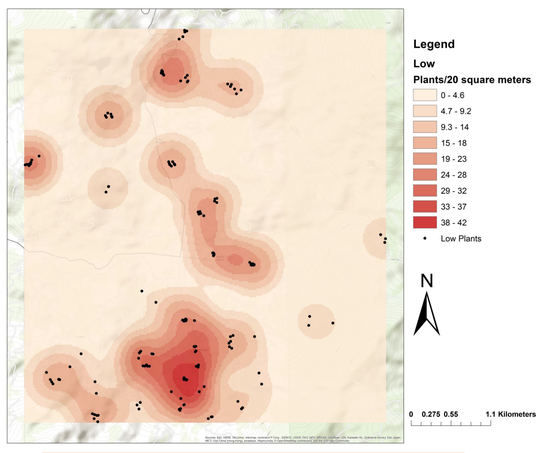
Bean Maps: Spatial Analysis of Potential Coffee Yields in Santa Maria, Costa Rica

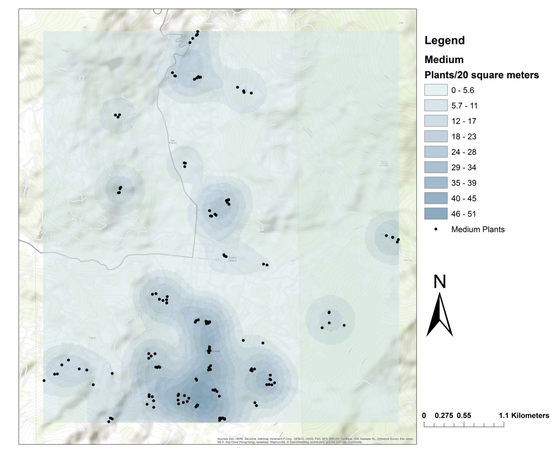
Introduction

Spatial farm traits, such as **slope, altitude and land cover type**, can have a significant impact on **crop yield** and quality. My doctoral research in global change biology addresses factors that affect coffee plant reproduction (yield), including climate, physiological tradeoffs, management practices, and spatial traits. For the present study, I have used ArcMap as a tool to explore the spatial distribution of plant **reproductive *effort*** (potential yield) in Santa Maria de Dota, Costa Rica, with a focus on slope, altitude, and land cover type. Santa Maria is characterized by its high-elevation and climate that are ideal for coffee production, but little is known about **how intraregional spatial variability affects potential yields.**

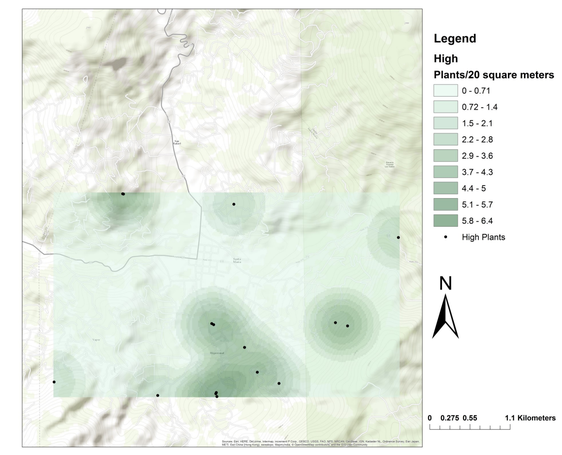
- Are coffee plants **clustered** by the magnitude of **reproductive effort** (high, medium, and low)?
- Is **coffee reproductive effort** (high, medium, and low) related to **slope, altitude, or land cover** type?



Clusters of Sample Plants with **Low** Reproductive Effort



Clusters of Sample Plants with **Medium** Reproductive Effort



Clusters of Sample Plants with **High** Reproductive Effort

Methods

In July and August, 2017, I collected data on reproductive effort of 10 coffee plants on 33 randomly-selected Santa Maria farms (n=330 sample plants). Reproductive effort was quantified as **number of immature fruits per reproductive node** (fruits are ripe in December). The Excel data of plant location and attribute data were geocoded as points. The regional raster tiles of MODIS global land cover and SRTM elevation were used for the analysis. The elevation raster was converted into a slope raster of percent rise. All layers were projected into CRTM05 and rasters were reclassified. A series of **attribute queries** were performed to separate values of reproductive effort into low (a<6 fruits/node), medium (6<a<12 fruits/node), and high (a>12 fruits/node) classes. The plant classes were based on the total range of values (0-20 fruits/node) and evidence that coffee plants can produce 12-20 fruits per node in favorable conditions (Clifford, 2012). Selections were exported into high (n=162), medium (n=152), and low (n=16) plant layers. **Kernel density** on each of the new plant layers with 20 m radii identified clusters of each class. The "**sample**" tool was used to add the raster pixel information to each plant point across the three plant layers. The output tables were used to **quantify** all the points in each raster classification. The data was entered to an excel to determine the percentages of each reproductive class (high, medium, low) that were in each raster class across the three raster layers.

