Planned Resettlement: A GIS-Assisted Identification of Areas Suitable for Irrigation-based Resettlement in Ethiopia

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ABSTRACT

Ethiopia is conducting a government-sponsored population resettlement but the site selection exercise lacks the objectivity that GIS can provide. A GIS-based site selection is performed in this study to identify settlement sites using national data at the Wereda (sub-district) levels. The results show that the application of GIS can yield satisfactory results even under conditions of data scarcity. Seven Weredas are deemed highly suitable while another twelve are classified as suitable. The list of selected sites includes many Weredas known to have received settlers in the past. The selected Weredas also include those being targeted by the government for land-leases to foreign agribusinesses companies. The lack of resources necessary to mitigate all of the environmental dangers including accelerated deforestation, wetland destruction, malaria, and flash-floods, point to serious challenges ahead in making the Weredas selected in this study suitable for large-scale resettlement. It is argued, therefore, that population control measures with a focus on fertility reduction would produce better long-term results.

Key words: Ethiopia, GIS, resettlement, site selection

INTRODUCTION

Geographic Information System (GIS) can help to rationalize spatial decision making including site selection (Zeng and Zhou 2001). The bibliography of a 2006 GIS-related literature survey listed 144 works relating to site selection (Malczewski 2006). GIS site selection applications have to date ranged from selection of sites for fast food outlets, warehouses, and to those with potential for geothermal energy development (Vlachopoulou, Silleos, and Manthou 2001; Demircan 2002; Yousefi and Noorollahi, 2007). Applications in ecology include soil erosion studies, safe habitats for nesting birds, restoration of estuaries, habitat creation, and assessment of flood risks (Pantoula 2004; Kunert, 2005; Alesheikh, et al. 2008; Strauss 2008; Solaimani and Lotfi 2009). GIS tools have also been used in route selection, urban transportation planning, and delineation of neighborhoods subject to excessive traffic noise (Farkas 2009; Banerjee, et al. 2009).

Though the potential benefits of GIS use in Africa's agricultural development, industry, health, education, poverty reduction, ecological conservation, habitat restoration, mining, telecommunications, transportation, and wild life monitoring are limitless, the work has hardly begun (ECA 2000). It is encouraging however that the Economic and Social Research Institute (ESRI)—one of the companies responsible for the development and global reach of GIS—recently organized a seminar entitled "Africa Agriculture GIS Week" (June 8–12, 2010) in Nairobi, Kenya (ESRI 2010). The main goal of the seminar was to share ideas and knowledge as well as disseminate geospatial information services for use in the future socioeconomic development of the continent.

In Ethiopia, recent GIS applications have included site selection for village schools, oil and gas explorations in the Ogaden desert, agriculture and forestry development, research activities in poverty reduction, drought management and irrigation suitability studies (Reusing 2000; Demeke 2003; Mezemir, et al. 2005; ESRI 2008; Latef and Kahar 2008; Negash 2004; Kebede 2010). However, this study represents the first attempt at using the power of GIS to identify suitable sites for a *Wereda* or sub-district-wide irrigation-based resettlement.

Background

Ethiopia faced recurrent droughts and subsequent famines throughout the 1970s, 1980s, and 1990s. Droughts and famines were partly responsible for the overthrow of the country's hereditary monarchy in 1974 by a socialist military coup. In turn, the military government was forced out of power by rebel forces that accused it of turning a blind eye to the starvation of millions of Ethiopians in the 1984/85 famine that killed an estimated one million people (Wolde-Selassie 1997; Vadala 2008; Hammond 2008).

The country's successive governments have since the 1970s tried to address its drought-famine crisis by moving people from degraded and environmentally vulnerable *Wereda*s in the northern central highlands to *Weredas* with so called "virgin lands" in the west and south of the country (Kassa 2004; Fosse 2006; Hammond 2008). Such resettlement has, at times, been on sites selected by the country's presidents from the air.

Resettling drought victims has not been the only objective of Ethiopia's population redistribution programs. Millions of farmers were also relocated in the 1980s following the military government's orders to create communal socialist villages (Kloos and Aynalem 1989). As a result, about 13 million people had been forcibly moved by 1989 (Ofcansky and Berry 1991)

The resettlement program that is now underway started in 2003 and is meant to move 2.2 million individuals (Kassa 2004; Hammond 2008). Half of the targeted population had been moved by 2008 despite objections from donor governments and NGOs (Hammond 2008). The stated objections included the apparent lack of planning and the rapid pace of resettlement. The critics also refuted the government's claim that the program was entirely voluntarily and feared for the health of the new settlers and the environment (Kassa 2004; Fosse 2006; Hammond 2008). The initial trigger was the 2002 drought in which insufficient *belg* rains (March through May) and sporadic *meher* rains (July through September) resulted in widespread food shortages and food insecurity affecting both pastoral and agricultural areas. The lowlands of the Southern Nations, Nationalities, and Peoples (SNNP), Tigray, Oromiya, and Amhara administrative regions were most impacted with an estimated total of 12.6 million Ethiopians requiring food-aid in 2003 (USAID 2003). These same regions were affected during the previous droughts of the 1980s and 1990s (Desalegn 1999).

POPULATION AND THE ENVIRONMENT

Ethiopia has a land area of 1.1 million km^2 (most of which consists of highlands above 1000 meters) which is divided into 9 semi-autonomous Administrative Regions and 2 Special City Administrations (UNDESA 2004). These are further divided into 63 Zones and 529 *Weredas* (the administrative units used in this study). The Ethiopian highlands have seen centuries of settled agricultural use and misuse which have contributed to the country's ongoing population-resource imbalance. Deforestation and soil erosion have led to massive top-soil loss. Temperature changes during the last three decades are estimated at 0.2 Celsius per year and are thought to be linked to global climate change (Yohannes and Mebratu 2009). This warming trend may explain the vicious cycles of droughts and famines over the last five decades.

It would be helpful to have an accurate population count for the 11 Administrative Regions in the country in order to arrive at a reasonable estimate of the number of people to be resettled. Unfortunately, the country's latest (2007) census gave a much lower population total (73.8 million) than was projected on the basis of the 1984 and 1994 censuses (FDRE 2010). A simple calculation on the basis of those projections (Table 1) suggests that about one in twelve persons (8.5%) or nearly 7 million people may have been missed by the 2007 census.

The calculation in Table 1 is based on a simple assumption. Given the undercounts of the 1984 and 1994 censuses, the 2007 census should have yielded at least as high a population (nationally and for individual regions) as that projected for 2008 based on the 1994 census (CSA 2006). Instead, only the 2008 projected population of Benishangul Gumuz came close to the actual 2007 census count. Hence, the Benishangul-Gumuz Administrative region is used as a benchmark.

