IN SUPPORT OF THE MILLENNIUM DEVELOPMENT GOALS: GIS USE FOR POVERTY REDUCTION TASKS

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ABSTRACT:

To achieve the goal of poverty reduction, as encapsulated within the Millennium Development Goals, the collection, analysis, and use of geographic information as it relates to the multidimensionality of poverty offers a starting point. The spatial handling of poverty is an emerging paradigm for which researches on the spatial modelling of poverty are required. Attempting to contribute to a better understanding of poverty mapping, this paper examines GIS suitability for use in poverty application areas. GIS analysis functions most appropriate for use in specific poverty mapping tasks are examined. The uses are identified as data integration of socio-economic, environmental, cultural data, etc.; delineation of areas lying within a specified threshold distance from selected features or places; deriving further data from spatial analysis for multivariate analysis of poverty; deriving straight-line and network distances; visualisation and presentation of the results of poverty analysis. Special emphasis is placed on ways in which GIS is being used and its suitability for poverty reduction tasks to help draw out some relevant methodological and policy lessons.

1. INTRODUCTION

Halving world extreme poverty (1.2 billion people) by year 2015 has been made the first and most prominent of the 8 United Nations' Millennium Development Goals (MDG) thus making the issue of poverty reduction a global challenge. Harnessing the potential of GIS-based ICTs (Information and Communication Technology) for poverty reduction is imperative. Poverty is a multidimensional problem which is best tackled using a multidisciplinary approach. It includes low income, low food consumption, ill-health, reduced life expectation, poor education, lack of assets, limited access to natural resources, low social status, lack of political voice, poor access to ICT, social services and welfare facilities. With poverty levels varying within and between countries or regions of the world, the fact remains that the different manifestations of poverty are as a result of the interplay of myriads of factors over time (such as geography, history, ethnicity, access to markets and public services and public policy (See Figure 1). Figure 1 reveals that poverty is multidimensional and the indicators are numerous. With these dimensions closely related one to another, indicators rarely occur alone as the presence of one form of poverty appreciably increases the probability of occurrence of all others (Akinyemi 2007a).

The multidimensional nature of poverty itself adds to the complexity of its handling because actors in poverty reduction often see poverty differently, both in their perception and approaches. How poverty is handled very much depends on how the problem is perceived and understood. Generally, poverty measures can be broadly categorized as income (monetary) based or non-monetary measures of poverty. The data requirements and implementation costs differ for each method. While monetary measures no longer have exclusive hold on our attention, they remain central to analysis. The past two decades of experience, though, reinforce the value of collecting health and education data, as well as other social indicators that describe broader conditions of poverty. Increasingly, researchers also find value in asking about subjective views of poverty and in seeking input on poverty through participatory exercises that involve participants from local communities. Direct measures of access to basic services and infrastructure also provide important inputs in the policy making process (United Nations Forthcoming).

Recent studies showing the importance of spatial variables in tackling poverty have promoted the use of poverty maps made within a Geographic Information System (GIS) environment to better understand who the poor are, where the poor are found and to some extent, why and how long they have been poor. Consequently, decision makers can better identify and understand from maps, the socio-economic and development variations among regions for planning purposes. This makes poverty maps invaluable tools for poverty reduction especially in their use for targeting poverty alleviation programmes (PAPs). With appropriate scale and robust poverty indicators, poverty maps can assist in the implementation of PAPs, making for efficient allocation of resources. Using geographic targeting techniques, as opposed to across the board subsidies, has been shown to be effective at maximizing the coverage of the poor while minimizing leakage to the non-poor (Baker and Grosh 1995 in Henninger 1998).

Spatial analysis of poverty has been utilized in a number of policy and research applications ranging from targeting emergency food aid and anti-poverty programmes to assessments of the determinants of poverty and food insecurity, in addition to providing visual representations of spatial relationships between variables. Poverty mapping applications have been used by organizations ranging from governments (municipality, state/province, national) to non-governmental organizations and multilateral development organizations.

