Building a Web Application and Land Navigation Course to Help Develop Military Relevant Informal GIS Education

by

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MASTER OF SCIENCE
GEOGRAPHIC INFORMATION SYSTEMS TECHNOLOGY

THE UNIVERSITY OF ARIZONA

2017

ACKNOWLEDGMENTS

I would like to thank Karen Siderelis for her mentorship and being my inspiration to enter this field, and to Craig Wissler, and Dr. Willem Van Leeuwen for their mentorship and advice on all things related to geographic information systems and remote sensing. I would also like to thank Dr. Peter Johnson for his instruction and guidance and for inspiring me to use Python. Special thanks to Tyson Swetnam for his assistance with Jupyter notebooks, expertise and technical advice, to Jarret Baker for his time, knowledge, and effort helping me troubleshoot, validate, and host this application, and to Capt. Kyle McCarley for assisting me with designing and setting up a land navigation course. I also want to thank Trevor Self and Dr. Christopher Lukinbeal for all of their support, guidance and knowledge throughout the MS-GIST program. Finally, thanks and love to my mother and late father who have forever encouraged me and to Allyson Fallows for her incredible support, and unfaltering belief in me during this endeavor.

To Ally and Brantley.

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ABSTRACT

Throughout history, military officers have relied on maps to provide spatial information and make informed battlefield and other problem-solving decisions. Today's officers can put even more spatial information at a soldier's fingertips if they are made aware of the power of geographic information systems and software. This paper makes the argument that an informal education and introduction to the uses of geographic information systems (GIS) during their participation in reserve officer training corps (ROTC) can help provide future officers with a basic understanding on how GIS can impact their ability to solve military relevant problems with these technologies and can aid in their decision making. This project created a web application using python and based on military mapping manuals and defense tools that allow a user to create a model of how quickly the user could be able to move over a given terrain. This web application was given to military officers in ROTC training at the University of Arizona prior to participation in a land navigation exercise to help them plan and prepare their path through the event. Students using the app prior to the exercise were able to see how the information provided by GIS can help them make decisions and times were compared between those that used the tool and those that did not. This tool, and the subsequent exercise provided increased awareness in military applications of GIS for those future military officers and helps inspire them to pursue more information on the technology.

INTRODUCTION

The use of spatial analysis has been prevalent in the military since the dawn of warfare. The importance of this skill was not lost upon the 5th century BC military strategist Sun Tzu who dedicated an entire chapter of his military treatise "The Art of War" to the reading of terrain. A military commander is often charged with having a firm understanding of the terrain that encompasses a battlefield and a contextualized understanding of maps and information. In the US Army Doctrine Reference Publication 5-0, "The Operations Process", the terrain is noted as one of the five operational variables that a military leader must be able to analyze. It states, "Commanders analyze terrain using the five military aspects of terrain expressed in the memory aid OAKOC: observation and fields of fire, avenues of approach, key and decisive terrain, obstacles, cover, and concealment." (Department of the Army, 2001, 1-9). US military commanders must be able to understand, visualize, and describe, this critical aspect of terrain to those that they command. In the past, this critical analysis was conducted through the use of military scouts and paper maps. However, these techniques are being modified with current technology such as satellite imagery, drones, handheld devices, geographic positioning systems (GPS), and geographic information systems (GIS).

Prior to the advent and use of GIS in the military, analysts had to construct a movement analysis, also known as an avenue of approach map, by hand using a topographic map, remotely sensed imagery and a clear overlay. This process is outlined in the US Army field manual 5-33 and required access to land cover information, and reference charts. This required time and procurement of physical resources like imagery, vegetation coverage, topographical and soil maps. GIS now allow a military commander to better understand, visualize, and describe their operating environment by utilizing geoprocessing tools to quickly process information, produce digital and paper map products, and leverage current remote sensing imagery to quickly create and disseminate a terrain analysis for a battlefield. However, in order to utilize the power of GIS within the military environment officers must first understand what a GIS is and be trained on how it can be used.

