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Applications of a GIS in Program Impact Evaluation: Lessons from the U.S. Agency for International Development (USAID) Experience

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THE IMPORTANCE OF GEOGRAPHY and the spatial scale of socioeconomic interaction have been underappreciated in development assistance activities. Awareness of spatial structure in data and tools for statistical inference based on spatial data is rare in development assistance agencies. Applications and use of these analytical tools have been almost invisible. It is not surprising, therefore, that analysis of data is rarely structured in the most geographically relevant ways.

It is critically important to improve the geographic use of data for three reasons. First, the geographic unit of analysis chosen partly determines the analytical result. False policy conclusions may result from improperly structured data, and subsequent targeting efforts based on this analysis will also be faulty. Second, ignoring the geographic structure of data limits the uses of new survey data in combination with existing data. Data is available for testing a far broader range of development questions than are currently the subject of most evaluation efforts. As a result, many critical development questions are simply not tested, even though data has already been collected that could be used geographically to better respond to these questions. Third, limited analytical uses of data means that expensive data are collected but used for only few analyses. A higher proportion of current funding could be allocated to data analysis rather than data collection if existing data were better utilized geographically.

U.S. development assistance activities are designed with specific development models in mind. From a targeting perspective, these models are

used to define necessary and sufficient conditions for development assistance to have an impact. GISs can help geographically identify population groups or areas with these conditions. From a program impact perspective, development models provide hypotheses that are testable using sample data on population groups that have received assistance and those that have not. The record of development assistance clearly shows the need for more testing and refining of development models for location-specific circumstances.

Unlike geographical targeting applications, impact evaluation can rely on a sample of locations. Geographical targeting generally relies on comprehensive coverage of descriptive statistics for an entire population or complete universe of locations. Targeting models rely on coefficients for weighting multiple criteria or GIS data layers. A comprehensive data set for all locations is needed to choose among locations. Impact evaluation uses real-world experiments to estimate weights for factors that result in specific outcomes. Through estimation of appropriate criteria weights, successful targeting is built upon successful impact evaluation. Successful impact evaluation is built upon empirically testing multivariate models and estimating the association between development interventions and impacts in a sample of locations. Geographically combining data allows more fully specified models to be used and more rigorous inferences to be drawn from fewer observations (Anselin 1988). Important classes of models can only be tested by compiling data geographically with the help of a GIS.

This chapter reviews applications of spatial analysis using a GIS as a tool for evaluation of U.S. development assistance in West and Central Africa. In Zaire, the emphasis was on moving from sectoral project evaluation to a country program level of impact evaluation. In West Africa, the emphasis was on moving from country program evaluation to a regional, multicountry program level of impact evaluation, targeting, and reporting. However, the approaches and challenges in data compilation, analysis, and definition of beneficiary groups were common to both cases. In Zaire and West Africa the approaches emphasized drawing useful inferences from existing spatial data about benefits that selected target groups received from U.S. assistance. A GIS was an indispensable tool for spatially referencing data, compiling databases for analysis, and presenting results.

Institutional Changes Leading to Broader Use of GISs in USAID

Before 1988 there was little interest in using geographic information systems to analyze the impact of U.S. development assistance programs in West and Central Africa. Evaluation tended to focus on project implementation within geographic project areas. Two fundamental shifts in management of development assistance began in the late 1980s. The first was the adoption of a "program impact evaluation" strategy of institutional reform. The second was an increasing emphasis on "performance based budgeting," formalized with the U.S. Government Performance and Results (GPRA) Act of 1993 (see also Pietrobelli and Scarpa 1992). These political decisions and subsequent institutional changes indirectly encouraged the adoption of GIS-based tools for program evaluation.

Impact Evaluation Strategy of Institutional Reform and Performance Budgeting

The U.S. Government is currently using what Taylor (1984, pp. 296, 316–317) called an "impact statement strategy" to improve the performance of USAID as a public organization and the foreign assistance programs it delivers. Taylor identified two key elements of this strategy of reform in his earlier study of other U.S. government agencies. The first is an external demand for increased data collection, analysis, and reporting on program impacts by agency staff and contractors. The second is more analytical competition between analysts inside the agency and those outside the agency in local governments, universities, and nonprofit organizations. New programming ideas and realistic feedback on program effectiveness are expected to come from more open and informed decisionmaking involving beneficiaries and partners outside the agency.

The combination of these two elements of reform were strengthened for USAID in 1988 when the U.S. Congress began separately funding bilateral development assistance to Sub-Saharan Africa as a budget line item called the Development Fund for Africa (DFA). Annual reporting requests under the Development Fund for Africa and now under the GPRA represent an external demand for USAID to improve its knowledge base and analysis. This annual analysis and reporting on results is leading USAID to formally set new goals, reorganize, and change the mix of its program portfolios. USAID's New Partnership Initiative is leading to more open decisionmaking involving beneficiaries' and partners' organizations. GIS databases and geographic analyses are tools to help achieve this reform through disseminating multisectoral data, communicating impact evaluation results, and building evaluation capacity among partner institutions.

The DFA allowed more flexible programming procedures for USAID field missions and encouraged performance-based allocation of funding. From 1993 to 1997, USAID was a pilot agency for implementing performance planning and reporting under the GPRA. The DFA and GPRA have led to reporting on expenditures by strategic objectives, which now serve as program budgeting categories. Impacts are increasingly measured and reported by these strategic objective budget categories that provide the link between budgeting and performance. A GIS is a tool for strengthening program performance budgeting through estimating cost ratios, combining data to evaluate impacts, and mapping the complex effects of budgeting alternatives.

