Model for Siting Coffee Washing Stations in Rwanda

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Coffee Washing Station Siting Model

Background

As Rwanda recovers from the devasting genocide of 1994, the development of new sources of national revenue assumes critical importance. In the past, coffee had been an important export crop, but the quality of the final product was poor because of the lack of modern processing methods and facilities, despite the high quality of trees and perfect growing conditions. With assistance from USAID, a project team of leading American agricultural universities was created to analyze, evaluate, and test measures that could develop a viable coffee producing sector.

This team, the PEARL project, concluded that the best strategy targeted the production of extremely high-quality specialty coffee, a market sector that could provide good economic returns, and was less volatile than the general coffee market. Coffee was already grown in the area in small plots by individual farmers, in addition to food crops grown largely for personal consumption, so elevating coffee to a higher financial yield would not add to food vulnerability within the country.

The team concentrated initially on growing practices and organizational issues. At the same time, a pilot project was started in the nearby Maraba district, possibly the poorest economic region in the area. A cooperative of coffee growers was formed, and plans were created to build a coffee washing station(CWS). These facilities use spring water to remove the fruity pulp from the coffee cherries, separating out the beans that are then dried and stored for market. The process is semi-automated, and allows for several quality control methods to be employed to sort the coffee into various grades.

The Maraba Coffee Washing Station

The pilot was a runaway success. The Maraba Co-op, which started with 20 members grew to 1,500 in less than two years, and incomes and other quality of life indicators improved dramatically. This led to increased national interest in building more CWS to replicate the financial miracle. Potential investors in these additional CWS facilities, however, lacked understanding of the critical success factors in siting and constructing these structures. The supply of investment capital in Rwanda is rather limited, and it is very important that it be used wisely and efficiently. Building a CWS in an inappropriate location can easily lead to enterprises which have no possibilty of financial viability.

The Director of the PEARL Project, Dr. Tim Schilling, asked the Center for GIS (CGIS) at the National University of Rwanda, Dr Michèle Schilling (an extremely convenient resource, since she is his wife), to explore whether GIS could assist in the process of site selection. The current state of that inquiry is the subject of this paper.

Short course in geography of Rwanda:

Rwanda is usually a footnote on maps of Africa. The country comprises about 26,000 square kilometers, equivalent to many counties in the US. It has a population of 8.5 million, making it one of the most densely populated countries in the world (340 per sq. km.). The population is overwhelmingly rural, with a strong urban population only in the capital city, Kigali.

Rwanda geography continued:

Rwanda is known as the land of a thousand hills. The entire country is at a high elevation, ranging from 4,519 meters in the northwest to 950 meters in the southeast. This means that despite its location between 1 and 2 degrees south of the equator, the climate is wonderfully mild. It receives a generous amount of rainfall, and is the source of both the Nile and Congo rivers. The three national parks are shown in dark green.

Politically, the country is divided into 12 provinces, which are subdivided into districts and sectors. In this map, the Butare Province is shown divided into its 10 districts. The Maraba District, colored rose, is labeled.

Objective
Assist the CGIS team to develop GIS analytical tools and methods to advise, regulate, control and monitor Washing Station placement and capacity, determine the capacity of Rwanda's coffee zones to provide sufficient quantities of quality water, sufficient close supply of coffee, energy, road accessibility, and the ability of an area to properly and inexpensively treat washing station effluent.

Model Approach
As Rwanda pursues increased earnings from coffee, and improved quality of life for its farm society, it is critically important that additional coffee washing stations be brought on line. The location of these new stations needs to be carefully planned in order to ensure adequate return on investment, and to avoid overlap with existing facilities.

The first step in developing this model was soliciting expert knowledge from agronomists and others familiar with the problem. This was accomplished through interviews and field visits to coffee association cooperatives, washing stations, and coffee fields. The special nature of the coffee market poses unusual conditions. The opportunity for Rwanda is not for expansion of coffee growing, but for increase in the production of only the highest quality product. The specialty coffee market requires a focus on "Better is better", as against "More is better". It also requires that excess capacity be avoided, since the demand to fill capacity almost inevitably leads to cutting corners with respect to quality. This orientation toward quality and away from increased volume runs counter to most farmers' traditional thinking.