This can be done by introducing some of the skills and tools used in geospatial analysis into training that is familiar to military members and Reserve Officer Training Corps (ROTC) students. Weaving this technology into existing or familiar training will help perform a crosswalk between traditional spatial analysis through military map reading and a newer GIS-based analysis; showcasing the usefulness of geographic information systems into the military environment. The military land navigation exercise provides an excellent entry point for this type of instruction as land navigation is a common exercise for all military branches and already provides instruction on how to read a map, find a distance, and read the terrain (Figure 1). These types of land navigation competitions or trainings are generally conducted in a wilderness environment that challenges participants to plot a coordinate on a map, determine the direction and distance to the point, move to the location as quickly as possible using a map and compass and find a post containing a code that is copied into a scorecard to verify the location was found. This process is often completed for multiple checkpoints during a training and is described in detail in Army Field Manual 3-25.26 Map Reading and Land Navigation. The importance of these trainings to military preparedness is also outlined in FM 3-25.26,

> *"Land navigation is a skill that is highly perishable. The Soldier must continually make use of the skills he has acquired to remain proficient in them. The institution is responsible for instruction in the basic techniques of land navigation. The institution tests these skills each time a Soldier attends a leadership course. However, it is the unit's responsibility to develop a program to maintain proficiency in these skills between institution courses." (Department of the Army, 2005, 14-1).*

The importance in maintaining proficiency in navigation demonstrates the necessity for broad spatial awareness in the military and also reveals an ideal insertion point for informal GIS education and exposure.

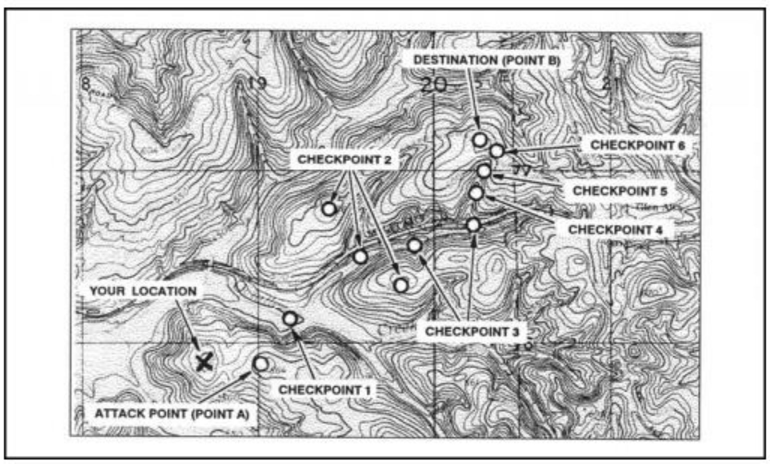

Figure 1 - Map showing how to use terrain features to find checkpoints in a land navigation competition. Army Field Manual 3-25.26.

Objectives

This project's goal is to create an informal exposure to military applicable GIS for those students who are training to become military officers in ROTC units at the University of Arizona. This project will expose students not already enrolled in GIS courses, as well as those that are, to the military uses of this technology through the development of a land navigation competition in Madera Canyon, Arizona and a corresponding online application that will allow a user to develop a movement analysis based on an existing Army Field Manual to aid with decision making and route planning for the event. This web application and project will a) provide a future military officer in ROTC with spatial information that was previously unavailable to them in order to help them make a decision regarding terrain, and b) provide an opportunity for those officers to use that geospatial information in an informal setting. This project will look at the number of students that used the web application, and the land navigation completion time and score for those students that used the web application to predict movement speed and those that did not. It is the expectation that those students that use the web application or perform the analysis will be able to complete the course in a faster time or with a higher score than those that did not use the web application.