Performance Reporting Requirements and Funding Stability That Encourage Use of GISs

Features of the DFA and GPRA led to an accelerated use of GISs for impact evaluation of U.S. assistance programs. First, both the DFA and GPRA increased the external demand for more rigorous quantitative reporting of impacts of government programs on human welfare indicators. Second, the DFA led to reporting on the impacts of country *programs* of assistance rather than impacts of individual *projects* in isolation. Under the DFA, a country program of assistance was defined by USAID as the "combination of all project, non-project, policy dialogue, and other activities using USAID human and financial resources" in a given country (USAID/W 1989). Third, the DFA provided increased stability in funding for development programs in Africa. These three changes coincided with the appearance on the market of affordable computers, GPS (global positioning system) equipment, and GIS software. These features encouraged the use of a GIS in impact analysis for the following four reasons.

First, evaluation efforts increasingly focused on the effects of assistance programs on the economic and physical welfare of target population groups, rather than tracking expenditures or trends in population characteristics. This meant that emphasis shifted from measuring changes in average population statistics to the association between program expenditures and changes in population statistics, either in space or time (Schmid 1989 and Schick 1993). Databases structured around relevant geographic areas were often the easiest way to obtain a large enough set of observations for comparative purposes.

Second, effects of multiple projects, sometimes in different sectors such as health and agriculture, needed to be aggregated to report program rather than project impacts. Since individual projects overlapped geographically in a complex manner, a GIS was the best way to identify target population groups benefiting from multiple projects. A GIS also made mapping a more cost-effective tool for communication about programs of assistance.

Third, investments in a GIS are particularly sensitive to timeframe and funding stability, because start-up costs are high and marginal operating costs are low. In the five-to-ten-year timeframe provided for programs by the DFA, GIS-based approaches to monitoring and impact evaluation are cheaper and can provide higher-quality analytical results than alternatives. In a time horizon of only a few years, approaches with low startup costs make sense because there are no expected long-term cost savings. The shift to a program focus rather than a project focus lengthened the investment timeframe, since programs were generally viewed as having a longer life span than individual projects.

Fourth, a program rather than project focus facilitated sharing overhead startup costs for using a GIS across projects. Even though USAID increased expenditures on monitoring and evaluation to between 5 and 10 percent of total assistance program cost, sharing of GIS overhead costs was required to make a GIS feasible for programs with a set of small projects.

In summary, DFA and GPRA reporting requirements and their longer timeframe encouraged the use of geographically structured databases. These databases have been used to identify population groups targeted by existing programs and for analysis of changes in human welfare indicators across locations with and without development assistance.

Framework for Analysis of Program Impact

In most developing countries, the shortage of well-organized and accurate longitudinal data makes it difficult to examine impacts and changes over time. Data are often fragmented and used for single purposes. Numerous household cluster surveys with samples drawn at a community, regional, and national level are often only analyzed at an individual or household level, or used to produce aggregate national statistics. Potential uses of the same data at the household cluster level or across national boundaries (when comparable surveys exist in multiple countries) have generally been ignored. Secondary data collected by administrative authorities for local-area populations are generally aggregated up for national ministries, and the geographic content is lost. Under these circumstances, it is useful to employ a more spatially oriented approach in which the juxtaposition of services (such as roads and health clinics) is analyzed to explain variation in the welfare status of the surrounding population. A GIS is a technology that is inherently spatial in terms of its data organization and analysis capabilities, and it therefore provides an ideal tool for supporting spatial analysis and the management of spatially referenced data.

Development of geographic databases and subsequent geographic analysis for program-impact evaluation can be divided into the four steps explained below: (1) identify spatial units of observation; (2) identify spatial units of analysis; (3) develop typologies of local-areas; and (4) analyze the variance of population characteristics and covariance of population indicators with assistance provided.

Identifying Shared Spatial Units of Observation in Existing Data Sets

Local-area socioeconomic data are often submerged in the aggregation of national statistics, with the result that local-area data for a developing

country are not available in any single archive for cross-sectional analysis. Local-area socioeconomic data are also not often geographically referenced, which means they cannot be used jointly with satellite imagery or infrastructure maps. In many countries the geographic boundaries of health service areas and administrative areas do not match. Data for local areas publicly reported from different ministries often cannot be combined due to these types of mismatch. For all these reasons it is difficult to bring together existing data into a single database for joint analyses.

In West and Central Africa socioeconomic sample survey data tend to be geographically representative of administrative areas, health service areas, and population census enumeration areas. These geographic categories used for sample stratification or census data collection provide three building blocks for geographically structuring socioeconomic data and merging them with biophysical data from maps or satellite imagery. A frequent problem is that agricultural production data are available for large subregions of a country while socioeconomic survey data are representative both of a smaller community level and at levels larger than the agricultural statistical areas. This mismatch means that the national level is the only common unit of observation for published agricultural production and socioeconomic data. In order to merge these different types of data geographically at a subnational level, data from original sampling areas may need to be recombined to geographically restructure the data. Good documentation of coding and sampling procedures are critical for meaningfully restructuring data geographically.

Since the 1980s round of population censuses, most household sample surveys are based on a systematic multistage sampling. First, primary sampling units (PSUs) of geographic clusters of households (often census enumeration areas) are chosen. Enumeration areas are often designed for ease of access during the census reference period, and in rural areas of Africa they may be between ten and fifty square kilometers with 700–1,500 people. Second, households within each PSU are selected with probability proportional to the size of the PSU based on a comprehensive listing of all households in the cluster. On this basis, the cluster-level random sample of 20 to 30 households provides an unbiased estimate of population statistics for all households in the geographic cluster. This means that these surveys have the household, PSU cluster level, subnational region, and national level as "units of observation" that can potentially be matched geographically with other data sets.

