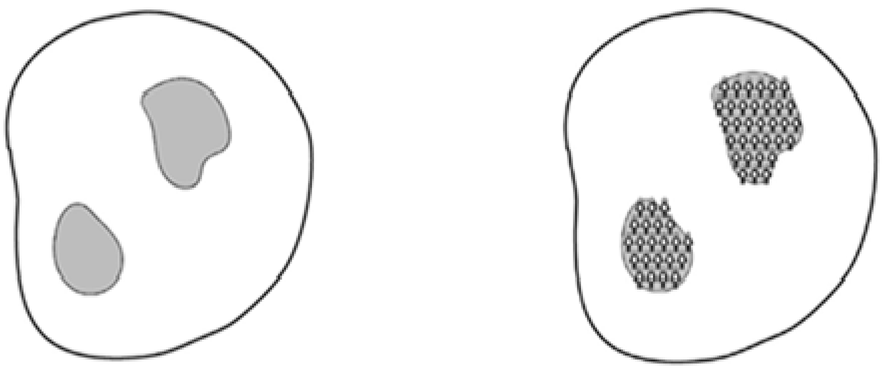
Geographical Information Systems (GIS) is widely used in planning facility sites for service provision. This is necessary as the demand for services depends on environmental and demographic factors (Kaneko et al. 2003). However, wider coverage of the demand area is considered to be the most important goal in siting service facility (Berman and Huang 2008). Population censuses make available reliable record of socioeconomic characteristics and geographical patterns in which geodemographic analyses are based on (Harris and Longley 2002). Population census data are commonly used to generate demand surfaces. Population counts are usually collected for each household and published as aggregate counts and statistics to maintain confidentiality and reduce data volume. In some countries (e.g. Nigeria), population census data are only published as aggregate counts and as summary statistics for States and Local Government Areas (LGAs) with the LGAs being the most detailed. For this reason, there is need for population data to be disaggregated to small areas to support spatial analyses. The problem of estimating population from aggregate census level to small areas within the aggregated boundary is referred to as areal interpolation of population counts (Mennis 2003).

Areal interpolation is the process of transforming values from source zone, census-reporting zone to estimate values to target zone (non-census reporting) where data are needed (Brinegar and Popick 2010). A number of areal interpolation techniques can be used to estimate population census based on assumptions about the original allocation of the known data and its dimension (Wu, Qiu and Wang 2005). The diversity of approaches is as a result of the absence of a universally accepted technique (Mennis 2009). However, the choice of technique to use generally depends on accuracy, variable of interest, data availability, prior knowledge of the study area and specifically for this research, lack of validation data for the study area. Regardless of approach, the major difficulty in applying interpolation techniques is that estimation of data to small areas changes the aggregated boundary and affects the results of spatial analysis (Openshaw 1984).

This study evaluates dasymetric surfaces generated using different satellite data of different resolutions with different scales of analysis in a location where small area census data is available, in order to infer the most appropriate methods for areas where it is not. This research uses a binary dasymetric mapping technique that incorporates remote sensing information on land cover to infer the underlying distribution of the population and thereby generate demand surfaces. The research will develop the methods and apply in Leicester, UK where the results can be validated and then apply to the study area in Nigeria making inferences about the reliability of the demand surface.

2. The Binary Dasymetric approach

The basic principle of dasymetric mapping is to split source zones into smaller spatial units with greater internal consistency in the density of the variable being mapped (Langford 2003). The advantage of the technique is that it eliminates boundary differences and reduces errors of within zone uniformity (Langford et al. 2008). In terms of population estimation, the model gives better information about the distribution of population (Cai et al. 2006). The most common application of dasymetric mapping is the Binary Dasymetric Method. It divides the zone into populated and unpopulated regions as shown in Figure 1(i), thereby making it easier for the source zone population to be allocated to only the populated regions as in Figure 1(ii) (Langford and Unwin 1994; Yuan, Smith and Limp 1997; Eicher and Brewer 2001; Mennis 2003; Langford 2007).



