Designing and Analyzing a Habitat Model of American Ginseng in the Southern United States

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Abstract

American ginseng (*Panax quinquefolius* L.) is a threatened plant harvested for its root, which when dried, can sell for $125-$500 per pound domestically and $1500-$2000 per pound internationally. Starting during the 2012 field season, resource management staff and law enforcement officials at the research study area (omitted for data privacy) began proactive efforts to help protect the plant and catch poachers within the study area's boundary. To aid in the effort of locating potential ginseng growth sites, a habitat model was created consisting of different habitat variables most favorable for ginseng growth and analyzed using point data of known ginseng locations. Statistical analysis was used to examine the legitimacy and usefulness of the model in being an effective tool.

Introduction

American ginseng (*Panax quinquefolius* L.) is a plant that grows in North American eastern deciduous forests, stretching from portions of southern Canada to the Midwest, Southeast, and the Northeast portions of the United States (USDA, 2014). The American Ginseng growth range in North America is provided in Appendix A. Despite the vast coverage in which ginseng grows, the United States Department of Agriculture lists the plant as threatened or endangered in Connecticut, Maine, Massachusetts, Michigan, New Hampshire, New York, North Carolina, Pennsylvania, Rhode Island, and Tennessee (USDA, 2014).

Nineteen States allow ginseng harvest on private lands. Each state has its own regulations for sustainable management of the plant, but generally a plant five years old and with at least three leaves can be harvested. Most state lands and all National Park Service lands prohibit harvesting of wild ginseng while some US Forest Service lands will allow harvesting with a permit (USFWS, 2015).

Ginseng is intensively harvested due to the high price at which its roots can be sold. The price for ginseng roots varies from year to year but Anderson, Anderson, and Houseman (2002) acknowledge that dry ginseng roots can sell from $125-$500 per pound domestically. More recently, the State of Kentucky listed the price of dried ginseng roots in the range of $300-$350 per pound domestically and $1500-$2000 per pound internationally (University of Kentucky College of Agriculture, 2012). Nearly 95% of all ginseng roots harvested within the United States end up being sold to China (Snow and Snow, 2009). Cultivated ginseng can be harvested at any age, but Hu (1976) states prices of cultivated roots are generally much lower due reduced chemical potency.

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Because of the staggering price at which ginseng can be sold, law enforcement efforts have increased within some locations to combat poaching. At Great Smoky Mountains National Park (GRSM), 13,000 plants were seized by Park Rangers over an 18-year period leading up to 2011 (National Parks Conservation Association, 2011). In 2012, resource management staff and law enforcement officials at this project's study area began taking proactive measures to try and reduce ginseng poaching. The study area is combed for ginseng plants and when found roots of plants are exposed and marked with a special dye and metal chip which are both specific identifiers to the study area. This does not simply prevent plants from being extracted, it allows law enforcement officials to prove if plants came from the study area when they make contact with someone with ginseng roots in their possession. Without dye and metal chips, it can be very difficult for law enforcement officials to make a case against an individual suspected of poaching roots.

A report furnished by the US Fish and Wildlife Service in 2000 lists both ginseng dealers and hunters confirming that American Ginseng is increasingly more difficult to find (Anderson *et al.*, 2002). Over-harvesting of ginseng, or any plant, can "drive populations to commercial and biological extinction" (Van der Voort, Bailey, Samuel, and McGraw, 2003). A study by McGraw, Souther, and Lubbers (2010) discusses the difficult recovery ginseng faces after an intense harvest. They focused on two study areas intensely harvested, one in Missouri and one in West Virginia. After five years in Missouri and 11 years in West Virginia, ginseng growth had yet to reach the pre-harvest number of plants. Findings suggest the number in which ginseng is being harvested is greater than the number of wild plants being grown, causing a decrease in the total population of ginseng (McGraw *et al.*, 2010).

When considering the ecological questions within a spatial context, "The environmental education and research potential for GIS applications is substantial" (Snow and Snow, 2009). This research explores the question of whether or not historical ginseng data at the study area can successfully validate the creation of a custom-built ginseng habitat model.

Ginseng Habitat

As with any flora, certain habitat characteristics must be present for ginseng to grow. Soil type, elevation, slope, aspect, and canopy cover can all play a role in achieving suitable growth. Each habitat variable can have a range of values favorable for ginseng growth.