In normal survey jargon, these surveys are not considered representative at the cluster level because they are not considered to have usefully small standard errors at that level. However, if cluster-level estimates are unbiased, then they can be used at the cluster level for covariance analysis across multiple clusters. This makes cluster survey data potentially useful for impact evaluation using the PSU cluster as the unit of analysis. A sufficiently large number of relevant clusters need to be geographically matched with complementary data, such as on development interventions. Some readers may find it difficult to switch to thinking of cluster level data as useful units of observation, or as subsequent units for statistical analysis across clusters. MACRO International completed an analysis of the standard errors of a wide range of Demographic and Health Survey (DHS) cluster-level variables and concluded that this unit of observation was statistically useful. On this basis, MACRO compiled a cluster-level data set for West Africa as part of the USAID-funded West Africa Spatial Analysis Prototype (WASAP) effort (see MACRO, Intl. 1997, and McGuire 1998).

Even when local-level data that provides unbiased estimates are available, the critical problem is that most of these local-level data are not georeferenced for a village, census area, or health clinic service area. This means they cannot be linked with other data geographically and thus cannot be analyzed jointly. The major task in creating geographic databases in the case studies reviewed in this chapter was georeferencing existing secondary data at the level of a health clinic service area and census enumeration areas (Rogers 1991a, BUCEN 1996). These cluster data were not previously used at this level in West Africa because of limited awareness of the spatial structure of the surveys that resulted in the lack of georeferencing. Greater flexibility in how data are geographically analyzed is critical to GIS use in impact evaluation, but this flexibility requires georeferenced data.

In Zaire, the geographic coding and secondary data were reviewed, including census data, household survey data, and project field records (Leirs 1990 and Rogers 1991b). Rural health clinic archives were examined and clinic data collection procedures were assessed. Specific villages had been assigned to each health clinic, so the service areas did not overlap and were roughly the same size. Child weighing was done monthly in each village, so time series and spatial cross-section data on malnutrition were based on the entire clinic service area population of children under age five, within a total population of 5,000 to 15,000. Malnutrition data was available by health zones, health clinic service areas within health zones, and villages. Clinic service areas fit geographically within a structure of larger health zones, so it was possible to analyze variance by health zone, as well as health clinic areas or villages, to guide the choice of relevant units of analysis. However, data for health zones was often not representative of the population due to incomplete coverage of services. Administratively and in the population census coding, villages have been organized into "groupements," "collectivities," and "sub-regions," so these groupings defined the units of observation that could potentially be matched for analysis of variance using census mortality (indirect methods with census data) and male migration data.

In West Africa hundreds of millions of dollars' worth of population censuses and sample surveys have collected data that provide unbiased estimates for census enumeration areas. However, none of these cluster samples

(such as the USAID funded Demographic and Health Surveys, Living Standards Measurement Surveys, and UNICEF Multiple Indicator Cluster Surveys) were mapped during fieldwork before 1995. This means the data could not be brought together without georeferencing them first. If household clusters are georeferenced with an error of only a few kilometers, then data may be usefully matched geographically with satellite imagery, natural resource maps, or infrastructure maps for multivariate analysis.

Useful units of observation should represent a spatial unit that is homogeneous enough to pool data from a variety of sources, and that should not be larger than the desired spatial unit of analysis. Identifying the spatial structure of existing data sets is an important first step in assessing what data are available, how representative the data are for specific geographic areas, and what is needed to organize disparate data geographically.

Identifying Independent and Relevant Geographic Units of Analysis

A unit of analysis must be feasible in terms of available data, meet criteria for credible statistical tests, and be relevant in terms of the spatial processes assumed in the model being tested. To be feasible, a spatial unit of analysis must be at least as large as the smallest common unit of observation at which data can be merged from different sources. Often analysts simply adopt the most obvious unit of observation for the unit of analysis, giving little thought to the implications for the analysis. In the United States, the county is often used as a convenient unit of analysis, although this may not always be appropriate (see Rogers, Shaffer, and Pulver 1988). Choice of the geographic unit of analysis partly determines the analytical result because of the implicit assumptions about spatial processes that determine the observed outcome. False policy conclusions may result from improperly structured data. There is a large literature on the modifiable areal unit problem or ecological fallacy problem that may lead to false statistical conclusions and subsequently misleading policy recommendations (Openshaw and Taylor 1979 and Arbia 1989).

To have credible statistical conclusions, the units should be roughly similar in size, be independent observations in terms of the dependent variable, be numerous enough to identify data patterns, and have a sufficiently small intra-unit variance for the parameters of interest for inter-unit analysis. Anselin (1992, pp. 2–3) concludes that "a major consequence of the dependence in a spatial sample is that statistical inference will not be as efficient as for an independent sample of the same size. This may result in larger variances for estimates, lower significance levels in tests of hypotheses and a poorer fit for models estimated with data from dependent samples, compared to independent samples of the same size. The loss in efficiency may be remedied by designing a sampling scheme that spaces observations such that their interaction is negligible." This design was the approach used for the spatial analysis in West and Central Africa, but it required significant initial analysis of existing spatial structures and processes.

To be relevant, the units must be related to the spatial processes that determine outcomes. The analyst needs to consider which processes cause the outcomes under study and over what size geographic area these relationships are important (see Rogers, Shaffer, and Pulver 1990, and Case 1992). Anthropological, marketing, and historical studies are valuable in understanding these relationships. Haining (1990, p. 24) identifies four spatial processes that may underlie outcomes being studied:

(1) *Diffusion processes* in which information, behavior, disease, or technology is adopted by or reaches population groups,
(2) *Exchange and transfer* of production, income, or services,
(3) *Interaction*, in which events at one location influence and are influenced by events in other locations, such as market prices, social group behavior, or political consensus building, and
(4) *Dispersal* such as the spread of population within a land tenure structure ranging from national borders to village-level group lands.