The population breakdown by administrative region shows that in the worst case, the Amhara Region had a 3.3 million (21.5%) difference between the projected population and the census count. This is too large a difference to be solely the result of undercounts since the Amhara Region has been undergoing a fertility transition (Akol et al. 2007) and has suffered significant population loss due to outmigration and elevated mortality from recurrent famines. Proportionally, the second highest shortfall in the expected population for a large region was in Addis Ababa (14.7%). Conversely, the 2007 census for Gambella suggests an over count which is clearly a reflection of recent migration to the region including settler in-migration during the inter-censal period.

The 2007 census figures will be used in this study despite the deficiencies shown in Table 1. This inevitably leads to errors such as lower densities for *Weredas* in Amhara than in all other regions (Figure 1) even though this does not affect the overall results of the study.

Table 1
Actual Population Numbers from the 2007 Census and Estimates Based on Projections

Region	2007* Census	2008** Projection	Difference	Est. Based on Standard	Total Under-Estimation (%)
Addis Ababa	2,738,248	3,147,000	-0.15	3209940	471,692
Afar	1,411,092	1,449,000	-0.03	1477980	66,888
Amhara	17,214,056	20,136,000	-0.17	20538720	3,324,664
Benishangul G.	**670,847**	**656,000**	**0.02**	**Standard**	**Standard**
Dire Dawa	342,827	428,000	-0.25	436560	93,733
Gambella	306,916	259,000	0.16	264180	-42,736
Harari	183,344	209,000	-0.14	213180	29,836
Oromiya	27,158,471	28,067,000	-0.03	28628340	1,469,869
SNNPR	15,042,531	15,745,000	-0.05	16059900	1,017,369
Somali	4,439,147	4,560,000	-0.03	4651200	212,053
Tigray	4,314,456	4,565,000	-0.06	4656300	341,844
Total	**73,821,935**	**79,221,000**			**6,985,212**

Source: *CSA 2010 **CSA 2006

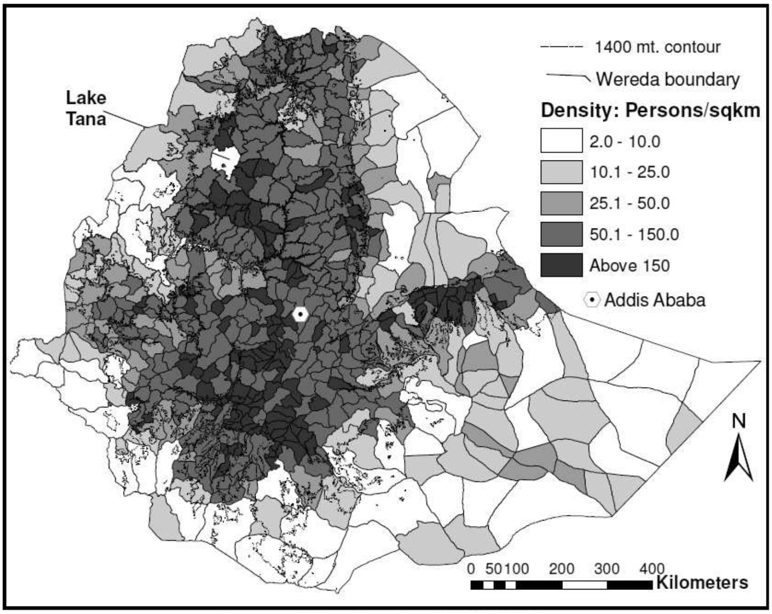
The vast majority of the regional populations in Table 1 live in the highlands (above 1000 meters). For this reason, the 1000 meter contour is added to the density map to show the high-low altitude dichotomy in population densities. As Figure 1 shows, the contour line tightly encloses most *Weredas* with densities of 25 persons per km^2 or higher except in the south, southeast, and northeast.

OBJECTIVES

Among the shortcomings of the previous and current governments' resettlement efforts have been the exclusive focus on rain-fed agriculture and traditional farming techniques which has resulted in the duplication of the environmental problems of the sending *Weredas* of the north central highlands in the new resettlement sites (Desalegn 1999). Thus, the main objective of this paper is to apply the power of GIS and its site selection tools to the task of identifying alternative settlement sites, that is, *Weredas* with substantial areas suitable for large-scale irrigation and settlement. Identification of the resettlement sites is based on the irrigation potential of entire *Weredas.* Additionally, *Weredas* with potential for in-fill resettlement based on rain-fed agriculture are identified based on population densities. The high and low population density *Wereda*s are shown in Figure 1.

While the selection criteria are mainly river-based, there is also a focus on: (a) accessibility or the number and length of roads per square kilometer of *Wereda* areas, (b) availability of centralized services as shown by the number and size of urban centers in or near a *Wereda*, (c) existing population densities, (d) the number and length of rivers per *Wereda* area, (e) physiography or the proportions of *Weredas* with slopes of 3 degrees or less, (f) malaria risk, and (g) type of soils.

Figure 1
Population Density (2007) and the 1400-Meter Contour



Source: Author. Based on FDRE (2010)

AVAILABLE DATA

GIS-ready base maps (shapefiles) were obtained from the Geography Department (Addis Ababa University) during a recent visit. The data used in this research include the 2007 Census data on population numbers by *Wereda*, the land areas of *Weredas* (km^2), the 2008 CSA projections of rural and urban populations, a *Wereda* administrative map, a drainage system map, a road network map, a 90-meter digital elevation model map (DEM), and a map of the proportion of *Wereda* areas with slope values of 3 degrees or less. All of the above were vector layers with the exception of the raster 90-meter DEM layer.