Soils

Nutrient-rich soils with a pH level greater than 5.5 are most suitable for ginseng growth (Rock, Tietjen, and Choberka, 1999). The University of Kentucky College of Agriculture (2012) adds that ginseng tends to grow in soils that are "moist, well-drained, and high in organic matter."

Elevation

In a study (Rock *et al.*, 1999) conducted at GRSM, ginseng was found to grow at lower elevations within the park, ranging from 2160-3620 feet. GRSM and the study area are both within the Appalachian mountain range.

Slope

According to Anderson *et al.* (2002), ginseng is usually found growing on slopes that are 10-40% and as far up to 60%. In the GRSM study, field verification was performed at locations known to have ginseng and observed slope ranged from 8-36% with an average of 24.2% (Rock *et al.*, 1999).

Aspect

Ginseng can grow on any aspect but Snow and Snow (2009) determined north or east orientation is best. Rock *et al.* (1999) found ginseng was typically found growing on aspects to the north, ranging between 354° and 10°. In addition, if west facing slopes or slopes of any other orientation are covered by shade for part of the day, ginseng may grow there as well (Anderson *et al.*, 2002).

Canopy

Excessive amounts of sunlight, or even too much shade, can be detrimental to the lifespan of a ginseng plant. At GRSM, ginseng was found to grow underneath a canopy ranging from 20-70% with an average canopy cover at 61.3% (Rock *et al.*, 1999). The University of Kentucky College of Agriculture (2012) suggests ideal canopy cover for ginseng growth is around 70-80%.

Purpose

Because ginseng is protected within the study area and because of high prices in which the plant's roots can be sold, the protection of ginseng is an ongoing process. The combined effort of searching for ginseng, carefully exposing and marking plants roots and collecting GPS data points is a tedious process requiring increased time and personnel.

This study analyzed different habitat variables to create a predictive model to target areas containing habitat most suitable for ginseng growth. Desired habitat was the result of a weighted sum of five reclassified habitat layers. The weighed sum’s output was reclassified into three categories: least suitable for ginseng growth, suitable for ginseng growth, and most suitable for ginseng growth. Known locations of ginseng plants were obtained to validate the model.

Hypothesis

To test the effectiveness of the model, statistics were used to determine if the sample population of ginseng points came from one of the suitability levels created by the weighted sum of habitat variables. It would be best if sample ginseng points came from the most suitable level of the weighted sum. Therefore, the null hypothesis (H_O) and alternative hypothesis (H_A) were stated as:

- H_O: The sample of ginseng points collected in the study area came from locations considered to be most suitable for ginseng growth according to the model.
- H_A: The sample of ginseng points collected in the study area came from a combination of habitat suitability levels created by the model.

Methods

Data Collection

A Digital Elevation Model (DEM) of the study area was created from the National Elevation Dataset furnished by the United States Geological Survey. Using the Spatial Analyst within ArcGIS, Slope and Aspect raster datasets were derived from the elevation data. Soils vector data was collected using the Web Soil Survey tool from the United States Department of Agriculture, National Resource Conservation Service. Finally, canopy cover vector data was collected from the LANDFIRE data site, a program created by the wildland fire management programs of the US Forest Service and Department of Interior.

GPS waypoints of ginseng locations were collected during ginseng growing seasons from 2012-2014. One waypoint did not specifically represent one plant; in some instances a waypoint may represent a cluster of plants within close proximity of each other. In total, 940 waypoints were collected from 2012-2014 while 4597 ginseng roots were marked during that same period. The ginseng vector point data and study area boundary vector data were provided by resource management staff at the study area.

Data Analysis

It should be noted that spatial and textual references to data and the study location was purposely omitted from the paper and Figures 1-5 due to the need to protect sensitive locational data. For this same reason, a map depicting actual ginseng plant locations was also omitted from this paper.

Raster Processing

Each dataset was clipped to the study area and projected to the coordinate system UTM NAD 1983 Zone 17N. Habitat variables in vector format were converted to raster data. Cells for each raster dataset were set to 30 x 30 meters. Once all the data were in raster format, cells in each habitat variable were reclassified according to attributes assigned to each cell. The higher the value assigned, the more likely ginseng could grow at that particular location for each variable.