Results

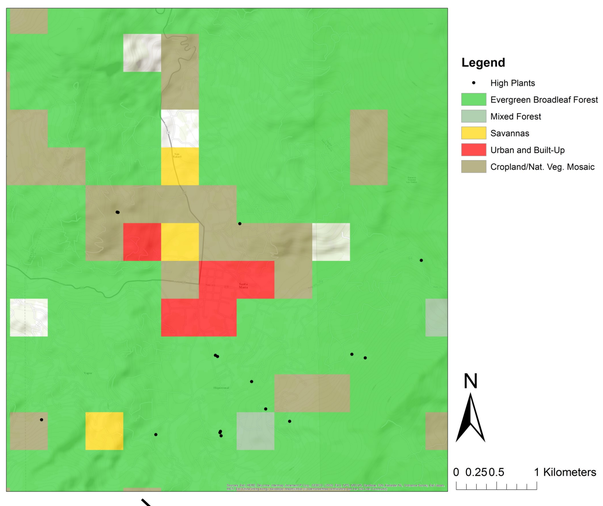
There was substantial **overlap** between the cluster layers, indicating that sample farms had a mix of plants with low, medium, and high reproductive effort. **Low and medium clusters almost entirely overlap**, so only low plants are depicted in the maps below. Spatial patterns in relation to land cover, elevation, and slope were consistent across all three classes of reproductive effort. Therefore, they are more indicative of ***where* coffee is planted rather than differences in potential yield**. The highest proportions of coffee plants occurred at **intermediate elevations between 1600 and 1800m.** There was a pronounced **decrease in all coffee plants as slope increased**, and the significant majority were in the dominant land cover type, **"Evergreen broadleaf forest."** Notably, no high plants were found in "savanna", "urban and built-up", or "mixed forests" land cover types, though at least small percentages of medium and low plants were found in all land cover types. This difference may be due to the much smaller sample size in the high plants, but it will be interesting to monitor in future analyses.

Red box indicates study area

Immature Coffee Fruit

Conclusion

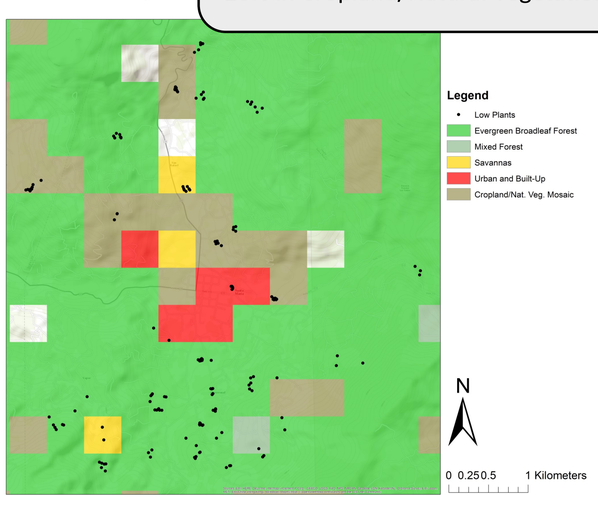
No notable **spatial relationships** were **dependent on reproductive effort** (low, medium, high), but there were **interesting patterns** consistent across **the total sample of coffee plants**. The highest proportion of plants were located in the land cover type "evergreen, broadleaf forest" at intermediate elevations with slopes under 60 percent-rise. With more data and GIS skills, I will perform further analyses with **a) harvest yield and bean quality data, b) multi-year yield variance, and c) intra-regional comparisons.** I am eager to explore if these initial patterns are consistent across temporal and spatial scales.