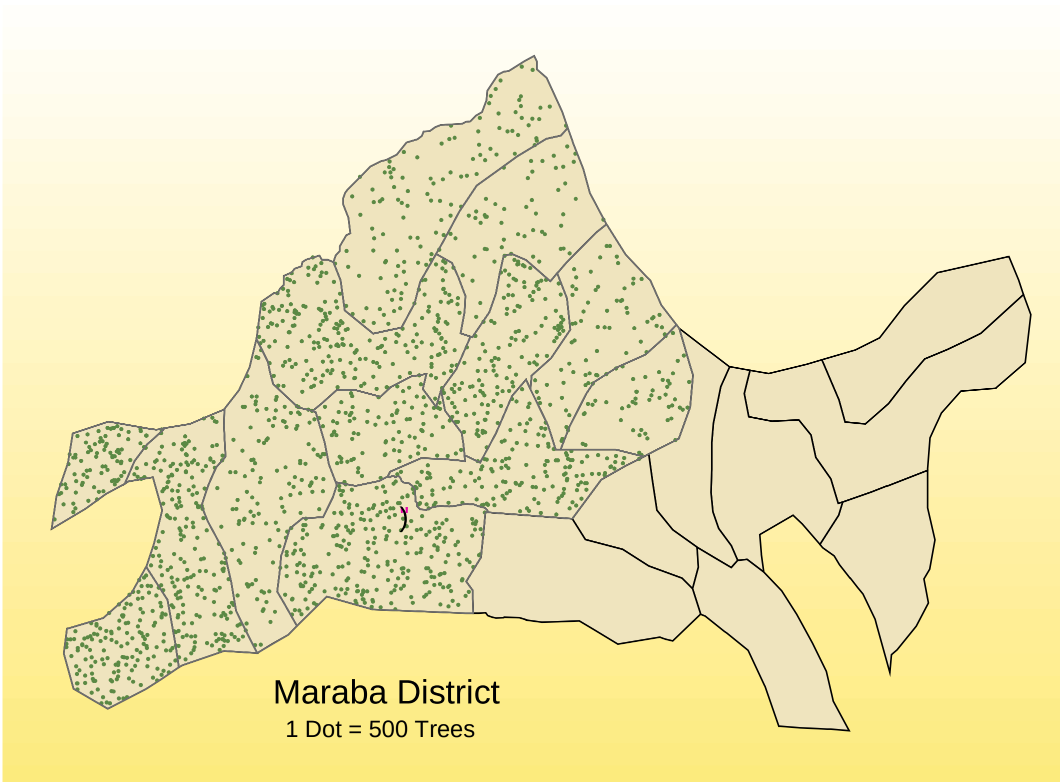
We have attempted to reduce the broad requirements for good washing station location to a series of quite specific tests that, by eliminating undesirable locations, will leave us with a set of promising candidates for further inspection. If this selective siting approach is to work, it will probably be necessary to support it with professional assistance to potential investors, and a restrictive permitting system to enforce compliance. As usual, a carrot-and-stick approach.

We propose a two-step procedure. The first step uses conventional vector-based spatial analysis to identify possible sites. This is a fairly coarse filter, but it has the advantage that most of the undesirable locations can be quickly eliminated. The second step will allow a more sophisticated and detailed examination of sites to select the very best. I have called these the 'macro' and 'micro' models. The micro model will use raster-based analytical techniques. The third step in the site evaluation process should be field-based site visit and evaluation. This will confirm the model results and can discover any anomalies present on the ground, but not properly represented in the data.

The initial pilot data are for the Maraba District. This permits validation using an existing and highly successful case study, and it is the only district for which we currently have elevation data and good field information on springs.