2. POVERTY MAPPING

Poverty mapping – the spatial representation and analysis of indicators of human wellbeing and poverty – is becoming an increasingly important instrument for investigating and discussing social, economic, and environmental problems (Henninger and Snel 2002). One of the main problems in poverty mapping is to combine socio-economic data aggregated by administrative boundaries with environmental data based on natural boundaries. But despite these difficulties, combining the data is important, because environmental data such as agro-ecological zones, are often important in terms of food production potential, market accessibility and vulnerability. Geo-referenced measures of child nutritional status can also be aggregated to aridity zones to examine the relationship between child nutritional status and aridity (Henninger 1998).

2.1 Spatial Datasets for Poverty Mapping

The types of spatial datasets required for use in poverty mapping depend on the way poverty is defined within context of the application. Akinyemi (2007b), in a poverty mapping measures in use, identified the most common spatial datasets as land cover, normalized differential vegetation index (NDVI), rainfall data, and soil fertility and quality. This finding is confirmed by Hyman *et al*. (2005), who noted that soil characteristics, topography, rainfall, evapotranspiration, and vegetative vigor proved to be important explanatory factors in describing poverty in several poverty-mapping studies. Datasets on travel times to markets and distances to towns and facilities are also important explanatory factors in poverty and food security outcomes in several studies. A search of the literature reveals that either a bottom-up or a top-down approach to poverty mapping is used. The former uses socio-economic data aggregated at the subnational level such as survey and census data. Whereas the latter approach uses satellite imagery, existing global environmental maps and GIS models (see FAO 2002). The examination of GIS use for poverty mapping in this study includes both approaches.

3. POVERTY MAPPING WITH GIS

The use of GIS to provide a spatial framework for poverty mapping allows the use of new units of analysis, for example, switching from administrative to ecological boundaries) and access to new variables like community characteristics, not collected in the original survey (see Henninger 1998). To derive greater benefits in poverty mapping with GIS, it is proper to identify available GIS functions. It is equally important to identify those functions that are required but are not traditionally available in a GIS. To successfully do these, the types of analysis for which the GIS is needed must be known. This involves identifying the types of analysis required for poverty management (e.g. poverty assessment) and the functions required of GIS to carry out the analysis involved. As a prerequisite, to knowing the analysis to be carried out, the information needed to be produced for poverty assessment must be known.
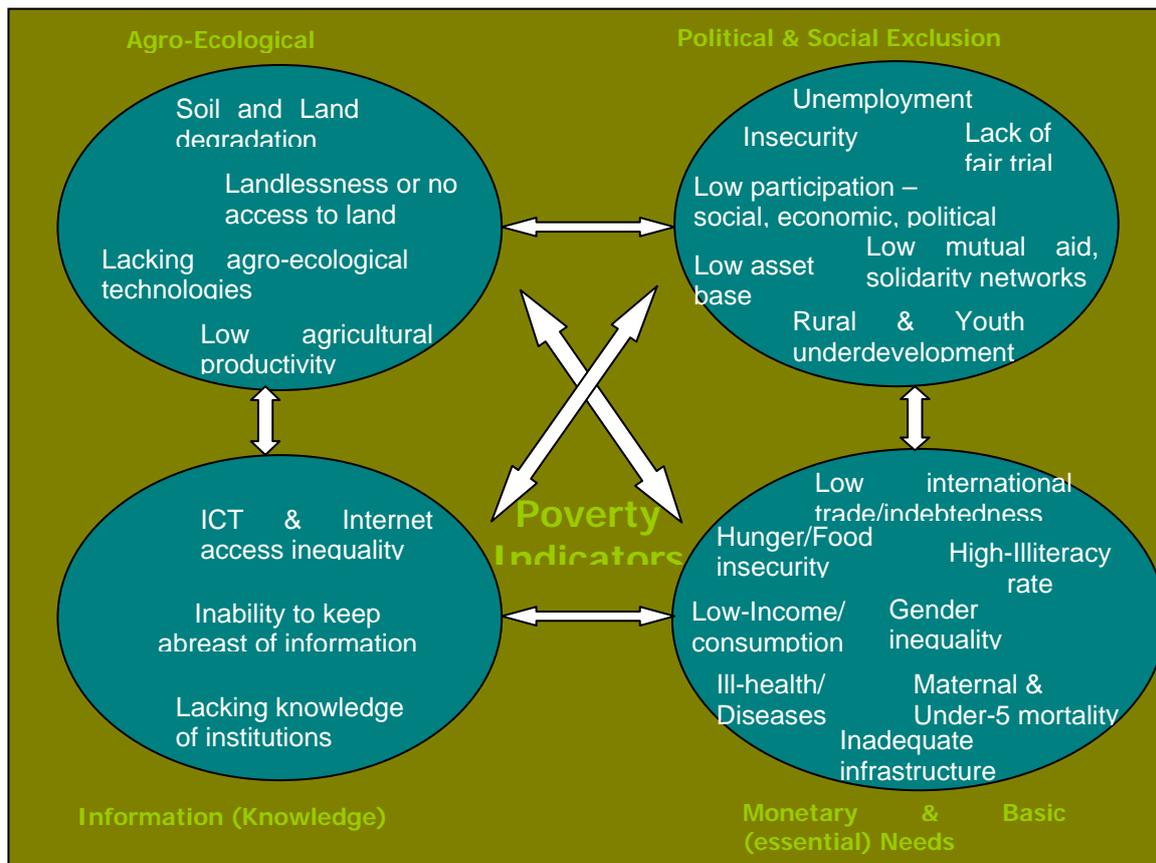

