Using a Geographical Information System within the BASIS Research Program in Ethiopia

A report prepared for the Institute for Development Anthropology (IDA)
under the BASIS/Institute for Development Research (IDR) program for Ethiopia

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This report provides a preliminary account of how a geographical information system (GIS) can be integrated within the BASIS research program in Ethiopia, and provides recommendations for its development and use. Part I shows how data from different levels of analysis, and diverse sources, are integrated into a comprehensive food security database for the South Wollo. Spatial analyses which can be used to organize, inform and extend the on-going market surveys and market inventories in the South Wollo are illustrated in Part II, and the final section provides suggestions for future data collection efforts. Data for this report were collected by Dr. Michael Shin during his visit to Ethiopia between 27 July 1999 and 7 August 1999, which was shortened by approximately one week due to inclement weather and sporadic travel times. Presentation graphics within this report were created with the ArcView (version 3.1) GIS distributed by Environmental Systems Research, Incorporated, and MacroMedia FreeHand (version 8.0.1) graphic design software. Due to high start-up costs, both financially and in terms of technical capacity building which are documented in Shin (1998), subsequent GIS analyses for the South Wollo food security project should be conducted in the United States.

1 Levels of Analysis and the South Wollo

Within the scope of BASIS research program in Ethiopia, Little and Gebre-Egziabher (1998) pose several research questions that involve various levels of analysis, from the household to the region. Integrating a geographical information system (GIS) into this research program provides a comprehensive and innovative way to archive, manipulate, analyze and visualize data and information from different sources at different levels of analysis. In order to incorporate effectively a GIS within any research program, it is necessary to obtain: (1) accurate spatial data, and (2) relevant attribute data. With regard to the former, a significant amount of spatial data, in digital format, were provided in August 1999 by Mr. John McHarris of the Vulnerability Assessment and Mapping Unit of the United Nations World Food Program, located in Addis Ababa. Table 1 provides a summary of the spatial data provided by UN-WFP, and Figure 1 illustrates these data as maps, with particular focus upon the study area of South Wollo in the Amhara region.

Feature	*Class*	*Number*	*Associated Attributes*
Regions of Ethiopia	polygon	11	Area in sq. km
Zones of Ethiopia	polygon	75	Area in sq. km
Weredas of South Wollo	polygon	17	% population w/access to water, rank of drought risk, rank of flood risk
Peasant Associations of South Wollo	polygon	593	Population
Roads in Ethiopia	arc	762	asphalt, gravel, primary, secondary
Towns of Ethiopia	point	1,695	latitude, longitude

Table 1. Summary of spatial data in South Wollo GIS database.
Source: UN-WFP, Addis Ababa, Ethiopia, 1999.

