Global Livestock CRSP

Disaggregating Human Population for Improved Land Use Management

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Understanding the spatial distribution of a population across a landscape is important in land use planning. In developing nations, where resources are limited, such information can facilitate more efficient decision-making and resource allocations. This brief examines three methods for better understanding the distribution of human population within a natural boundary based on available census data: simple areal weighting, binary dasymetric mapping, and global regression. The study area is a rapidly changing watershed located in Kenya's Rift Valley. Variation in population estimates (ranging from 59,000 to over 150,000) resulting from different interpolation techniques underscores the importance of developing additional methods for spatially distributing population for improved land management. Census data alone are not sufficient to accomplish this task. Results indicated that appropriate methods for determining the correct spatial distribution of human population are essential and would be beneficial in land use management to better serve those most affected by the decisions. More specific to the Nakuru district, this knowledge will allow land managers to target areas for conservation measures where people are actually living. It also allows managers to discover areas where access to ecological services may be more diminished due to population pressure and puts the focus towards resource allocation solutions in areas where it is most needed.

Background

Humans derive a host of benefits from the natural environment: food, climate regulation, clean water and air, soil nutrient cycling, and fiber to name a few. Collectively, these benefits are known as ecosystem services. As human populations continue to increase, ecosystem services management and resource accessibility is coming to the forefront of applied research in natural resource management. To this end, understanding the size and distribution of human populations across landscapes is essential. Census data are used by governments to allocate financial resources, though these data may misrepresent true distribution and, ultimately, resource access of people.

It is now commonplace to use Geographic Information Systems (GIS) tools and models to more accurately represent complex spatial relationships on landscapes. GIS are readily available and affordable, and their usage is both practical and encouraged given the many freely accessible data that can be used in spatial analysis. Having access to such tools and data has the potential to increase stakeholders' ability to identify and target ecosystem services that are at risk as well as those who are dependent upon such services. For developing nations, where economic resources for assessing landscapes are scarce, there is a particular need to make use of available data and tools. Methods that maximize information gained from inexpensive or freely available spatial data sets describing natural resources and human population distribution are needed.

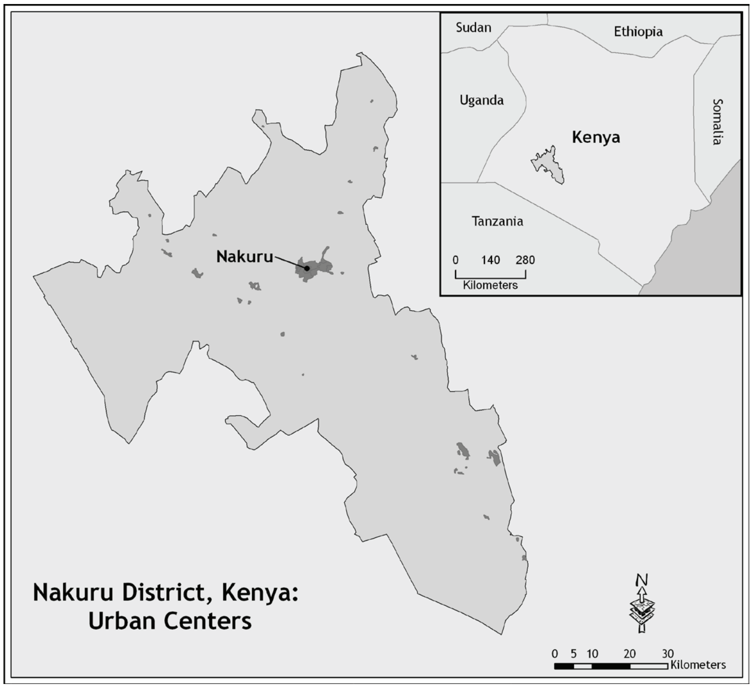
Census data are the primary sources of human population data. They are, however, often available at scales that are inadequate for land use management, which may occur on a farm or in a village and do not adequately represent human population variation within the census boundary. Census boundaries are not always drawn in relation to the numbers of people they represent but are often geopolitical boundaries that may be drawn and redrawn as political climates warrant (Crampton 2004). Analyses based solely on such data may produce erroneous information about the population and its distribution on a landscape (Monmonier 1996).

This study explores the benefits and drawbacks of three methods for mapping human population density: simple area weighting, binary dasymetric mapping, and global regression. All analyses are carried out using freely available data for disaggregating population within a natural watershed boundary in Kenya, with a primary goal to provide a resource for improved resources planning and decision-making.

Preliminary Findings

The Nakuru administrative district, Rift Valley, Kenya was used as the study area because it encompasses the River Njoro watershed, site of the SUMAWA (Sustainable Management of Rural Watersheds) project. Within the district there is one large urban centre, Nakuru town, and several smaller urbanized areas (Figure 1). Agricultural

Figure 1. Nakuru is the largest urban centre within the Nakuru district as well as Kenya's fourth largest city. Throughout the district, there are several other smaller urban areas, all highlighted in dark grey.



the watershed based on the proportion of the watershed that falls within the census boundary.