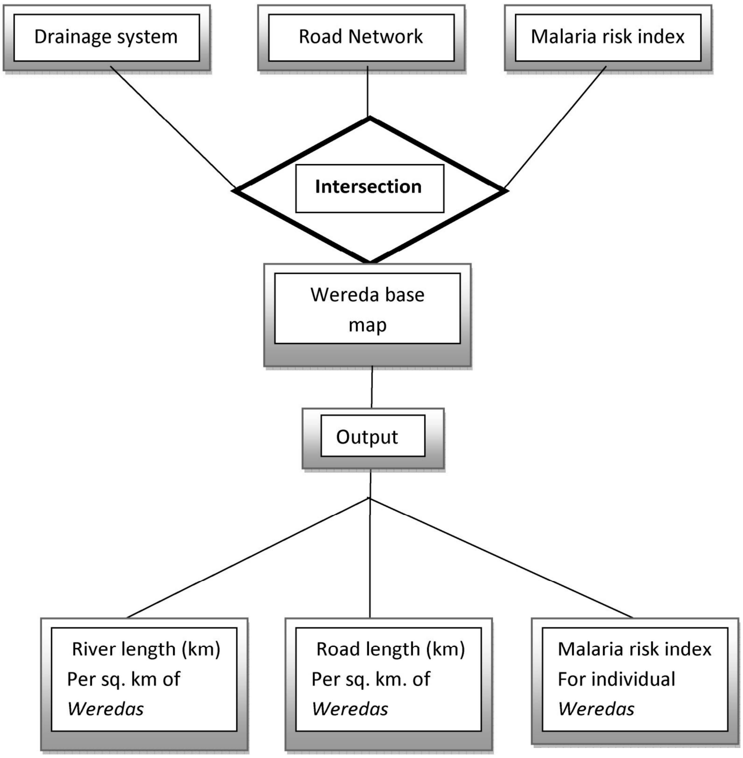
The selection of the base-maps and data for the study was guided by a number of criteria: (a) everything else being equal, *Weredas* with high river lengths per unit area and a high percentage of areas with slopes less or equal to three degrees provide the most suitable grounds for irrigation-based resettlement; (b) *Weredas* with higher road lengths per unit area provide the best access to settlement sites by facilitating easy flow of people, goods, and services; (c) *Weredas* with high numbers of urban centers and urban populations offer the best opportunities for the delivery of centralized services; (d) *Weredas* with high scores on the malaria risk index present settlers with challenges that lessen or possibly cancel-out the preceding positive effects; (e) everything else being equal, *Weredas* with high population densities offer less attractive alternative settlements than those with low population densities, and (f) *Weredas* with sizeable areas under the Nitosols soil group present more ideal grounds for irrigation-based resettlement than those with other soil types (see W. Negash 2004; Kebede 2010).

METHODOLOGY

The study methodology is outlined in Figure 2. To start with, the *Wereda* boundary map and all other maps were re-projected from the Geographic Coordinate System (GCS) to Adindan_UTM_Zone_37N projection coordinate system (PCS) so they could match when overlayed. The DEM Map produced by NASA (no date available) was transformed from the Geographic to the Goode Homolosine projection to facilitate the calculation of slope. Slope is defined as "the change in elevation (a rise) with a change in horizontal position (a run)" (Bolstad 2008: 417). Portions of *Weredas* were then reclassified into two slope categories: less or equal to 3 degrees, and greater than 3 degrees. This is a very important step because slope values are used as the principal weighting factor in the calculation of *Wereda* suitability indices (see formula in the Results section). A slope of 3 degrees is used as a reasonable cutoff point, and as an upper limit of gravity-assisted irrigation with no need for mechanical pumping.

Next, the 2007 census population numbers were entered, and density values calculated. An Adobe Portable Document Format (pdf) malaria map was subsequently obtained from the online Mapping Malaria Risk in Africa (MARA/ARMA) portal and converted into the Tiff file format and then geo-referenced. This step allowed the reclassification of *Weredas* or portions of *Wereda*s into three malaria risk categories: severe, moderate, and non-malarious. The final step involved use of the ArcGIS "intersect" tool to obtain new attribute entries for individual *Weredas*. For example, the *Wereda* base-map was intersected with the drainage map to produce new data on river lengths per *Wereda* (Figure 2).

Figure 2
Intersection: Drainage System, Road Networks, and Malaria Risk Index on *Wereda* Boundaries



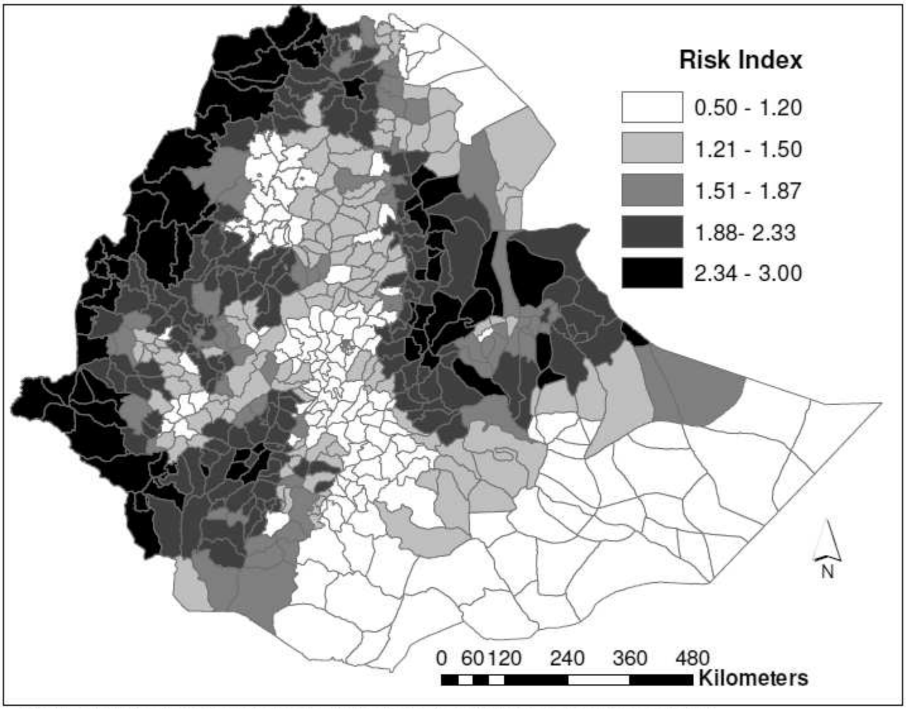
RESULTS OF THE OPERATION

The operation in Figure 2 yielded 391 *Weredas* (out of a total of 529) with perennial rivers long enough to be entered on the country's drainage base-map. The sums of the lengths of individual rivers within a *Wereda* ranged from just over 2 kilometers to almost 2,000 kilometers. The total length of all listed rivers is 94,326 kilometers with a mean length (per *Wereda*) of 241 kilometers.

The operation in Figure 2 also produced new results relating to the distribution (by *Wereda*) of the country's road networks. Almost all of the *Weredas* (509 out of 529) have a combined (all-weather and dry-weather) road length of at least 10 kilometers each. The road lengths varied from 16.5 kilometers to 558 kilometers per *Wereda*. There are no roads in the remaining 20 *Weredas*. The sum of all roads in the country (all-weather and dry-weather roads combined) is 57,443 kilometers with a mean length (per *Wereda*) of 112 kilometers.