Figure 1: The many dimensions of poverty and indicators (Source: Akinyemi 2005)

Defining the terms functions and analysis within the context of GIS, functions are the operations that a GIS can perform. For example, most systems contain functions for digitizing, querying, and overlaying spatial data. Analysis is the process used to explore the details of some phenomenon using the system's functions. The types of functions a GIS system can perform determine the possibilities for analysis (ESRI and TAL 2001, 2002).

Table 1 shows the objectives in most poverty assessment activities, the GIS functions that are available and those required in addition (the listed poverty assessment objectives and GIS functions shown in Table 1 are by no means exhaustive. The table is still under construction).

It is evident that the non-availability of some required functions for poverty mapping, for example, poverty measures is limiting GIS use. Core poverty assessment activities presently have to be carried out outside the GIS environment. Consequently, poverty analysis has to be done in other software packages. The
poverty results are then brought into GIS afterwards for further

analysis and/or visualization. Where required functions for specific poverty reduction analysis are not available, there is the possibility to add these functions by customizing GIS packages, for example, with ESRI ArcObjects. An example of poverty related customizations of GIS is the SAS Bridge to ESRI which adds the analytic intelligence of SAS to the mapping capabilities of ArcGIS (see Tesfamicael 2005). For other studies, see Manansala (1999), Hall and Conning 1991).

In our quest to identify GIS use and suitability for poverty management tasks, we will look at some core GIS functions and their uses in poverty mapping.

4. USING AVAILABLE GIS FUNCTIONS IN POVERTY MAPPING

GIS use is important in poverty mapping for its data integration capability. Data for poverty analysis come from various sources such as census (with wider coverage of a country's population), household surveys, and agricultural surveys.

