Towards a Spatial Information Model for Poverty Reduction and Management in Sub-Saharan Africa

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Key words: Geoinformation, Poverty management, Sub-Saharan Africa, Poverty reduction

SUMMARY

In sub-Saharan Africa, poverty is prevalent despite the availability of abundant natural and human resources. Its magnitude and dimension has made poverty reduction the core challenge for African's development in the 21st century. In the United Nations Millennium Development Goals (MDGs), there is the resolve to halve global extreme poverty (people living below one dollar a day) as well as other goals by 2015 from the present 1.2 billion people living in deep deprivation. Five years after the setting of the MDGs, sub-Saharan Africa's performance towards achieving the targets are negligible for most indicators of the MGDs. Whereas in most regions of the world, including Northern Africa, poverty rates are fast dropping. As emerging studies are gradually establishing an indisputable link between geographic location and poverty, taking spatial determinants into cognizance in better understanding the distribution of poverty as well as that of assets that are fundamental for poverty alleviation is imperative. This would require some effort in designing and developing appropriate spatial information systems to aid the modelling of a socio-economic problem as poverty. This paper describes an ongoing effort, which is attempting to model within a spatial context the management of poverty, using Nigerian as case study.

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1. INTRODUCTION

In Africa, 407.4 million people out of a total population of 804 million are extremely poor, making poverty reduction to rank highest on Africa's development agenda. Poverty, being heterogeneous with dimensional links to problems of hunger, illiteracy, child and maternal mortality, and diseases, is a fundamental challenge facing Africa as well as the rest of the world in the 21st century. That the problem of poverty is of global concern is underscored by the United Nations (UN) Millennium Development Goals (MDGs) on poverty which calls for a reduction (by half) of the 1.2 billion people currently living below a dollar a day (international poverty line below which a person is poor) by 2015. Table 1 shows the breakdown of the poor as a percentage of the total population in the regions of the world.

Table 1: Population below $1 purchasing power parity (PPP) per day

Percentage of population living below a $1 per day[a]			
Region	**1990**	**1999**	**2001**
Northern Africa	2.6	2.0	1.9
Sub-Saharan Africa	46.9	42.7	46.6
Latin America and the Caribbean	10.6	10.6	10.0
Eastern Asia	33.0	17.8	16.6
Southern Asia	39.7	30.5	30.4
South-Eastern Asia	18.4	10.8	10.2
Western Asia	1.6	4.2	3.7
Commonwealth of Independent States	0.5	10.3	5.0
Transition countries of Southeastern Europe	0.4	1.7	2.1

[a] High-income economies, as defined by the World Bank, are excluded (source: UN, 2004a)

Of all the regions of the world, SSA has the highest percentage of extremely poor people. As of 2001, almost half the population of SSA was struggling to survive on $1 per day or less, the same proportion as in 1990. SSA's poverty gap ratio is almost three times that in Southern Asia, the next most impoverished region (UN, 2004a).

The achievement of the poverty goal for example is more likely in Northern Africa than in SSA (see Table 2). Table 2 shows the indicators for monitoring the MDGs and the progress made so far in Africa by region. After five years into the setting of the MDGs, many SSA countries are making little progress towards any of the goals and are thus in need of new ideas and actions to accelerate progress sufficiently to catch up.

Table 2: The MDGs indicators and Progress made in Africa

Goals and Targets	Region	
	Northern	**Sub-Saharan**
Reduce extreme poverty by half	on track	high, no change
Reduce hunger by half	on track	very high, no change
Universal primary schooling	on track	Progress but lagging
Equal girls' enrolment in primary school	on track	Progress but lagging
Equal girls' enrolment in secondary school	Met	no significant change
Literacy parity between young women and men	Lagging	Lagging
Women's equal representation in national parliaments	Progress but lagging	Progress but lagging
Reduce mortality of under-five year-olds by two thirds	on track	very high, no change
Measles immunization	met	Low, no change
Reduce maternal mortality by three quarters	Moderate level	very high level
Halt and reverse spread of HIV/AIDS	…	Stable
Halt and reverse spread of malaria	low risk	high risk
Halt and reverse spread of tuberculosis	low, declining	high, increasing
Reverse loss of forests	less than 1% forest	Decline
Halve proportion without improved drinking water in urban areas	met	no change
Halve proportion without improved drinking water in rural areas	high access but little change	Progress but lagging
Halve proportion without sanitation in urban areas	on track	Low access, no change
Halve proportion without sanitation in rural areas	progress but lagging	no significant change
Improve the lives of slum-dwellers	on track	Rising number & proportion of slum-dwellers
Youth unemployment	high, no change	high, no change

Source: UN, 2004b

They are caught in a poverty trap, in which a limited availability of domestic resources, accentuated by high population growth, restricts the public and private investment and public expenditure on both social services and development administration needed to escape from the trap (UN, 2004a).

