GIS for Good
Optimal Site Selection for Refugee Camps in Uganda: A GIS Based Methodology

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In Collaboration with ENNEAD Architects
Spring 2014

ABSTRACT

In partnership with Ennead Architects, a team of Stanford students developed a methodology to determine the best locations for refugee camps using Geographic Information Systems. The goal of this project was to determine how both environmental and social factors could be used together to locate the best places in a country for refugee camps and settlements. Using data and background knowledge available on Uganda, the team designed two scenarios to apply in analyzing site suitability for refugee placement.

In the first scenario, analysts determined that refugee camps would be positioned so that refugees would be able to utilize many of the resources and infrastructure already in place. In the second scenario, analysts determined that refugee camps would be placed in areas lacking social infrastructure on the premise that the office of the United Nations High Commissioner for Refugees would be building infrastructure to fulfill the needs of the camps and the needs of the surrounding communities that are currently lacking in resources.

Using available data on environmental factors and infrastructure such as locations of towns, health facilities, educations centers, etc., analysts were able to create a ranking system of the importance of each factor and weight their values accordingly. The relative values of each dataset were combined using the GIS software, and the resulting maps for each scenario created a composite suitability score for each 0.5 km^2 in Uganda.

The methodology developed in this project can be applied to emergency situations in which aid workers must make quick decisions on where to move people in the aftermath of a crisis. This will greatly change to way in which humanitarian workers use data to make decisions on site selection in crisis situations.

INTRODUCTION AND BACKGROUND

Uganda has been hosting an average of 161,000 refugees per year since 1961. The country signed the legal document that defined who is considered a refugee at the 1951 Refugee Convention and proceeded to sign the 1967 Protocol that removed geographical and temporal restrictions that were part of the original Convention. In 2006, Uganda implemented a progressive Refugee Act that recognized the right of the country's refugees to work, move around the country, and live in the community. This differed greatly from previous restrictions, which relegated refugees to life in rural settlements with no access to work opportunities and community interaction.

Table 1 below shows the country of origin of refugees in Uganda as of February 28, 2014 (UNHCR Uganda Fact Sheet, 2014). The three largest populations of concern are refugees and asylum seekers originating from the Democratic Republic of the Congo (DRC), South Sudan, and Somalia. Major cities of conflict in the DRC are North Kivu and Province Orientale; attacks on the citizens of these cities have resulted in a major influx of Congolese into the south and midwest region of Uganda. In 1989, refugees from South Sudan fled the prolonged conflict between the Sudanese Government and the Sudan People's Liberation Army and entered Uganda. Today, South Sudanese refugees are seeking safety in the West Nile area of Uganda from local clashes and inter-tribal violence in their home country. Refugees from Somalia are fleeing from the insecure central and southern regions.

Country of Origin	Refugees / Asylum Seekers
DRC	175,498
South Sudan	97,194
Somalia	18,213
Rwanda	14,856
Burundi	11,459
Eritrea	6,700
Sudan	1,796
Kenya	1,543
Ethiopia	1,519
Others	219
Total	328,997

Table 1. Country of Origin of Refugees and Asylum-Seekers in Uganda (Thousands).
Source: UNHCR Uganda Fact Sheet, 2014. Current as of Feb. 2014.

PROJECT OBJECTIVES

This project had several objectives in order to determine the best sites for refugee placement.

The **first objective** of the project was to develop two separate scenarios for refugee campsite selection.

Scenario 1: Existing Community Infrastructure, was designed such that the selection of sites would assume that refugees would be reliant on the community infrastructure that already exists. This would provide refugees an opportunity to integrate with local communities to a certain extent, and put less pressure on UNHCR to develop the infrastructure for new camps in rapid crisis situations.

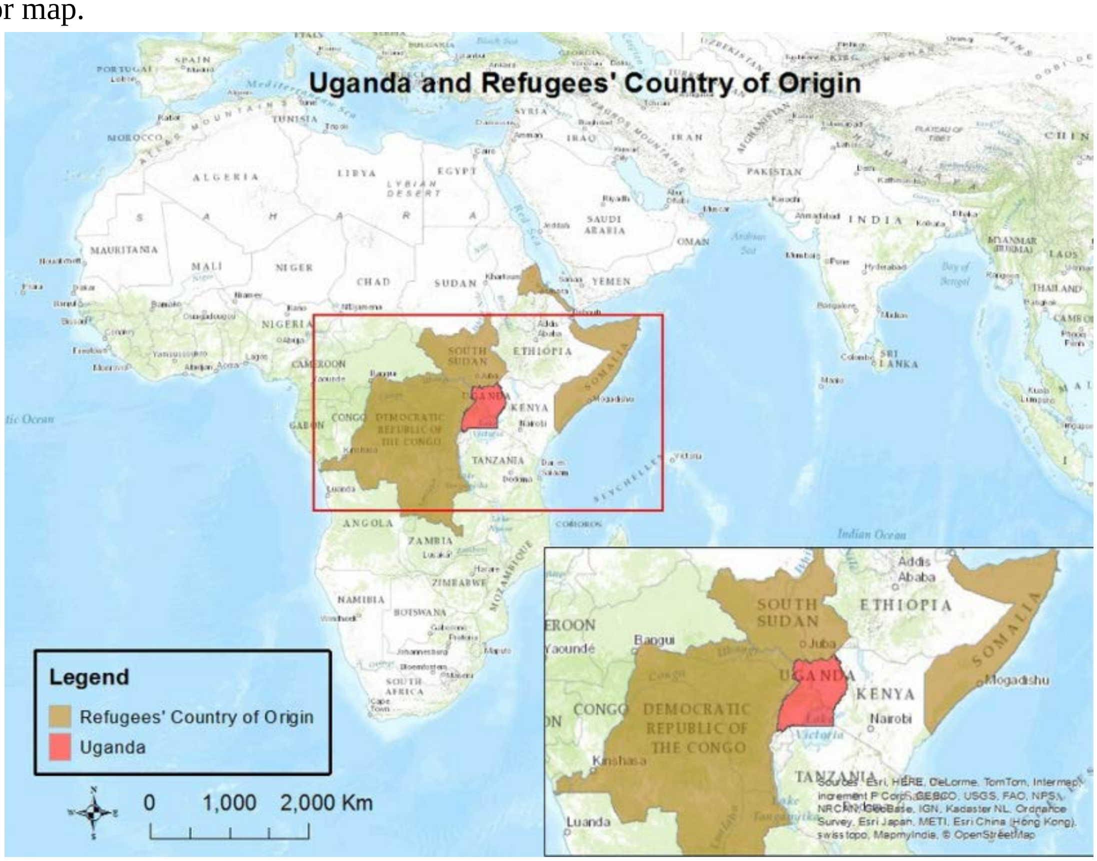
Scenario 2: New Community Infrastructure, was designed under the assumption that UNHCR would be able to provide infrastructure to new camps. Although both models aspire to a level of community integration, this model would be undertaken under the hope that the presence of UNHCR and thus, refugees, would actually benefit communities that had previously suffered from poor access to certain resources. These camps might prove a bit more difficult to develop, but the hope is that the positive effects of a camp would benefit the communities for a long time to come.

Our **second objective** was to use GIS to develop a methodology for ENNEAD Architects, in partnership with UNHCR, to determine the best locations for refugee camps and settlements in Uganda based on both environmental and social factors.

Our **third objective** was to use the methodology created to determine the best sites for refugee placement, and to determine ways that this methodology could be used in other countries and humanitarian emergencies.

STUDY AREA

Our study focuses on determining the best locations to build refugee camps in Uganda. As mentioned in the introduction, the three largest refugee populations of concern are originating from the Democratic Republic of the Congo, South Sudan, and Somalia. Below you will find our locator map.



DATA SOURCES

Data was collected from several sources in order to complete the analysis; information about each of those sources are reference below.

