PRELIMINARY DESIGN OF A SPATIAL DECISION SUPPORT SYSTEM FOR POVERTY MANAGEMENT

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ABSTRACT:

Saddled with the burden of increasing poverty among majority of their populace, many African countries are initiating various Poverty Alleviation Programmes (PAP). Many of these programmes however miss out the influence of geography and spatial variables as determinants of poverty, that is, the spatial dimension of the problem of poverty. Attempts are increasing being made to use GIS for poverty analysis and visualization in the emerging field of poverty mapping sees which poverty maps as useful input into decision making. However, experience with the use of GIS for decision making in the social sciences, especially for poverty handling has revealed several shortcomings. A major problem arises from the fuzzy nature of such a social problem which makes it in most cases to be “unstructured”. Hence, this necessitates the input of preferences, intuitive judgement and the to examine choices of alternatives in the decision making process. This limits GIS as a decision support tool when handling complex, multifaceted, ill-structured social problems, despite its increasing analytical capabilities. This paper describes the preliminary design of the Geographic Targeting Geo-Information System (GTGIS) which integrates various GIS tools, socio-economic data modelling and Decision Support System’s (DSS) capabilities of choice modelling for poverty management.

1. THE POVERTY SCOURGE

1.1 Introduction

The poverty scourge is being tackled at global, regional, national and local levels as 1.2 billion people are estimated to be currently living on less than one dollar a day (extreme poverty). This need for Global Poverty Reduction has been identified over the years. Principle 5 of the 1992 RIO Declaration on environment and development states that:

> "all States and all people shall cooperate in the essential task of eradicating poverty as an indispensable requirement for sustainable development, in order to decrease the disparities in standards of living and better meet the needs of the majority of the people of the world" (UN, 1999).

The United Nations Millennium Development Goal also has as its focus the halving, between 1990 and 2015, the proportion of people living in extreme poverty and those who suffer from hunger (World Bank, 2002).

1.2 Poverty Measurement

Poverty comprises of both income and human poverty, the two basic categories of measures often used in measuring poverty. Income poverty involves the inability to fulfil basic material needs, including securing adequate nutrition, health, education and shelter. Income poverty can be further classified into extreme (absolute) poverty which is a lack of income necessary to satisfy basic food needs and overall (relative) poverty which is a lack of income necessary to satisfy essential non-food needs, such as for clothing, energy and shelter as well as food needs. A person is considered poor if he or she is unable to secure the goods and services to meet these basic material needs. Human poverty widens the concept of deprivation to include quality of life, risk, vulnerability to poverty, lack of autonomy, powerlessness and lack of self respect (see Bank, 2002). By definition, human poverty is lack of basic human capabilities: illiteracy, malnutrition, abbreviated life span, poor maternal health, illness from preventable diseases. Indirect measures are lack of access to goods, services and infrastructure-energy, sanitation, education, communication, drinking water, all necessary to sustain basic human capabilities (UNDP, 2000).

Income poverty is measured in its three dimensions of incidence (headcount), intensity (depth), severity (degree). Income measures are unable to capture aspects of welfare such as health, access to social services, water or household composition such as household size. This shortcoming makes the measurement of human poverty important with the use of anthropometric measures such as quality of life. Several indices have been developed to measure either type of poverty *e.g.*, FGT (Foster-Greer-Thorbecke) decomposable class of poverty index (Foster *et al.*, 1984), QHL (Household Quality of Life) poverty index (Akinyemi, 2002), HPI (Human Poverty Index: UNDP, 1997, 2000).

A best practice for poverty reduction is an integrated management approach which combines several indices of poverty assessment, alleviation and monitoring. This approach would enable collaboration between government authorities, non-governmental organizations, donor agencies, international organizations, the research community and also include public participation. Until now sectoral, piecemeal approaches characterize many PAPs in different parts of the world, especially in developing countries. Most PAPs are geographically blind revealing a weak link, theoretically and practically, between poverty and geographic location. The spatial dimension to the problem of poverty is often missed out in effort to combat poverty. For instance, knowing the spatial pattern of poverty facilitates the targeting of PAP especially with the use of geographic targeting techniques (Akinyemi, 2003).