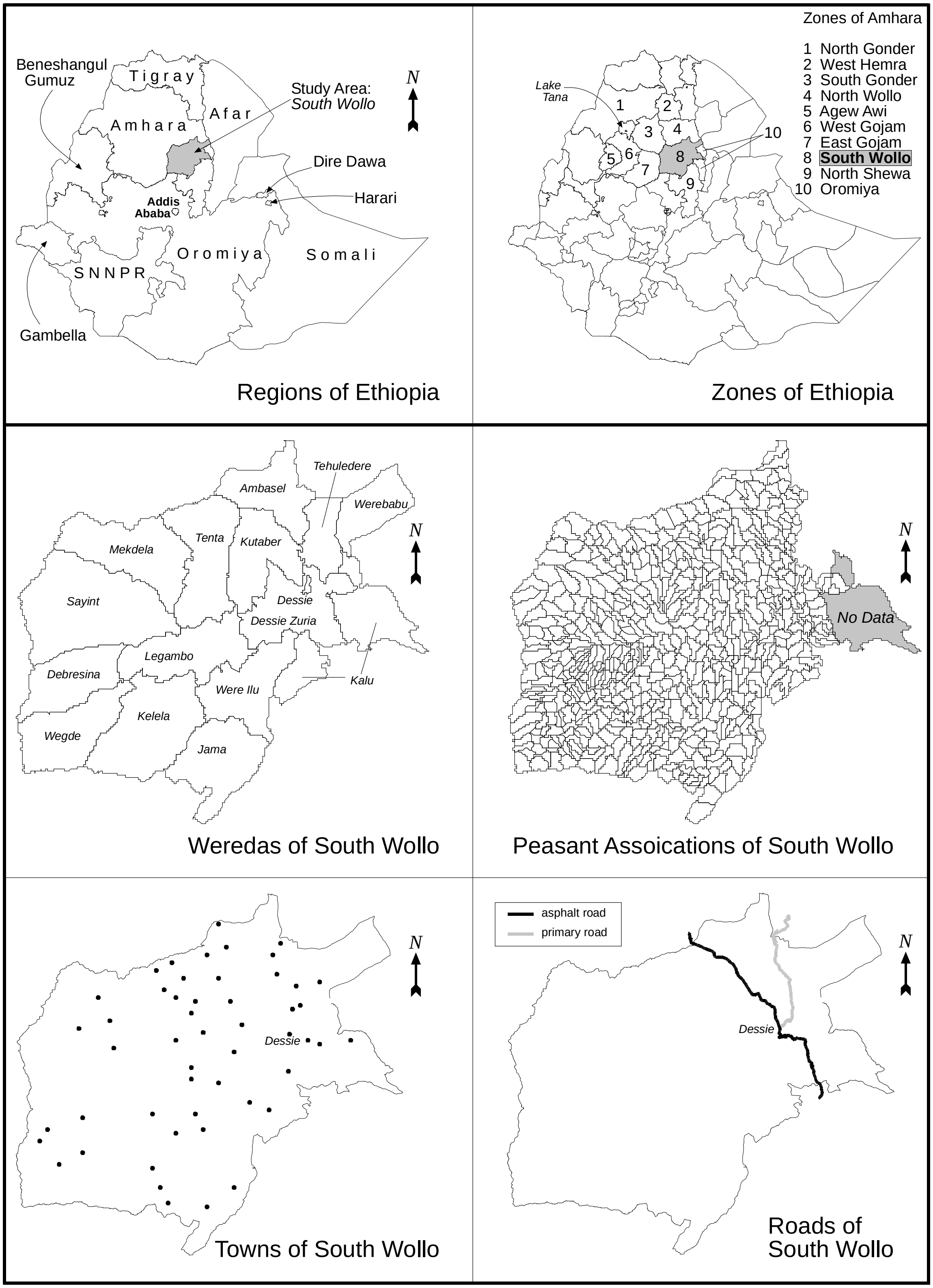

Figure 1. Geographic Units of Analysis in Ethiopia and South Wollo.
Source: UN-WFP, Addis Ababa, Ethiopia, 1999.

The series of maps in Figure 1 illustrate well the three classes of spatial data that have been compiled within the GIS that is being used for the BASIS research program. Polygon, or area data, exist for the regions, zones and weredas of Ethiopia, and for a large portion of the peasant associations in the South Wollo. Regional and zonal maps (Figure 1, top row) are provided only to situate the study area within Ethiopia. The majority of attribute data that have been collected to date exist at the wereda-level, of which there are seventeen within the South Wollo. It should be noted that the peasant association data layer is incomplete (i.e., PAs in Werebabu wereda and in the northern portion of Kalu wereda are missing). With regard to line data, the asphalt and primary roads of South Wollo are identified and can be used in future spatial analyses, though there is some uncertainty about the reliability of secondary and gravel roads within this particular layer. Finally, several towns within the South Wollo are registered within the GIS, and some records include population data.

The issue of missing spatial data is not necessarily critical at this stage of the research program, but it needs to be addressed. Little, if any, data are collected at the level of the peasant association in Ethiopia and on-going data collection efforts do not indicate that any reliable source of PA-level data exist. Therefore, most of the maps created with the GIS utilize wereda-level data, in association with the line and point data. In light of the lack of data at the level of the peasant association, data collection efforts should concentrate upon weredas, specific locations, markets and towns that are already geographically referenced within the GIS (see Table 2), or that can be geographically referenced with a global positioning system (GPS).