Dataset	Description	Data Collection Date	Data Source	Data Type	Spatial Resolution / Scale of Capture
Aqueduct Global Maps 2.0	Poverty index for 855 rural counties in Uganda	2005	Uganda Bureau of Statistics (UBOS) and International Livestock Research Institute (ILRI).	Vector	County level
Camp Coordinates	Satellite imagery of entire world that can be used to find the population densities per county in Uganda	2012	Oak Ridge National Laboratory	Raster	Country Level 1km resolution (30"x30")
Global Active Archive of Large Flood Events	Coordinates for existing camps in Uganda		Ennead Architects	Excel	
Global Land Data Assimilation System Version 2 (GLDAS-2)	World Countries provides a base map layer for the countries of the world. Provided the country boundaries necessary for Uganda and countries of origin for refugees.	2013	Esri	Vector	World Level
Health Centers	Major roads of Uganda (used to calculate distance to roads)	2009	Food and Agriculture Organization (FAO)	Vector	Uganda
LandScan 2012 Global Population	This polygon dataset contains the Level 5 Admininstrative Boundaries (sub-counties) for Uganda. Also contained districts for Uganda.	2010	Ugandan Bureau of Statistics (UBOS)	Vector	Sub-County
Projected Changes in Drought Occurrence under Future Global Warming from Multi-Model, Multi-Scenario, IPCC AR4 Simulations	This point dataset contains the locations of towns in Uganda based on GPS coordinates (used to calculate distance to towns)	2009	Ugandan Bureau of Statistics (UBOS)	Vector	Uganda
Rural Poverty Index 2005	Rural safe water coverage as defined by the Directoarte of Water Development, Ministry of Water and Environment	2008	Uganda Bureau of Statistics (UBOS) and International Livestock Research Institute (ILRI).	Vector	District Level
Safe Water Coverage 2008	Aggregates flood events from news, governmental, instrumental, and remote sensing sources and estimates the extent of flooding based on reports of affected regions. Recorded the number fo floods from 1985-2011	1985-2011	Brakenridge, Dartmouth Flood Observatory (collected dataset from the World Resource Institute)	Vector	Flood Extent Polygons (multiple scales)
Schools	Shows the variation in water supply between years in Uganda. Standard deviation of annual total blue water (the accumulated runoff upstream of the catchment plus the runoff in the catchment) divided by the mean of total blue water (1950–2008).	1950-2008	National Aeronautics and Space Administration (NASA)	Vector	1 degree raster
Soil	Drought severity measures the average length of drought times the dryness of the droughts from 1901 to 2008. Drought is defined as a contiguous period when soil moisture remains below the 20th percentile. Length is measured in month and dryness is the average number of percentage points by which soil moisture drops below the 20th percentile.	1901-2008	J.SHeffiel and E.F. Wood (collected dataset from the World Resource Institute)	Vector	1 degree raster
Sub-Counties: Uganda 2010	Satellite imagery depicting land use and land cover for Africa	2000	Joint Research Centre, European Commission, Institute for Environment and Sustainability	Raster	Africa; 1 Degree raster resolution
The Land Cover Map for Africaa in the Year 2000	Provides a base map layer for the rivers and streams of the world.	2013	Esri	Vector	World Level; Scale denominator 1000000
Towns: Uganda, 2009	Provides a base map layer for the lakes, seas, oceans, and large rivers of the world.	2013	Esri	Vector	World Level; Scale denominator 1000000

Uganda Other Land 2006	Compilation of location of schools throughout Uganda as well as their ownership type from various organizationss. Used to calculate distance to schools.	2011	UBOS and others	Excel/Vector	parish level (some villages)
Uganda Roads Feb 2009	Rural safe water coverage as defined by the Directorate of Water Development, Ministry of Water and Environment, Uganda.	2008	Ministry of Health, Uganda; Ministry of Water and Environment, Uganda; Uganda Bureau of Statistics; International Livestock Research Institute; and World Resources Institute	Vector	Uganda
Uganda Safe Water Coverage 2008	Compilation of location of health centers throughout Uganda as well as their ownership type from various organizations. Used to calculate distance to health facilities.	compilitation of datasets ranging from 2005-2011	UBOS and Makere University Geography Department	Excel/Vector	parish level (some village)
World Countries	Name, type, and size of reserved lands in Uganda. Used to mask out areas that could not be built on for Uganda.	2006	Stanford's Q Drive	Vector	Uganda
World Elevation ASTER 30m DEM v2	Includes indicators of water quantity, water variability, water quality, public awareness of water issues, access to water, and ecosystem vulnerability. Field for interannual water variability was used for this project.	2013	World Resources Institute	Vector	World level
World Linear Water	Soil types, morphology and drainage. Provided data on soil suitability for crop production.Also used to mask out areas containing peat for soil type as this is unsuitable to build on.		The National Environment Management Authority (NEMA)	Vector	Uganda
World Water Bodies	Elevation / Topography (slope derived from elevation)	2011	Q drive	Raster	1 degree-by-1 degree tiles

METHODS

Factor Selection

A list of both environmental and social factors that play important roles in site selection for building a refugee camp were created. Based on the available datasets, sixteen factors were chosen to conduct an analysis on. Other data could have proven helpful, but the project is limited by the amount of data about Uganda that is currently available.

Environmental Factors:

1. Distance to Water
2. Flood Risk
3. Drought Risk
4. Interannual Water Variability
5. Safe Water Coverage
6. Elevation
7. Slope
8. Landuse
9. Soil Type - Food Suitability

Social Factors:

10. Population Density
11. Poverty Density
12. Distance from Borders
13. Distance to Roads
14. Distance to Health Centers
15. Distance to Education Facilities
16. Distance to Towns

Data Reclassification

In order to complete our analysis, it was important that the data be organized in a way that made them comparable. Data about the number of people per square kilometer in a district is not directly comparable to data about average rainfall in the same district. We created a ranking system from 1-10 and reclassified all of our data into that system, with 10 representing the most optimal conditions, and 1 representing the least. Some conditions were such that we chose to remove them entirely from the analysis because it would be impossible to build a refugee camp there. Those values are ranked as "masked" or "NIL".

The table of the classifications is located on the next page.