In Zaire, statistical analysis of rural clinic records and local-area groupement census data were used to establish that significant variation in death rates and malnutrition occurred across very local areas within rural Zaire. Health zones serving hundreds of thousands of people were found to be too large a geographic unit of analysis because access to natural resources, markets, and health services varied significantly within health zones. Grouping communities by administrative subregions of several million people explained significant variation in the value of agricultural production, because this grouped related areas with a similar natural resource base and market access. Rapid rural appraisals, satellite imagery, and preliminary analysis of census data led to the conclusion that rural health clinic service areas were the most appropriate unit of analysis for program impacts on malnutrition. One limitation of this approach was that malnutrition data was available only for areas with a functioning clinic. Use of this type of cross-sectional data may result in substantial biases in the estimates of program effects because of the evident nonrandom spatial allocation of public programs (Pitt, Rosenzweig, and Gibbons 1993). Without careful analysis, preexisting factors that determined the location of public programs may be interpreted as impacts of those programs.

Health clinic service areas and villages were the smallest unit for which representative malnutrition data, information on project services provided, and landcover statistics from satellite imagery could be put together in Zaire. However, villages did not meet the criteria for statistical analysis and did not reflect the spatial processes determining outcomes. Villages varied by orders of magnitude in population size, land resource access across villages was not independent due to the structure of land tenure, and access to

health care varied because distance to the health clinic varied systematically across villages.

When villages in Zaire are grouped by health clinic service areas, however, the population size only varies by a factor of two, average distances between villages and clinics are similar, land access tends to be limited to areas within the clinic service area, and by definition the quality of health care across villages served by the same clinic is the same. The geographic area served by a health clinic was often large enough to capture diffusion processes for information, the exchanges related to services, and interactions related to marketing. For these reasons, the health clinic service area was chosen as a primary unit of analysis for malnutrition.

In rural West Africa, census enumeration areas were chosen as the unit of analysis because they were similar in size, could be considered independent observations given the distance between rural sample sites, thousands of observations were available, and each observation had a sufficiently small variance for the parameters of interest. On this basis the West Africa Spatial Analysis Prototype (WASAP) was initiated in 1992 by USAID's Regional Economic Development Services Office for West and Central Africa (REDSO/WCA) in Abidjan, Côte d'Ivoire. WASAP was designed to georeference cluster household survey locations, conduct spatial analysis using these clusters as a unit of analysis, and make the data publicly available. WASAP was a US$600 thousand cooperative effort with funding provided by USAID to MACRO, Intl. (for DHS work), the World Resources Institute (WRI), the Famine Early Warning System (FEWS), and the U.S. Bureau of the Census (BUCEN) to develop a prototype for using GIS technology to integrate diverse socioeconomic data sets and to facilitate spatial analysis of those data. (Note that all dollar amounts in this paper are U.S.) Since 1997 this activity has been supported by the USAID-funded FEWS project and referred to as the West Africa Spatial Analysis Project (see the WASAP website at http://edcintl.cr.usgs.gov/adds/data/wasa/wasa.html).

Developing Typologies for Local Units of Analysis to Classify Population Groups

Typology development classifies local units of analysis into sets that are relevant for the analysis or implementation of development programs. If there are already commonly accepted groupings of the local areas chosen for analysis, then it may be helpful to adopt these to facilitate comparison with previous analytical results (see the USDA website at http://www.econ.ag.gov/epubs/other/typolog/). The local units that are grouped will generally not be geographically adjacent, though there may be clustering of local areas with similar characteristics.

Development of typologies for local geographic areas is necessary to identify and compare population categories with and without development assistance. The concept of groups receiving or not receiving new infrastructure assistance, such as a road, is fairly clear. However, even if policy reform is taken at a national level, the preexisting conditions make the impacts vary geographically by community. Communities without the preexisting conditions that enable them to benefit from a policy reform can be classified as not having received assistance. Conceptually this parallels the vulnerability analysis of FEWS in which certain baseline conditions make certain communities more or less vulnerable to climatic, political, or market changes (McGuire 1998, p. 7). Geographic identification of population groups benefiting from multiple programs, or with similar capacity to benefit from existing programs such as policy reforms or agricultural technology development, is a result that can be used for targeting, extrapolation of case study results on impacts, interpolation of missing data for small areas, and aggregation of beneficiary groups.

In Zaire, typologies of local areas were developed on the basis of total cost of the USAID assistance program per capita. Using a combination of project reports, census data, and community household registrations, the total population served by USAID projects was mapped. These maps were then overlaid to identify categories of program beneficiaries. Based on the geographic overlap, four categories of beneficiary were identified and combined with project expenditure data to estimate total program cost per beneficiary during the 1986–1990 five-year period. A population of 2.8 million was receiving only child immunizations at a total cost of $7 per capita. A population of 1.1 million received immunizations and improved access to potable water at a total cost of $19 per capita. A population of 400,000 received immunizations and improved access to water, as well as road access, at a cost of $45 per capita. In the fourth category, a population of 700,000 received immunizations, road access, and agricultural extension services at a total cost of $60 per capita.