Town	*Wereda*	*Latitude*	*Longitude*
Irshama	TENTA (EAST)	11 15 N	39 14 E
Ajebar	WERE ILU	10 49 N	39 28 E
Kabi	LEGAMBO	10 54 N	39 20 E
Akesta	DESIE ZURIYA	11 05 N	39 43 E
Kembolcha	MEKDELA	10 58 N	39 13 E
Koke Ager	ALBUKO	10 47 N	39 33 E
Albuko	LEGE HIDA	10 46 N	39 14 E
Kurkura 03	AMBASEL	11 22 N	39 35 E
Mariye	DEBRE SINA	10 45 N	38 45 E
Mekane Selam	AMBASEL	11 27 N	39 34 E
Alet	MEKDELA	11 21 N	39 11 E
Mekdela	SAYINT	11 03 N	38 53 E
Menkorar	MEKDELA	11 05 N	39 09 E
Nib Gedel	SAYINT	11 08 N	38 44 E
Sayint	TENTA (EAST)	11 21 N	39 20 E
Segoda	AMBASEL	11 35 N	39 20 E
Segora	MEKDELA	11 12 N	39 13 E
Amba Mariam	KELELA	10 32 N	39 03 E
Shafi	AMBASEL	11 29 N	39 22 E
Amba Not	TEHULE DERE (WEST)	11 14 N	39 41 E
Sulula	LEGAMBO	10 55 N	39 13 E
Terad	KUTA BER	11 09 N	39 26 E
Amora Genda	DESIE ZURIYA	11 04 N	39 46 E
Ancharo	DESIE ZURIYA	11 02 N	39 24 E
Webeden	DEBRE SINA	10 36 N	38 45 E
Mahdere Selam (Wegedi)	TENTA (NORTH)	11 18 N	39 06 E
Wegesa	TENTA (EAST)	11 27 N	39 17 E
Wenz Amba	DEBRE SINA	10 39 N	38 34 E
Werke Amba	AMBASEL	11 30 N	39 36 E
Wuchale	DEBRE SINA	10 42 N	38 36 E
Wobo	MEKDELA	11 16 N	38 49 E
Yeberet		NA	NA
Berumieda	KUTA BER	11 15 N	39 23 E
Aba ali	MEKDELA	11 23 N	39 04 E
Aroge	MEKDELA	11 16 N	39 09 E
Bazura	WERE BABO	11 20 N	39 46 E
Bisitima	JAMA	10 23 N	39 07 E
Bita	JAMA	10 27 N	39 24 E
Borena	TEHULE DERE (WEST)	11 13 N	39 39 E
Boru Selassie	MEKDELA	11 25 N	39 08 E
Dega Majeti	LEGE HIDA	10 42 N	39 16 E
Weyin Amba (Derek Amba)	KELELA	10 27 N	39 05 E
Dire	LEGE HIDA	10 41 N	39 09 E
Feres Bet Welo	DEBRE SINA	10 33 N	38 39 E
Gelebe	DESIE ZURIYA	10 57 N	39 38 E
Gelemo Ager	LEGAMBO	10 46 N	39 03 E
Genete	KALU	11 05 N	39 54 E
Girar Amba	SAYINT	11 10 N	38 52 E
Goshit	TENTA (EAST)	11 07 N	39 16 E
Agaye	TEHULE DERE (WEST)	11 19 N	39 40 E
Hayik	DESSIE ZURIYA	11 07N	39 54E
Dessie	DESSIE	11 15 N	39 14 E

Table 2. Georeferenced towns of SouthWollo.

It is also necessary to incorporate topographic/elevation data, hydrographic data, and other spatial data pertaining to the various agro-ecological zones of the South Wollo into the GIS. Though such data and maps are believed to exist, efforts to obtain such data and information have been unsuccessful.

Each class of spatial data previously discussed includes a certain amount of associated attribute data. Figure 2 maps a few of the wereda-level attributes that are relevant to food security; specifically, the proportion of a wereda's population with access to water, and the categorization of weredas according to the risk of either drought or flood. The final map in the series illustrates the spatial distribution of population density across the South Wollo.