Factor	Classification					
	Scenario 1		Explanation/Source	Scenario 2		Explanation/Source
	Rank (1-10)	Classification		Rank (1-10)	Classification	
Population Density	10	10,000-18,000	Natural breaks	10	400-900	Natural breaks
	9	18,000-33000		9	125-400	
	8	33,000-53,000		8	0-125	
	7	6,000-10,000		7	900-1,800	
	6	3,000-6,000		6	1,800-3000	
	5	1,800-3000		5	3,000-6,000	
	4	900-1,800		4	6,000-10,000	
	3	400-900		3	10,000-18,000	
	2	125-400		2	18,000-33000	
	1	0-125		1	33,000-53,000	
Poverty Density (Number of poor people per square km)	10	391-281.83	Natural Breaks	10	9.99-0	Natural Breaks
	9	273.48-191.92		9	24.97-10.03	
	8	187.48-135.43		8	39.98-25.28	
	7	134.88-100.54		7	54.98-40.05	
	6	99.78-75.69		6	74.9-55.04	
	5	74.9-55.04		5	99.78-75.69	
	4	54.98-40.05		4	134.88-100.54	
	3	39.98-25.28		3	187.48-135.43	
	2	24.97-10.03		2	273.48-191.92	
	1	9.99-0		1	391-281.83	
Distance to Towns	10	0 - 1 km	Manual Classification	10	50 - 60 km	Manual Classification
	9	1 - 2 km		9	40 - 50 km	
	8	2 - 3 km		8	30 - 40 km	
	7	3 - 5 km		7	20 - 30 km	
	6	5 - 10 km		6	10 - 20 km	
	5	10 - 20 km		5	5 - 10 km	
	4	20 - 30 km		4	3 - 5 km	
	3	30 - 40 km		3	2 - 3 km	
	2	40 - 50 km		2	1 - 2 km	
	1	50 - 60 km		1	0 - 1 km	
Distance to Water	10	0 - 0.5 km	Distance to water is one of the more difficult characteristics to rank for the two different scenarios. UNHCR has a standard of a maximum value of 100 m between water and camps. In both scenarios, it is important to be as close to water as possible because water is necesary to sustain life. Here the classifications were initially broken down into 0.5 km increments because 0.5 km can make a big distance in terms of going to retrieve water and having to carry it back in a container.	10	0 - 0.5 km	Distance to water is one of the more difficult characteristics to rank for the two different scenarios. UNHCR has a standard of a maximum value of 100 m between water and camps. In both scenarios, it is important to be as close to water as possible because water is necesary to sustain life. Here the classifications were initially broken down into 0.5 km increments because 0.5 km can make a big distance in terms of going to retrieve water and having to carry it back in a container.
	9	0.5 - 1 km		9	0.5 - 1 km	
	8	1 - 1.5 km		8	1 - 1.5 km	
	7	1.5 - 2 km		7	1.5 - 2 km	
	6	2 - 2.5 km		6	2 - 2.5 km	
	5	2.5 - 3 km		5	2.5 - 3 km	
	4	3 - 5 km		4	3 - 5 km	
	3	5 - 10 km		3	5 - 10 km	
	2	10 - 20 km		2	10 - 20 km	
	1	20 - 90 km	Source: Guidelines Relating to Water in Refugee Camps (UNHCR)	1	20 - 90 km	Source: Guidelines Relating to Water in Refugee Camps (UNHCR)
Distance to Roads	10	0 - 1 km	Values for walkable distances are used from a previous project looking at Syrian Refugee camps.	10	0 - 1 km	Values for walkable distances are used from a previous project looking at Syrian Refugee camps.
	9	1 - 3 km		9	1 - 3 km	
	8	3 - 5 km		8	3 - 5 km	
	7	5 - 7 km		7	5 - 7 km	
	6	7 - 9 km		6	7 - 9 km	
	5	9 - 11 km		5	9 - 11 km	
	4	11 - 13 km		4	11 - 13 km	
	3	13 - 15 km		3	13 - 15 km	
	2	15 - 18 km		2	15 - 18 km	
	1	18 - 32 km	Source: A Crtitical Examination of Syrian Refugee Camps, Stanford University	1	18 - 32 km	Source: A Crtitical Examination of Syrian Refugee Camps, Stanford University
Soil Type Crop Suitability	10	High Suitability	Classifications were pre-made with the dataset collected from The National Environment Management Authority (NEMA).	10	High Suitability	Classifications were pre-made with the dataset collected from The National Environment Management Authority (NEMA).
	6	Medium Suitability		6	Medium Suitability	
	2	Low Suitability		2	Low Suitability	
	Masked	LAKE		Masked	LAKE	
	Masked	NIL	Source: The National Environment Management Authority (NEMA)	Masked	NIL	Source: The National Environment Management Authority (NEMA)

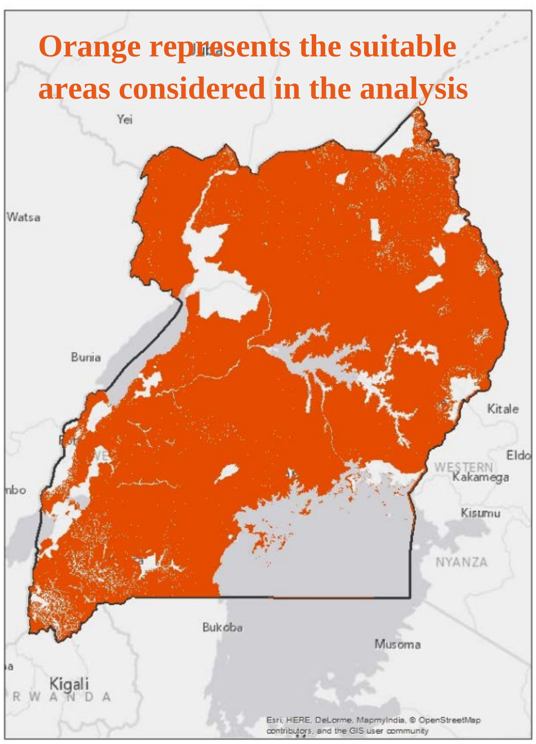
Factor	Classification					
	Scenario 1		Explanation/Source	Scenario 2		Explanation/Source
	Rank (1-10)	Classification		Rank (1-10)	Classification	
Distance to Health Centers	10	0 - 1 km	A case study of hospitals in Kenya used buffers of 4km, 2km, and 1km as walkable distances to reach each of the clinics. It was seen that 4km served as a threshold for the distance people were willing or able to walk to reach a clinic.	10	> 15 km	A case study of hospitals in Kenya used buffers of 4km, 2km, and 1km as walkable distances to reach each of the clinics. It was seen that 4km served as a threshold for the distance people were willing or able to walk to reach a clinic. The reclassification was reversed for this Scenario with the assumption that UNHCR will be building new health centers. It would be best to place these health centers away from the exisiting centers to allow the populations without access to an existing center to be in walkable distance to a new facility.
	9	1 - 2 km		9	10 - 15 km	
	8	2 - 3 km		8	7.5 - 10 km	
	7	3 - 4 km		7	5 - 7.5 km	
	5	4 - 5 km		5	4 - 5 km	
	3	5 - 7.5 km		3	3 - 4 km	
	2	7.5 - 10 km		2	2 - 3 km	
	1	10 - 15 km		1	1 - 2 km	
	0	> 15 km	Source: Spatial Analysis and GIS for Planning in Developing Countries	0	0 - 1 km	Source: Spatial Analysis and GIS for Planning in Developing Countries
Distance to Education Facilities	10	0 - 1 km	Ranking is based on a study conducted by The World Bank in order to make education more accessible. The study found that schools farther than 1 km demonstrated a significant drop in attendence. Schools had almost zero attendance on the part of students farther than 3 km. However, this study did not indicate whether or not the school being in the same village played a greater influence as opposed to just looking at distance. Refugees will always be "outsiders" as they are displaced and therefore this has less of an influence. As such, the same classification system was used as distance to health centers.	10	> 15 km	The reclassification was reversed for this Scenario with the assumption that UNHCR will be building new education facilities. It would be best to place these education facilities away from the exisiting schools to allow the populations without access to an existing school to be in walkable distance to a new facility.
	9	1 - 2 km		9	10 - 15 km	
	8	2 - 3 km		8	7.5 - 10 km	
	7	3 - 4 km		7	5 - 7.5 km	
	6	4 - 5 km		6	4 - 5 km	
	5	5 - 7.5 km		5	3 - 4 km	
	3	7.5 - 10 km		3	2 - 3 km	
	2	10 - 15 km		2	1 - 2 km	
	0	> 15 km	Source: The World Bank: Rural Education Accessability	0	0 - 1 km	Source: The World Bank: Rural Education Accessability
Flood Risk Factor	10	Low-Medium Risk (2-3 floods)	The flood risk ranking is based on the number of floods recorded in the different catchment areas in Uganda from 1985 to 2011. The indicator scores were created by the World Resources Institute. The extremely high flood risk is masked out because there is no way a refugee camp should be built in such a dangerous area. The remaining three categories are broken down into 10, 5 and 1.	10	Low-Medium Risk (2-3 floods)	The flood risk ranking is based on the number of floods recorded in the different catchment areas in Uganda from 1985 to 2011. The indicator scores were created by the World Resources Institute. The extremely high flood risk is masked out because there is no way a refugee camp should be built in such a dangerous area. The remaining three categories are broken down into 10, 5 and 1.
	5	Medium-High Risk (4-9 floods)		5	Medium-High Risk (4-9 floods)	
	1	High Risk (10-27 floods)		1	High Risk (10-27 floods)	
	Masked	Extremely High Risk (>27 floods)	Source: World Resources Institute (Brakenridge Dartmouth Flood)	Masked	Extremely High Risk (>27 floods)	Source: World Resources Institute (Brakenridge Dartmouth Flood)
Drought Risk Factor	10	Low to Medium Risk (20-30)	Drought severity measures the average length of drought x the dryness of the droughts from 1901 to 2008. Drought is defined as a contiguous period when soil moisture remains below the 20th percentile. Length is measured in month and dryness is the average number of percentage points by which soil moisture drops below the 20th percentile. Drought is compared to the rest of the world. The indicator scores were created by the World Resources Institute. The medium to high risk is given a rank of 3 as opposed to 1, because compared to the other factors these locations are not ideal, but they are also not unrealistic to have a refugee camp built there.	10	Low to Medium Risk (20-30)	Drought severity measures the average length of drought x the dryness of the droughts from 1901 to 2008. Drought is defined as a contiguous period when soil moisture remains below the 20th percentile. Length is measured in month and dryness is the average number of percentage points by which soil moisture drops below the 20th percentile. Drought is compared to the rest of the world. The indicator scores were created by the World Resources Institute. The medium to high risk is given a rank of 3 as opposed to 1, because compared to the other factors these locations are not ideal, but they are also not unrealistic to have a refugee camp built there.
	3	Medium to High Risk (30-40)	Source: World Resources Institute (Sheffield and Wood)	3	Medium to High Risk (30-40)	Source: World Resources Institute (Sheffield and Wood)
Interannual Water Variability Risk Factor	10	Low to medium (0.25-0.5)	Inter-annual variability measures the variation in water supply between years. The variation is calculated as the standard deviation of annual total water in Uganda catchment areas divided by the mean of total water from the years 1950-2008. The indicator scores were created by the World Reosurces Institute. As is the case with the drought risk factor, the high riskfor interannual water variability is given a rank of 3 as opposed to 1. This is because compared to the other factors these locations are not ideal, but they are also not unrealistic to have a refugee camp built there.	10	Low to medium (0.25-0.5)	Inter-annual variability measures the variation in water supply between years. The variation is calculated as the standard deviation of annual total water in Uganda catchment areas divided by the mean of total water from the years 1950-2008. The indicator scores were created by the World Reosurces Institute. As is the case with the drought risk factor, the high riskfor interannual water variability is given a rank of 3 as opposed to 1. This is because compared to the other factors these locations are not ideal, but they are also not unrealistic to have a refugee camp built there.
	5	Medium to high (0.5-0.75)		5	Medium to high (0.5-0.75)	
	3	High (0.75-1.0)	Source: World Resource Institute Aqueduct; NASA GLDAS-2	3	High (0.75-1.0)	Source: World Resource Institute Aqueduct; NASA GLDAS-2