The Geographic Targeting Geo-Information System (GTGIS) designed as a Spatial Decision Support System (SDSS) for poverty management integrates:

1. Econometric and anthropometric (Income and quality of life) measures in its poverty assessment module
2. Knowledge of social, economic, demographic and geographic determinants of poverty and its alleviation
3. Monitoring of impacts of PAP on poverty levels over time

The preliminary design of the GTGIS focuses on:

1. The use of relational data structure in defining the conceptual schema of the database. The non-spatial information was modelled to create a comprehensive database model for poverty management using the Entity-Relationship (ER) semantic data modelling technique
2. Geometrically representing poverty (although an intangible social phenomenon) as a vector for formalization in the GIS
3. A modular system to create a socio-economic data abstraction model for poverty assessment which is input into targeted poverty alleviation schemes
4. Annexing available knowledge about impact of the various PAP on poverty reduction in order to indicate the best practices to adopt for poverty management

This paper describes the spatial analysis requirements of the GTGIS, the system modular architecture and illustrates with the income poverty assessment module by identifying objects and their properties in the database.

2. GEOGRAPHIC TARGETING GEO-INFORMATION SYSTEM (GTGIS) MODEL

GTGIS is a geographic targeting model developed to assess poverty and to simulate poverty alleviation schemes targeted at the poor based on where they live. The model exemplifies the poverty management concept which comprises of poverty assessment, alleviation simulation and poverty monitoring modules in a GIS based SDSS (see figure 1).

A detailed review of the modular structure used in the GTGIS model can be found in Akinyemi (2003).

2.1 Poverty Assessment Module

This module is concerned with measuring poverty levels of both income poverty and human poverty. Maps produced in this module fall into the category of Poverty Inventory Mapping (PIM), which connotes the idea of "what is where", *i.e.* the spatial distribution of poverty levels (both income and human poverty).

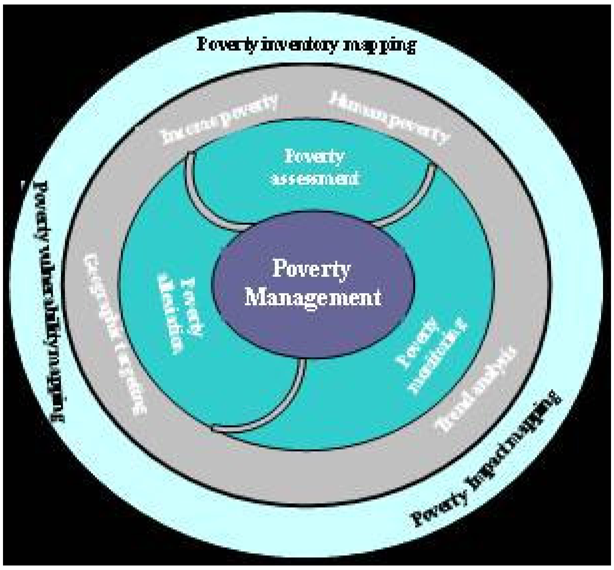


Figure 1: Integrated poverty management concept of the GTGIS (Source: Akinyemi, 2003)

2.2 Poverty Alleviation Module

It involves the use of geographic targeting method in transferring benefits to poor households or neighbourhoods. Based on the concept of Poverty Vulnerability Mapping (PVM), the balance of factors (of strengths and weaknesses) of households, communities and states which render them poverty prone to varying degrees are mapped. With those vulnerability maps, interventions can be transferred to the poor based on where they are located using geographic targeting. Furthermore, the household socio-economic indicators stored in the GIS database enables the intelligent transfer of interventions based on what their needs are, as opposed to what decision makers think the poor need. In analysing for the PVM, households are divided into poverty classes based on their vulnerability levels.

2.3 Poverty Monitoring Module

It is concerned with the regular monitoring of poverty performance indicators using analysis of poverty trend between different time periods. It evaluates the impacts of interventions on reducing poverty over a period of time.

Tools in the three modules culminate in the ability of the system to manage poverty in a comprehensive manner as against the piecemeal manner in which most systems handle the poverty problem (Akinyemi, 2003).

3. DATA REQUIREMENT OF THE GTGIS

The GTGIS model requires data about **HOUSEHOLD HEAD, BUILDING, EMPLOYMENT, SPOUSE, STREET AND NEIGHBOURHOOD** as superclasses (regular entities). While HEALTH, DEPENDANT (children), INFORMAL OCCUPATION, FORMAL OCCUPATION and PENSION are subclasses (weak entities) for the Poverty Assessment Module. These datasets are processed as poverty levels for input into the Poverty Alleviation Module to generate poverty maps for households and neighbourhoods. Constructing poverty maps at such fine level of geographic disaggregation enhances the usefulness of poverty maps. This is due to the fact that aggregated poverty data at state and local government levels hide much variation in poverty.