The z-unit (altitude) for the elevation data was originally in meters and then converted to feet by multiplying the dataset by 3.28083 using Spatial Analyst. Because ginseng was observed more frequently at lower elevations at GRSM (Rock *et al.*, 1999), cells between 1111-1911 feet were assigned a value of 3, cells between 1911-2710 feet were assigned a value of 2, and cells between 2710-3509 feet were assigned a value of 1 (Figure 1). The greater the value assigned to a cell, the more desirable the habitat characteristic is at that location.

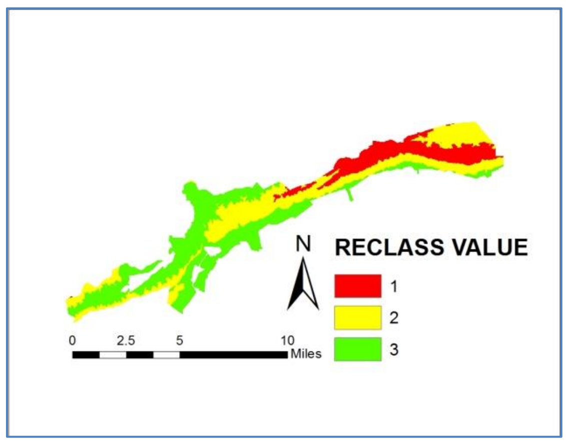

Figure 1. Elevation: 1111-1911 feet (green), 1911-2710 feet (yellow), 2710-3509 feet (red).

Aspect was consistent with north-facing slopes best for ginseng growth, while east and west slopes were suitable as well. South-facing slopes were not recommended, but the possibility for growth exists depending on slope position and shelter from sunlight (Anderson *et al.*, 2002). Therefore, north-facing slopes were given a value of 3, east- and west-facing slopes were given a value of 2, and south-facing slopes were given a value of 1 (Figure 2).

Average slope for each 30 x 30 meter cell within the slope layer ranged anywhere from 0% to 80%. Relying heavily on the study conducted at GRSM and other literature (Anderson *et al.*, 2002), slopes between 10-40% were

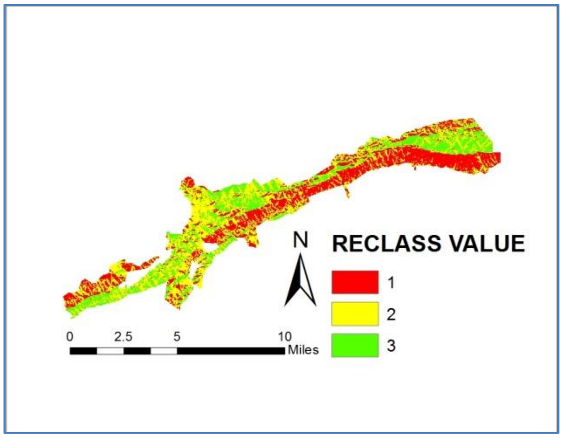

Figure 2. Aspect: North (green), East and West (yellow), South (red). Areas in green represent orientations most suitable for ginseng growth while areas in red represent orientations least suitable for ginseng growth.

assigned values of 3, slopes between 40-60% were assigned values of 2, and slopes between 0-10%, and 60% and greater were assigned values of 1 (Figure 3).

Ginseng requires a balance of shade and sunlight to generate growth. According to the University of Kentucky

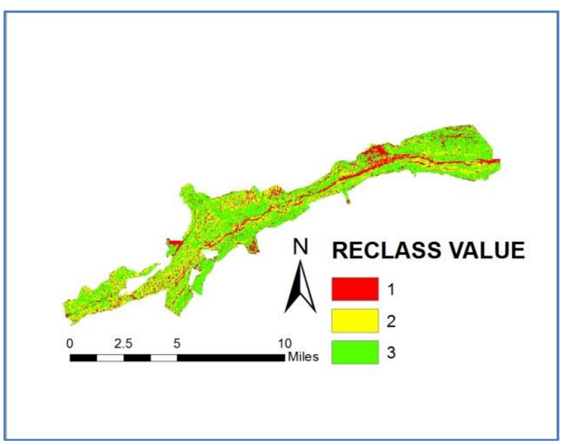

Figure 3. Slope: 10-40% (green), 40-60% (yellow), 0-10% and 60% and greater (red). Suitable (yellow) and most suitable (green) slope for ginseng growth dominate the study area with some least suitable slope (red) scattered throughout.