The operation also produced useful results regarding malaria. Lowland *Weredas* with high temperatures and precipitation ranked highest on the malaria severity index. While sixty eight *Weredas* were in the "severe" category with indexes ranging from 2.34 to 3.00; 207 were in the intermediate risk group with indexes ranging from 1.51 to 2.33; and the rest were in the "low risk" and "no risk" group with indexes of 1.50 or less (Figure 3).

Figure 3
***Weredas* by Malaria Risk Index**



Source: Author. Based on base maps from the Department of Geography, Addis Ababa University, http://www.reiseklinniken.no/EthDistribution.pdf

Site Selection: Initial Observations

A map based on the operations in Figure 2 yielded a mix of good and not so good choices of *Weredas* for river-based resettlement (Figure 4). The peripheral margins of the country's western border areas had a "severe" malaria index. Moreover, lack of access to all-weather roads posed serious accessibility challenges for these areas. Most of the unshaded *Weredas* in the eastern part of the country were also unsuitable because they either lie in the hot and arid Afar Depression or are part of the inhospitable Ogaden desert (Figure 4). These were therefore excluded. Given these realities and the unsuitability of much of the rugged central highlands (unshaded areas in Figure 4), we proceeded with two opposing scenarios, the first of which allows for the inclusion of new areas in the site selection process:

1. The high-rainfall/high-temperature *Wereda*s, or parts of *Wereda*s in the "severe" malaria category could control the disease through effective antimalarial measures including the ongoing anti-malarial campaign (FDRE 2007; USAID 2010). The campaign is expected to lower the malaria risk in western and southern Ethiopia from "severe" to "moderate."
2. The dangers of malaria and other tropical disease risks in areas under the "severe" category (Figure 3) will not be lessened despite all of the ongoing mitigation efforts.

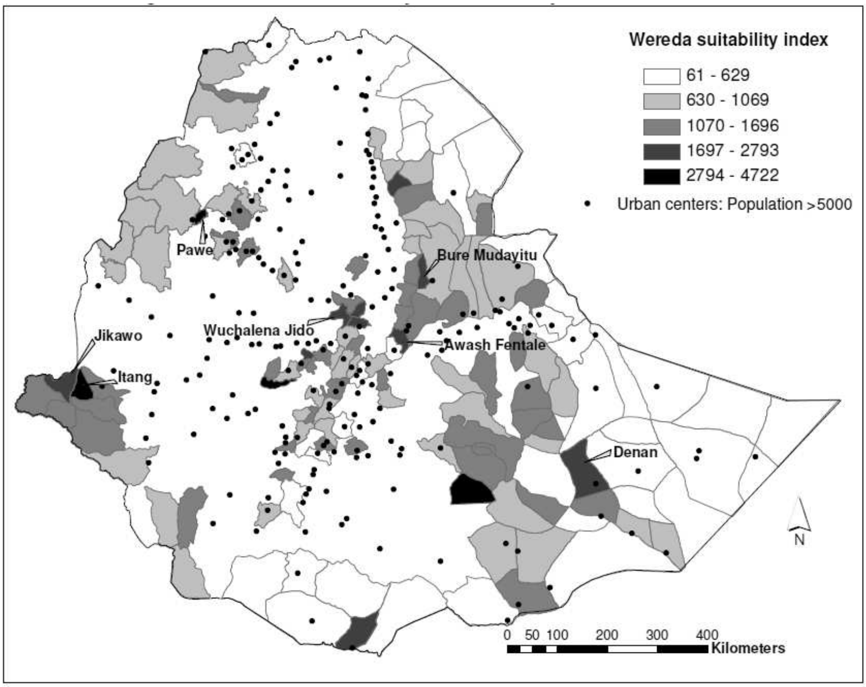
The first assumption included more than a third of the land area under "severe" malaria risk (Figure 3) in the site selection process. As a result, the main determining factors became: slope, population density, the length of rivers by *Wereda*, the length of roads by *Wereda*, and the presence or absence and size of nearby urban centers.

Results

Slope and River Lengths

The operation in Figure 5 (the big rectangular box) produced a list of 574 *Weredas* (including those in Addis Ababa), mostly with entries for river lengths (meters). The operation also generated a new data column on the proportion of *Wereda* areas (out of 10) with slopes of 3 degrees or less. A selection was then made on the basis of both river length and slope. A cut-off length of 50,000 meters was used for rivers. The overall exercise produced a list of 139 *Weredas* (Figure 4); mostly in the outlying regions where elevations are low and less variable. The 139 *Weredas* fell into three classes: those that qualified due to their low altitudes and less variable physiography; those that qualified on the basis of both river and slope criteria (suitability index, 1070 or higher); and an intermediate group that qualified on the basis of the total length of rivers within their boundaries (suitability index 630 to 1069).

Figure 4
***Wereda* Distribution by Site Suitability Index**



Source: Author, Based on the operations in Figure 2

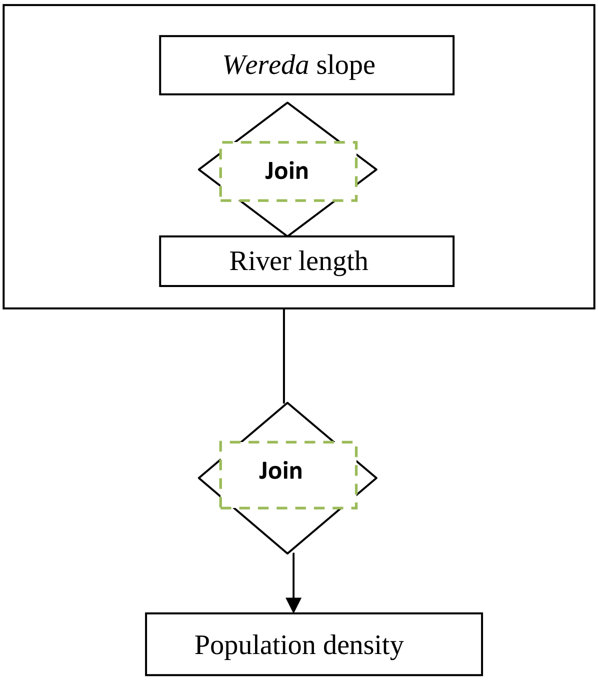
The distribution of the 139 *Weredas* in the preliminary list is shown in Figure 4. To make this map, the length of rivers by *Wereda* was divided by area size of *Weredas* (see formula below) and then multiplied by the proportions of *Wereda* areas with a slope of 3 degrees or less. The "natural breaks" option in ArcMap was then used to map *Wereda*s by suitability scores as shown in Figure 4.

$$\mathrm{WSI} = \mathrm{PWLS}\,(\mathrm{RL} \div \mathrm{WA})$$

Where:
- WSI: *Wereda* Suitability Index
- PWLS: Proportion (out of 10) of *Wereda* area in low slope category – 3 degrees or less
- RL: River Length
- WA: *Wereda* Area

Table 2 shows the 56 *Weredas* with scores of 1070 or higher which represent just under one-quarter of all *Wereda*s in Ethiopia. Many of these *Wereda*s were excluded from the final list on density grounds. With a score of over 4500, Pawe, Goro, and Guradamole took the top three spots on suitability rankings. As Figure 4 shows, these *Wereda*s are located in different parts of the country. Pawe is one of the original settler destinations of the 1980s and 1990s (Wolde-Selassie 1997; Yntiso, 2002). Its number 1 ranking on Table 2 confirms the validity of this study's GIS-based selection process.