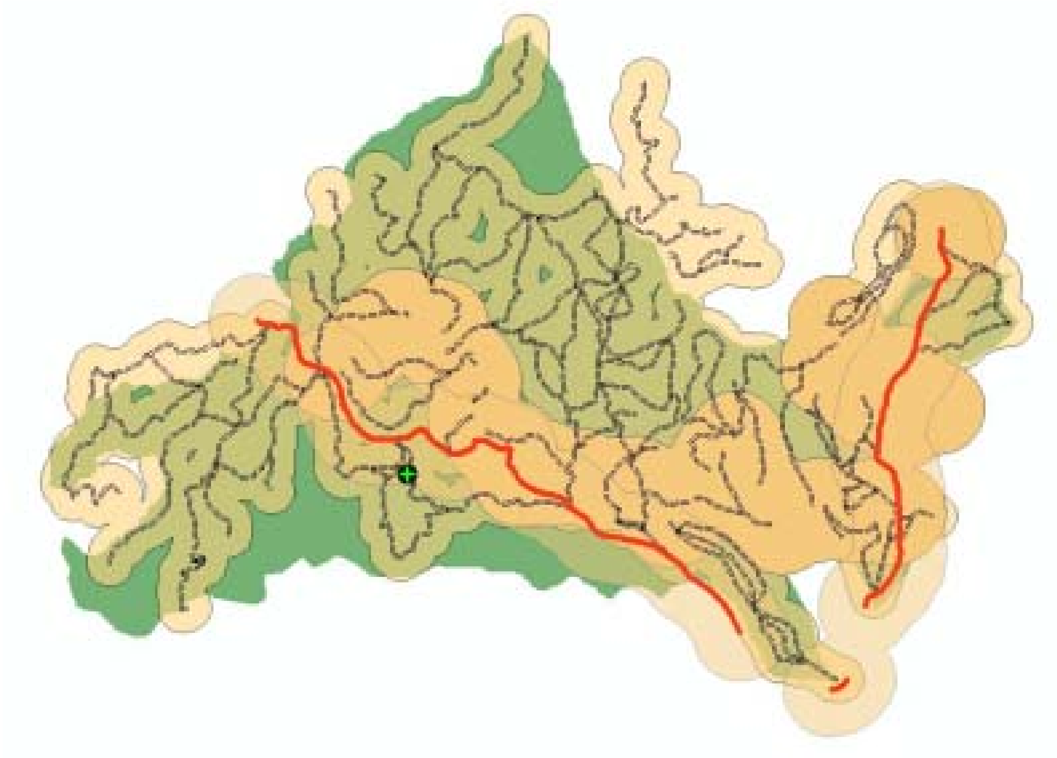
Macro Model

The following steps highlight the reason for the step in bold, and indicate the spatial analysis procedure for implementing it in red.



1. Washing station should be near major coffee-growing area.
This ensures that we concentrate on areas already producing a significant volume of coffee. Coffee trees need at least four years before producing, so this criterion will need to be re-evaulated in the future, but periodic surveys of tree planting are monitored by the national coffee board (OCIR-Café).

Attribute selection
Select sectors with tree count >30,000.



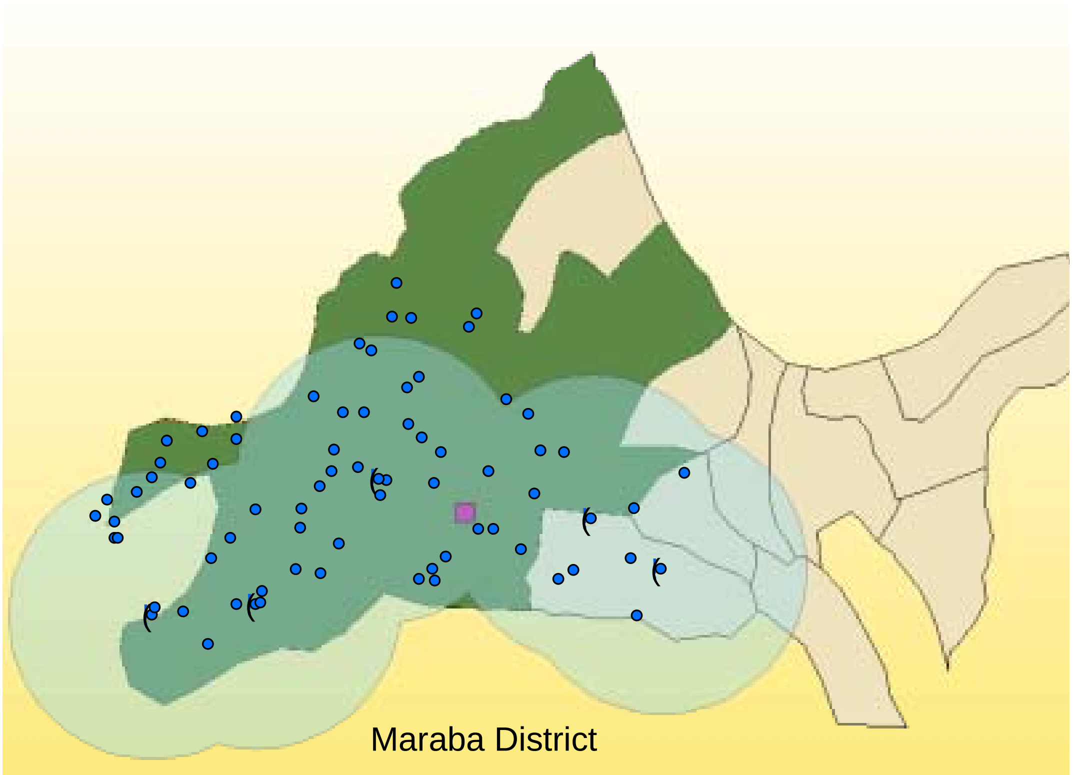
2. Good transportation should be available.

The coffee cherries are transported to the CWS on foot, usually by women carrying about 30 kilos (66 pounds) in plastic buckets on their heads. The need for access to roads is for the final transport of dried parchment coffee to markets. We have included trails in this step, even though they are barely useable by small 4WD trucks. The reasoning is that this stage of the process should be inclusive, and these trails can be improved if such investment is warranted.

Attribute selection. Create buffers.

Select areas within 1 km of paved road or 1 km of unpaved road or 1 km of trail.

Merge transport features, create 1 km buffer.