College of Agriculture (2012), approximately 70-80% canopy cover is needed for ginseng growth; the average shade found at GRSM was 61.3%. For the canopy layer, cells with cover between 50-80% were reclassified as 3, cells between 20-50% were reclassified as 2, and cells between 10-20% and between 80-100% were reclassified as 1 (Figure 4).

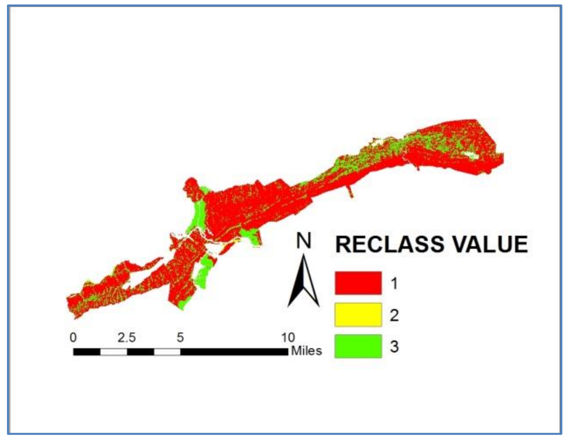

Figure 4. Canopy Cover: 50-80% (green), 20-50% (yellow), 10-20% and 80-100% (red). A vast majority of the study area contains canopy cover least suitable for ginseng growth (red) while some pockets of the study area contain suitable canopy cover (yellow) and most suitable canopy cover (green).

The drainage class for each soil type was used to determine ideal conditions for ginseng growth. Well drained soils were given a value of 3, somewhat well drained soils were given a value of 2, and excessively drained soils, somewhat excessively drained soils, and poorly drained soils were given a value of 1 (Figure 5). An example of the map unit soil description report is provided in Appendix B.

Weighted Sum

With each habitat layer reclassified to represent the likelihood for ginseng growth, the weighted sum function in ArcGIS was used to combine the raster datasets. Aspect, slope, canopy cover, and soils layers were all given equal weight and multiplied by a coefficient of .225.

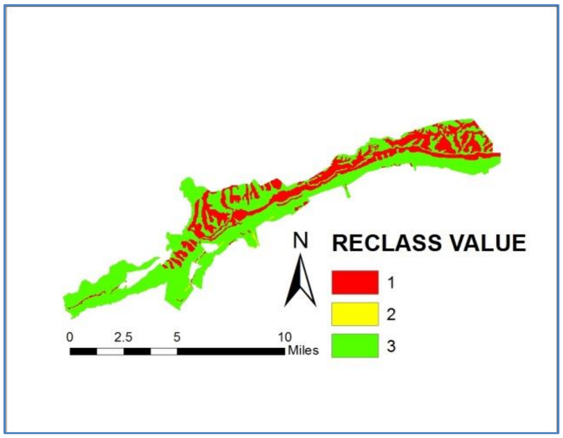

Figure 5. Soils: Well Drained (green), Somewhat Well Drained (yellow), Excessively Drained, Somewhat Excessively Drained, and Poorly Drained (red). The study area is practically split in half between most suitable soils for ginseng growth (green) and least suitable soils for ginseng growth (red).

Because literature only suggested ginseng tends to grow at lower altitude, but failed to give specifics (Rock *et al.*, 1999), the elevation layer was multiplied by a coefficient of .1.

A resulting dataset was created with each cell value between 0-3—the higher the cell value, the greater chance for ginseng growth. This dataset was reclassified into three classes using the natural breaks (Jenks) method. The Jenks natural breaks optimization method clusters data based on natural groupings. Similar values are clustered into a group while groups are divided based on the largest gaps between values in the data distribution. Due to the sensitive nature of the results, a map of the output is restricted from published results; however, a breakdown of acreage between classes is provided in Table 1.

Point Data

Three separate shapefiles of ginseng points were provided for each year from 2012-2014. To start, each of the three point shapefiles were merged together to create

Table 1. Breakdown of acreage between ginseng habitat suitability levels for the study area.

Suitability Level	**Acres**	**%**
Least Suitable	4059	17.5
Suitable	11528	49.7
Most Suitable	7622	32.8
	23209	100

one master shapefile of all ginseng waypoints collected. ArcGIS was used to assign a suitability score from the cells of the ginseng habitat suitability raster to each ginseng waypoint by its location. This value was appended to the ginseng point attribute table.