METHODS

The study area for the land navigation competition and cross-country mobility tool will be in Madera Canyon, Arizona. Madera Canyon is located within the Coronado National Forest 25 miles southeast of Tucson, Arizona. The Madera Canyon competition area is at the base of Mt. Wrightson in the foothills of the Santa Rita Mountains. The competition area contains elevations as low as 5,000 ft and as high as 6,135 ft., with a few hills containing elevations of 5,745 ft. and 5,455 ft. Vegetation within the Madera Canyon competition area consists of oak, juniper, and pinion trees at the lowest elevations and ponderosa pine intermittently populated towards the higher elevations. The terrain also contains the Madera Canyon stream and two other intermittent streams that provide unique terrain features for a navigation course. The terrain relief and vegetation in this area provide a limited line of sight and add to the challenge of this competition. The two smaller hills in the area provide opportunities to overlook nearly the entire competition area, but the vegetation limits the ability of the view to see beyond the canopy.

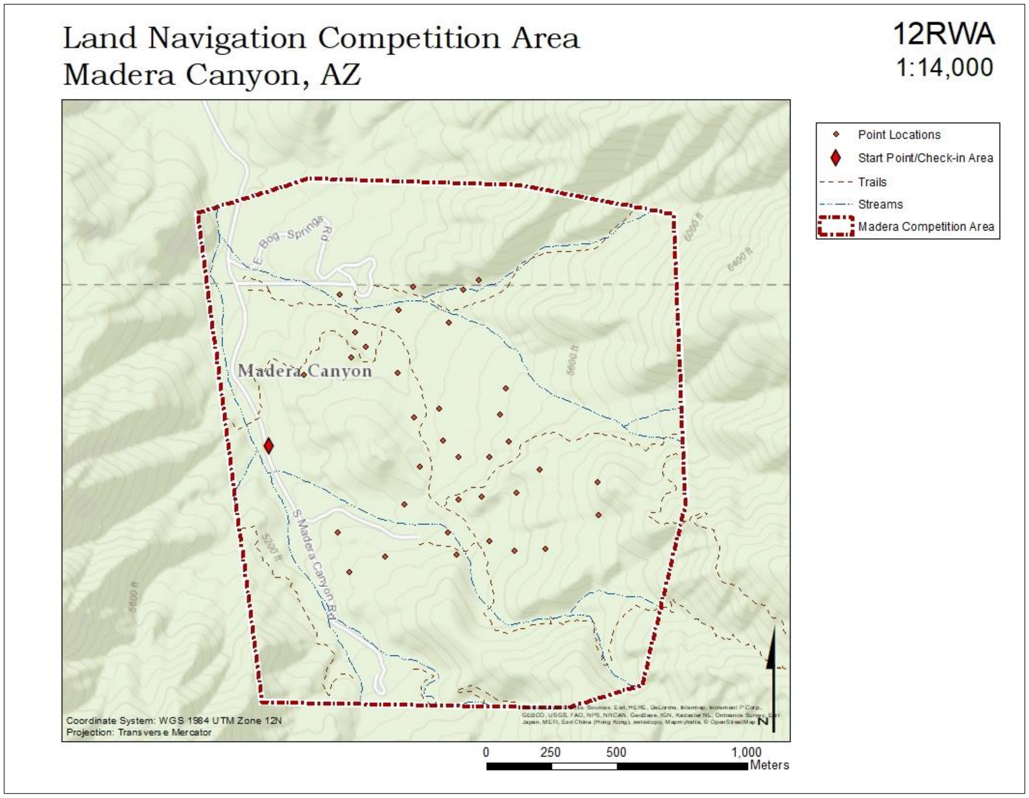

Figure 2 - Study area and point locations for the land navigation challenge in Madera Canyon, AZ

Geographic information systems (GIS) analysis was performed using ESRI's ArcGIS Online, ArcMap v10.5.1, and ArcGIS Pro v2.0. Geoprocessing tool editing was performed using Python script in Pyscripter and Jupyter Notebooks. All data have a common projection: WGS 1984 UTM Zone 12N, the distance was noted in meters, and coordinates were listed using the Military Grid Reference System (MGRS).