Factor	Classification					
	Scenario 1		Explanation/Source	Scenario 2		Explanation/Source
	Rank (1-10)	Classification		Rank (1-10)	Classification	
Elevation	10	391-661m	The elevation was separted based on perceived differences in functional accessibility to suitable water. Elevation higher than 1200m is considered poor because intakes for two major pipelines are located at approximately 1100m elevation. High elevation has few water points, whereas low elevation has many water points. Elevation <1200m was divided into 3 equal intervals.	10	391-661m	The elevation was separted based on perceived differences in functional accessibility to suitable water. Elevation higher than 1200m is considered poor because intakes for two major pipelines are located at approximately 1100m elevation. High elevation has few water points, whereas low elevation has many water points. Elevation <1200m was divided into 3 equal intervals.
	8	661-931m		8	661-931m	
	6	931-1200m		6	931-1200m	
	1	>1200m	Source: "Mapping Accessibility to Water Supply in Rural Uganda" (Clark University)	1	>1200m	Source: "Mapping Accessibility to Water Supply in Rural Uganda" (Clark University)
Slope	6	0-2% (0-1.15 degrees)	The slope should be gentle, between 2% and 5-6% gradient for proper drainage, gravity water distribution, and agricultural opportunites. Steep slopes (10% and above) are difficult and costly to develop and should be avoided. Flat sites (0-2%) often face drainage problems and are likely to become marshy in the wet season.	6	0-2% (0-1.15 degrees)	The slope should be gentle, between 2% and 5-6% gradient for proper drainage, gravity water distribution, and agricultural opportunites. Steep slopes (10% and above) are difficult and costly to develop and should be avoided. Flat sites (0-2%) often face drainage problems and are likely to become marshy in the wet season.
	10	2-5.5% (1.15-3.15		10	2-5.5% (1.15-3.15	
	8	5.5-10% (3.15-5.71		8	5.5-10% (3.15-5.71	
	2	10-25% (5.71-14.04 degrees)		2	10-25% (5.71-14.04 degrees)	
	masked	>25% (>14.04 degrees)	Source: Norwegian Refugee Council(NRC)/The Camp Management Project	masked	>25% (>14.04 degrees)	Source: Norwegian Refugee Council(NRC)/The Camp Management Project
Safe Water	10	82-95%	The Safe Water Coverage dataset provides the percent of the population in a district that has access to safe water. Natural Breaks was used to givide the data in 5 classes. The districts with the largest percentage of its people having access to safe water was given a 10.	1	0-17%	The Safe Water Coverage dataset provides the percent of the population in a district that has access to safe water. Natural Breaks was used to givide the data in 5 classes. The districts with 43-61% of its population having access to safe water was given a 10 because we believed these districts would benefit the most from having new forms of safe water available. The districts with the lowest percentage was not given the highest rank because it would be too difficult for UNHCR to provide safe water to that many people.
	7	62-81%		4	18-42%	
	4	43-61%		10	43-61%	
	2	18-42%		7	62-81%	
	1	0-17%		4	82-95%	
Distance from Borders	10	20-50 km	Some refugee camps, like the famous Kakuma, are about 90km inland. Literature says this helps keep refugees safe from conflict, but often they are unwilling to settle that far from home, and the distance from international borders can cause logistical challenges. In the case of Sierra Leone, many refugees along the border (in Guinea at distances less than 12km from home) still expereinced enough violence from rebels that they chose to go home stating they would rather die at home than at Guinea. Refugees are likely to find similar cultures closer to borders and can still have some connection to home when closer, but still need to be safe, so the 20 to 90km range is most ideal.	10	20-50km	Some refugee camps, like the famous Kakuma, are about 90km inland. Literature says this helps keep refugees safe from conflict, but often they are unwilling to settle that far from home, and the distance from international borders can cause logistical challenges. In the case of Sierra Leone, many refugees along the border (in Guinea at distances less than 12km from home) still expereinced enough violence from rebels that they chose to go home stating they would rather die at home than at Guinea. Refugees are likely to find similar cultures closer to borders and can still have some connection to home when closer, but still need to be safe, so the 20 to 90km range is most ideal.
	7	50-90 km		7	50-90km	
	4	12-20 km		4	12-20km	
	4	90-185 km		4	90-185km	
	1	0-12 km	Source: http://www.fmreview.org/sites/fmr/files/FMRdownloads/en/FMRpdfs/FMR03/fmr307.pdf	1	0-12 km	Source: http://www.fmreview.org/sites/fmr/files/FMRdownloads/en/FMRpdfs/FMR03/fmr307.pdf
Landuse	10	Mossaic Forest/Savanna, Open grassland with sparse shrubs, Sparse grassland	Grassland was chosen as the most suitable land to build a camp on because the area is open and easy to clear areas for structures. The forest areas in Uganda were given a lower classification because it takes time and effort to deforest an area before building a camp. Cropland was also given a low ranking because the Ugnada government would not be willing to set aside areas used for producing food. Swamp land was given the lowest ranking because of its drainage issues and flooding risk.	10	Mossaic Forest / Savanna, Open grassland with sparse shrubs, Sparse grassland	Grassland was chosen as the most suitable land to build a camp on because the area is open and easy to clear areas for structures. The forest areas in Uganda were given a lower classification because it takes time and effort to deforest an area before building a camp. Cropland was also given a low ranking because the Ugnada government would not be willing to set aside areas used for producing food. Swamp land was given the lowest ranking because of its drainage issues and flooding risk.
	8	Deciduous shrubland with sparse shrubs, Open deciduous shrubland		8	Deciduous shrubland with sparse shrubs, Open deciduous shrubland	
	4	Submontane forest (900-1500m), Mosaic Forest/Croplands, Deciduous woodland, Croplands		4	Submontane forest (900-1500m), Mosaic Forest/Croplands, Deciduous woodland	
	1	Montane forest (>1500m), Swamp bushland and grassland		1	Montane forest (>1500m), Swamp bushland and grassland, Croplands	
	Masked	Closed land, Waterbodies, Cities		Masked	Closed land, Waterbodies, Cities	

Masking Out Unsuitable Locations

Creating a mask means indicating to the GIS program that a certain area should be removed from analysis. Essentially, we are creating blind areas for the program to ignore. As shown in the reclassification table above, some areas within the geographical boundaries of Uganda were deemed completely unsuitable for refugee placement. The table below outlines the factors that had masked values and the reasons for each value being masked.