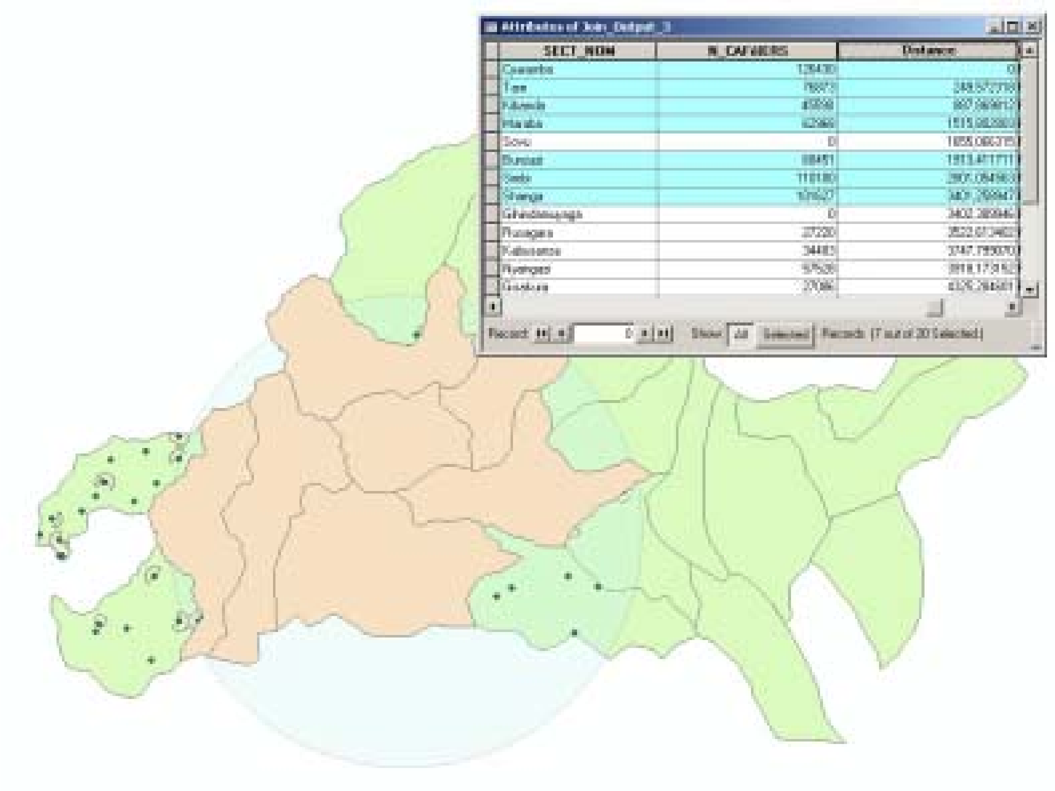


3. Plentiful, clean water should be nearby.

Consider only springs with flow > 0.5 l/second (for small washing station). We are still trying to include all reasonable possibilities. Later, in the micro model, we will look at characteristics such as relative elevation of the spring.

Attribute selection; buffer; export data.

Select springs with adequate flow (>0.5 l/second).
Select areas within 3 km of major spring.
Create 3 km spring buffer. Create new feature class of these major springs



4a. Should not be in the service area of an existing washing station.
Must be outside the service area of any existing washing station, defined by aggregating sectors nearest to each washing station, aggregating tree count until station capacity is reached.

Select by location, sectors nearest washing stations. Open sector table and sort by ascending distance. Use statistics (sum) to find cutoff point.
Assign washing station name, operator name to those in service area,
Clear for unassigned sectors.
Save sectors with named washing station as service area feature class.

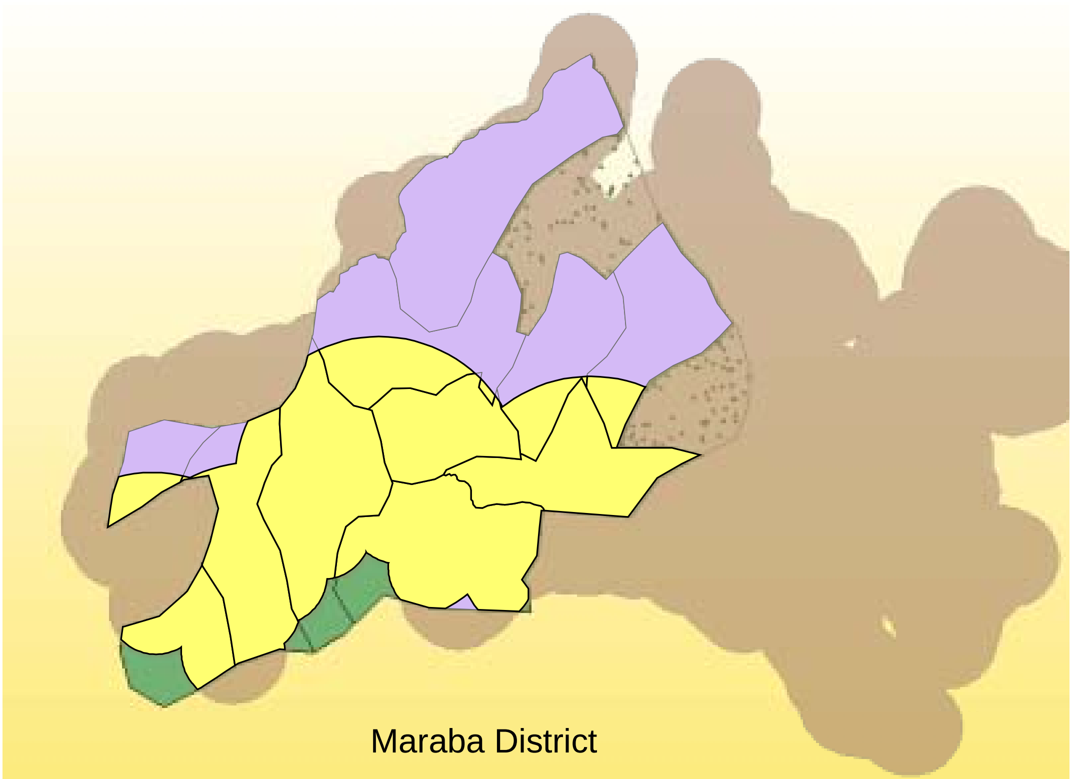
4b. Must be at least 5 km from existing washing station.
If coffee cherries are transported (on foot) more than this distance, about five hours, there is significant risk that mold or mildew will develop, impacting cofee flavor.