Figure 5
Flow Chart: "Join" Operations to Merge Slope, River Lengths and Population Density by *Wereda*



Source: Author

POPULATION DENSITY

The population density criterion allows for selection of medium to low density *Weredas* (Figure 1) and helps to exclude high density *Wereda*s. A cut-off density class of 100+ persons per square kilometer was chosen somewhat arbitrarily, leading to the exclusion of 22 *Wereda*s on high population density grounds.

Table 2
***Wereda*s by Suitability Scores**

Wereda	Score	*Wereda*	Score	*Wereda*	Score
Pawe	4722	Badawacho	1490	Gedeb	1189
Goro	4588	Fedis	1469	Ameya	1188
Guradamole	3362	Becho	1429	Jeju	1185
Itang	3223	Siya Debirna W. E.	1403	Selamgo	1178
Denan	2793	Fik	1382	Rayitu	1175
Ilu	2700	Jabi Tehnan	1379	Jor	1174
Jikawo	2644	Jama	1373	Simurobi Gele'alo	1156
Awash Fentale	2357	Gambela	1370	Humbo	1155
Bure Mudaytu	2209	Gimbichu	1344	Golo Odo	1152
Moyale	2160	Miesso	1337	Banja	1135
Kembibit	2119	Fursi	1327	Dugda Bora	1134
Ewa	1856	Amibara	1318	Afambo	1130
Abichuna Gne'a	1848	Merawi	1286	Segeg	1130
Wuchalena Jido	1845	Dembel	1280	Dolobay	1130
Hamero	1696	Alem Gena	1263	Tsegede	1111
West Imi	1641	Gode	1261	Shashemene	1108
Chifra	1580	Abobo	1231	Seweyna	1105
Dulecha	1514	Lanfero	1213	Gog	1080
Akobo	1510	Tole	1203		

Source: Author. Based on the operations in Figure 2

Accessibility to Road Networks, and Proximity to Major Urban Centers

Proximity to urban centers offers significant advantages including the supply of, and accessibility to, goods and services. However, proximity becomes less critical if ease of access can be achieved through available road networks. Hence, being served by an all-weather road or at least by a dry-weather road is a good criterion for inclusion of a *Wereda* whether or not it has urban centers within its borders, or it is located near one of the urban centers shown on Figure 4 (population 5,000 or greater).

Soils

The final selection criteria focused on *Weredas* that have a sizeable portion of their land under the deep and well-drained Nitosol soil group. This soil type covers about 12% of the country and is considered to have good agricultural potential despite its low PH and low phosphorous content (IFPRI 2006; Negash 2004; Kebede 2010). Verisols and Luvisols are also present in many *Weredas* targeted for selection including all of the *Weredas* in Gambella and those further north in Guba, Dangur, Sanja, and Kafta Humera (see Figure 4).

Vertisols and Luvisols do not have as much agricultural potential as Nitosols. Vertisols are heavy black clay soils, and are difficult to work because of poor drainage (IFPRI 2006). However, these are only present in small isolated sections of Guba, Dangur, Sanja, and Kafta Humera. As a result, none of the finalist *Weredas* in Table 3 were excluded due to inferior soil types or quality—a detailed map of Ethiopian soils can be found on page 36 of the Ethiopian Statistical Authority's (PDF) Atlas of the country (IFPRI 2006).

FINAL SELECTION

After exclusion of *Weredas* on density grounds, accessibility, and soils, the final cut of 34 *Weredas* suitable for large-scale irrigation-based resettlement in Ethiopia emerged (Table 3). All of the *Weredas* in the final selection have at least a dry-weather road system (based on visual inspection) and a suitability index of 630 or higher.

Table 3
Final List of *Weredas* Selected for Irrigation-Based Resettlement

Highly Suitable * (WSI 1697 or Higher)	**Suitable (WSI 1070–1696)**	**Somewhat Suitable (WSI 630–1069)**
Pawe	Gambela	Kafta Humera
Itang	Akobo	Sanja
Jikawo	Gog	Dangur
Denan	Tsegede	Guba
Bure Mudaytu	Amibara	Raya Azebo
Awash Fentale	Dolo Odo	Mille
Wuchalena Jido	Seweyna	Telalak
	Rayitu	Erer
	Dembel	Shinile
	Fiq	Babille
	Gode	Kelafo
	Dolobay	Mustahil
		Kuraz
		Menge

Source: Author. Based on operations shown in Figure 2 and Figure 5
WSI = Werede Suitability Index
*See Figure 4 for the location of the highly suitable *Weredas*

Discussion

Eighty-five percent of Ethiopia's population lives in rural areas. Agriculture employs over four-fifths of the labor force and accounts for 90 percent of national export earnings (World Bank 2004). To make way for agriculture, the forest cover has been reduced from about 40 percent a century ago to 3 percent today with human activities extending to slopes as steep as 16 degrees (Badege 2001). Deforestation has been exacerbated by lack of land reform and insecurity of land-holdings which hinders effective stewardship of soil resources (Badege 2001; Pender 2006). Historically, among the various mechanisms of adjustment to deterioration in the physical environment and/or a diminishing resource-base has been voluntary out-migration including the often quoted Oromo migration of the 16th century (Ofcansky and Berry 1991). However, lack of land, meaningful land reform, insecurity of holdings, and the fear of losing one's plot, no matter how small, makes out-migration all but impossible at the present time (Desalegn 1999).

Evidence-based resettlement planning with adequate capital expenditure can help create a more conducive living environment for millions of Ethiopians in drought-prone and ecologically vulnerable *Weredas*. However, much of the resettlement so far has neither been well planned nor river-based. Thus, irrigable agricultural lands remain undeveloped with a reported less than 5 percent of the the Blue Nile basin having been developed for food production (Block, Strzepek, and Rajagopalan 2007). A top-down approach has also meant that fertile land and forest areas previously held by local populations has been given to resettlers thereby triggering conflicts that have forced the repatriation of a substantial proportion of settlers (Wolde-Selassie 1997; Mellese 2005; Ayke 2005; Dessalegn 2005; Assefa 2005; Gebre 2005; Kassahun 2005).