Because each ginseng waypoint had a suitability score assigned to it, further analysis was performed to see how many points fell into each suitability category. Eleven points were assigned a value of -9999 meaning that the point fell outside of the area composed of the habitat ginseng suitability raster. This could be due to the accuracy of the GPS signal during data collection which can include, but is not limited to, the number of GPS satellites available, GPS receiver quality, or user error. Cell size used in the analysis could have also been a factor, potentially leaving gaps along the study area's boundary (Figure 6). For this study, these 11 points were excluded from further analysis.

Statistical Analysis

To determine the effectiveness of the spatial model, parametric statistics were used to compare the mean of ginseng points to determine if it equaled the mean of the cells from the most suitable habitat level. The mean of the ginseng points was also compared to the mean of the least suitable habitat level and compared to the mean of the suitable level for further

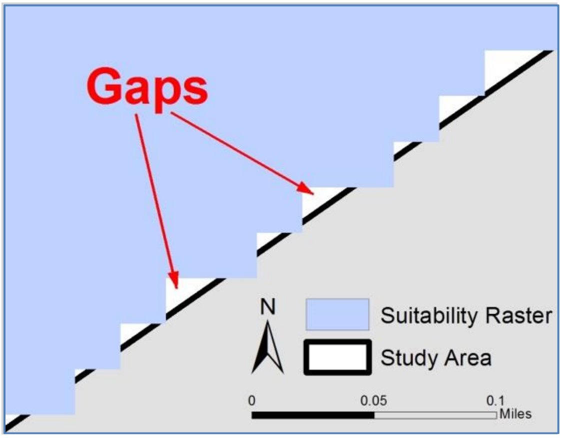

Figure 6. Example of gaps along study area boundary due to raster cell size.

analysis. Ruxton (2006) suggests when comparing "2 populations based on samples of unrelated data, then the unequal variance *t*-test should always be used in preference to the Student's *t*-test or Mann-Whitney *U* test." Thus using Microsoft Excel, a two-sample *t*-test assuming unequal variances was used. If the null hypothesis was rejected, the hypothesis was modified to state ginseng plant locations came from a combination of the habitat levels created by the model.

Results

Out of the 929 ginseng waypoints collected within the study area, 434 of them, or 46.7%, were within cells labeled as most suitable for ginseng growth. Along with this an additional 462 waypoints were within suitable cells. Together these points comprised 97.4% of the ginseng points collected from 2012-2014 (suitable or most suitable for ginseng growth) (Table 2).

It is assumed the variances of the two populations are unequal because they come from two unrelated datasets. This was confirmed in Microsoft Excel by performing a two-sample F-test for variances for each of the following

Table 2. Description of ginseng points across ginseng habitat suitability levels for the study area.

Suitability Level	# of Points	% of Points
Least Suitable	33	3.6
Suitable	462	49.7
Most Suitable	434	46.7
	929	100

scenarios. Welch's *t*-test, a variation of the student's *t*-test, was used because of the unequal variances in this study. For the first two tests the null hypothesis was adjusted to be specific to each test, aiming to prove or disprove the ginseng points came from the suitability level being tested.

Table 3 shows descriptive statistics of the first *t*-test in which ginseng points were compared to cells from the least suitable level. In this test, the *t* statistic was highly significant ($p < .001$) and therefore the null hypothesis was rejected. The mean of the ginseng points is not equal to the mean of cells from the least suitable level.

Table 3. Two-sample *t*-test assuming unequal variances descriptive statistics, ginseng points (GP) against least suitable cells (LS).

	GP	LS
Mean	2.22	1.46
Variance	0.108	0.0428
Observations	929	18255

Table 4 shows descriptive statistics of the two-sample *t*-test comparing the mean of ginseng points with cells from the suitable habitat level. Once again, the *t* statistic was highly significant ($p < .001$) and the null hypothesis was rejected. Although the end result was the same as the least suitable level, there is a shift in the mean of the suitable cells towards the mean of the ginseng points. The same results of the previous two tests can be seen in results of comparing the mean of ginseng points to the mean of cells from the most suitable level (Table 5).

Table 4. Two-sample *t*-test assuming unequal variances descriptive statistics, ginseng points (GP) against suitable cells (S).