This is an alternative method for determining service area, but can be combined with the cumulative distance approach. In any event, it is a good reality check.

Create 5 km buffer around existing washing station.
Use for spatial selection to select sectors completely or partially within buffer.

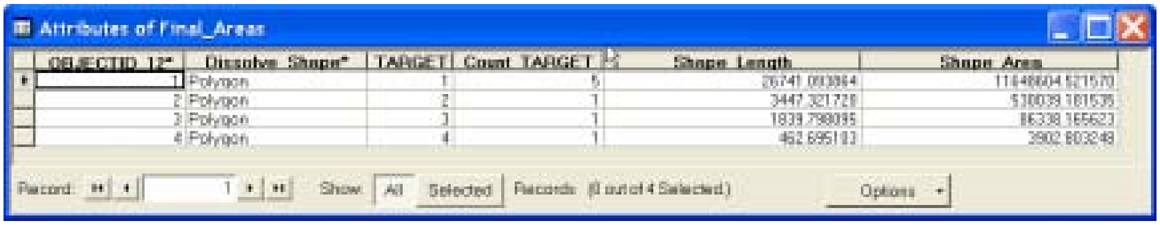
Invoking the Geoprocessing Wizard…

Intersect the buffer polygons for transportation and major springs.
Intersect result with dense coffee-growing sectors.



Create union with Maraba Service Area.
Select polygons outside the service area.

Dissolve adjacent polygons to create new feature class for final target areas.
Delete unneeded fields.


Attributes of Final_Areas

OBJECTID_12*	Dissolve_Shape*	TARGET	Count_TARGET	Shape_Length	Shape_Area
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2	Polygon	2	1	3447.321728	530039.181538
3	Polygon	3	1	1839.798095	86338.165623
4	Polygon	4	1	462.695103	3902.803248

Record: 1 Show: All Selected Records (0 out of 4 Selected) Options

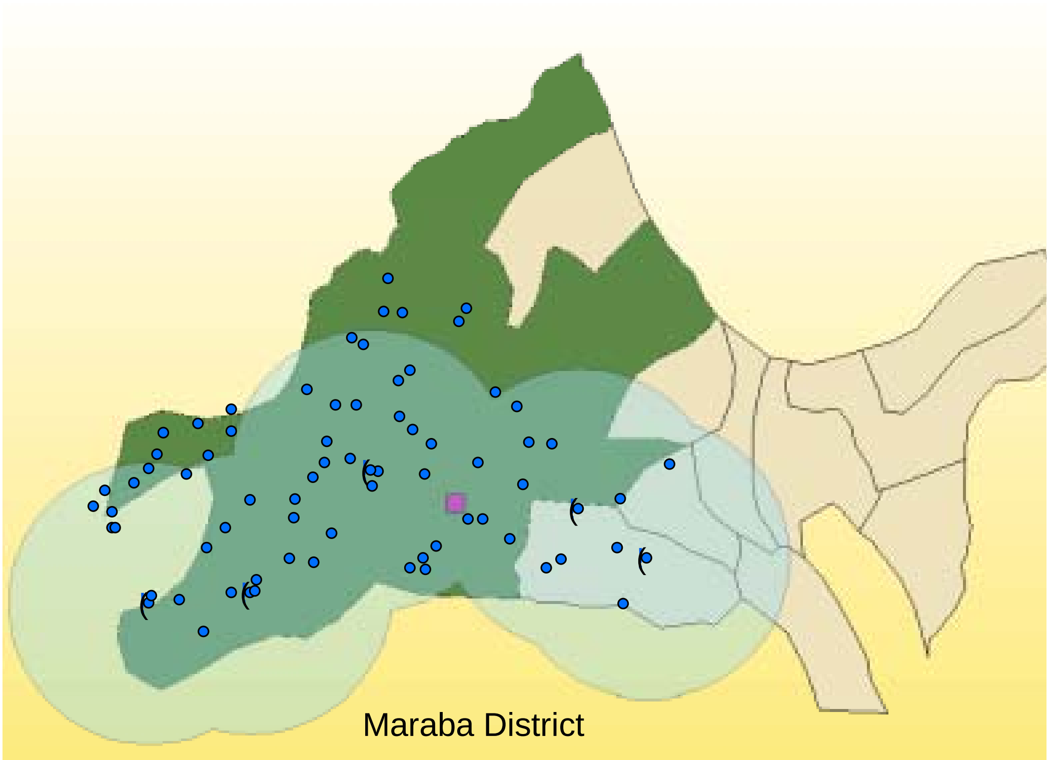
5. Available land should be large enough for a washing station.
Must be at least 4 hectares. We can eliminate potential site polygons that are too small for construction.