2. THE NATURE OF POVERTY

There is no generally accepted definition of poverty. It can be seen as an unacceptable deprivation in human well being that can comprise of low monetary income and consumption levels as well as social deprivation such as risk, vulnerability, etc. It is to be noted that social processes generally are not as amenable to spatial analysis as natural and environmental processes. This is mainly due to the complex, multifaceted, ill-structured nature of most social problems of which poverty is a good example. Poverty is multifaceted and can be rightly likened to the legendary Hydra, a creature in ancient Greek stories, with many heads that grew again when cut off. Poverty in SSA seems to be a difficult problem that keeps returning, although in actual fact it has never left before. The non-recognition of this multifaceted nature of poverty is the major failure of the sectoral approach, which only succeeds, in addressing one or more of its facets. Often poverty, health, illiteracy, unemployment, gender among others are handled as separate problems. Although each of these problems have their characteristics, yet there is much overlap between them and they all vary over space. Also, the understanding that there are different causes of poverty observable from place to place is essential and this calls for flexibility in approach, such as tackling poverty within a spatial framework. To be effective, national Poverty Alleviation Programmes (PAPs) would need to be flexible enough to address the diversity of the needs of poor individuals, communities and states (World Bank, 1996).

With studies having established an indisputable link between geographic location and poverty, it is imperative that PAPs in Africa should employ the use of Geoinformation (GI). This would take into cognisance geographic variations of poverty indicators and aid the identification of the determinants of poverty.

2.1 Geoinformation use in poverty reduction

In SSA, the use of GI had been restricted to natural resources applications for decades mainly in the environmental, mineral exploration fields and public utilities for managing services and infrastructure. It has not been as extensively used, as it should have been in the socio-economic field considering that many of the environmental problems that Africa faces are as a result of social issues such as poverty (Schwabe, 2001). The use of GI in addressing poverty problems should be encouraged as its use for poverty reduction is still in its infancy. Where GI is being employed in poverty related activities in other regions or within Africa, tremendous results are being experienced. In Brazil, the Atlas of Human Development was produced using 38 geo-referenced variables including two composite indices from three consecutive population censuses (1970, 1980 and 1991). The Atlas proved highly successful in its use for decision making on public investment and targeting of billions of dollars worth social programmes. The Mexican tortilla and Milk programs, the Venezuelan Day Care Centres program, and the Honduran Food Stamp Program, all used geographic location in targeting direct transfers to the poor (Baker and Grosh, 1994). Also, the Human Development Indicators in West Africa and SSA had been mapped, with the former used to support regional priority setting by the U.S. Agency for International Development (USAID; see Henninger, 1998 and Akinyemi, 2003).

Important uses of GI in poverty reduction are mainly for poverty mapping and Geographic Targeting. Identifying spatial patterns with poverty maps give new insights into the causes of poverty, for example how much are physical isolation and poor agro-ecological endowments impediments to escape poverty. This in turn affects what type of interventions to consider for poverty alleviation. Poverty maps help to visualize spatial relationships and the geographic targeting of PAPs. Geographic targeting aims at identifying and transferring resources to the poor in need of intervention using geo-information based on their location. This can be very effective in reaching policy makers, providing an additional return on investments in survey data, which often remain unused and unanalysed after the initial report or study is completed. The use of GIS to provide a spatial framework for poverty mapping allows the use of new units of analysis (such as switching from administrative to ecological boundaries) and access to new variables like community characteristics, not collected in the original survey (see

Henninger, 1998). He gives a detailed review of the applications of poverty mapping. However laudable the potentials of GI use, the near absence of available geo-referenced data is the bane of GI utilization for poverty reduction in Africa.

2.1.1 Geo-referencing socio-economic data

The dearth, incompleteness and non-currency of data generally in Africa have often been cited as a problem. The non-georeferencing of available socio-economic data further compounds the problem, especially as it relates to the employment of GI in reducing poverty. The lack of geo-referenced socio-economic data is partly explained by the failure of many African national data collection agencies as well as initiatives (poverty programmes inclusive) in not considering the influence of geography on their subject matter, especially poverty. Thus, the collection of social, economic and environmental data in Africa needs to reflect geographic variation. This is because the lack of readily available geo-referenced data is limiting poverty and other development efforts.