These datasets are all socio-economic and demographic in nature and are to be derived principally from census or specialized sample surveys. Non – release of disaggregated household level census information diminishes the usefulness of census data (detailed household census figures are withheld for years before release for the purpose of confidentiality). We can resolve this problem by developing poverty maps on the basis of welfare using indicators like access to water, education, health etc.

Poverty at the household (micro-economic) level is the main focus of the GTGIS system because it is at this level that the primary manifestation of poverty occurs. Moreover, poverty at neighbourhood, regional and national levels are but aggregates of poverty occurrences in households. Since household poverty is an intangible phenomenon, how do we formalize its geometric component as a spatial object?

We opted for a vector mode of geometric representation in which the outline of buildings housing each household is captured as the basic unit of space to which household information is explicitly recorded in the database (figure 2).

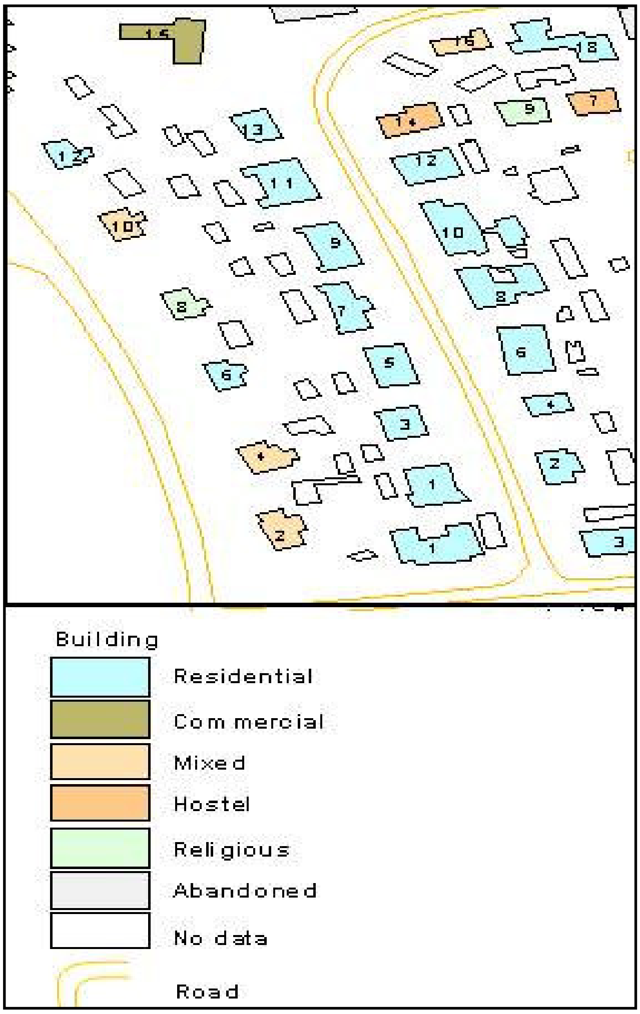


Figure 2: Buildings housing each household as the basic unit of space

The model calculates for each household in a sample area, assessed poverty levels using both econometric and anthropometric poverty measures. Based on these assessments, each household is consequently classified either as poor or non-poor in relation to a specified poverty line or quality of life indicator. Income poverty is calculated using the FGT (Foster-Greer-Thorbecke) decomposable class of poverty index. Household quality of life is calculated using indicators such as educational attainment of household head, health, children's schooling, and household expenditure on food and clothing. Household expenditure on food and clothing is especially useful in our developing world context in order to study the impact of the Structural Adjustment Programme implemented in many Sub-Saharan African (SSA) countries. By aggregating income poverty levels and quality of life values of each household in a neighbourhood, neighbourhood poverty levels and composite quality of life index value can be derived.

Furthermore, the spatial distribution of poverty can be mapped by using household composition such as age grouping, gender, household size, ethnicity, employment status, education and type of occupation. These sets of information are later useful in evaluating the degree of household and neighbourhood vulnerability to poverty as well as in designing alleviation schemes to be geographically targeted to poor households and neighbourhoods.