Attribute selection.
ShapeArea > 4 hectares

6. Should be at least 10 kilometers from any national park boundary.
This restriction has little impact on potential sites except in the far northwest near the Parc des Volcans; its purpose is to discourage expansion of farming into the park (home of the last mountain gorillas in existence). The conservation effort by the Dian Fossey Gorilla Fund International has achieved remarkable results through well-planned efforts to improve the quality of life for people near the park through public health initiatives, promotion of controlled tourism, and through the creation of employment opportunities that de-emphasize poaching and destruction of habitat by increased farming.

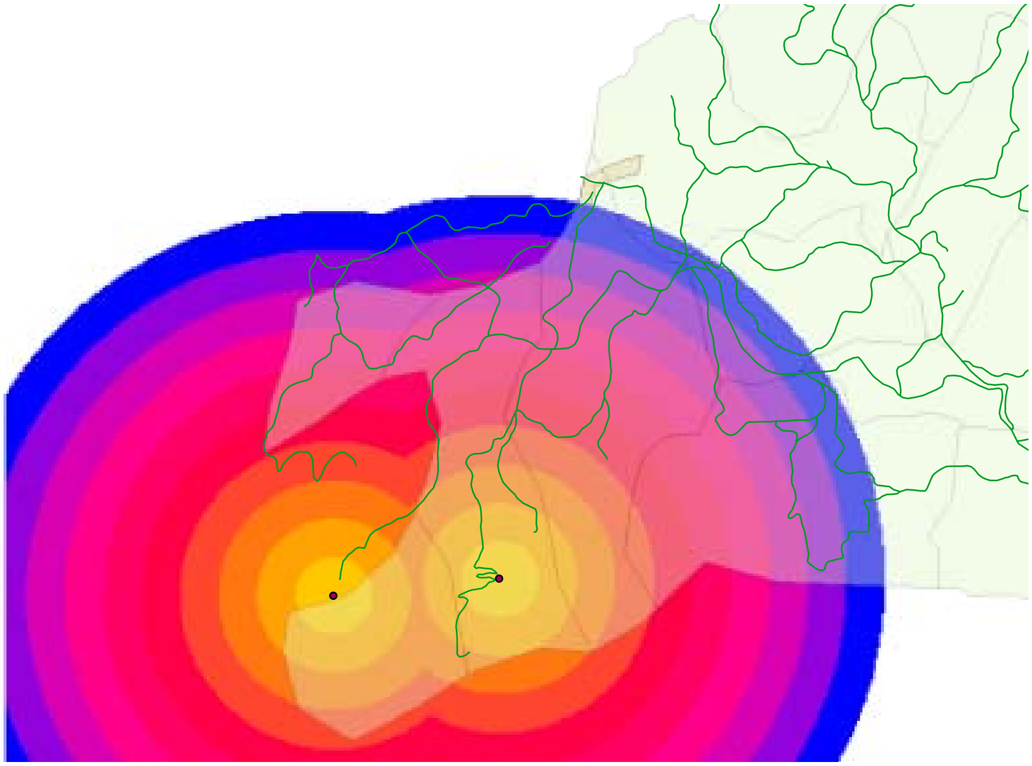
Create 10 km. Buffer.
Remove intersecting polygons.