In an on going study on the use of geo-spatial predictive drivers for reducing malnutrition levels of poor rural households in Nigeria, data from two surveys are to be utilized, namely: the rural food demand survey and the food consumption and nutrition survey. Unfortunately, neither of the surveys geo-referenced their survey locations. A major initial task to move the study forward is to carry out GPS mapping of all 947 villages in 14 states covered in the two surveys (Povertymap, 2004). In an earlier study, the understanding of the nature of and distribution of marginal lands for instance, was said to be limited by the lack of readily available data in a geo-referenced framework, in particular with respect to the incidence, nature and probability of land degradation by land type (TAC, 1996 cited in Henninger, 1998). These examples help to bring to the fore a major impediment facing Africa in harnessing the benefits accruable through the use of GI for its development. Moreover, for many initiatives, the collection of new data is often unrealistically costly and time-consuming.

2.1.2 Regional cooperation in GI use for poverty reduction

Regional cooperation in Africa is very vital in the successful use of GI for development in general and poverty reduction in particular. This is reasonable since most poverty engendering factors whether environmental factors, social and cultural conditions or natural disasters normally stretch beyond national political boundaries. Those that occur within a nation more often than not invariably have spillover effect on surrounding nations. A good example is the effort of researchers from the International Food Policy Research Institute (IFPRI) in designing the national maps of Malawi and Mozambique with the aim of building a regional poverty map that could be expanded to include other East African countries. Such an effort means that the challenge of constructing comparative poverty lines and indices over two or more countries will have to be overcome (Davis, 2003). Another example of such regional cooperation in the use of GI is the Andean Network of Spatial Data (REDANDA) comprising of statistical agencies and universities in Bolivia, Columbia, Ecuador, Peru and Venezuela. They created disaggregated municipal-level regional maps of development indicators from population census data. This network achieved homogenisation of standards among the five countries for the 2000 census (REDANDA, 2001 cited in Davis, 2003).

Data from surveys such as the DHS creates the opportunity for regional collaboration in the use of GI for Africa's development. The DHS data collection was conducted on themes such as health, nutrition, etc on country basis. The data was not collected for poverty analysis as it does not include consumption data, but studies are beginning to proxy income for example by creating asset (wealth) indices (Filmer and Pritchett, 1998). Also the DHS data has proved very useful in the creation and mapping of a wealth index for many countries of which twenty-three are from Africa (World Bank, 2005). Efforts focused on the increased geo-referencing of agricultural, population and infrastructural censuses as well as household social surveys should be initiated and encouraged. Examples are the production and availability of digital maps showing enumeration area boundaries and the development of a consistent coding system for cross-border usage.

Regional effort should not only be limited to the aspect of data but there is also the need to focus on critical mass production of manpower under the umbrella field of Geo-Information Science. This will help in training the 'humanware' necessary to man the technology and improve the skills base which is low at present. People should not only be trained in the use of GIS software but knowledge of basic principles of GIS, data acquisition and integration as well as data management is very important. Geographic Information Technology (GIT) and its suite of tools becomes very important for data handling, the mapping of assessed poverty levels and geographic targeting of benefits to the poor. Thus, making the use of GI in poverty reduction in Africa imperative.

3. EVOLVING ROLE OF GIT IN POVERTY MODELLING

Modelling poverty using GIT provides important insights into poverty distribution through the linkage of variables such as in household income or consumption alongside their socio-demographic characteristics to specific geographic locations. The spatial location of poor people facilitates integration of data from sources such as satellites, censuses, households' surveys, sectoral surveys, models and simulations for the analysis of the determinants and impacts of poverty (Davis, 2003). Moreover the overlay function in GIS enables the analysis of various poverty indicators in order to understand the spatial association existing between these indicators. Explanatory and dependent variables for use in multivariate analysis of the determinants of poverty are spatially generated, including natural capital and infrastructure, and access to public services, product and labour markets (Bigman and Deichmann, 2000).