4. SPATIAL ANALYSIS REQUIREMENTS OF THE GTGIS

Socio-economic and development inequalities among different geographic and administrative levels of aggregation can be mapped and identified using GIS. With GIS overlay functions for example, various poverty indicators can be overlaid in order to understand the spatial dimension and relationships existing between these indicators (Akinyemi, Forthcoming). However, analysis with GIS has been limited to the generation of complementary variables which are input into multi-criteria and multi-objective models of the determinants of poverty.

5. THE SYSTEM ARCHITECTURE FOR POVERTY MANAGEMENT

Figure 3 shows the architecture of the proposed system, "The Geographic Targeting Geo-Information System" (GTGIS), which is an integration of GIS and a 'Multi-Criteria' Decision Support System (DSS). While GIS is useful for pattern-seeking geographical analysis, it would benefit from the integration of Multi-Criteria Evaluation (MCE) techniques. GIS software is limited as a decision support tool when handling complex, multifaceted, ill-structured social problems. The missing link between GIS and MCE techniques is the absence of planning/policy analysis methodology in GIS which enables decision makers to consider multiple agendas, evaluate multiple decision criteria and select alternatives most closely aligned with their priorities. This necessitates the integration of GIS and Multi-Criteria DSS in a flexible manner to enable the input of weights and human choice or judgement into the decision making process (see Enache, 1994 and Qingpu, 2001).

Against this background, this study is centred on the design and development of a GIS based DSS to handle applications for managing urban poverty in the SSA region. The ability of decision makers in managing poverty can be substantially improved with the use of such Spatial Decision Support Systems (SDSS). SDSS are interactive, computer-based diagnostic tools designed to support a user or group of users in achieving consensus-based and collectively acceptable outcomes in decision making while solving a semi-structured spatial problem (Uy and O'Rourke, 2000, Hall, 2001).

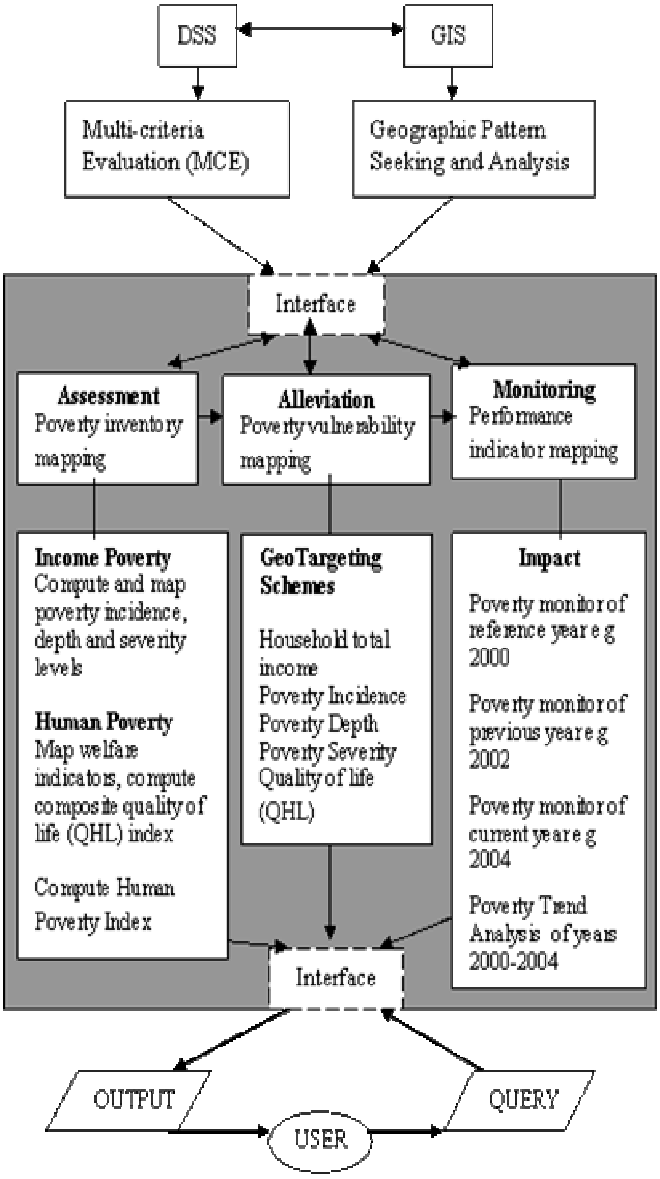
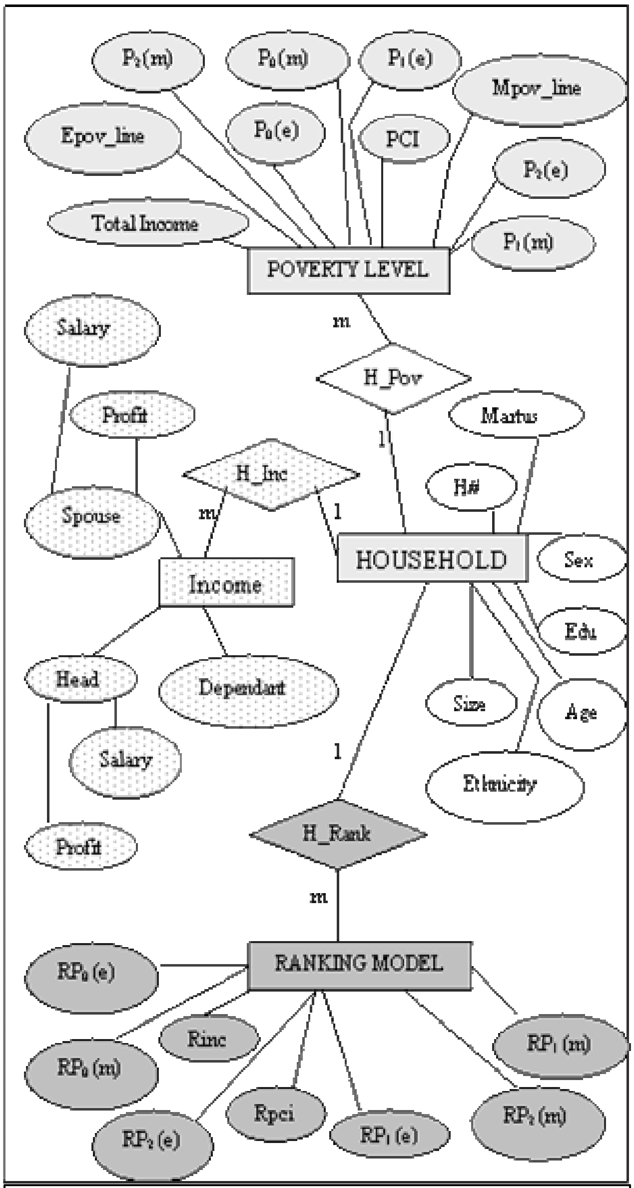