Factor	Masked Value	Reason for Mask
Flood Risk	"Extremely High"	Because infrastructure for refugee camps is often composed of tents and other transient structures, locations with high flood risks would pose a great danger to refugees in such areas, and would create a great challenge for UNHCR to constantly adapt to changing conditions due to flooding.
Soil Type	Peat	Peat soil is unsuitable for building and farming, and would thus make it difficult to create viable settlements on such land.
Slope	>25%	Areas with a slope greater than 25% would be challenging to build on, and also create dangers for people living in those areas.
Landuse	Lakes, Rivers, National Parks, Hunting Reserves, Game Reserves	For environmental, legal, and conservation reasons, these areas were deemed unsuitable for settlement building.



Weighting Factors

The factors we view as the most important when considering site selection for a refugee camp are the distance to water, the flood risk, and the slope. Having access to water is one of the first priorities because it is needed to sustain life. If there is no water available in an area, it is unsuitable to build a camp there. Uganda experiences frequent floods, and these natural disasters not only endanger the lives of people, but they also destroy infrastructure. Thus, it is important not to build a camp in high flood risk areas. Slope is given a high weight because structures can only be built on a specific range of slope gradients or else the foundation of the structure will be extremely unstable. The next most important factors are the distances one must walk to reach roads and health centers, followed closely by the distance to education facilities. Having walkable access to roads, health centers and schools is crucial because refugees typically have no means of transportation besides walking, and there is a certain threshold in which people are willing and capable of walking.

Weights of Factors		
Factor	Scenario 1: Existing Community Infrastructure	Scenario 2: New Camp Infrastructure
Distance to Water	0.15	0.15
Flood Risk	0.15	0.15
Slope	0.15	0.15
Distance to Roads	0.075	0.075
Distance to Health Centers	0.075	0.025
Distance to Education Facilities	0.05	0.025
Population Density	0.05	0.05
Poverty Density	0.05	0.1
Drought Risk	0.05	0.05
Landuse	0.05	0.05
Distance to Towns	0.025	0.025
Soil Type – Food Suitability	0.025	0.025
Interannual Water Variability Risk	0.025	0.05
Elevation	0.025	0.025
Safe Water Coverage	0.025	0.025
Distance from Borders	0.025	0.025

Drought risk was given a lower weighting factor than flood risk because the drought data only provided two categories of risk for Uganda and the entire country was almost uniform, thus the factor did not provide too much information. Safe Water Coverage similarly was given a low weight because it did not provide precise information for all locations in Uganda since the data was broken down into district. This meant that each district was assumed to have the same safe water coverage which is not always the case. Elevation was given a low weight because the weather conditions in Uganda are neutral and do not change drastically at higher elevations.

The only changes we made in the weighting of factors from Scenario 1 to Scenario 2 was lowering the weight for distance to health centers and education centers, and raising the weight of poverty density. In Scenario 2 we are assuming that the UNHCR will be willing to build new schools and health centers, which is why the distance to the current facilities are not as important. The poverty density plays a greater role in this scenario because the goal is to help not only the refugees, but also the Ugandan citizens who could are currently without some aspects of social infrastructure. The remaining factors kept the same weight.

Raster Calculator

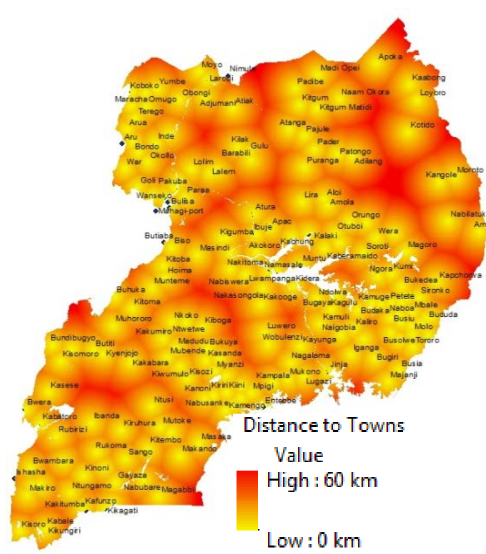
All sixteen factors were combined together using the formula below to create a map that shows the best locations to build a refugee camp in Uganda. By assigning weights to the factors, the map with the 16 factors compiled together will have a score from 1-10 for every 0.5 square kilometers in Uganda that was not initially masked out.

(Population Density*.05) +(Poverty Density*0.05) +(Distance to Towns*0.025) +(Distance to Water*0.15) +(Distance to Roads*0.075) +(Distance to Health Centers*0.075) +(Distance to Education Facilities*0.05) +(Soil Type*0.025) +(Flood Risk*0.15) +(Drought Risk*0.05) +(Interannual Water Risk*0.025) +(Elevation*0.025) +(Slope*0.15) +(Safe Water Coverage*0.025) +(Distance from Borders*0.025) +(Landuse*0.05)
= Scenario 1 Raster

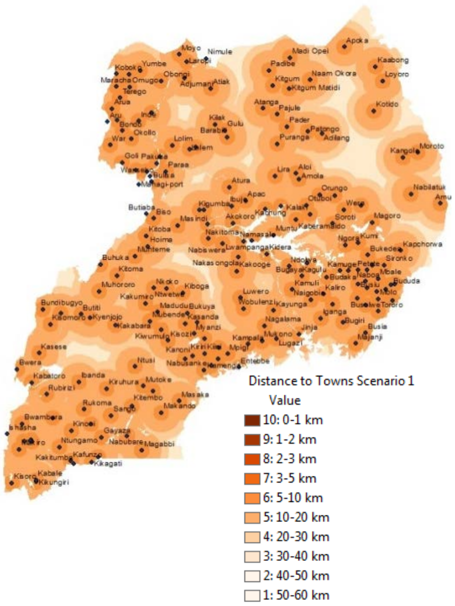
Scenario 2 was calculated in a similar way as Scenario 1, except the weights and classifications for some of the factors changed.

Data Processing Example

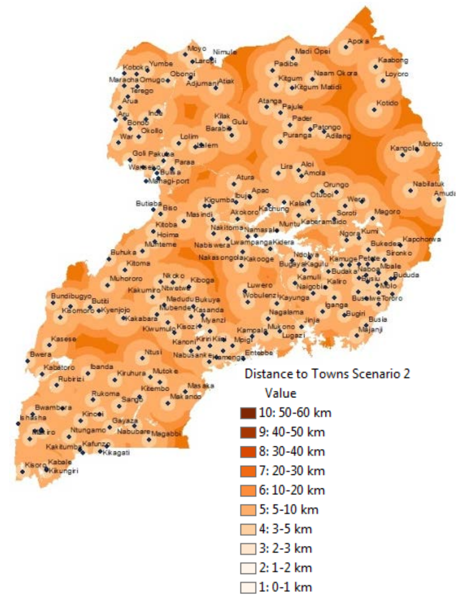
This is an example of the steps that went into creating a map for Distance to Roads. The data collected was GPS locations of the towns in Uganda, which were overlaid onto a map of the country. Next the mask discussed above was used to remove all areas deemed unsuitable to build a camp at. The Euclidean Distance tool in ArcMap was used to measure the distance of every point in Uganda to the nearest town. As is shown in the map below, the furthest point away from a town in Uganda is 60 km. Finally, the distances were reclassified based on the classifications predetermined for each scenario and two maps were created.