Expanding more on GIT use in generating explanatory and dependent variables for multivariate analysis, the example of the household unit small-area estimation poverty measure is given (World Bank, 2000). The equation models poverty using ordinary least squares:

(1) $\ln C = \alpha + \beta 1X + \beta 2V + \varepsilon$

Where C is total per-capita consumption or poverty proxy, X is a matrix of household-level characteristics and V a matrix of geographical-level characteristics. In estimating for "V" in the equation, which is in the particular domain of spatial scientists, a set of geographically derived indicators are needed. For commune – level (municipality) estimation of poverty in Cambodia, Fujii (2004) utilized the following indicators in estimating for geographical-level characteristics:

- Distance: Distances from villages to roads, other towns, health facilities and major rivers;
- Land use/cover within the commune (agriculture, urban, forested, etc);
- Normalized Differential Vegetation Index (NDVI) to proxy agricultural productivity;
- Climatological variables, elevation, soil quality indicators, and flooding;
- Degree of nighttime lighting as a proxy of urbanization.

The resulting parameter estimates in the equation are then applied to the census data for a country. For each household, the estimated parameters from the regression are used to compute the probability of each household in the census living in poverty. Household-level results can then be aggregated by the geographical region concerned by taking the mean of the probabilities for the chosen geographical entities and mapped (see Davis, 2003).

The advent of high spatial resolution, multispectral satellite imagery has allowed analysis of remotely sensed images with which pockets of urban poverty were identified and mapped in Rosario, Argentina (Hall *et al.*, 2001). The study employed the use of Canadian RADARSAT-1, American Landsat TM satellite imagery and ground-based GIS data in its analysis. They defined poverty based on a limited number of census variables related to dwelling construction materials and per household overcrowding. The addition of radar imagery at relatively high spatial resolution (6 metres at best), with the advantages that it is not affected by cloud and diurnal light conditions and that it is sensitive to the target's geometric shape, surface roughness and moisture content offers additional capability in this regard. The results suggest that the approach used is reasonable and that, with future refinement, it offers planners and decision makers a timely and cost effective means to locate and monitor poverty pockets in urban areas. This is especially important in large, rapidly urbanising areas of Africa, where maps may be non-existent or outdated.

The analysis and maps so produced enable better understanding of the households or places that are less developed, which are in greater need of social assistance. Such knowledge of the spatial patterning of poverty is invaluable and increasingly needed in decision making for example, in the targeting of PAPs with the use of poverty mapping techniques.

3.1 Poverty modelling schema

The design of a poverty schema and its actual implementation in a geodatabase is pivotal to the successful use of GIT for poverty reduction. This abstraction involves three levels of poverty data modelling in the design phase, namely the conceptual, logical and physical models which are to be implemented for poverty reduction. To successfully use GI in PAPs would require the development of appropriate models that capture all aspects of poverty reduction. As poverty is an intangible phenomenon, in most studies, attempts are made to find proxy socio-economic, demographic and/or geographic indicators whose variables (characteristics) can then be examined. Such variables needed in assessing poverty are to be covered by the datasets housed in the geodatabase. The actual design of a data model for poverty reduction is beyond the scope of this paper, however it is currently on within the GTGIS (Geographic Targeting Geo-Information System) project (the GTGIS will be further discussed in the last subsection). The effort of the ESRI in developing industry-related data models for use in many applications is worth mentioning because of its relevance to GI use in SSA (ESRI, 2005).

Some aspects of poverty reduction in which GI is needed are for example, in assessing poverty, geographically targeting PAPs and dynamic mapping for monitoring poverty levels. An all-encompassing concept that helps to incorporate all these aspects of poverty reduction (poverty assessment, poverty alleviation and its monitoring) within a spatial framework is known as ‘Poverty Management’ (PM).

3.1.1 Poverty Management

In its conceptualisation of poverty reduction, PM activities comprise of three modules, namely: The Poverty Assessment Module (PAM) enabling the use of econometric and anthropometric measures of poverty following an income/consumption model and a welfare model respectively; the Poverty Alleviation Module (PALM) which enables the examination of the determinants of poverty (that is, interplay of socio-economic, demographic and geographic variables in making households vulnerable to poverty) as well as design of alleviation schemes; the Poverty Monitoring Module (PMM) which enables the examination of the impact of poverty reduction initiatives on poverty level within a given context over a period of time. Different mapping themes are utilized in each module, namely: Poverty Inventory Mapping in the PAM, which connotes the idea of “what is where”; Poverty Vulnerability Mapping in the PALM, that is, mapping of factors engendering household poverty; Poverty Impact Mapping in the PMM to map poverty trend over time. Two very simple types of poverty inventory maps are illustrated using the Foster-Greer-Thorbecke (FGT; Foster *et al.*, 1984) poverty index as well as anthropometric (welfare) based indices respectively (see Figures 1 and 2).