(i) **(ii)**

Figure 1. A demonstration of binary dasymetric model (Langford 2007, p.21)

It is defined algebraically as in Equation 1 below (Fisher and Langford 1996):

$$\hat{P}_t = \sum_{s=1}^{S} \frac{A_{tsp} P_s}{A_{sp}} = \sum_{s=1}^{S} A_{tsp} d_{sp} \qquad (1)$$

Where,

$\hat{P}_t$ = Estimated population of target zone t

A_{sp} = Area of source zone S having land cover identified as populated

P_s = Population of source zone S

S = Number of source zones

A_{tsp} = Area of overlap between target zone t and source zone S, and having land cover identified as populated

d_{sp} = P_s/A_{sp} = Dasymetric density of the populated class in source zone S

Theoretically, dasymetric mapping is simple, robust to classification errors (Fisher and Langford 1996) and has consistently been shown to be better than other areal interpolation techniques when compared (Langford, Fisher and Troughear 1993; Fisher and Langford 1995; Martin, Tate and Langford 2000; Eicher and Brewer 2001).

3. Method

This research will make use of binary dasymetric mapping technique using different satellite data of different resolutions and different scales of analysis to generate demand surfaces. The data to be used are:

- Land cover map of Rivers State, Nigeria with different resolutions (30m, 10m and 2.5m)
- 2006 Nigerian population census data
- Digital boundaries for Local Government Areas (LGAs) in Rivers State, Nigeria
- Land cover map of Leicester with different resolutions (30m, 10m and 25cm)
- 2011 UK population census data
- Digital boundaries for output areas in Leicester

The satellite imagery was classified using supervised classification with Maximum Likelihood parametric rule. Thirty eight (38) training sites were selected and merged into four (4) classes namely; water, roads, green space and built-up areas. The classified imagery of different resolutions was re-classified to only show built up areas as in figure below. The land cover for residential areas was converted to shape file to be able to intersect with different scales of analysis. Populations of the target zones were estimated and a population density surfaces obtained. The flow chart of binary dasymetric model used in this research is shown in Figure 2 below.

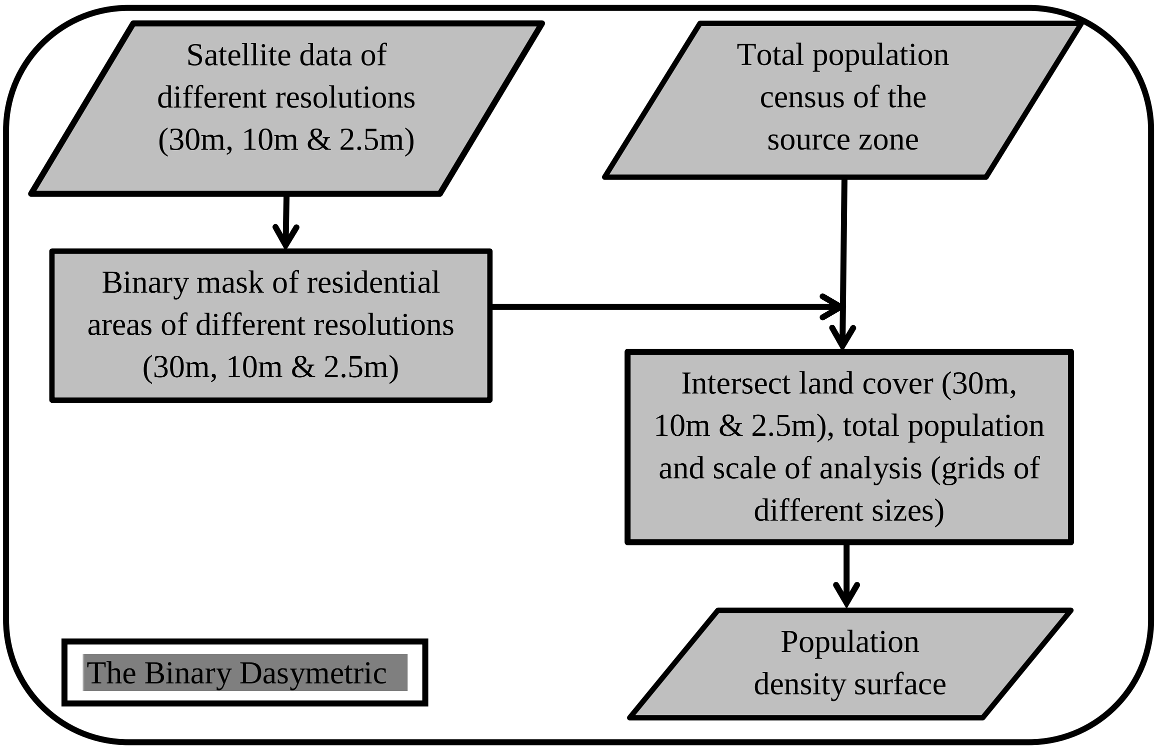
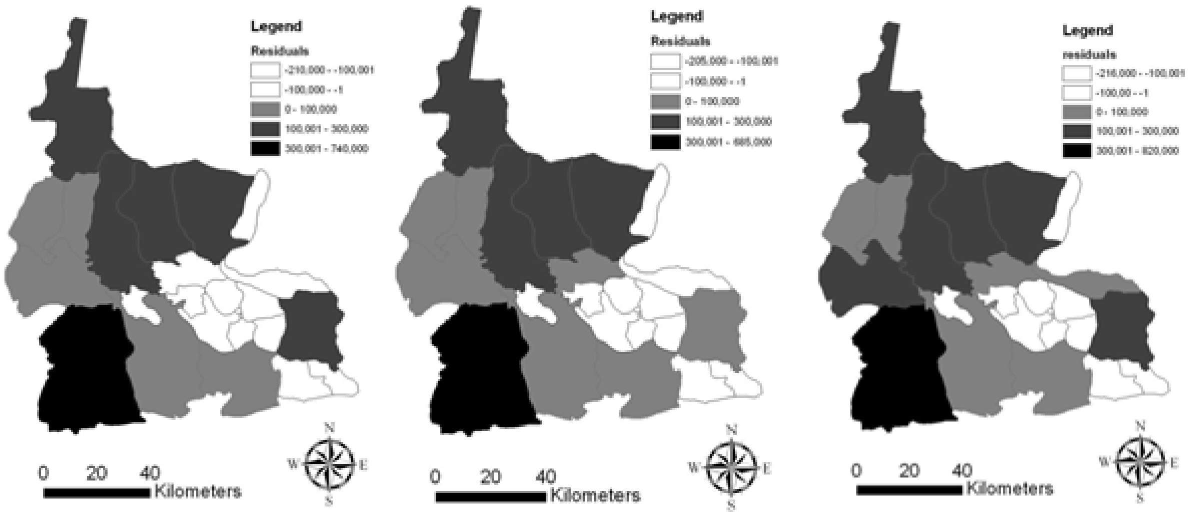