Trail network, streams, and roads for Madera Canyon were downloaded from the Coronado National Forest GIS data. A General Soil Map was downloaded from the US Department of Agriculture's Web Soil Survey as a vector dataset. Digital Elevation Model (DEM) data was downloaded from US Geological Survey's Earth Explorer at 10-meter resolution. Ortho imagery from the National Agriculture Imagery Program (NAIP) was downloaded from USGS's EarthExplorer and was collected on July 2nd, 2015. Footmarch, soil, land cover and surface roughness reference tables were developed by Environmental Systems Research Institute (ESRI) and downloaded from ESRI's GitHub repository. The initial Cross Country mobility script was downloaded from ESRI's GitHub Repository. Challenge point locations were collected using Garmin GPSmap 60 GPS receivers.

In order to accurately reflect the movement speed over terrain, input parameters were curated for the Madera Canyon Area of interest. These parameters included soils, surface roughness, and land cover.

Soils

A US Department of Agriculture General Soil Map layer for the Madera Canyon area of interest was used to determine the soil type and develop a movement value for each soil type. The General Soil Map contained map unit symbols for the various types of soil found within the area. In order to properly join the soil map to the reference table a field of Soil_Code was added to the soil map. The soil code field referenced the soil type referenced in Army Field Manual 5-33 (Table 1). A soil code was then designated to each corresponding map unit symbol within the general soil map. For example, within the general soil map, there were areas designated with the map unit abbreviation BgF, or Barkerville-Gaddes Association, which has a description of "Gravelly sandy loam and sandy clay loam" (Norman et al. 2002, 6). Areas with this mapping code were given the soil code of 04, "Gravel or Sand Gravel, clayed". A third symbol was included in the map unit key to indicate slope and was not used to determine a soil code. For example, BgF contained the third letter code of F that related to the slope of the area. All other soils were given soil codes as noted in table 2.

Table 1 - Soils Table from FM 5-33.

SOILS CATEGORY	TYPE	RCI VALUES DRY	MOIST	WET
01(GW)	Gravel or sandy gravel, well graded	163	123	83
02 (GP)	Gravel or sandy gravel, poorly graded	160	120	81
03 (GM)	Gravel, silty	120	76	32
04 (GC)	Gravel or sand gravel, clayed	130	91	52
05 (SW)	Sand, well graded	155	116	78
06 (SP)	Sand, poorly graded	145	109	73
07 (SM)	Sand, silty	119	72	25
08 (SC)	Sand, clayey	126	86	46
09 (ML)	Silts	118	69	20
10 (CL)	Clays	123	81	40
11 (OL)	Organic silts	111	57	3
12 (MH)	Inorganic elastic silts	114	61	8
13 (CH)	Fat clays	136	99	62
14 (OH)	Fat organic clays	107	54	1
15 (PT)	High organic soils or peat	106	52	0
20 (R)	Rock outcrops	165	165	165
30 (NE)	Not evaluated	-	-	-
W (W)	Open water	0	0	0

Table 2 - Map Unit symbols, their association, textures and given soil code. Modified from US Department of Agriculture: Soil Consecration Service and Forest Service in cooperation with Arizona Agriculture Experiment Service.

Map Unit Symbol	**Soils' Association**	**USDA Surface Textures**	**Corresponding FM5-33 Code**
Ba	Barkerville-Gaddes Complex	Gravelly sandy loam and sandy clay loam	02
Bg	Barkerville-Gaddes Association	Gravelly sandy loam and sandy clay loam	04
Cr	Chiricahua- Lampshire Association	Cobbly or gravelly heavy clay loam or clay	10
Fr	Faraway- Rock Outcrop Complex	Very cobbly fine sandy loam	05
Lc	Lampshire-Chiricahua Association	Very cobbly loam	04
Rn	Rock Outcrop- Lithic Haplustolls Association	Properties too variable to be estimated	20