Poverty assessment objectives	Poverty mapping measures and indicators	GIS functions and analysis	
		Available	**Not available**
Assess poverty level using a particular poverty measure and indicators	**Econometrics** – Small area estimation (current consumption expenditures, income, and wealth); **Social – Unsatisfied basic needs** (nutrition, water, health, and education); **Demographic** (gender and age structure of households, child nutritional status - calorie intake, low height for age, low weight for age, low weight for height, body mass index, low birth weight, and household size and age structure); **Vulnerability** (level of household exposure to shocks, environmental endowment and hazard, physical insecurity, empowerment, governance, diversification and risk of alternative livelihood strategies, structural inequities)	Distance measurement with proximity analysis e.g. distance from villages to main roads, other towns, health facilities; multi-criteria evaluation tools	Econometrics e.g. small area estimation routines, Foster-Greer-Thorbecke poverty index; principal components analysis, factor analysis human development indices - human development index, human poverty indices
Relate poverty patterns with socio-economic, environmental variables, etc.	As in **Poverty-biodiversity** which relate poverty with, for example, major tropical wilderness and biodiversity hot spots; examine people's susceptibility to poverty	Overlay analysis for understanding spatial association between variables; Ranking of units of interest based on a poverty indicator	
Examine spatial and temporal variations in poverty	Poverty dynamics – movement in and out of poverty	Poverty time series maps, dynamic mapping	Poverty dynamics indices

Table 1: Poverty Assessment with GIS

The increasing number of variables from these different sources used in poverty mapping applications shows the usefulness of GIS for data integration. GIS use also includes the generation of spatial variables such as distance measurement with proximity analysis, for example, distance to nearest urban centre or health facility; overlay analysis, for example, in seeking to understand the association between land use type (change) and population density or race (see Mennis and Liu 2005).

Below are some standard GIS functions used for poverty mapping applications:

1. data integration - Integration of multiple databases from different sources such as socio-economic, environmental, cultural data, etc.
2. overlay - analysis of spatial association between variables
3. buffer - delineating the area that lies within a specified threshold distance from selected features or places
4. query - deriving further data from spatial analysis such as spatially generated explanatory variables as input for multivariate analysis of poverty (such as distance to markets, urban centres and facilities)
5. visualisation and data presentation

The uses of these GIS functions in poverty mapping are treated in details in the next subsection.

4.1 Data Integration

A GIS allows a wide variety of data integration forms. One layer of data (such as districts) can be presented on top of another (such as climate zones), not only to create a visual display but also to generate a new data set in which each point has attributes from the two original data sets. The points in the integrated data set can then be used to analyze social, economic, and spatial relationships using either cross tabulations or formal statistical and econometric methods. Thus, for example, information on the distance from a village to an urban centre can be combined with area-based soil data in order to assess the

agricultural potential of rural communities; information on the road network can be combined with information on population density to generate indicators of transportation density for each district (Bigman and Fofack 2000).

4.2 Overlay

Overlay is of exceptional use in poverty mapping, such as the overlay of different datasets in a health related poverty application, for example, rivers, treatment areas, settlement/village are needed for identifying high risk population. Overlaying poverty maps atop maps of local infrastructure (schools, health clinics, hospitals, water supply facilities, and roads) may improve the understanding of poverty dynamics, shed more light on the possible constraints to growth and poverty reduction, and improve priority setting, impact assessment, and policymaking (Fofack 2000).

Overlaying data on stunting rates in under-age 5 children (a proxy for poverty) and that of amphibian species and endemic bird areas helps to highlight spatial correlations and disparities between the datasets. With these areas where high percentage of underweight children coincide with a high occurrence of amphibian species and endemic bird areas may indicate areas in which poor people likely have no other choice than the unsustainable extraction of resources, which in turn threatens biodiversity. The highlighted areas can then be given the highest priorities for poverty alleviation and conservation (Snel 2004). Henninger and Snel (2002) analysed the correlation of some Human Development Indicators (HDI) surrogates with the marginal condition factors using point and polygon overlay analysis functions in Arc/Info and Arc/View software. For each HDI sample point, a geographically referenced value was extracted from each thematic layer.