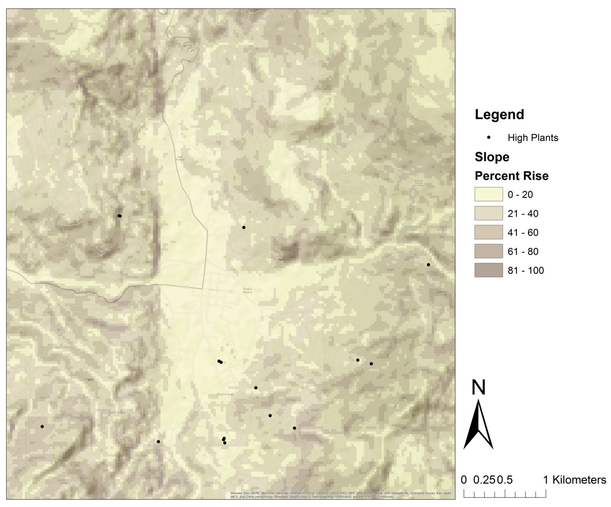


Land Cover

~70% of all plants in Evergreen forest

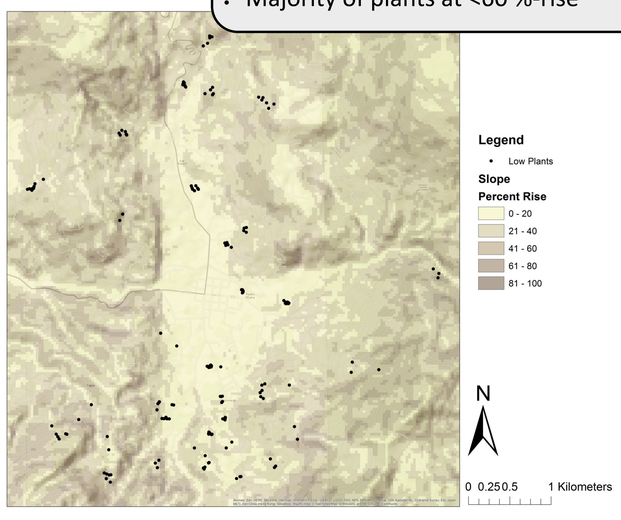
~20% in Cropland/Natural Vegetation mosaic

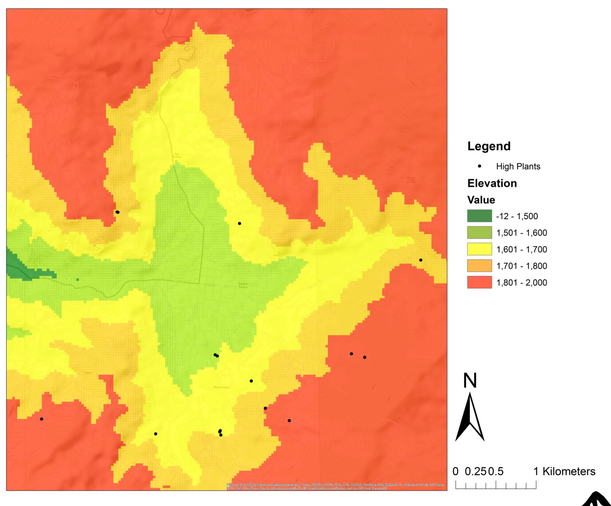




Slope

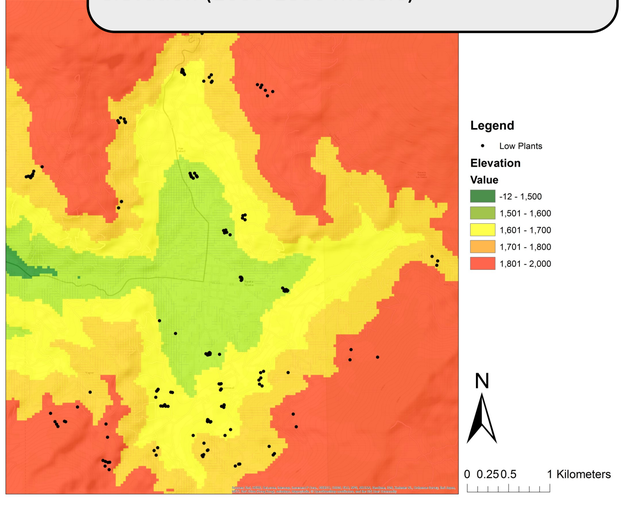
- All plants decrease with increasing slope.
- Majority of plants at <60 %-rise





Elevation

- Majority of all plants are at intermediate elevation (1600-1800 meters)



Tufts

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Sources and References

Global Land Cover Facility, MODIS Land Cover: www.landcover.org

Shuttle Radar Topography Mission (SRTM) 1-arc second

Geographic Coordinate System
Horizontal Datum: WGS 1984
Vertical Datum: Earth Gravitational Model 1996

Costa Rica Transverse Meracator 2005 projection (CRTM05)

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Clipart: (tree) freestockphotos.biz, (slope and elevation) pixabay.com

Photos: author