Two techniques were used to refine the results given by simple area weighting. First, binary dasymetric mapping is a technique that distinguishes uninhabited areas within an areal unit and redistributes the population only within the populated areas; in this way the total population remains the same but the population density changes throughout the study area. This technique relies on field knowledge in order to identify those areas that are not inhabited and GIS to define those areas within the census boundaries.

While binary dasymetric mapping gives a better representation of where people are actually living, it still does not account for people living in greater densities based on land use. To account for the impact of land use on population density, a global regression model is used. This model identifies relationships between land cover and population density; for example, agriculture zones are less densely settled than urban zones. Fieldwork and remote sensing techniques are used to establish these relationships. A final population density map of detailed census blocks within the study area (Figure 2) illustrates that from the watershed center to the headwaters in the south, population density calculations based on binary dasymetric mapping and global regression analyses in several census areas are greater than those where simple areal weighting was used. There are also marked differences between binary dasymetric mapping and global regression modeling. When employing a global regression model, several sublocations in critical headwaters areas are illustrated to have population densities that are several times greater than those calculated using binary dasymetric mapping. Conversely, the model fails to identify many people living in dense urban centers, and is thus unsuitable for use in that setting, where people may in fact be more evenly distributed.

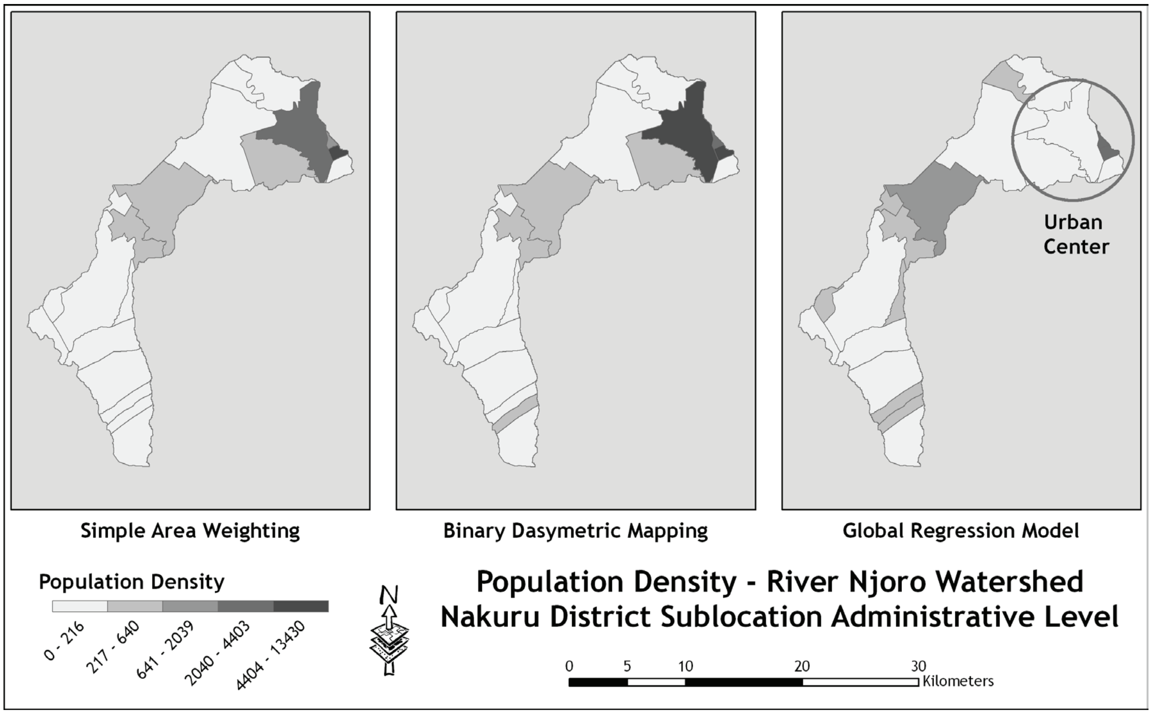
and livestock activities are the primary livelihoods within the district, evidenced by the majority of land cover falling into agriculture, which accounts for 4315 km^2 of the 7558 km^2 study area (Baldyga et al. 2007). Within the Nakuru district lies one of Kenya's five water towers: the Mau Forest. This area has undergone many changes since Kenya's independence from British rule in 1963. Many large-scale farms and plantations still exist, although several have been subdivided and are now classified as small-scale subsistence agriculture. Human population in the district is estimated to have increased from 522,709 in 1979 to 1,186,703 in 1999 (Central Bureau of Statistics-CBS 1981, CBS 2001).