Micro Model



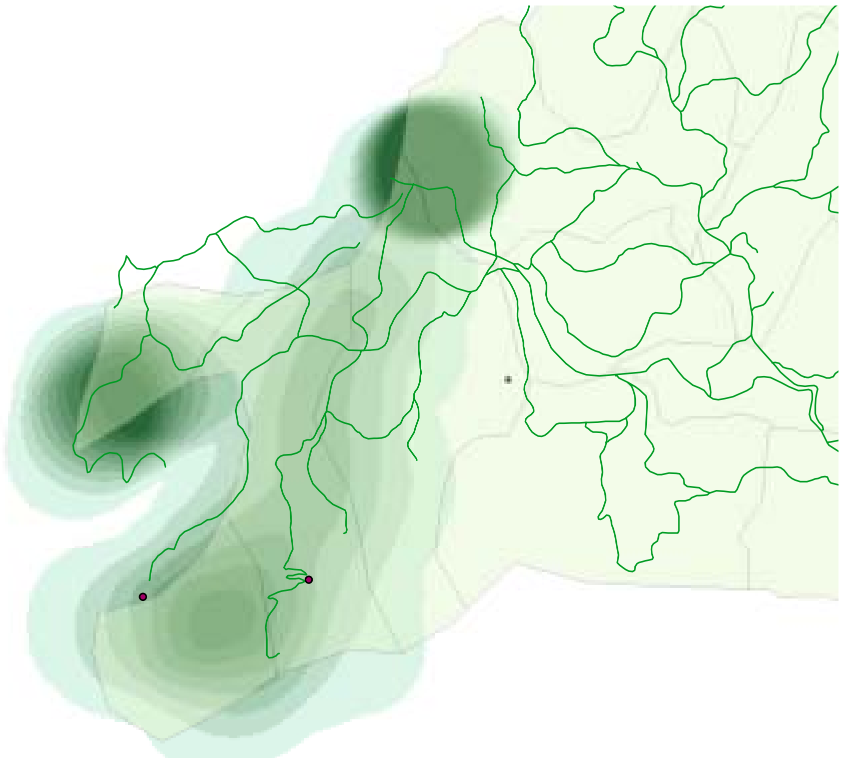
1. Spring should be at least 10 m higher than washing station.
Spring elevation should be measured in same way as DEM derived elevation. This is best achieved by conversion to point raster, then calculation using ((SpringExists > 0) * 3DRasterElev). We did not construct a rule to eliminate potential sites; this was done through later examination.

1. Create TIN from hand-digitized contours (3Danalyst)
2. Create an elevation raster dataset from TIN data with 30m cells.
3. Convert Major Spring feature class (for selected springs) to raster.
4. Assign elevation from raster dataset



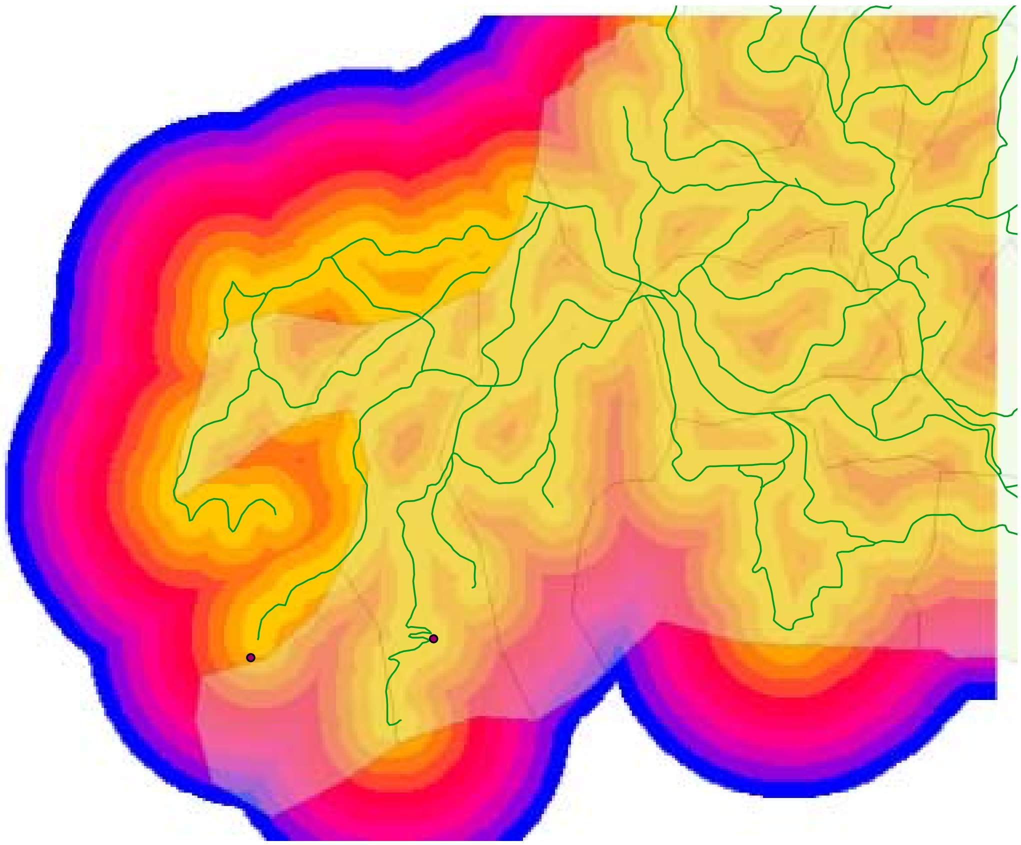
2. Create raster of straight-line distances from springs.
This is a cost consideration. Piping from the spring to the chosen CWS site runs about $1 per meter. This raises the issue of why <u>some</u> dollars are more important than others. Capital funds for this project will likely come from foreign aid; operating funds will be derived from local operations. To maximize the probablity of financial success, the donor agencies concur in initial spending that supports long-term viability.