	GP	S
Mean	2.22	2.01
Variance	0.108	0.0208
Observations	929	51839

The *t* statistics was highly significant ($p < .001$), rejecting the null hypothesis. The mean for the most suitable cells showed a large increase compared to the means of the least suitable and suitable levels and ended up being larger than the mean of the ginseng points.

Table 5. Two-sample *t*-test assuming unequal variances descriptive statistics, ginseng points (GP) against most suitable cells (MS).

	GP	MS
Mean	2.22	2.50
Variance	0.108	0.0376
Observations	929	34724

Discussion

Dividing cells into three sections would allow a solid starting point for resource management staff, provided that the model proves to be accurate. Many reclassifications could take place in the future to target areas with the next highest suitability score.

The first two *t*-tests, ginseng points vs. least suitable and ginseng points vs. ‘Suitable, were performed to either eliminate or show that the ginseng points came from one of the less desirable habitat levels created by the model. Because the null hypothesis was rejected in both scenarios, it can be inferred that ginseng points are not located in areas containing habitat specific to least suitable or suitable cells. If the null hypothesis was accepted, then the mean of the ginseng points would be equal to the mean of the cells from the least suitable or suitable level and model variables may need to be re-examined.

Evaluating results of the second and third *t*-tests, ginseng points vs. suitable and ginseng points vs. most suitable, show the mean of the suitable level was smaller than the mean of the ginseng points and the mean of the most suitable level was larger than the mean of the ginseng points. One could suggest that an equal mean between ginseng points and cells from the habitat model could be found by combining the two suitability levels. A fourth *t*-test was performed to determine if the mean of the ginseng points was equal to the mean of cells from the suitable and most suitable levels.

The difference between means showed a large decrease for the fourth *t*-test (Table 6). This test differed from the previous three tests as the *t* statistic was not significant ($p > .05$) and therefore the null hypothesis was not rejected here.

Table 6. Two-sample *t*-test assuming unequal variances descriptive statistics, ginseng points (GP) against suitable and most suitable cells (S/MS).

	GP	S/MS
Mean	2.22	2.20
Variance	0.108	0.0851
Observations	929	86563

The fourth *t*-test helps show the mean of the ginseng points is equal to the mean made up of cells from the suitable and most suitable levels. The original null hypothesis is still rejected for the first three tests, but it can be determined that the ginseng points do not come from cells of the least suitable level.

Sources of Potential Error

Data were collected on many different occasions, by different individuals over a three-year period, during different times of day, and under different atmospheric conditions. A combination of these factors could affect the horizontal accuracy of the GPS receiver during the data collection process. In addition, data were collected on different GPS receivers of different quality in which precision of location could have varied.

GPS horizontal accuracy error can reach upwards to 15 meters depending on the conditions described above (Unger, Hung, Zhang, and Kulhavy, 2014). Some or all of the 11 ginseng points that received a valued of -9999 could be within 15 meters of a cell in the habitat suitability raster (Figure 7). A useable value assigned

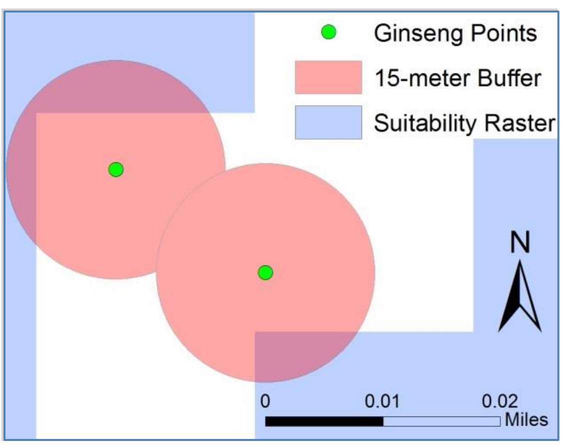

Figure 7. Ginseng points outside of suitability raster with 15-meter buffer.

to any number of these points could change the outcome of the statistical analysis. Because a definitive solution could not be found to resolve this problem, the 11 points were not included in this study.

Accessibility is also a factor that could have led to potential error. Because of the large size of the study area and the short timeframe in which ginseng can be found, it is much more advantageous for resource management staff to target areas that are fairly easy to get to save time and also to target areas that are easy for poachers to access as well. Because of this, ginseng points collected may not be a normal representation of the entirety of ginseng within the study area. Of the ginseng points collected, habitat characteristics may be much more similar than a random collection of ginseng points that covers the whole study area.