This study sought to address some of these issues by focusing, for the first time, on river-based resettlement. It used GIS tools to conduct a nationwide survey of landforms and drainage systems as well as assess population densities, accessibility, and type of soil cover. It identified low population density *Weredas* with large expanses of unused or little used areas that are potentially suitable for irrigation-based resettlement. Some of the selected *Weredas* are being targeted by the government for a controversial land-lease program (also referred to "land-grab") in which foreign agribusiness companies are given extended lease rights for pennies per hectare (Cotula, et al. 2009; *Guardian* nd). "Ethiopia, Madagascar and Sudan are the three countries with the highest number of individual land deals, which cover approximately 2.8–3 [million] ha" (GLP Report 2010: 14).

The study does not, however, address other challenges such as flash-floods which have killed hundreds as recently as 2006 (Samson 2008; EEWS 2007), and have forced out tens of thousands of people including some in the *Weredas* selected in this study. Moreover, we have not assessed the potential impacts of water mismanagement and the accelerated loss of wetlands which according to

IUCN (no date available) is already underway (see Wood 1993; Wood 2000; FDRE 2007).

On the malaria risk index, it is obvious that most of the selected sites in the outlying regions of western Ethiopia fall under the “severe” malaria category (Figure 3). Three-quarters of the country’s land area is at risk of malarial infections at least once a year (Tedros, et al. 2006; Gabriel and Verdin 2005). Given the patterns in Figure 3, it would be difficult to identify suitable *Weredas* in the outlying regions of western Ethiopia unless we assume a reduced malaria risk (from “severe” to “moderate”) going forward. Reduction in malaria rates is already underway due to ongoing government malaria eradication efforts (USAID, 2010). Moreover, the implementation of the “Presidents Malaria Initiative” in Ethiopia (financed by the U.S. since 2005) is projected to reduce malaria-related mortality by 50% (FDRE 2008). Specific goals for the plan-period ending in 2010 included a 100 percent national coverage of insecticide treated nets (ITN) and complete access to effective antimalarial drugs (FDRE 2008). Given these facts, it is clear that our initial assumption that malaria severity in at-risk *Weredas* selected for resettlement will be reduced is tenable.

In sum, the GIS approach used here and the final selection of low density *Wereda*s with lots of rivers and at least 50% of areas under flat plains (Table 3), represents a departure from past efforts that have been haphazard and rain-based. The unshaded areas in the central, northern, and eastern highlands of Ethiopia (Figure 4) represent *Weredas* that failed to make it into the final selection due primarily to the slope criteria. This does not mean, however, that there are no *Wereda*s or sections of *Wereda*s in the central, northern, and eastern highlands suitable for irrigation-based resettlement. On the contrary, there are millions of hectares of suitable lands. In fact, *Wereda*s in the central and eastern highlands have many of the key ingredients for successful resettlement including: (a) malaria-free environments year round, (b) a high number of urban service centers, and (c) the best accessibility by all-weather and dry-weather roads. Therefore, Figure 4 is best interpreted as a ranking of an individual *Wereda*’s suitability for large scale irrigation-based resettlement given the availability of land areas that meet all of the suitability requirements of this study, particularly the slope and river length requirements. At the very the top are the darkest of the three shades of gray (highest percentage of suitable land). At the very bottom are high population density *Weredas* in the central, northern, and eastern highlands (shown as unshaded spaces in Figure 4) that also have the steepest slopes and the lowest percentages of suitable land for *Wereda*-wide irrigation-based resettlement.

In not addressing potential obstacles to resettlement in Ethiopia, including possible socio-cultural and political opposition at local levels, this study is not minimizing the possibility of a push-back by local populations. The public has long been wary of the many top-down government resettlement approaches. Individual success stories abound but, generally, the lack of the human and financial resources needed to bring measurable success to the country's settlement activities, has added to the public's lack of faith in the virtues of resettlement as a solution to the country's population problems. We believe, therefore, that population control measures with a focus on fertility reduction would produce better long-term results in achieving a healthy population-resource balance in Ethiopia. In this regard, it is encouraging to note that the percentage of women using contraception has tripled in the last 25 years and the average fertility in Ethiopia has decreased from 7.7 to 5.4 children per woman (FDRE 2002; CSA and ORC Macro 2006). Until desirable fertility levels are reached, resettlement should be viewed mainly as a crucial safety valve to help relieve population pressure in high density *Weredas* as well as those beset by severe environmental degradation from natural and man-made causes.

DATA PROBLEMS AND RECOMMENDATIONS

This study encountered many data problems that need to be addressed in order to facilitate greater GIS use in dealing with Ethiopia's many socioeconomic and environmental problems. First is that the base maps used in this study had many inconsistent place name spellings compared to those used by the Ethiopian Central Statistical Authority's (CSA) population reports. While this problem was ameliorated by a meticulous matching of names from the various data sources, thereby allowing for the transfer of relevant population data from CSA's census publications to the shapefiles used in this study, the tediousness of the process does limit or slow down the use of GIS in dealing with the country's problems.

Second is that the base maps came in different map projections that had to be harmonized. Third is that even with the harmonization of the map projections, the *Wereda* and region boundary lines often varied from one map to another thereby making the overlaying of maps difficult in some cases. But by far the most serious challenge was the total absence of metadata like date, purpose, responsible agencies, contact person(s), and projection systems for many of the shapefiles used in the study. Without such metadata, it is difficult to judge the accuracy of many of the shapefiles utilized herein. Consequently, this somewhat undermines the reliability of the study findings.

To address these challenges and boost the use of GIS in Ethiopia, we recommend that:

- The spelling of place names in Ethiopia be standardized;
- The creation of metadata be a standard practice among GIS professionals in the country; and

- That a GIS data clearinghouse be set-up to house and improve the quality of all of the available GIS data in the country. The data can then be published online to facilitate its global access by interested individuals and researchers. While the Ethiopian Mapping Authority is the most qualified agency to take on this role, its lack of openness points to an urgent need for its change of attitude and work-practices. This paper would have benefited greatly from such openness, and from the availability of freely accessible data on the Internet.

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References

Akol, A., et al. 2009. Demographic Data for Development Decision Making: Case Studies from Ethiopia and Uganda. Addis Ababa: Population Reference Bureau Assessment Team. PRB. http://www.prb.org/pdf09/demographicdatadecisionmaking.pdf.