Create raster using straight line distance calculator.



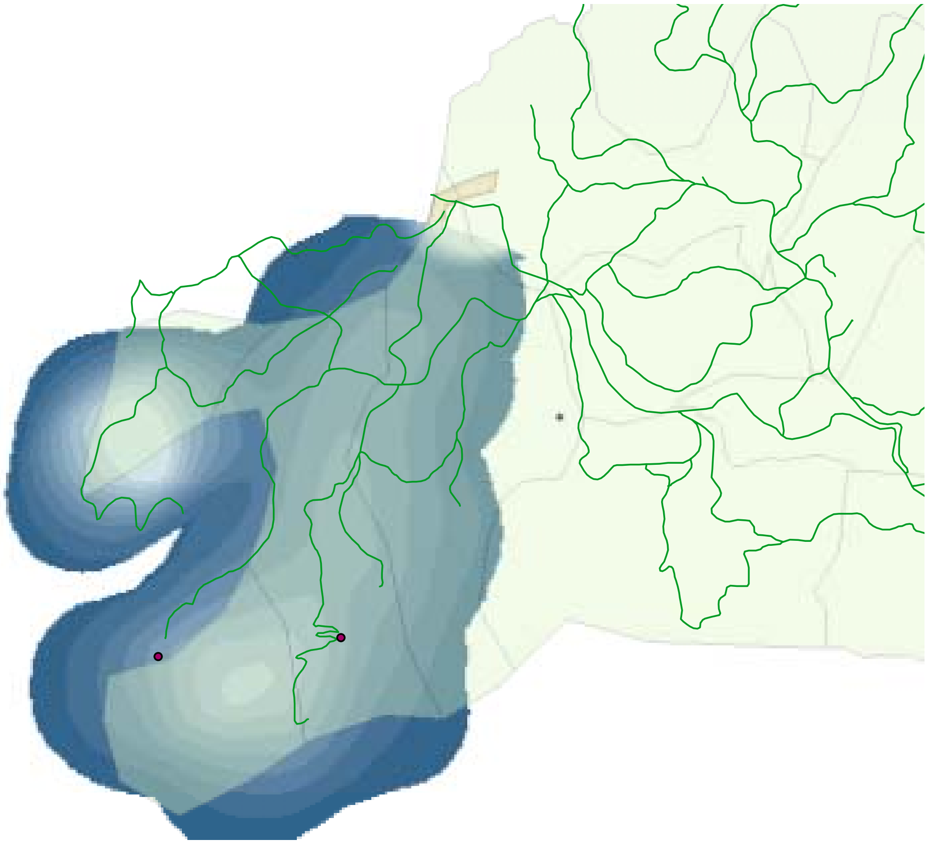
3. Create raster of tree density using SUM neighborhood function.
This is an attempt to measure the number of trees concentrated around each potential site. The labor of piping from the nearest spring and connecting to the nearest road are one-time efforts. The labor of hauling cherries to the CWS is a daily occurrence for 3-4 months each year, so we want to minimize this.

Sum tree density over 30x30 neighborhoods.



4. Create raster of distance from roads.
The cost of connecting to existing trails or roads is also a one-time capital cost. It is mostly labor, and can be started while the CWS is under construction. We assigned it a cost of $2 per meter.

Create a raster of distance from existing roads/trails.



5. Put the three raster layers together using the raster calculator to create a "suitability" raster.

We assigned a weight of 0.2 to the tree density function, 2 to the road distance, and 1 to the spring distance. This is basically intuitive, with input from local experts (Maraba Coop staff).

Calculate result raster.

6. Evaluate site potential using TIN, 3D, ArcScene
There is no substitute for fooling around with the data to test multiple hypotheses. We aso planned a field inspection to check out the site. This required about a dozen “experts”, two 4WD vehicles, a GPS unit, and several hours time.

Recommendations:

1. Refine these models while waiting for the availablilty of the National DEM data.

2. Do field evaluation of the potential sites for the western portion of Maraba district.

3. Create the Service Area polygons for all existing washing stations and any that are in development. Review these service area maps with OCIR-Café and washing station operators.

4. Investigate feasability of combining multiple adjacent springs to simulate a single major spring. Do this for any dense area of trees that cannot be serviced from a major spring.

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