In West Africa, WRI (1996) developed typologies of local administrative areas based on categories of access to economic opportunities, such as road access to metropolitan areas and aridity zones reflecting the natural resource base. Their report contains a detailed description of the database developed by WRI, including the georeferenced household survey clusters. McGuire (1998) developed typologies of household survey sample clusters in West Africa using an approach similar to Rogers and others (1988), and found that principle component analysis captured over 80 percent of the variation with four categories of variables. The four principal components identified were:

PC1—Education/literacy/household income status
PC2—Biophysical or resource base status
PC3—Demographic and fertility status
PC4—Children's nutritional status.

Groups of clusters can be identified based on combinations of their rankings on these principal components. For example, household clusters with high educational and income status, but low nutritional status, may benefit more from cost recovery and selected educational efforts than communities with low educational and income status. Categories of geographic areas were defined drawing on PC1 and PC3 elements during design of USAID's regional family health and HIV-AIDS project. This helped focus debate on policy issues and the types of communities where assistance impacts were expected. A different set of geographic areas was defined drawing on PC2 and PC4 during design of USAID support for West Africa regional trade. The geographic zones with greater potential for regional horticultural exports were found to have high malnutrition rates, suggesting that export-based income growth might have strong health effects.

Analysis of Variance of Population Characteristics and Covariance with Assistance Provided

Impact evaluation using geographic databases tests hypotheses related to the covariance between program expenditures and changes in population outcomes using a quasi-experimental design. This use of statistical inference requires the development and testing of models. Development of conceptual models based on an understanding of the spatial processes is necessary to interpret the conclusions of any subsequent analysis.

Although specialized statistical tools are increasingly being used, they are rarely available for impact evaluation in Africa (for an exception, see Deichmann 1993). Simpler techniques such as mapping residuals from regression analysis are useful for identifying problems with definition of units of analysis and missing variables. For example, these simpler approaches led to the inclusion of deforestation and land degradation as a key control variable for the second round of impact evaluations in rural Zaire. Currently available GIS packages should not be regarded as a substitute for statistical and regression analysis packages, but rather as another complementary analytical tool (Anselin and Hudak 1992).

Analysis of impact can be done in three stages. First, characterize and compare geographic population groups by typology categories. Second, estimate specific impact coefficients using time-series or cross-sectional data in such a way that differences can be interpreted as a temporal change related to assistance provided. Third, use a multivariate analysis that incorporates impact coefficients from findings in the second stage and decomposes the total variation described in the first phase. This sequence of analyses was used for impact evaluation at a country program level in Zaire and on a multicountry regional basis in West Africa. In practice, a series of rapid appraisals, carefully selected location-specific before and after studies, and broader testing of whether expected impact coefficients can explain spatial and temporal variation were used to establish whether any impact occurred, the number of beneficiaries, and a plausible magnitude of change associated with the assistance provided.

USAID Program Impact Evaluation in Zaire, 1988–1991

Under the DFA, monitoring and evaluation was increasingly expected to identify the contributions of sectoral projects and policy reform to overall cumulative program effects on human welfare indicators. A new GIS-based program impact evaluation system, initiated in response to the DFA, did allow the USAID/Zaire field mission to fully and systematically address these questions of higher-level impact at a lower cost (Rogers 1991a, 1991b).

Four categories of indicators were identified to measure program achievement at the strategic objective and goal levels: (1) per capita consumption, (2) labor productivity, (3) nutritional status, and (4) child survival. These were considered key economic welfare and physical quality of life indicators, provided information for those concerned with ultimate impact, were useful indicators of goal level achievement, and ultimately were used to provide criteria for selecting country assistance program elements. Secondary data or primary data already being processed was available on specific indicators in each of these four categories.

In the first phase several independent sources of data for the same population groups were compared to identify shared units of observation. USAID/Zaire developed geographic databases that combined existing data from the population census, rural health clinics, satellite imagery, and agricultural development projects to examine the effects of assistance programs on child malnutrition. The objective was to report cost-effectively on the association between program expenditures and changes in "people-level impacts." A conceptual model was developed as the foundation for setting priorities in data compilation, and for testing hypotheses related to impacts of development assistance (see Larson and others 1996). Primary data was also collected in six health zones to evaluate data quality (see Toko 1989 and USAID/Zaire February 1989).

Characterizing and Comparing Population Groups by Typology Categories

Typologies of areas were developed based on per capita assistance provided, and case studies of population characteristics in these zones were completed. The observed association of malnutrition with deforested areas while mapping regression residuals led to the processing of satellite imagery to identify long-term change in forest cover. A surprisingly high rate of malnutrition in areas with low death rates led to an increased focus in subsequent analysis on the independent causes of mortality as opposed to causes of malnutrition.

Estimates of Specific Program Impact Coefficients

In this phase, a series of individual studies were completed using different geographic units of analysis. Variation in life expectancy as a function of agricultural income, holding access to health care constant, was analyzed at an administrative subregion level to estimate the effect of agricultural extension and improved road access. To estimate the impact of agricultural extension without a change in road access, changes over time in malnutrition were compared in villages receiving agricultural extension services with villages in the same health clinic service areas that did not receive these services. Through analysis of small-area data, multiyear cycles in malnutrition were found to be associated with four-to-five-year agricultural cycles reflected in manioc prices.

Case studies of five health zones indicated that child malnutrition is caused by natural resource degradation—directly through declining agricultural labor productivity and indirectly through reducing the labor allocated to child care. It was not possible to separate these two effects, but the net effect associated with cross-sectional and time-series variation was estimated. In later rounds of analysis, 30-year historical time-series data on deforestation was collected to improve the analysis.

Synthesizing Available Evidence on Program Impacts

An area stretching from 16 to 21 degrees longitude (south) and from 2.5 to 7 degrees latitude (east), in the Kwilu Subregion of the Bandundu Region, was chosen for more detailed multivariate analysis as it had a relatively complete set of local-area data. This phase of the analysis examined three development interventions (immunizations, road access, and agricultural extension) and the impact that these have had on nutrition, mortality, and labor productivity, controlling for forest cover.