Figure 2. A flow chart of the binary dasymetric model

4. Results

Initial results, error maps for Rivers State, Nigeria, using satellite data at 30m resolution with different scales of analysis are shown in Figure 3 below. The count error is calculated as the actual population subtracted from the estimated population of each LGA. Figure 3(i) shows error map using 90m grid as the scale of analysis. Figure 3(ii) and 3(iii) shows 150m and 330m as the scale of analysis respectively.



(i) 90m grid **(ii) 150m grid** **(iii) 330m grid**

Figure 3: Error maps at different scales of analysis for a land cover with 30m resolution

5. Discussion

It can be seen from figure 3(i) below that large section of the study area is over estimated as compared to underestimation. This reflects the fact that LGAs that are predominantly rural are overestimated while small urban LGAs (cities) are underestimated. This pattern is similar to findings of other researchers that uses dasymetric mapping to estimate population (Mennis and Hultgren 2006; Harvey 2002; Eicher and Brewer 2001). The scale of analysis was increased from 30m to 330m and more rural LGAs were overestimated with an increase in scale. In the study region, the overestimated rural areas are in the North and South of the study area. The rural areas in the North are largely farmlands and thick forest with small dispersed settlements while those in the South are small towns with more than sixty percent of the area covered by water. The initial result suggests a classification error as the non-residential area should have been masked out in the binary classification. The misclassification is as a result of the reflectance of clouds and smoke from farmlands and small towns that corresponds to that of some of the built up areas. The underestimation in small urban areas is as a result of large part of non-residential areas within the small urban areas that were masked out and they actually contain population in the census data.

6. Conclusion

The initial result shows the weakness of low resolution imagery in inferring the underlying distribution of the population which in turn will affect the estimated population from the binary mask. It also shows that estimation error increases as the scale of analysis is increased. The procedure will be conducted with medium and high resolution imagery and the results will be compared. It is expected that classified high resolution imagery will be more accurate and likely to produce better dasymetric surface that will provide a wider coverage of the demand.

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9. Biographies

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