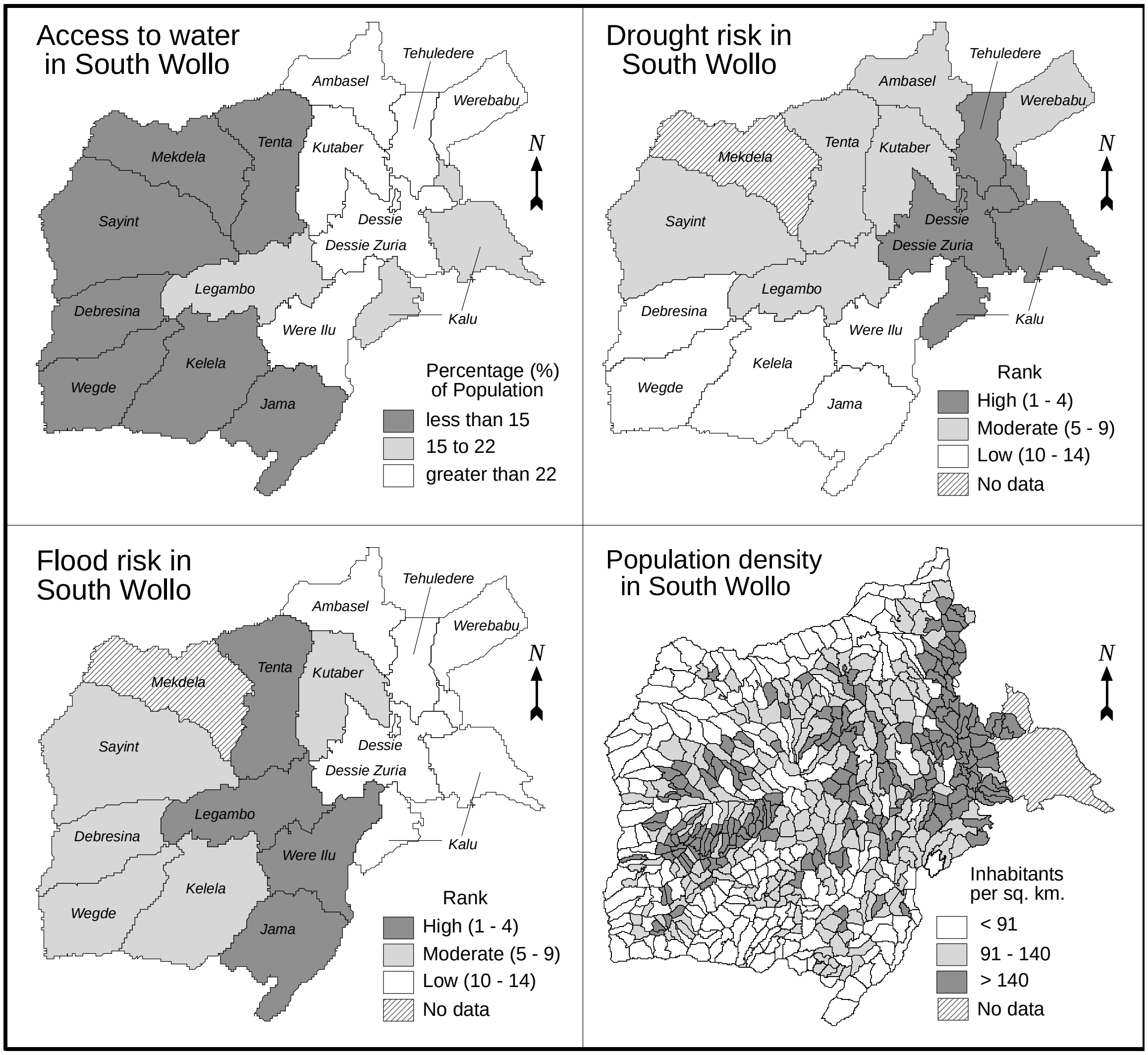

Figure 2. Thematic maps of the South Wollo.

Looking at the first map, it is interesting to note that access to water appears to be divided between the eastern and western weredas of the South Wollo. If limited access to water is a possible determinant of food insecurity, further analyses may be necessary in the western weredas of the study area. The drought risk map confirms what is already known about the South Wollo, the area surrounding Dessie is highly prone to drought, and the failed *belg* rains of 1999 confirm and reinforce the message underlying this map (FEWS 1999a; 1999b; 1999c). Similarly, the lowlands of the study area are exposed to seasonal flooding, which can also affect levels of food security.

Through simple visual comparisons of these three maps, it is interesting to note that limited access to water, high drought risk and high flood risk do not tend to afflict the same weredas in the South Wollo. In other words, it seems that different factors contribute to food insecurity in different places. Hence, diverse environmental circumstances found throughout the study area (i.e., drought, flood, limited access to clean water, etc.) are likely to elicit different social and economic responses on a wereda by wereda basis. Though it is necessary to explicitly define food (in)security from a relief-efforts perspective, a typology of food security based upon environmental and geographic criteria may inform and complement both food security research and relief efforts.

The series of maps above illustrate how a GIS can help researchers identify the spatial patterns and geographic distributions of various types of data. Simple map comparisons also shed light upon possible relations between variables in question, as well as between geographic units of analysis. The next section illustrates how spatial analyses and overlay operations can help BASIS researchers analyze the data collected from the market surveys and market inventories.