The analysis of variation in malnutrition was broken into three categories: chronic, which was common to all areas, cyclical changes, and transitional. Cyclical changes included an annual marketing cycle and a five-year price cycle for manioc. Transitional factors included improved road access, a deteriorating natural resource base, and rapid improvements in child survival due to immunization programs. When the impact coefficients estimated separately in the individual studies described above were combined, it was confirmed that they could jointly explain much of the extreme variation in malnutrition rates over time and across locations in rural Bandundu (Rogers 1990).

The next step was to refine the spatial database to statistically test the joint set of relationships identified in the set of individual studies. Attribute data for 162 health centers (Centres de Sante) were compiled and the geographic location of each clinic was recorded on a 1:200,000 scale map. Although some locations of clinics were identified on existing maps, these were cross-checked and completed with the help of a GPS during field visits. For each clinic service area, information was obtained on malnutrition rates, long-term change in forest cover, whether road and agricultural extension services were received, and how many years had passed since health services (immunization programs) had been initiated in the health zone. Seasonal factors were excluded by using annual data rather than monthly data, but the multiyear agricultural cycles were more difficult to control for because of the complex spatial structure of the effect and limited time-series data.

Impact evaluation is iterative and initial analysis usually suggests the need for new data. The problem with analyses based on a single survey is that all variables to be included in the analysis need to be decided upon before the survey is started. A GIS provides an excellent framework for sequentially incorporating new data as analysis proceeds. The analysis of malnutrition in rural Bandundu, Zaire, described below is a good example of this sequential approach that a GIS made possible.

An initial analysis of malnutrition in five health zones showed significant variation at a local level within health zones. A map of regression residuals showed unexplained spatial patterns in malnutrition after accounting for variation associated with road access and agricultural extension services. Most surprising was the fact that the Vanga health zone, with perhaps the best health care and immunization coverage, also had the highest malnutrition rates. To confirm these cross-sectional results, a longitudinal study of malnutrition in seven health clinic service areas within the Vanga Health Zone was initiated using archive data. From 1980 to 1984 the percentage of children under age five that were two standard deviations below standard weight for age was constant at about 25 percent. Between 1984 and 1990 this category of malnourished children increased to approximately 35 percent. Because the health clinic service areas were mapped, it was possible to examine change in forest cover for these health service areas during the preceding decade. No significant change in forest cover was identified in landcover change analysis based on the satellite imagery.

At this point, a rapid rural appraisal was conducted among women farmers in the same area. The women said that the forests had been cut down in the 1960s (before our baseline satellite images in the 1970s), and that with growing population and shortening of fallow cycles they had run out of good forest soils in 1985. In 1985 they started farming the poorer savanna soils where yields were much lower per unit area and per day of labor invested. They recognized that because of better health care their children no longer died, but now the problem was hunger. Based on this information, landcover maps from the 1950s were collected for incorporation into the next round of analysis, using landcover change since 1950 as a control variable. A pilot analysis using a longer time period for landcover change was completed (Fowler and Barnes 1992 and Fowler 1993).

Due to civil unrest and evacuation of the USAID/Zaire staff in 1991, the sequential improvement in analysis of program impacts ended. However, without the GIS-based approach to program impact evaluation, the importance of incorporating changes in resource base over the last 30 years, pinpointing relevant communities in which to conduct rapid rural appraisals, and the confounding effect that multiyear cycles in agricultural prices have in overwhelming measurement of impacts of health services would not have been identified.

Spatial Analysis to Estimate Program Cost-Effectiveness in Zaire

In many sectoral programs there are useful estimates of project impacts on target beneficiaries. For example, agricultural development projects may estimate their impact on production or even farm income. Project-level analysis of agricultural development assistance estimated that the USAID/Zaire provision of roads and agricultural extension had increased agricultural income by 25 percent (Poulin, Appleby, and Quan 1987. pp.12–13). Health projects may estimate their impact on mortality, morbidity, or malnutrition rates. For example, a number of health program evaluations estimated a reduction of between 20 and 60 child deaths per thousand due to immunization programs, similar to the findings of Koenig, Fauveau, and Wojtyniak (1991). Given a five-year program cost in Zaire of $7 per capita, this suggests an expected reduction in death rates of 6 per 1,000 of population per dollar of assistance.

Impacts of increased agricultural income on health outcomes (or impact of health outcomes on agricultural productivity) are rarely addressed in project evaluations. These cross-sectoral impacts are a critical foundation of program budgets based on results. Two cross-sectoral questions to be answered for the Zaire program impact evaluation were the following:

(1) What are the per-unit costs of improvements in child mortality from agricultural development programs compared to health programs?
(2) What are the per-unit costs of improved nutritional status from agricultural development compared to health programs?

The key to estimating cross-sectoral impacts in Zaire was analysis of the geographic structure of the data and potential units of analysis. Several potential units of analysis were identified, including health clinic service area, health zone, and administrative areas including village, groupement, collectivity, and subregion. The use of existing data to estimate per-unit costs of the effects of agricultural development on child survival or life expectancy (using indirect methods based on population census data) is a good example of how the choice of unit of analysis was critical.

Child mortality and life expectancy were assumed to be a function of agricultural production and access to health care. It was known that agricultural production per capita varied significantly across administrative subregions with several million people due to differences in access to land, markets, and forest resources. It was also known that child mortality varied significantly across health zones with several hundred thousand people, and even across clinic service areas containing five to fifteen thousand people within a health zone. However, there was no agricultural production or income data by health clinic service area, so estimates of impact could not be obtained using this unit of analysis.