Figure 1 shows examples of poverty inventory maps of representative residential density zones (RDZs; high, medium and low densities) of Ibadan Metropolis, Nigeria. It is showing the distribution of households by simply comparing whether they are above or below the extreme poverty line of ₦1,101.

Figure 1: Incidence of moderate poverty

The extreme poverty line is calculated as 1/3 (one-third) of the mean per capita income of households living in the sample RDZs. This follows the methodology of Canagarajah *et al*., (1997), in the absence of a national poverty line. Constructing a poverty map at such a fine level of geographic disaggregation such as household instead of at state level can greatly enhance the usefulness of poverty maps (see Baker and Grosh, 1994). Aggregated data at state or national government levels tend to hide much variation in poverty. Detailed information to construct poverty maps at fine levels of geographic disaggregation is not available from population censuses for confidentiality. A way often used to circumvent this problem is to develop poverty maps on the basis of welfare indicators using anthropometric measures of poverty. This is often constructed by combining information on social services indicators such as sanitation, access to water, electricity or educational level of the household (see World Bank, 2002).

Using sanitation as an indicator, figure 2 shows the spatial distribution of the various types of toilet in use and the number of households having to share each toilet for the same RDZs as in figure 1. Most households share toilet and the number of households sharing a toilet is up to twelve in both the high and medium RDZs. In the low RDZ, there was only one case of two households showing a toilet. The type of toilet in use is indicative of the household quality of life, while the level of sharing of these facilities among households is indicative of the neighbourhood quality of life. The local pit latrine is of common use in both the high and medium RDZ. The removable bucket type is in common use in the high RDZ and was reported once in the low RDZ. Households without a toilet resort to defecating in nearby bushes or in the open drain (gutters) as reported in the high RDZ making this neighbourhood more disease-prone.

The PM concept and its three mapping themes are being developed and implemented in the GTGIS, a Spatial Decision Support System (SDSS) for poverty reduction with particular focus on SSA. Detailed reviews of the PM concept and the GTGIS can be found in Akinyemi (2003) and Akinyemi (2004) respectively. However, aspects that relate to enhancing GIS functionality in the GTGIS are further discussed because of its relevance to this paper.

3.1.2 The Geographic Targeting Geo-Information System (GTGIS)

GIS is limited as a decision support system as it lacks the capability for choice modelling which is very useful in decision making for poverty reduction. Often decision makers would like to consider multiple agendas, evaluate multiple decision criteria and select alternatives most closely aligned with their priorities in alleviating poverty. Moreover, functionalities for conventional econometric and anthropometric indices for the measurement of poverty, for instance, are lacking in a typical GIS. Consequently, it becomes very necessary to enhance its functionalities for better performance in poverty reduction.