2 Spatial Analysis in the South Wollo

The acquisition of georeferenced line (e.g., roads) and point (e.g., towns) data make possible a variety of spatial analytic operations that are of use within the BASIS research program in Ethiopia. Distance/location operations, described by Shin (1998), may be of particular use with respect to answering research questions pertaining to market access. The content of the spatial database within the GIS also permits the integration of locational attribute data (e.g., prices of *teff* in different markets, maximum distances traveled to markets, rainfall measurements in different towns, etc.) which can be compared and analyzed further, or which can be displayed as surfaces overlayed, or superimposed, upon another map.

Briefly, as described by Shin (1998), buffers are used to delineate areas around particular features (e.g., roads, towns, etc.) based upon distance. Three of the four maps in Figure 3 show how buffers are represented on maps for different features (i.e., roads and towns), as well as how a buffer can be overlayed upon another map in order to visualize the intersection of geographic information. The first map in Figure 3 shows a series of three buffers around the primary and secondary roads within the South Wollo. The black line represents the roads, dark gray corresponds to areas within five kilometers of the roads, lighter gray corresponds to areas within ten kilometers of the roads, and the outer boundary of the buffer corresponds to areas that fall within fifteen kilometers of the roads. This buffer is subsequently overlayed upon the map that shows the location of towns in the South Wollo, and a simple visual count reveals that seventeen of the fifty-two georeferenced towns are situated within fifteen kilometers of an asphalt or primary road. Questions that arise from this relatively simple operation include:

- How does proximity to an asphalt/primary road affect market supply and demand?
- How does proximity to an asphalt/primary road affect food prices?
- What are the differences between vendors and traders that are within fifteen kilometers of an asphalt/primary road, and those that are not?