Rr	Rock Outcrop		20
Th	Torrifluvents and Haplustolls	Properties too variable to be estimated	09
Wt	White House- Hathaway Association	Gravelly loam, clay loam, and clay	09

Surface Roughness

Army Field Manual 5-33 defines Surface roughness factors as “estimated factors used to compute the degree of degradation of the rate of vehicle movement of the rate of vehicle movement caused by surface characteristics.” The degradation is directly related to the variability of terrain elevation and was calculated using the DEM raster layer. The surface roughness of the terrain was calculated using the relative topographic position, which identifies the height of each cell in relation to its neighbors, thus looking at the variability within each cell’s “neighborhood” (Cooley, 2017). This was calculated by using the Madera Canyon DEM and using focal statistics. A minimum elevation model (MIN_DEM) was first created to determine the lowest valued cells in its neighborhood using the Focal Statistics tool (Figure 2). Similarly, a maximum value raster (MAX_DEM) and a mean value raster (MEAN_DEM) were also calculated using the DEM and Focal Statistics tool. To determine the variability of the surface, the following formula was used in conjunction with the rasters that were derived from the Focal Statistics calculation.

$$\frac{(MEAN_{DEM} - MIN_{DEM})}{(MAX_{DEM} - MIN_{DEM})}$$

The resulting raster from this calculation contained values between 0 and 1, with those areas containing more variability in elevation having a value closer to 1. These values were then converted into four discrete categories to allow integration with the Surface Roughness reference table. This was done using the reclassify tool and creating new values from 1 to 4 with 4 being the areas of higher variability (Figure 3). Finally, the reclassified raster was converted to polygon features using the Raster to Polygon tool. This allowed the reference table to be joined the surface roughness layer using the roughness code values in both tables.

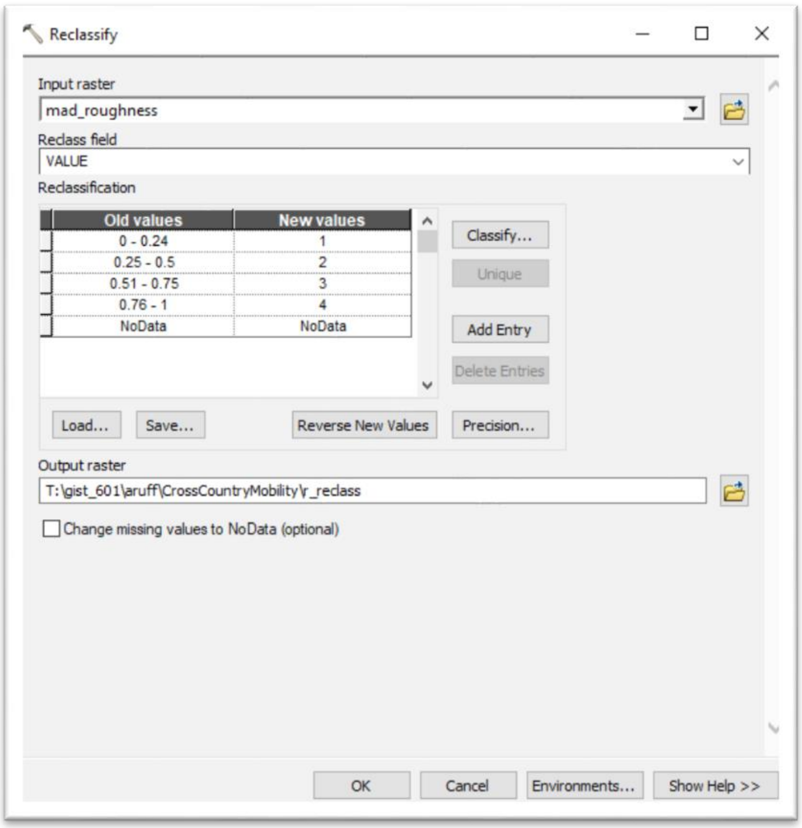

Figure 3 - A minimum value raster was created using the DEM and the focal statistics tool in ArcMap.