Examination of the health zone data by subregion showed that each subregion had the same proportion of population living in operational health zones, meaning the same proportion of the population had access to health care. This was an important finding, because it meant that a bivariate analysis of mortality rates or life expectancy as a function of agricultural production at the subregion level "controlled" for access to health care through choice of the unit of analysis. The regression coefficient of life expectancy as a function of agricultural production per capita at the subregion level could be interpreted as the impact of increased agricultural production on life expectancy, holding access to health care constant. Agricultural development and road rehabilitation programs were estimated to have together increased life expectance by two to four years. Given a five-year program cost of $52 per capita for roads and agricultural extension, these programs were estimated to increase life expectancy at birth (to mothers 25–30 years old) by up to one month per dollar of assistance provided per capita. In the project areas this roughly translated into a reduction of child death rates by 10 to 30 per thousand or 0.4 per dollar of assistance per capita.

Under conditions prevailing in rural Zaire in the mid-1980s, five years of assistance for immunization programs was more cost-effective in reducing death rates, while agricultural extension programs were more cost-effective in reducing malnutrition. In selected areas, improved access to potable water was found to be the most cost effective intervention to increase labor productivity (directly through time saved and indirectly through better health). These results might well be different after two years or after ten years, depending on the sustainability of the technologies transferred. However, a GIS-based approach made it possible to understand the per-unit costs for achieving similar improvements in human welfare indicators through alternative interventions and combinations of projects. This is a necessary foundation for meaningful, performance-based budgeting that

must rely on comparative cost-effectiveness of alternative means to achieve common goals (see Schmid 1989).

Regional Program Impact Evaluation in West Africa, 1992–1997

In the 1990s USAID was closing country field offices in West Africa and reconsidering expansion of multicountry programs based on political commitment to long-term funding for the region, which is one of the poorest in the world. A growing emphasis on multicountry programs and cross-border health and trade issues increased the need for understanding of the geography of regional development in new ways. The GPRA led to efforts to aggregate results across country programs, and these efforts encouraged use of standardized welfare indicators and redefinition of beneficiary populations. This context encouraged the development and use of regional (multicountry) GIS databases for analysis of program impacts and targeting.

In West Africa sequential efforts have been made to pool multisectoral data in regional GIS databases. These include the USAID-financed FEWS Project, which was the first regional impact evaluation effort to support local-area targeting; the Sahelian Permanent Interstate Committee for Drought Control (CILSS-AGRHYMET) efforts to strengthen biophysical data analysis for planning; the Club du Sahel–supported West Africa Long-Term Perspective Study (WALTPS), which incorporated extensive demographic and infrastructure data with existing data sets for long-term trend analysis; and the REDSO/WCA West Africa Spatial Analysis Prototype, which incorporated health data with these earlier data sets for regional impact evaluation and targeting of development assistance.

A key weakness of regional GIS databases in the 1990s was the lack of comparable local-area data on quality of life, such as health and vital statistics, and human capital indicators, such as education levels. The basic units of observation for data in rural West Africa are agricultural/statistical or local administrative areas (such as counties and sous-prefectures), health or marketing service areas, and census enumeration areas, which form the sampling frame for a growing number of cluster sample surveys. The last two categories of data are neither well-delineated on basemaps nor georeferenced, and computer coding does not use any standard location codes to allow geographic linking of these data.

In response to this situation, in 1993 USAID began to support the development of methods to incorporate the wealth of cluster survey data into existing GIS databases in West Africa (Rogers 1993 and 1994). Initial cluster-mapping efforts, using basemaps and existing coding schemes in several countries such as Guinea and Ghana, were not successful. In some cases geographic codes or village names had not been keypunched as part of the data set, even though they were included on survey forms. Though census enumeration area maps existed for West African countries as they did in Zaire, they were not georeferenced. A critical initial priority was to identify the most cost-effective methods for georeferencing new survey data as well as previously collected household cluster survey data.

Methods combining existing basemaps and GPS equipment proved successful, as they did in Zaire for mapping health clinics and new survey data. In Côte d'Ivoire georeferencing was done with handheld GPS equipment during fieldwork for the DHS in 1995—the first time this worldwide survey was georeferenced in this manner. Subsequent surveys in Mali and Benin completed with USAID funding were also georeferenced using a GPS at less than $20 per cluster. The Chad survey funded by several U.N. agencies and the Nigeria survey are the only DHSs in West Africa since 1995 not georeferenced during fieldwork, which reflects the difficulty of collaboration to meet regional data needs at the same time as short-term national-level data needs.

However, using GPS equipment, which required field visits, was too expensive a method for georeferencing surveys already completed. To address this problem USAID funded the U.S. Bureau of the Census to evaluate the cost of alternative approaches for mapping cluster survey sites, devise codes for national administrative areas, and to locate and georeference over 2,000 cluster survey sample sites across West Africa (BUCEN 1996). On the basis of this experience, it costs between $20 and $40 per cluster to georeference survey data after the survey has been completed. Of the total of 2,594 clusters, BUCEN georeferenced 85 percent from the U.S. Defense Mapping Agency gazetteers using degrees and minutes. For clusters BUCEN could not find in the gazetteers, they used maps to locate them and then read the coordinates in degrees, minutes, and seconds off the maps. The location of almost all clusters is based on a populated place, whether from the gazetteers or the maps. A populated place in the DMA gazetteers is defined as a "city, town, village, settlement," including "some seasonal and shifting agricultural settlements."