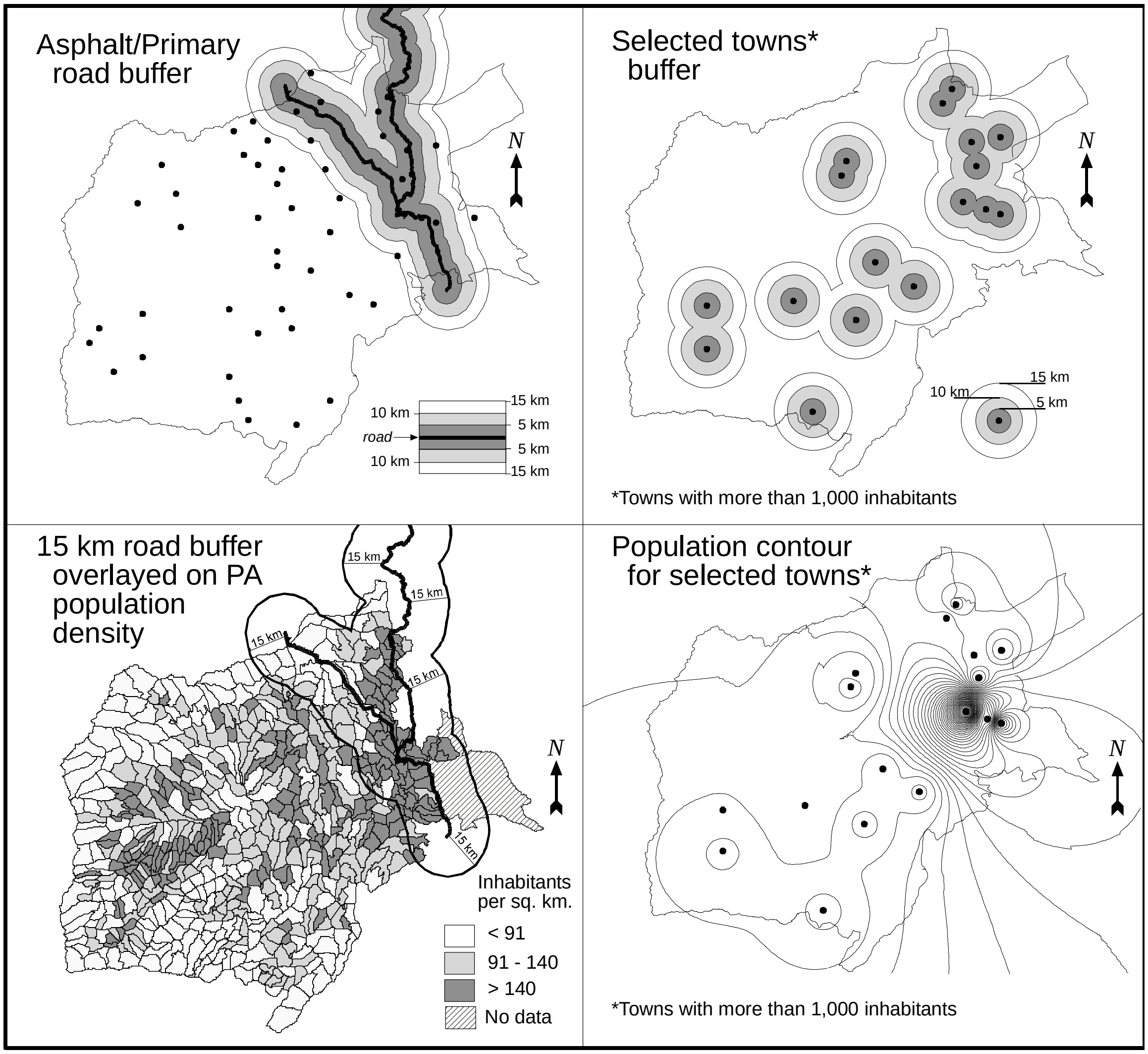

Figure 3. Spatial analyses of South Wollo spatial data.

If it is determined that proximity to a major road somehow influences markets, the above questions can be answered by comparing the data for markets that fall within the buffer to those that are outside of it. Furthermore, comparisons of town attributes may shed light upon the effects of road accessibility upon food security. Below the five, ten and fifteen kilometer road buffer map is a graphic overlay of only the fifteen kilometer road buffer upon the peasant association population density map. This map shows clearly how a significant number of the most densely populated PAs of the South Wollo are clustered within fifteen kilometers of an asphalt or primary road. The GIS can also identify all of the PAs within the fifteen kilometer buffer for further analyses, for example, if it was determined that comparisons to those PAs that fall outside of the buffer were of interest.

The selected towns map illustrates how buffers appear around point data As in the first road buffer map, the black dot represents the town, dark gray circles correspond to the areas falling within five kilometers of towns, light gray circles correspond to areas falling within ten kilometers of towns and the outermost circles correspond to areas falling within fifteen kilometers of towns. To illustrate how a GIS can subset data, only towns with more than 1,000 inhabitants were selected prior to creating the buffer. Consider the following hypothetical example:

> Assumption #1: Markets tend to exist in towns with at least 1,000 inhabitants;
> Assumption #2: People of the South Wollo are only willing to travel fifteen kilometers per day to a market,
> Assumption #3: PA-level population data are accurate and complete.

Overlaying the fifteen kilometer market (i.e., towns with more than 1,000 inhabitants) buffer onto a PA-level population map would provide a visual indication of how much of the population is within one day of travel to a market. Additionally, the GIS can identify those PAs within the buffers, an exact number can be calculated from the associated population data and a ratio for the entire study area could be made (e.g., population within one day's travel to a market/total population of South Wollo). In this sense, the GIS is used as a tool to explore, as well as analyze, data.

The final population contour map illustrates how point data can be represented as a series of contour lines, or a surface. In this map, the GIS uses an algorithm to create contour lines based upon the populations of towns in the South Wollo with more than 1,000 inhabitants. As population increases, the contour lines get closer and closer together; the 'twin peaks' of this contour map are the towns of Dessie and Kembolcha. This example is more illustrative than substantive because, at this time, only population data exist for the town layer within the GIS database. This technique could be used to create contours and surfaces for the prices of foodstuffs in the markets of South Wollo, travel times to markets, as well as average levels of town income. Furthermore, such surfaces can be overlayed upon other data layers in order to visually correlate, for example, the price of *teff* to wereda-level rainfall data, or to identify weredas and peasant associations that that fall within a particular *teff* price contour.

The above examples illustrate the ways in which a GIS can complement and extend the BASIS research program in Ethiopia. The greatest obstacle to the successful integration and implementation of the GIS within the research program concerns the acquisition of reliable and complete data, which is the subject of the final section.