It should also be noted once again that each ginseng point is not representative of a single ginseng plant. Instead of taking a GPS waypoint for the nearly 4,600 plants whose roots were marked, it was much more efficient to take one point for a cluster of plants, which was often the case. There was no attribute field in the ginseng point data that described how many plants associated with each point. With this being known, the results of the parametric statistics could potentially be affected. Had a waypoint been collected for every marked plant, the number of plants and percentage of plants within a certain suitability level could have changed the results.

Error could have also occurred during the spatial analysis portion of this study. Thirty by thirty meter cells were used to create a general snapshot of habitat characteristics within a given area within the study area. Smaller cells could lead to lengthy processing times and crashes within the ArcMap program while larger cells may generalize too much the habitat characteristics over a large area. Within an arbitrary area, there can be many changes in elevation, aspect, slope, canopy, or even soil. The aim of the model in this study was to locate general areas where ginseng is most likely to be found.

The results of the analysis will also be affected by the manner in which the final habitat suitability raster was reclassified and the map scale at which raster and vector data was derived. Depending on the reclassification method chosen and the number of classes chosen could affect how many points were within each suitability level. If raster and vector data created under National Map Accuracy Standards was derived at a map scale of 1:24,000, data has a positional accuracy of +/- 40 feet. This means that any cell or point used in this study could potentially shift any direction up to 40 feet (USGS, 1999). As map scale decreases positional accuracy decreases.

Further Research

Another way to test the effectiveness of the habitat model would be to perform field verification. A set number of cells could be randomly selected from each of the three suitability levels. A small team could mark out a 30 x 30 meter area at the coordinates of the center point for a given cell. The number of ginseng plants could then be recorded as well as the type of associated plants at that location. The habitat variables at each cell could also be recorded and compared to those that were used for that cell in the model.

Further analysis could also be conducted on the ginseng data points. Instead of relying solely on literature to determine values of habitat characteristics best for ginseng growth, best habitat characteristics could be extracted from the known locations of ginseng points. It may not be the case that habitat characteristics are the same in the study area as they are in say, New York, Missouri, Georgia, etc. and that the model should be based on which habitat characteristics are present at this specific study area. A new model based off of this information could result in more favorable statistical results and possibly help crews locate areas better suited for ginseng growth.

Conclusions

Although the results of the statistical analysis proved that many of the ginseng points did not come from the most suitable habitat level, it does not necessarily mean that the model created for this project is not a useful tool; it just means that it could be reworked to get a more favorable result. A balance can be found between relying on statistical analysis and using reason.

When looking back at Table 2, 97.4% of the waypoints collected were within the suitable or most suitable level, with nearly half of those points in the latter. Given the fact that habitat layers were reclassified based on what scholars suggested through literature, a conclusion can be made that the model has potential to be a useful tool, but further research should be performed to make improvements.

There is potential to rework the model based on characteristics of the ginseng waypoints. Information could be extracted from each habitat layer and assigned to each point. Using that information, a new habitat suitability layer could be formed to garnish a more favorable end result.

But, that may not tell the whole story. Field work must be performed be to assist in creating a more accurate picture of the usefulness of the model. Actually finding ginseng in the wild by using suggested locations created by the model is the only real way to show that a habitat suitability model can work for such a purpose.

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Appendix A. American ginseng range in North America (USDA, 2014).

Appendix B. Example of Map Unit Description report for soils (USDA, 2014).

Report — Map Unit Description

AtF—Alticrest-Totz-Helechawa complex, rocky, 20 to 55 percent slopes

Map Unit Setting

National map unit symbol: ljhy
Elevation: 1,000 to 3,400 feet
Mean annual precipitation: 43 to 55 inches
Mean annual air temperature: 42 to 67 degrees F
Frost-free period: 159 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Alticrest and similar soils: 35 percent
Totz and similar soils: 20 percent
Helechawa and similar soils: 20 percent
Minor components: 25 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Alticrest

Setting

Landform: Ridges
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Mountaintop
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Coarse-loamy residuum weathered from sandstone

Typical profile

H1 - 0 to 2 inches: fine sandy loam
H2 - 2 to 33 inches: gravelly fine sandy loam
R - 33 to 43 inches: unweathered bedrock

Properties and qualities

Slope: 20 to 55 percent
Depth to restrictive feature: 20 to 40 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 4.3 inches)