Scenario 1: Existing Community Infrastructure



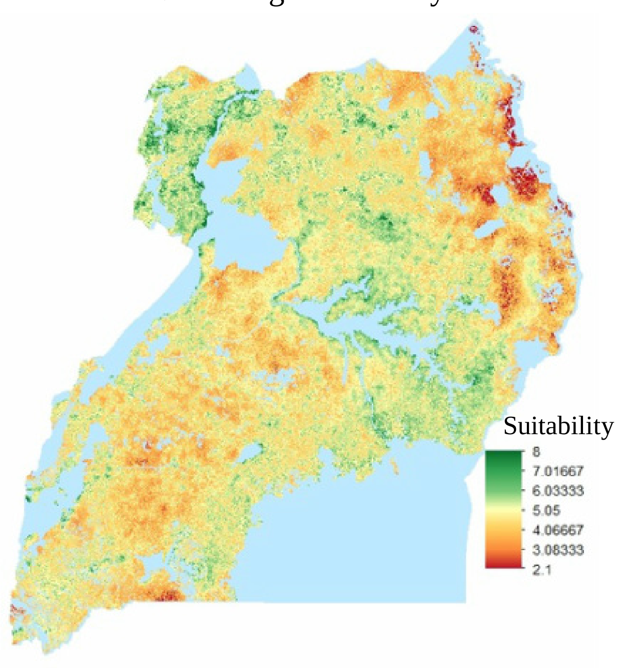
Scenario 2: New Camp Infrastructure



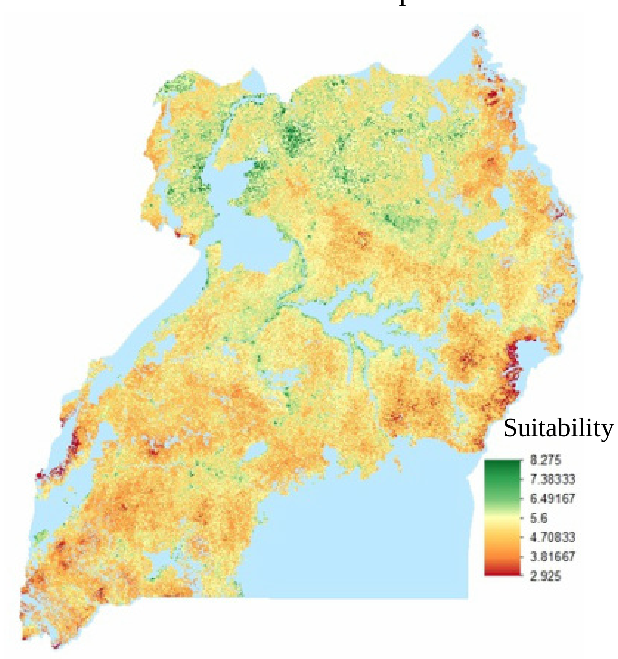
RESULTS

Below are the final maps for our two scenarios. The distinct difference between the two maps is evidence of a successful methodology. The green to red color scale indicates a spectrum of good to bad areas to build camps. It is important to note that while we ranked each factor on a scale of 1-10, our lowest value was 2.1 and our highest was 8.275, indicating that no location is perfect and no location is without some benefits.

Scenario 1: Existing Community Infrastructure

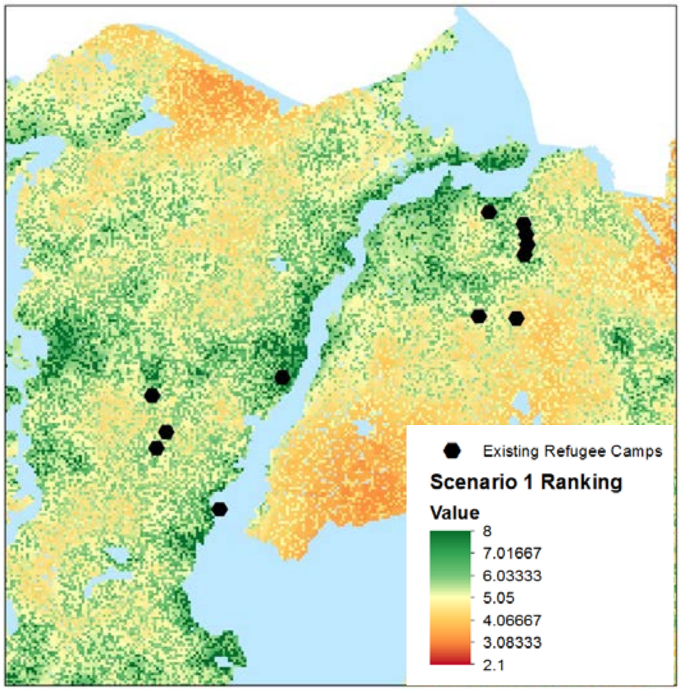


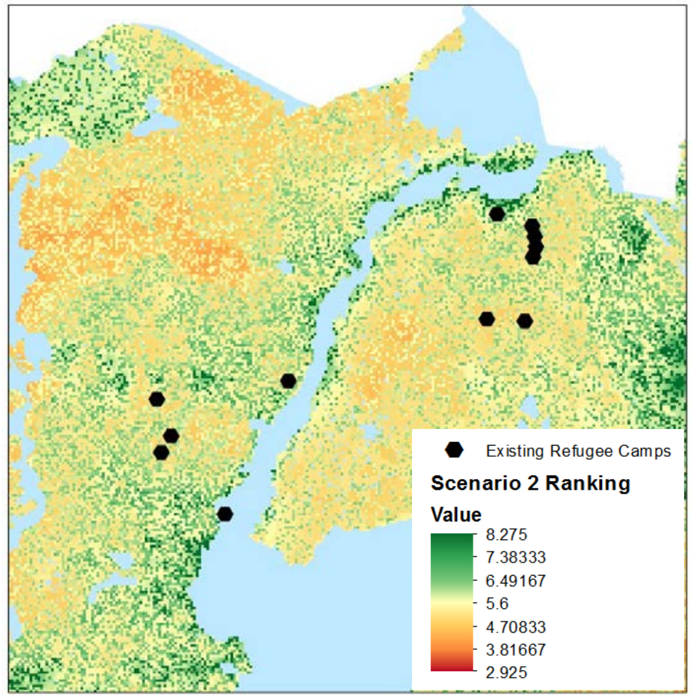
Scenario 2: New Camp Infrastructure



Maps of all 16 factors are shown in the Appendix.

The results from the GIS based methodology were compared to existing refugee settlements in Uganda. As shown in the maps below, the existing camps are located in areas that are green in the results of Scenario 1, and are located in the yellow areas of Scenario 2.





The following link will take you to an interactive map where you can see all 16 factors on one map and switch the layers on and off.
http://www.arcgis.com/home/webmap/viewer.html?webmap=3ef387597c6547c8aa7cf0ec52c40cb4&extent=28.5283,-2.1496,40.5363,4.3386

This second link will take you to a web application where you can see the results of the two scenarios and have the ability to zoom in and out of locations.
http://stanford.maps.arcgis.com/apps/Compare/storytelling_compare/index.html?appid=e87e780b44c8489a8f0c92d33fe0201e

CONCLUSIONS

We conclude that the methodology created in this project was successful in determining the optimal site selection for refugee camps in Uganda based on the two distinct scenarios. As shown in the map results for the two scenarios, there are some areas that appear to have the same suitability score for each scenario, and other areas that have different scores for the existing community infrastructure scenario and the new camp infrastructure scenario. This is the case because only some of the factors changed classification between the two scenarios. For example, all of the environmental factors, such as flood risk, had the same classification and it was only the social factors, such as distance to education facilities, that changed.

This methodology can easily be applied to other countries. One unique thing about the project is that the methodology is flexible and it allows an analyst to decide which factors to include, how to classify each factor, and what weight each factor should receive when deciding on the optimal locations. Any of those three steps can be altered and the analyst will get a different result.