To facilitate integration of the sampling cluster data in a GIS environment, BUCEN used U.S. Federal Information Processing Standards codes for first-order administrative areas and devised a uniform coding scheme for the second and third administrative divisions. For some countries, such as Côte d'Ivoire and Senegal, BUCEN used codes contained in census publications. For other countries BUCEN had to devise codes. What this shows is the importance and the need for standardized geographic codes and use of these codes when cluster survey data sets are keypunched.

Human welfare indicators based on DHS data were used as dependent variables, so the primary unit of analysis selected was the area represented by a DHS sample cluster or group of clusters in urban areas. Rather than using small-area data from sample clusters to represent larger areas, the statistical analysis was structured to test whether, on average, sample clusters

located in areas with specific characteristics were significantly different from clusters located in areas without those characteristics. This allowed incorporation of other spatial data and enabled the analysis to avoid assumptions about the homogeneity required for using point data to infer conditions in broader geographic areas.

More detailed descriptions of how cluster data can be analyzed is described in WRI (1996) and McGuire (1998). The DHS is a standardized household-cluster survey that has been completed in almost every country in West Africa. In some countries two surveys have been completed at least five years apart. As the second round of these surveys become available, it will be possible to complete joint time-series and cross-sectional analyses. However, since the survey clusters cannot always be the same over time, it will be necessary to use typology categories of clusters for time-series analysis. This means that change over time can be estimated for categories of local areas (though not one specific local area) by grouping survey clusters from different points in time into sets of comparable typologies of local areas. A wide range of hypotheses about changes in DHS indicators by typology of local area can be evaluated by using data from non-DHS sources to classify survey clusters into appropriate categories. As the second round of DHS surveys is just now becoming available for much of West Africa—and possibly a second UNICEF–Multiple Indicator Cluster Survey—this type of time-series analysis has not yet been accomplished.

Conclusions on Broader GIS Use in Program Evaluation

GIS has been a critically important tool and process in the evolution of USAID impact evaluation and targeting efforts. As a donor agency, USAID chose, under the WASAP effort, to allocate funding to make existing data more usable to a broad audience of analysts in a regional GIS framework for West Africa. This has lowered the cost of subsequent analyses and helped shift the type of questions which analysts are addressing (see references in McGuire, Chapter 7 of this volume). In a review of data available on the Internet, including the WASAP data, the International Food Policy Research Institute concluded that once having obtained the data from Internet sources, an analyst would be able to indicate, with less than one hour of desk-based research in some cases, which areas of a particular country could be targeted for various projects. This has the potential to revolutionize NGO and donor project design and proposal evaluation by increasing analytical competition and access to information.

Multicountry programs are part of an organizational solution for donors, but progress will require political or senior management decisions to address the lack of country project-level incentives to better use existing data geographically. On a regional level in West Africa, investments in improving the fundamentals of geographic data coding, compatible data standards, and joint analysis of existing data in a geographic framework offer far higher returns than increased collection of new data.

There are tens of millions of dollars in surveys that have been completed across West African countries in the last decade using a cluster sampling method. Most remain inaccessible to use in a GIS or to use in combination with one another because they are not georeferenced. Under existing organizational arrangements, surveys may not be georeferenced in the future since much of the benefit accrues in the future to those outside the institution or country funding the survey. For this reason, donor funding for enabling and facilitating geographic analysis of existing cluster sample data by a broad range of analysts should be a high priority.

Over the past decade, availability of multisectoral data within individual USAID country programs facilitated the construction of geographic databases for analysis at the country level. In Zaire, as well as across West Africa, USAID country programs focused on socioeconomic as well as biophysical data collection. In West Africa the USAID-funded DHSs provided health data that could be combined with biophysical data compiled from numerous sources by the USAID-funded FEWS project (see McGuire 1998 or the WASAP and DHS websites). Individual donor programs are now tending to concentrate on fewer sectors and fewer countries. This means that in the future, blending of existing geographic data will require more collaboration across donors and multiple ministries in multiple countries. Increased collaboration and easier access to existing data in a georeferenced format is required to avoid spending the already limited research and evaluation funding on discrete analyses that independently spend an excessively large share of their budgets collecting incompatible data.

Political decisions regarding the timeframe of program funding and requirements for public reporting and debate on development impacts will continue to determine whether the use of GISs spreads rapidly in donor programs. Limited awareness of spatial processes that underlie development will continue to slow the adoption of low-cost use of existing data in a geographic framework. There is wide agreement that improving technical capabilities to extract statistical inferences from existing data requires improved awareness of spatial processes, broader access to data, and refinement of technical approaches used in program evaluation and design. However, technical capabilities are already far ahead of the institutional and organizational capabilities required to use a GIS as a tool to broaden input in the competition for better development ideas.

Bilateral and multilateral donors can best promote GIS applications through three actions. First, increase the demand for geographic data collection, analysis, and reporting on program impacts. Second, facilitate the supply of geographically referenced data sets. Third, continue opening up

possibilities for more analytical competition between analysts inside donor organizations and those outside in host country governments, universities, and nonprofit organizations that can use this data. New programming ideas and realistic feedback on program effectiveness are expected to come from more open decisionmaking involving better-informed beneficiaries and partners. The primary constraints to increased benefits from GISs are institutional and organizational, not technical.

Notes

Dr. Rogers served as the USAID/Zaire Program Research Officer in Kinshasa from 1988 to 1991 and as the Regional Program Economist in the USAID Regional Economic Development Services Office for West and Central Africa (REDSO/WCA) in Abidjan, Côte d'Ivoire from 1992 to 1997. The author thanks John Bierke, who also served at the same time in USADI/Zaire and REDSO/WCA, for assistance in exploring and structuring the approaches presented. The views expressed in this chapter are those of the author and are not meant to represent official USAID policy.

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