Widely varying human population counts have been discussed for the River Njoro watershed, ranging from 250,000 to 700,000. Such discrepancies likely result from using census data at multiple administrative levels without regard to populated and unpopulated areas within the actual watershed boundary. In addition, there have been significant changes in the census unit boundaries between census enumerations, further confounding efforts to identify those residing strictly within the watershed itself.

Simple area weighting is used as a baseline for representing population within the watershed for the present study. This method bases population on the area of overlap between a given administrative/census boundary (location, a medium-scale unit or sublocation, a fine-scale unit) and the watershed. It is defined by assigning people into

Simple areal weighting yielded a total population within the Njoro watershed of 146,915, with a 4.5% difference (154,774) in population calculated using binary dasymetric mapping. While the total population difference appears small, more striking differences are noted when analyzing population density both within the watershed and in the greater study area. Urban areas, such as Baruti and Njoro show little variation in population density between the two methods. Their population densities are calculated as 249 persons/km^2 and 391 persons/km^2, respectively, using simple areal weighting. Using the binary dasymetric

Figure 2. Final population density maps of the River Njoro watershed using three different mapping methods. Urban centers are highlighted in the Global Regression Model results and are considered inaccurate.



method, population densities of 251 persons/km^2 and 391 persons/km^2, respectively were calculated. In locations where a greater proportion of land is considered uninhabited, differences in population density are naturally much greater when comparing the two methods. For example, using simple area weighting and binary dasymetric mapping, the population density for Njoro is as 365 persons/km^2 and 362 persons/km^2, respectively. However, when applying the global regression model, which accounts for land use in the area, a population density of 666 persons/km^2 is calculated. In many instances, the global regression model produced markedly different results from the other two methods (59,000 people), with most of the discrepancy within the urbanized areas.

Researchers found that all three methods produced much lower population estimates within the watershed than previous reports; however, the model results also implied that many areas have much higher human population densities than presumed. Important to management, the models differed in the distribution of people with significant differences in estimates of population density. Population densities in the forested upper watershed show the greatest difference among methods (urban centers not withstanding), which was noticeable at a range of spatial scales. Such variations in population density could potentially lead to different decisions for land management or resource allocation. Importantly, these results indicate that even high-performing models have limitations, which must be taken into account as part of the analysis.

Practical Implications

In this study, it was clear that changes in scale and spatial distribution fundamentally change population density estimates and, consequently, total population estimates. Results indicated that appropriate methods for determining the correct spatial distribution of human population are essential and would be beneficial in land use management to better serve those most affected by the decisions. More specific to the Nakuru district, this knowledge will allow land managers to target areas for conservation measures where people are actually living. It also allows managers to discover areas where access to ecological services may be more diminished due to population pressure and puts the focus towards resource allocation solutions in areas where it is most needed.

Methods presented in this research brief can be carried out using freely available data sets, such as Africover (FAO 2000) and human census data. The results serve as a call to work with and refine the available data to develop additional methods that facilitate improved and targeted decision-making. Population density estimation alone cannot account for where people obtain their resources (such as water or fuel wood), but it refines the process of identifying areas of potential interest. This analysis could be extended by analyzing patterns of resources extraction and producing opportunity maps to incorporate with land management decision-making and alternative land use scenario design.

Further Reading

Baldyga, T.J., S.N. Miller, K.L. Driese, and C.M. Gichaba. 2007. "Assessing land cover change in Kenya's Mau Forest region using remotely sensed data." *African Journal of Ecology* 46: 46-54.

Central Bureau of Statistics, Ministry of Finance and Planning (CBS). 1981. *1979 Population and Housing Census: Volume 1.* Census, Nairobi: Kenya Government.

Central Bureau of Statistics, Ministry of Finance and Planning (CBS). 2001. "Population Distribution by Administrative Areas and Urban Centres." In *1999 Population and Housing Census: Counting our People for Development: Volume 1.* Census, Nairobi: Kenya Government.

Crampton, J.W. 2004. "GIS and geographic governance: Reconstructing the choropleth map." *Cartographica* 39(1): 41-53.

Food and Agriculture Organization of the United Nations (FAO). 2000. "Africover Multipurpose Land Cover Databases for Kenya." Available from: http://www.africover.org. Accessed July 2008.

Monmonier, M. 1996. *How to Lie with Maps*. Chicago: University of Chicago.

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The GL-CRSP Sustainable Management of Rural Watersheds (SUMAWA) project was established in 2003 and is a multidisciplinary research effort focusing on biophysical and human-related factors governing health in the River Njoro watershed in Kenya. The Principal Investigator for SUMAWA is Dr. Patterson Semenye. Email: semenye@sumawa.or.ke.

The Global Livestock CRSP is comprised of multidisciplinary, collaborative projects focused on human nutrition, economic growth, environment and policy related to animal agriculture and linked by a global theme of risk in a changing environment. The program is active in East and West Africa, Central Asia and Latin America.

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