Not only can this project help with creating new refugee camps, but it also provides an opportunity to analyze current camps worldwide. Analysts can investigate different refugee camps using the methodology created and see which factors play an important role in making a refugee camp location a good or poor site. For example, one may find out that an existing refugee camp is optimal in terms of distance to health facilities, but has a poor score in terms of the soil suitability for growing crops. This information can help aid organizations, such as UNHCR, learn from previous camps that have been built.

NEXT STEPS

Future steps for this project would include inviting experts to provide more analysis and details on factors, which would allow different types of data to be used in the selection of optimal site locations for refugee camps. A limitation of this project is that we did not have expertise in all the factors we wanted to include in our analysis. One example is that we wanted to include a factor on the soil suitability for building stable structures. Data of the various soil types existing in Uganda is available, however an expert is needed to interpret the data and classify each soil type by its suitability for building infrastructure on it.

Experts would also be able to improve this project by providing more social analysis, such as the language, ethnicity, and religious affiliation break downs of a country. This would help with camp site selection by determining if there will be any social conflicts between the hosting community and the refugees, and by attempting to place refugees of the same language or religion together.

We hope that this methodology can be applied to other countries and serve as a useful tool for policy makers and humanitarian groups.

LITERATURE REVIEW

- In ***The Application of Geographic Information Systems and Global Positioning Systems in Humanitarian Emergencies: Lessons Learned, Programme Implications and Future Research***, Spiegel and Gerber looked at the use of GIS in Humanitarian Emergencies, and found that the inclusion of GIS information allowed humanitarian workers to be better equipped in responding to emergencies. The authors found that GIS was very useful in assessing hazard, risk and vulnerability as in the Ethiopian drought and food insecurity crises. The authors exhaust several ways in which GIS can be useful in crisis management, and conclude that the only major limitations to using GIS in these scenarios is the cost of equipment and training.

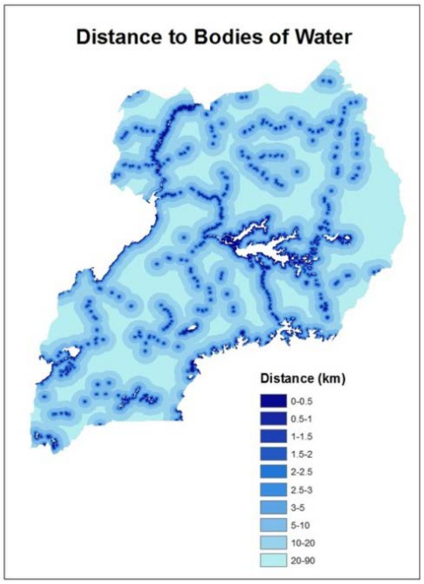
Kibreab, G. (1997). Environmental causes and impact of refugee movements: a critique of the current debate. *Disasters, 21*(1), 20-38.

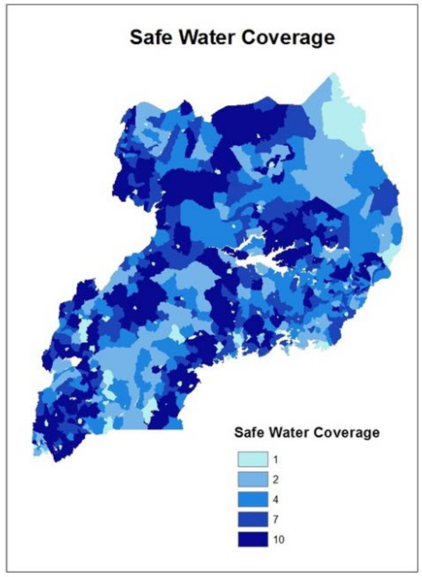
- In ***The need for a digital aid framework in humanitarian relief***, Sargent and Michael find that traditional methods of transmitting information to those needing and delivering aid has been in the telecommunications framework, but the adoption of more thorough web-based technologies like GIS will improve the way information is shared and received. They claim that a general web-based framework can be implemented to help all humanitarian relief organization rather than the current ad hoc applications which are not standardized and are not always available to all parties seeking information.

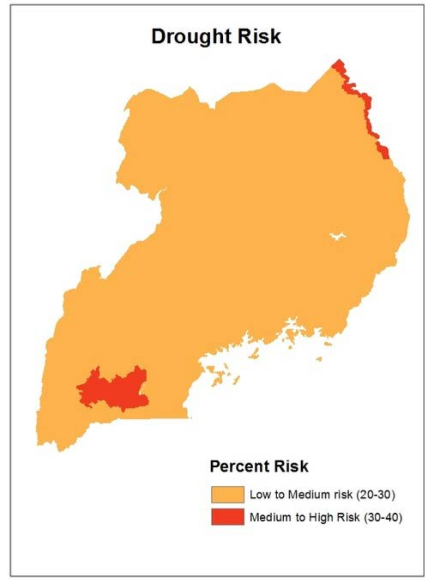
Sargent, J. & Michael, K. (2005). The need for a digital aid framework in humanitarian relief. *Faculty of Informatics-Papers*, 377.

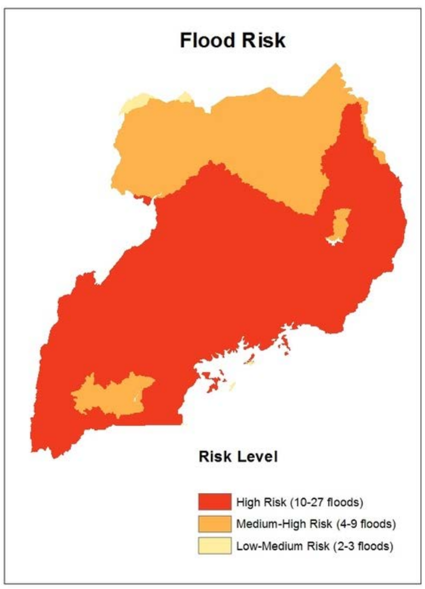
APPENDIX

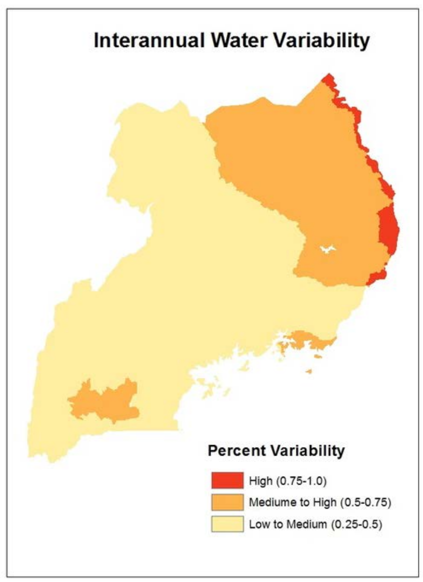
Maps of the 16 factors for Scenario 1:

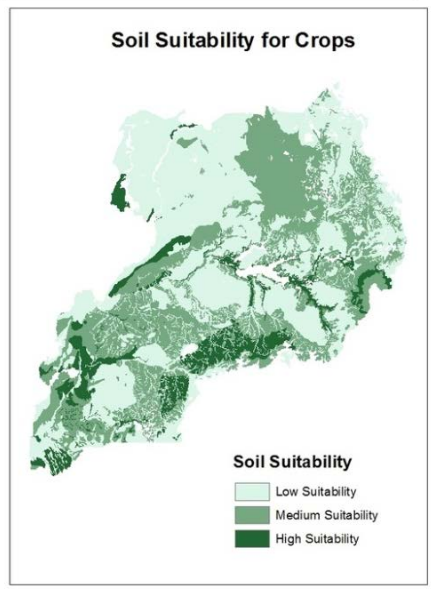


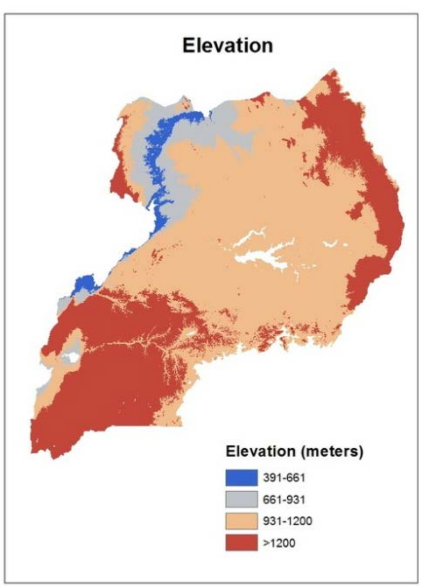


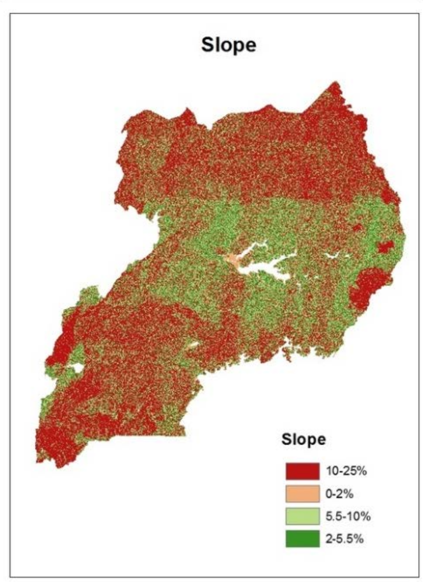


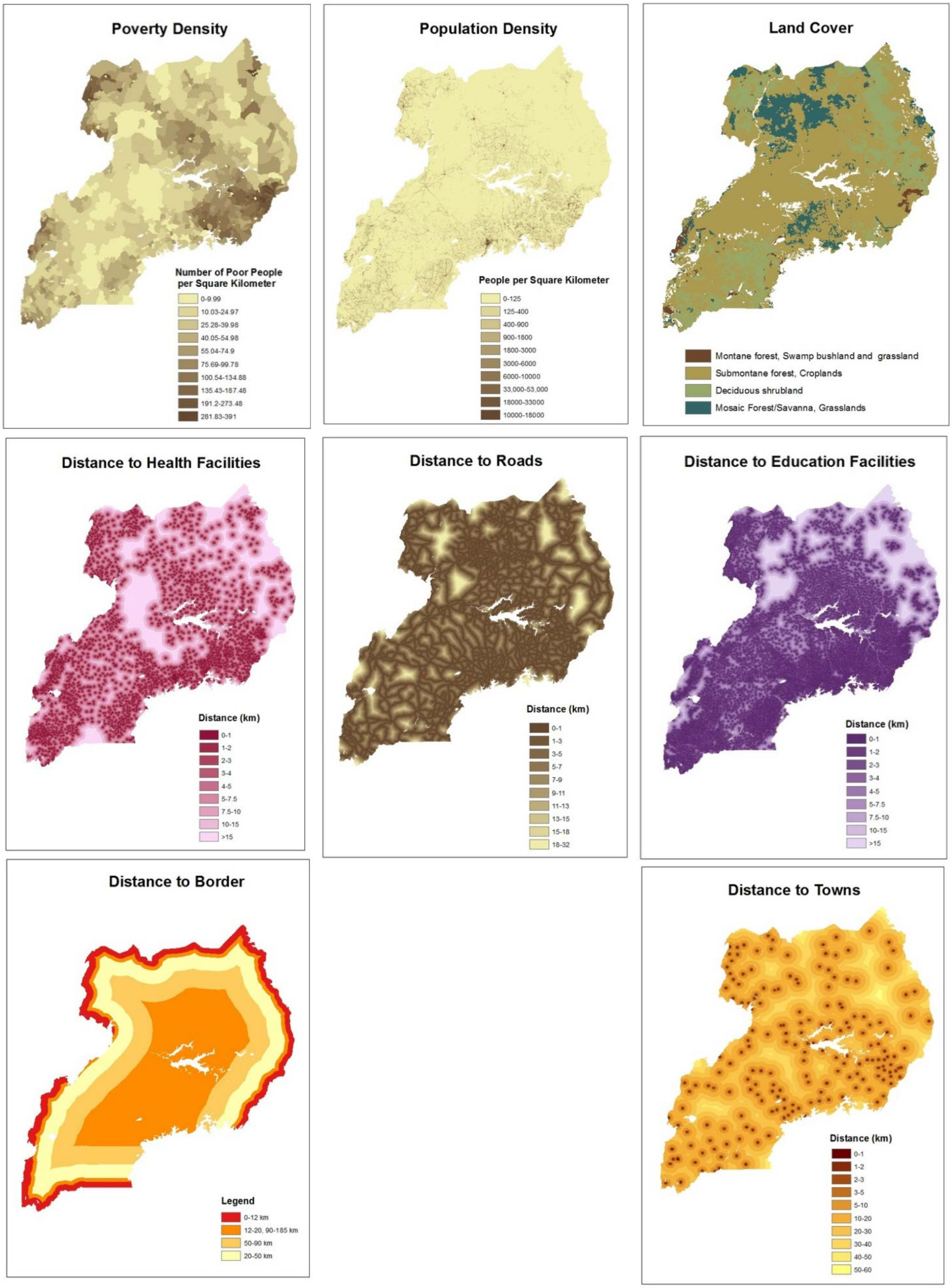











Poverty Density
Number of Poor People per Square Kilometer
0-9.99
10.03-24.97
25.28-39.98
40.05-54.98
55.04-74.9
75.69-99.78
100.54-134.88
135.43-187.48
191.2-273.48
281.83-391
Population Density
People per Square Kilometer
0-125
125-400
400-900
900-1800
1800-3000
3000-6000
6000-10000
33,000-53,000
18000-33000
10000-18000
Land Cover
Montane forest, Swamp bushland and grassland
Submontane forest, Croplands
Deciduous shrubland
Mosaic Forest/Savanna, Grasslands
Distance to Health Facilities
Distance (km)
0-1
1-2
2-3
3-4
4-5
5-7.5
7.5-10
10-15
>15
Distance to Roads
Distance (km)
0-1
1-3
3-5
5-7
7-9
9-11
11-13
13-15
15-18
18-32
Distance to Education Facilities
Distance (km)
0-1
1-2
2-3
3-4
4-5
5-7.5
7.5-10
10-15
>15
Distance to Border
Legend
0-12 km
12-20, 90-185 km
50-90 km
20-50 km
Distance to Towns
Distance (km)
0-1
1-2
2-3
3-5
5-10
10-20
20-30
30-40
40-50
50-60

Works Cited

Brown, Justin, et al. *Factors Influencing the Movement of Syrian Refugees into Lebanon*., 2014. Print.

Crisp, Jeff, et al. "Refugee Camps Reconsidered "Web.

"Data.Ug: Open Data in Uganda "Web.

Forgotten Children of War: Human Rights Report..Print.

Gassert, F., M. Luck, M. Landis, P. Reig, and T. Shiao. 2013. "Aqueduct Global Maps 2.0." Working Paper. Washington, DC: World Resources Institute. Available online at http://wri.org/publication/aqueduct-global-maps-20.

Kennedy, James. *Towards a Rationalisation of the Construction of Refugee Camps*. Katholieke Universitiet Leuven (ASRO), 2004. Print.

Meehl, Jay. "Using GIS and Other Location Based Tools for the Registration, Design, Maintenance, and Mapping of Refugee Camps." Department of Resource Analysis St. Mary's University, Print.

"Open Source for Africa: Data for Uganda "Web

"Norwegian Refugee Council - CM Toolkit - Camp Management Toolkit "Web.

"Refugee camps on the border: A recipe for disaster in West Africa" Web.

"UNHCR - Uganda "Web.

"UNHCR - Uganda Fact Sheet "Web.

"UNHCR Water Manual for Refugee Situations." 1992. Web.

Williams, K. G. "Spatial Analysis and GIS for Planning in Developing Countries; Case Studies from Africa: Mauritius and Kenya " Institution of Planning Studies University of Nottingham, Print.

Yang Yang, Wang, and Joe Masselink. "Mapping Accessibility to Water Supply in Rural Uganda." *Clark University*. Print.