Figure 3: GTGIS architecture

The functions performed by the GIS are the traditional tasks such as spatial and non-spatial data collection and storage, spatial operations among other functions. The MCE technique takes care of poverty problem definition and a range of criteria that influence the decision are also defined. A method of adding weights to the criteria to assess their importance (a decision rule) is then constructed and analysed. To take into cognisance the limited GIS and computing knowledge of the user, an intelligent user interface is designed to be simple and interactive.

6. OBJECTS AND THEIR PROPERTIES IN THE INCOME POVERTY ASSESSMENT DATABASE

There are different data requirements for the three modules whereby output of a module becomes the input into another module. The analyses to be generated in the system would employ the multi-criteria and multi-objectives approach which will integrate a vast array of objects in the database. However for the purpose of illustration, discussion will be limited to the identification of objects and their properties in the income poverty model (figure 4).



$P_0(m)$ - Incidence of moderate poverty, $P_0(e)$ - Incidence of extreme poverty, $P_1(m)$ - depth of moderate poverty, $P_1(e)$ - depth of extreme poverty, $P_2(m)$ - severity of moderate poverty, $P_2(e)$ - severity of extreme poverty, PCI – total household per capita income, $RP_0(m)$ - Rank of Incidence of moderate poverty, $RP_0(e)$ - Rank of Incidence of extreme poverty, $RP_1(m)$ - Rank of depth of moderate poverty, $RP_1(e)$ – Rank of depth of extreme poverty, $RP_2(m)$ - Rank of severity of moderate poverty, $RP_2(e)$ - Rank of severity of extreme poverty, Rinc - Rank for total household income, Rpci - Rank for total household per capita income scheme

Figure 4: Objets and properties in the income poverty model

Figure 5 shows the steps in the income poverty modelling. These are: (1) calculation of household income (the household income model); (2) measurement of household income poverty level in its three dimensions of poverty incidence, depth and severity (household income poverty level model); (3) geographic targeting simulation model (ranking model);
(4) Multi – Criteria valuation model (MCE model).