3 Data Issues within the South Wollo

There is little question that a GIS can complement and enhance the BASIS research program in Ethiopia. The most significant obstacle to the successful implementation of the GIS, however, is obtaining the remaining spatial data (i.e., elevation data, soil maps, etc.) as well as obtaining accurate and complete attribute data (i.e., market prices for food stuffs, consistent market survey and market inventory responses, comprehensive rainfall data, etc.). On-site evaluations suggest that such data exist, but a variety of factors have prevented the acquisition and use of such data. The following list clarifies several of the data/research issues related to the GIS by identifying gaps that need to be filled and providing guidelines that will permit the efficient integration of data into the GIS.

- Topographic and agro-ecological maps, data and information are believed to exist, yet efforts to obtain such data and information have been unsuccessful. As this information is important within the framework of the research program, priority should be given to obtaining these data, maps and information.

- There is no indication that comprehensive peasant association (PA)-level data, aside from population, exist, therefore data collection efforts should concentrate upon: (1) wereda-level data, and (2) data collected at different markets that are georeferenced (see Table 2) or that can be georeferenced with a global positioning system (GPS).

- Some data that may be relevant to the project are available through the African Data Dissemination Service (`http://edcintl.cr.usgs.gov/adds/adds.html`). Additional research into the availability of other public domain data sets may be constructive.

- What research questions can be answered or explored, either partially or in full, by using the GIS? Given the variety of exploratory and analytic operations that a GIS can perform, identifying specific purposes and goals, as well as what maps need to be created, will expedite the collection of data and make GIS analysis more efficient.

- All data collected by enumerators needs to be properly translated, standardized if necessary, logically coded and properly formatted (either as a tab or comma delimited digital file) in order to be integrated within the GIS.

This last point needs to be underscored. Data cleaning and data formatting are perhaps the most time consuming stages of any GIS project, and the ability to use data that are pre-cleaned and in a useable format increases greatly the efficiency of GIS implementation.

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Appendix A: Trip report for Michael Shin
Travel for IDA/BASIS in the South Wollo, Ethiopia

The purpose of the trip was to collect relevant and necessary geographic data for the geographic information system (GIS) component of the BASIS research program in South Wollo, Ethiopia. The scheduled departure date from Miami, Florida was 22 July 1999, but inclement weather conditions and limited travel times postponed departure until 26 July 1999.

Upon arrival in Ethiopia, Dr. Shin met with Dr. Gary Gaile to coordinate data collection efforts in Ethiopia. It was decided that Dr. Shin spend the first few days of his visit in the South Wollo area to obtain precise market locations using a global positioning system (GPS). Dr. Shin was in the field from 29 July until 1 August. During that time, precise geographic coordinates and elevation data were obtained for the following markets: Bati, Boromeda, Degan, Dessie, Gerba, Haik, Tita and Kombolcha. Drs. Shin and Gaile also supervised market and urban inventories carried out by Ethiopian enumerators at the above locations. The task of collecting GPS coordinates was turned over to Dr. Gebre-Egziabher so that Dr. Shin could return to Addis Ababa (1 August) to collect additional data and information from relevant individuals and institutions.

Upon return from Dessie to Addis Ababa, Dr. Shin met with Dr. Peter Little and discussed the recent work that was conducted in the field, as well as additional avenues of inquiry in Addis Ababa. The $2000 given to Dr. Shin to deliver to the Institute for Development Research at Addis Ababa University from BASIS for data processing purposes was also transferred on 4 August 1999. The receipt of transfer has been forwarded to Danielle Hartmann at BASIS.

While in Addis Ababa, Dr. Shin contacted the Famine Early Warning System Division of USAID about obtaining data for the South Wollo region. Dr. Little suggested contacting Mr. Laketch Michael of FEWS-USAID, but he was unavailable at the time. After discussions with other members of FEWS-USAID, it was determined that the data and information disseminated by FEWS-USAID was already in possession, and not at the appropriate spatial resolution (i.e., regional and zonal level data versus woreda and farmer association level).

At Addis Ababa University, Mr. Degefa Degaga of the Department of Geography provided population data for the study area at the woreda level, but efforts to retrieve data and information in digital format were largely unsuccessful at the university. The most useful information and data collected by Dr. Shin was provided by Mr. John McHarris of the Vulnerability Assessment and Mapping Division of the United Nations' World Food Program (UN-WFP). Various digital boundary files for the South Wollo were obtained, as were data regarding population and agricultural prices. These data files are currently being converted (Mr. McHarris uses different computer software than does Dr. Shin), and will be analyzed as part of Dr. Shin's final report to IDA/BASIS.