Alesheikh, A. A., et al. 2008. "Land Assessment for Flood Spreading Site Selection Using Geospatial Information System" *International Journal of Environmental Sciences and Technology* 5(4): 455–462.

Assefa, T. 2005. "Impact on Environment and Host Communities. Research Project Workshop." Forum for Social Studies. Addis Ababa.

Ayke, A. 2005. "Challenges and Opportunities of Salamgo: A Resettlement Scheme in South-Omo Zone, Southern Nations and Nationalities and Peoples Regional State." Research Project Workshop. Forum for Social Studies. Addis Ababa.

Badege, B. 2001. "Deforestation and Land Degradation in the Ethiopian Highlands: A Strategy for Physical Recovery." *Northeast African Studies* 8(1): 7–26 (New Series).

Banerjee, D. 2009. "Appraisal and Mapping the Spatial-Temporal Distribution of Urban Road Traffic Noise" *International Journal of Environmental Science and Technology* 6(2): 325–335.

Block, P. J., K. Strzepek and B. Rajagopalan. 2007. "Integrated Management of the Blue Nile Basin in Ethiopia: Hydropower and Irrigation Modeling." *International Food Policy Research Institute*. IFPRI Discussion Paper 00700.

Bolstad, P. 2008. *GIS Fundamentals: A First Text on Geographic Information Systems.* Third Edition. Eider Press. White Bear Lake, Minnesota.

CSA. 2006. "Population" Federal Democratic Republic of Ethiopia. Central Statistical Authority. Addis Ababa. http://www.csa.org.et.

CSA and ORC Macro. 2006. *Ethiopia Demographic and Health Survey 2005*. Addis Ababa: Central Statistical Authority, Addis Ababa and, Calverton, Maryland, USA: ORC Macro.

Cotula, L., S. Vermeulen, R. Leonard, and J. Keeley, 2009. "Land Grab or Development Opportunity? Agricultural Investment and International Land Deals in Africa," *Iied/Fao/Ifad*. London/Rome. ISBN: 978-1-84369-741-1.

Demeke, N. 2003. "The Need for Introducing GIS and Remote Sensing in the Agricultural Research System of Ethiopia." *Proceedings of the National Sensitisation Workshop on Agrometeorology and GIS*. December 17–18, 2001, EARO, Addis Ababa, Ethiopia.

Demircan, M. L. 2002. "Site Selection in Fast Food Industry." Paper presented at the International Symposium on GIS, September 23–26, Istanbul Turkey.

Desalegn, R. 1999. "Water Resource Development in Ethiopia: Issues of Sustainability and Participation" *Forum for Social Studies*. Addis Ababa.

Desalegn, W. 2005. "The Post 1991 Resettlement Planning and Administration, and Changing Patterns of People's Access to Local Resources: The Case of Kenaf, Western Oromiya" Research Project Workshop. *Forum for Social Studies*. Addis Ababa.

ESRI. 2010. "Africa Agriculture GIS week 2010." http://africaagriculturegisweek.org.

ECA. 2000. "The Future Orientation of Geographic Information Systems (GIS) in Africa." Economic Commission for Africa. Development Information Services Division Geoinformation Team. A discussion paper produced for the ad hoc meeting of experts convened by the Development Information Services Division (DISD) United Nations Economic Commission for Africa.

EEWS. 2007. "Flood Vulnerability and Risks in Ethiopia in 2007: Flood Prone Areas." Ethiopian Early Warning System. Early Warning Special Report 02 July, 2007.

ESRI. 2009. "GIS in Africa: Best Practices." Economic and Social Research Institute. http://www.esri.com/library/bestpractices/gis-in-africa.pdf.

Farkas, A. 2009 "Route/Site Selection of Urban Transportation Facilities: An Integrated GIS/MCDM Approach." 7th International Conference on Management, Enterprise and Benchmarking June 5–6, Budapest, Hungary.

FDRE. 2002. Federal Democratic Republic of Ethiopia. Environmental Protection Agency. The Second National Report on the Implementation of UNCCD/NAP in Ethiopia. April 2002. Addis Ababa Ethiopia.

FDRE. 2007. "Ethiopian National Malaria Indicator Survey." Federal Democratic Republic of Ethiopia. Ministry of Health. Technical Summary.

FDRE. 2008. "President's Malaria Initiative." Malaria Operational Plan. FY 2008. Federal Democratic Republic of Ethiopian. Ministry of Health. Addis Ababa.

FDRE. 2010. "Population and Housing Census 2007." Federal Democratic Republic of Ethiopia: Central Statistical Agency. Addis Ababa. Online publication (PDF), http://www.csa.gov.et/.

Fosse, T. E. 2006. "Migration and Livelihoods—The Voluntary Resettlement Program in Ethiopia." Norwegian University of Life Sciences. Department of International Environment and Development Studies (Noragric) Master Thesis 30/60 Credits.

Gabriel, S. and J. Verdin. 2005. "Developing a Malaria Early Warning System for Ethiopia." National Center for EROS. Sioux Falls, SD. Twenty Fifth Annual ESRI International User Conference. Paper No. UC2409.

Gebre, Y. 2005. "Stakeholder Participation in Resettlement Decision-Making in Ethiopia." Research Project Workshop. Forum for Social Studies. Addis Ababa.

GLP Report. 2010. "Land Grab in Africa: Emerging Land System Drivers in a Teleconnected World." The Global Land Project International Project Office. Report No. 1. University of Copenhagen.

Guardian. (nd). http://www.guardian.co.uk/world/2011/mar/21/ethiopia-centre-global-farm land-rush.

Hammond, L. 2008. "Strategies of Invisibilization: How Ethiopia's Resettlement Programme Hides the Poorest of the Poor." *Journal of Refugee Studies* 21(4): 517–536; doi:10.1093/jrs/fen041.

IFPRI. 2006. "Atlas of the Ethiopian Rural Economy." International Food Policy Research Institute. Washigton D.C. and Central Statistical Authority. Addis Ababa. Advance copy.

IUCN. (nd). "Wetlands of Ethiopia" The World Conservation Union. Wetland and Water Resources Program. http://wetlands.hud.ac.uk/pdf/gender.pdf.

Kassa, B. 2004. "Resettlement of Peasants in Ethiopia." *Journal of Rural Development* 27 (Winter): 223–253.

Kassahun, B. 2005. "Site Selection, Infrastructure, Services, Provisions, and Resettlement Administration." Research Project Workshop. Forum for Social Studies. Addis Ababa.