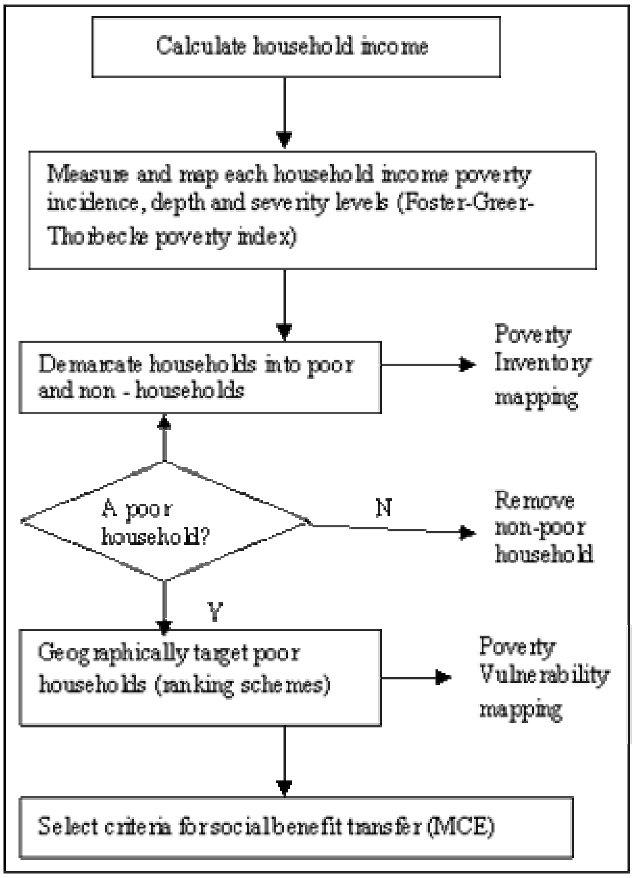


Figure 5: The rule base for benefit transfer to the poor

6.1 The household income model

The variable, ‘household income’ comprises of income from various sources accruing to each household. Income sources include household head’s salary/pension (a retiree) from formal occupation and/or profit from informal occupation, spouse (s) income and dependant’s financial support (in modelling the African poverty scene, dependants such as children have emerged as significant generators of income for the household). Total household income is required for input into the income poverty model for computation of income poverty indices of incidence, depth and severity.

6.2 The household income poverty level model

The three dimensions of income poverty (incidence, depth, severity) in each of the households were measured using the variants of the FGT poverty index (Foster *et al.*, 1984).

$$P_a = (1/n) \sum_{i=1}^{q} [(Z-Yi)/Z]^a$$

Where Z = the poverty line
q = the number of household heads below the poverty line
n = the total no of households in reference population
Yi = the income of the household in which household head i lives;
P_a = the FGT index
Σ = summation

6.3 The ranking model

Household total income; per capita income (PCI); assessed poverty levels such as incidence, depth, and severity indices can be used as geographically targeted schemes. This is done by ranking poor households according to their assessed poverty levels using a rating scale from 1….n: where 1 is most vulnerable and n is least vulnerable (n is the last number signifying the position of the least vulnerable household.

6.4 MCE model

Having ranked the households and/or neighbourhoods by a chosen poverty measure, the decision maker is now faced with deciding where to draw the line between those that will receive social benefits and those to be excluded. The MCE is useful to define the 'suitability' of a particular solution on the basis of the geographically targeted schemes.

7.0 Conclusion

This study has been concerned with the possibility of managing poverty with the GTGIS, an integrated GIS and multi-criteria evaluation DSS. It advocates an integrated management approach which combines several indices of poverty assessment, simulates geographically targeted alleviation schemes and monitors the impact of poverty reduction programmes on poverty levels over a period of time. In this paper, income poverty was conceptually modelled in which objects, their properties and relationships were identified. Furthermore, the rule base for geographically transferring benefits to poor households was illustrated.

The GTGIS is designed and developed to support the aforementioned three application modules for managing poverty, especially in the Sub-Saharan African region. The ability of decision makers to effectively manage poverty in this region can thus be substantially improved with the use of the GTGIS. This work is an ongoing one for which further work is still required to enhance the overall performance of the system.

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