4.3 Buffer

This involves delineating the area that lies within a specified threshold distance from selected features or places. Buffers can then be created around selected features (e.g. health facilities, school, village, water point) for specific rates to be computed (e.g. calculate population, number of disease cases, or prevalence within a radius, see WHO 2003).

4.4 Query

The use of GIS query tool is also very important. GIS allows querying based on attribute or by location and both selection methods are appropriate for use in poverty mapping. Since most data in use are socioeconomic or demographic variables derived, for example, from a census, these data are linked to geographic units appropriate to the levels of data publication. Linking of socioeconomic and/or cultural data to a specific

location makes the data available for spatial analysis, which in a sense makes such data spatial (Akinyemi 2007b).

Queries can be applied that use the features of one layer to choose features in another layer such as distance from village to urban centres, travel times to markets and distances to facilities. Utilizing such measures of distance and physical accessibility is increasingly important in poverty mapping studies, since income generation for small-scale farmers, for example, often depends on distances to markets and associated transport costs (Van De Walle 2002, Jacoby 2000, both cited in Hyman *et al.* 2005).

4.5 Visualization and Representation

The Geostatistical tool in ESRI ArcGIS is useful in visualization for the better understanding of data used for mapping poverty. Spatial units of use in poverty mapping could be represented as dots or represented as polygons e.g. census tracks, enumeration areas. Graphical representation of point data can be used to convey information about other data dimensions by plotting them as symbols that may vary in size, shape, colour, hue or saturation.

GIS also provides a function that let you construct histograms of the classification scheme with which the data is represented on a map. The classification histogram aids the visualization of how attribute values of features are distributed across the overall range of values. If the data is multidimensional, this technique can not only improve the clarity of the graphical display but also portray information about the data in ways that may induce viewers to discover patterns or trends. When the number of data points is large, representing aggregate numbers of a variable in the same area using graduated symbol mapping for example, is not appropriate as it is difficult to identify a coherent pattern. In the alternative, such data representing discrete objects can be treated as continuous. Bracken and Martin (1989) cited in (Longley and Batty 2003) have suggested that a field or surface approach provides a useful way of handling socio-economic data.

Poverty maps are means of visually communicating the results of poverty assessment. Most poverty maps are meant for printing on paper such as hardcopy maps produced in reports and atlases etc. which can be made available on the internet.

5. CONCLUSION

The immense value of GIS as the singular tool for understanding human-environment interaction is resulting in its increasing use. Consequent upon these increasing uses of GIS in handling poverty and other social problems, it became necessary to examine GIS suitability, for example, in poverty assessment and to identify where enhancement of GIS functionalities is required. Most common GIS uses were identified as data integration, delineation of areas lying within a specified threshold distance from selected features or places, deriving further data from spatial analysis for multivariate analysis of poverty, visualisation and presentation of the results of poverty analysis in the form of maps.

The uses we just identified help to demonstrate GIS suitability for poverty mapping applications. Some of the functions required for poverty mapping, although absent in today's GIS, can be added by implementing some econometric (income poverty) and anthropometric measures (human poverty) within

GIS. Enhancing GIS capabilities for poverty mapping is important so as to facilitate finding answers that will help in policy formulation and implementation for poverty alleviation using spatial relationships. According to Sui (2002), the development of appropriate policies for reduction and eventual eradication of poverty and hunger hinges on the extent to which we can delineate the spatial patterns of hunger and poverty.

Identifying which conceptual and methodological gaps to be filled in the spatial analysis of poverty is essential in enhancing GIS use. These researches can contribute to developing procedures for GIS use in development related application areas which can facilitate the achievement of the MDGs. It is also necessary to evaluate how appropriate and effective these procedures are in various context. These are some of the research areas that need to be continually investigated for the spatial sciences to contribute to the poverty mapping literature. Spatial scientists are best suited to provide the spatial tools and the theoretical base upon which poverty mapping practitioners can build applications.

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