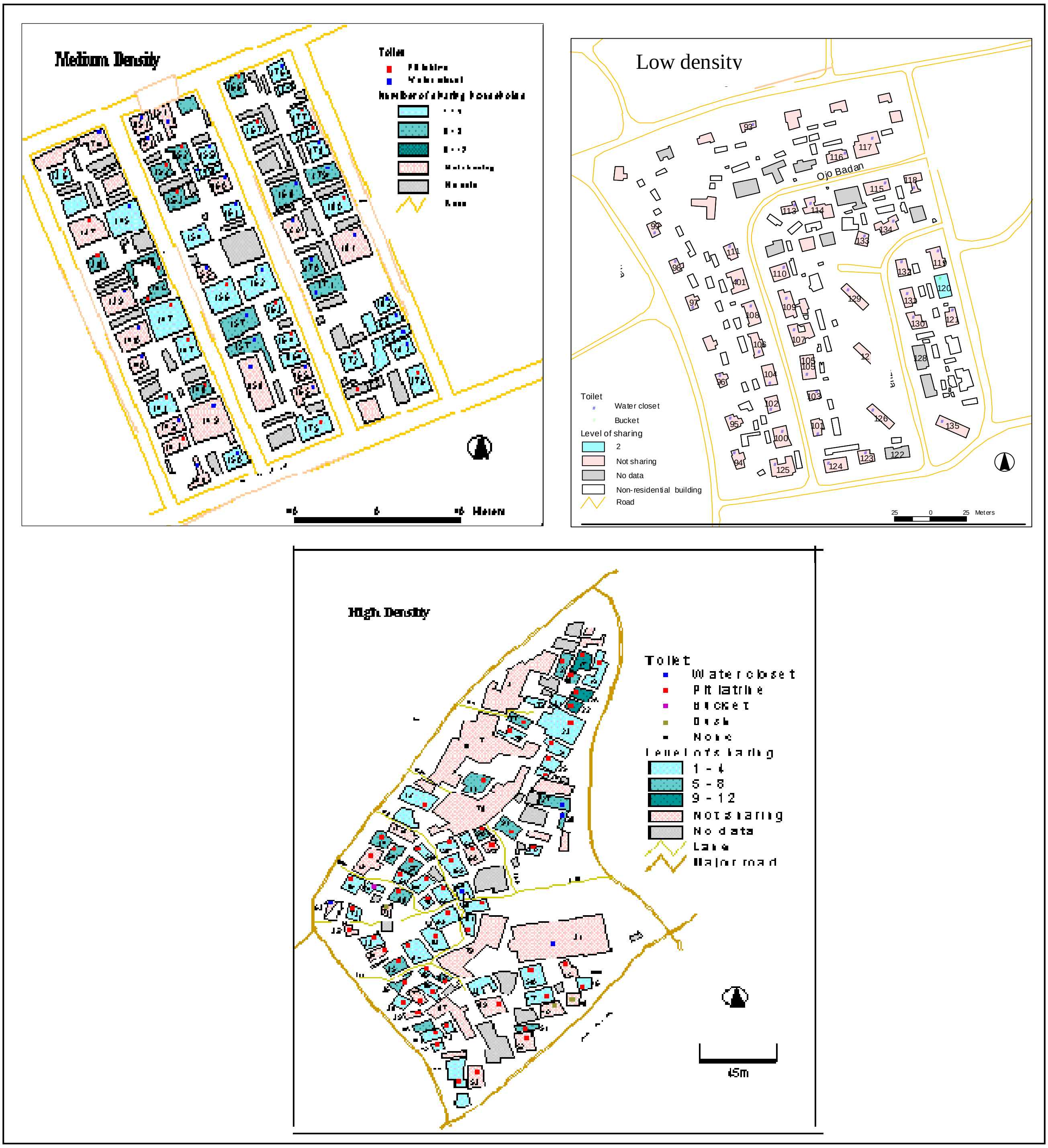

Figure 2: The type of toilet utilized and the number of households sharing a toilet

These factors are the main motivations for the development of the GTGIS, which is aimed at the developing functionalities in GIS to carry out the assessment of poverty, development of poverty alleviation schemes using Multiple Criteria Evaluation (MCE) techniques and poverty monitoring. Another similar effort on the implementation of MCE in GIS is by the International Institute for Geo-Information Science and Earth Observation (ITC) called the ILWIS SMCE (Spatial Multiple Criteria Evaluation; ITC, 2005). With this added capability of MCE in GIS, for poverty related decision making, i.e 'what if' scenarios, greater possibilities is being opened up for GIS use in not only poverty reduction, but for other development related initiatives.

4. CONCLUSION

The United Nation's review of implementation of the UN Millennium Development Goals takes place this year, 2005. In the words of the UK's Commission for Africa, the year offers a further opportunity for poverty reduction in Africa to be on course, with the knowledge that the goals will not be met in Africa by the 2015 deadline unless there are new ideas and action (CFA, 2004). This paper has explored the prospects of developing a spatial information model for poverty reduction and management in Sub-Saharan Africa, which is crucial for successful incorporation of a ***spatial dimension*** into poverty alleviation programmes. Carrying out poverty reduction within a spatial framework is foreseen to help bring about a greater use of geoinformation for better understanding and handling of the poverty problem. The poverty management concept, which offers an integrated approach to poverty reduction within a spatial framework, was also reviewed and simply illustrated. There are however, several limitations inherent in GIS as a spatial decision support tool for poverty related decision making. These limitations are its lack of functionalities for econometric and anthropometric measurement of poverty as well as its inability to handle multiple criteria for use in poverty alleviation schemes. These limitations form the main features of the GTGIS, which is a GIS based poverty management tool currently at the design stage.

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BIOGRAPHICAL NOTES

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Her research interests are in the application of geoinformation to development especially in the poverty mapping domain. Her current research is on developing a spatial decision support tool for poverty management in Sub-Saharan Africa. Currently, she is a member of the Nigerian Cartographic Association, ISPRS Technical Commission VI/WG III on International Cooperation and Technology Transfer, Joint ICA/ISPRS Work Group on Incremental Updating and Versioning of Spatial Data Bases. She is Chair, United Nations Group of Experts on Geographical Names (UNGEGN) Africa West Division. She was born in 1970 and is married having a family with two children.

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