Kebede, G. 2010. Gis-Based Surface Irrigation Potential Asssessment of River Catchments for Irrigation Development in Dale Woreda, Sidama Zone, SNNP. A Thesis Submitted to the Institute of Technology, School of Natural Resource and Environmental Engineering. In Partial Fulfillment of the Requirements for the Degree of Master of Science in Irrigation Engineering Haramaya University. Ethiopia.

Kloos, H. and A. Aynalem. 1989. "The Ethiopian Population: Growth and Distribution." *The Geographical Journal*: Vol. 155, No. 1, March, pp. 33–51.

Kunert, K. 2005. "A Gis Approach to Habitat Restoration Site Selection and Prioritization in The New York-New Jersey Harbor Estuary." Masters project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment and Earth Sciences of Duke University.

Latef, M. and R. B. Kahar. 2008. "Oil and Gas Exploration in Ethiopia Using GIS." Petronas. Kuala Lumpur, Malaysia, Mimeographed.

Malczewski, J. 2006. "GIS-Based Multicriteria Decision Analysis: A Survey of the Literature." *International Journal of Geographical Information Science*, Vol. 20, No. 7, August, 703–726.

MARA/ARMA. (nd). Mapping Malaria Risk in Africa. http://www.reiseklinikken.no/ Eth Distribution.pdf.

Mellese, M. 2005. "Challenges of Inadequate Preparation and the Dilemma of 'Voluntary' Displacement: The Case of Intra-Zonal Resettlement in Wolayta (SNNPR)." Research Project Workshop. Forum for Social Studies. Addis Ababa.

Mezemir, W., et al. 2005. "GIS Implementation to Support Poverty Reduction Policy and Drought Management in Ethiopia." United Nations Economic Commission for Africa (UN ECA). Fourth Meeting of the Committee on Development Information

(CODI IV). Addis Ababa, Ethiopia, April. Committee for Development Information (CODI) IV.

NASA. (nd). The CGRI Consortium for Spatial Information. http://srtm.csi.cgiar.org.

Negash, W. 2004. GIS Based Irrigation Suitability Analysis: A Case Study of Abaya-Chamo Basin, Southern Rift Valley of Ethiopia. Lake Abaya Research Symposium 2004-Proceedings.

Ofcansky, T. P. and L. Berry. 1991. *Ethiopia: A Country Study*. Washington: GPO for the Library of Congress. http://countrystudies.us/ethiopia.

Pantoula, N. 2004. "A GIS Site-Selection Process for Habitat Creation: Estimating Connectivity of Habitat Patches" *Landscape and Urban Planning* 68, pp. 77–94.

Reusing, M. 2000. "Change Detection of Natural High Forests in Ethiopia Using Remote Sensing and GIS Techniques." International Archives of Photogrammetry and Remote Sensing. Vol. XXXIII, Part B7. Amsterdam.

Samson, W. Abaya. 2008. "Floods and Health in Gambella Region, Ethiopia: An Assessment of the Strength and Weakness of the Coping Mechanism." M.Sc. Thesis submitted to Lund University Centre for Sustainability Studies.

Solaimani, K, S. Modallaldoust and S. Losfi. 2009. "Investigation of Land Use Changes on Soil Erosion Process Using Geographical Information System." *International Journal of Environmental Science and Technology* 6(3): 415–424.

Strauss, B. 2008. "Nesting Mallard (*Anas platyrhynchos*) Habitat Site Selection and Management Using GIS." Masters project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment and Earth Sciences of Duke University.

Tedros, A., et al. 2006. "Malaria" in *Epidemiology and Ecology of Health and Disease in Ethiopia*, eds. B. Yemane, H. M. Damen and K. Helmut. Shama books. Addis Ababa.

UNDESA. 2004. "Federal Democratic Republic of Ethiopia: Public Administration Country Profile." United Nations Department of Economic and Social Affairs. Division for Public Administration and Development Management (DPADM), June.

USAID. 2003. "Fact Sheet #5, Fiscal Year (FY) 2003." Bureau for Democracy, Conflict, and Humanitarian Assistance (DCHA), Office of U.S. Foreign Disaster Assistance (OFDA).

USAID. 2010. "Malaria Operation Plan (MOP) in Ethiopia Fiscal Year 2011." Online publication. http://www.fightingmalaria.gov/countries/mops/fy11/ethiopia_mop-fy11.pdf.

Vadala, A. A. 2008. "Understanding Famine in Ethiopia: Poverty, Politics, and Human Rights." *Political Perspectives* 2(1).

Vlachopoulou, M., G. Silleos, and V. Manthou. 2001. "Geographic Information Systems in Warehouse Site Selection Decisions." *International Journal of Production Economics* 71: 205–212.

Wolde-Selassie, A. 1997. "The Dynamics of Socioeconomic Differentiation and Change in the Beles-Valley/Pawe Resettlement area, North Western Ethiopia." A Thesis Submitted to the School of Graduate Studies. In Partial Fulfillment of the Requirements for the Degree of Masters of Arts in Social Anthropology. Addis Ababa University.

Wood, A. 1993. “Natural Resource Conflicts in South-West Ethiopia: State Communities, and the Role of the National Conservation Strategy in the Search for Sustainable Development.” *Nordic Journal of African Studies* 2(2): 83–99.

Wood, A. 2000. “Wetlands, Gender and Poverty: Some Elements in the Development of Sustainable and Equitable Wetland Management.” *Wetlands of Ethiopia*. Proceedings of a seminar on the resources and status of Ethiopia’s wetlands, eds. A. Yilma and K. Keheb. http://wetlands.hud.ac.uk/pdf/gender.pdf.

World Bank. 2004. “A Country Status Report on Health and Poverty.” African Regional Human Development and Ministry of Health Ethiopia. Draft Report No. 28963-ET.

Yntiso, G. 2002. “Differential Reestablishment of Voluntary and Involuntary Migrants: The Case of Metekel Settlers in Ethiopia.” *African Study Monographs* 23(1): 31–46, March.

Yousefi, H., S. Ehara, and Y. Noorollahi. 2007. “Geothermal Potential Site Selection Using GIS in Iran.” Proceedings, Thirty-Second Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, January 22–24, SGP-TR-183.

Yohannes, G. and K. Mebratu. 2009. “Local Innovation in Climate-Change Adaptation by Ethiopian Pastoralists.” PROLINNOVA—Ethiopia and Pastoralist Forum Ethiopia (PFE) final report, January. Addis Ababa, Ethiopia.

Zeng, T. Q. and Q. Zhou. 2001. “Optimal Spatial Decision Making Using GIS: A Prototype of a Real Estate Geographical Information System (REGIS).” *International Journal of Geographical Information Science* 15 4(3).