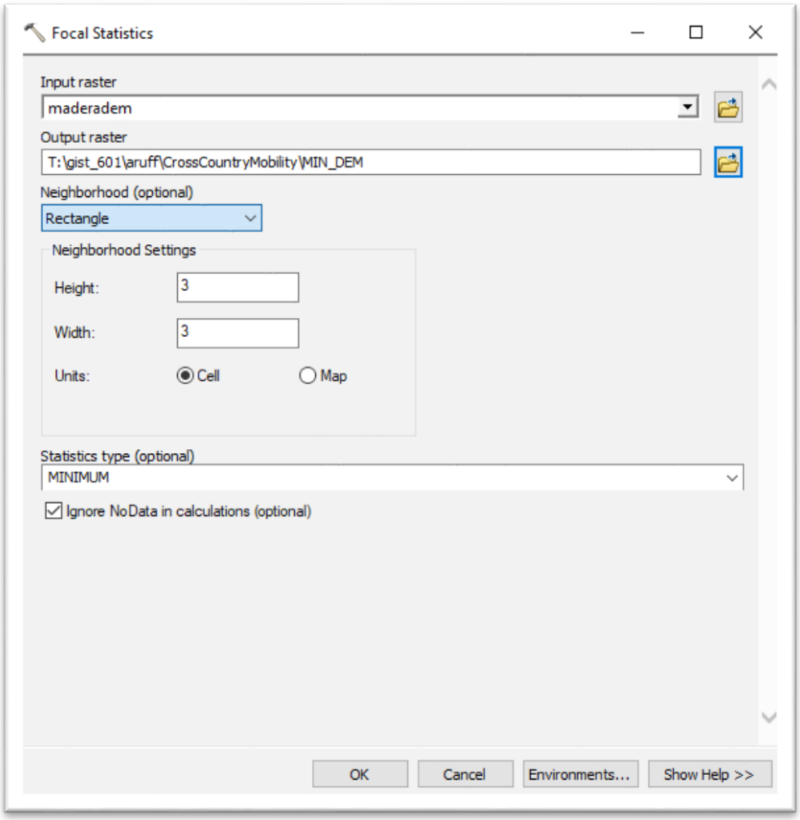

Figure 4 - Reclassifying the surface roughness values to correspond with the surface roughness reference table.

Land Cover

Modeling travel over terrain requires an understanding of the vegetation and cover within the area of interest. A land cover feature layer for Madera Canyon was created from a NAIP imagery set downloaded from the USGS EarthExplorer. Land cover was identified by using the unsupervised classification tool within the "Image Classification Wizard" in ArcGIS Pro v2.0. The categories of land cover used for this unsupervised classification were developed, barren, forest, and shrubland. The resulting raster was then converted to a polygon vector feature layer using the Raster to Polygon tool. A f_code field was added to this feature class and each category of land cover was given a f_code that corresponded to the land cover reference table. (Table 3). The resulting land cover vector layer is displayed in figure 5.

Table 3 – F_Code definitions within the land cover reference table. (ESRI, 2016)

OBJECTID *	f_code	Description	Minimum Veg. Roughness	Maximum Veg. Roughness
1	AL020	Built-Up Area	0	0
2	BH070	Brush	0.6	0.7
3	BH077	Hummock	0	0
4	BH090	Land subject to inundation	0.3	0.6
5	BH095	Marsh/Swamp	0.1	0.8
6	BH135	Rice Field	0.3	0.6
7	BJ110	Tundra	0.1	0.6
8	DA020	Barren Ground	1	1
9	EA010	Cropland	0.7	0.9
10	EA020	Hedgerow	0.4	0.6
11	EA030	Nursery	0.4	0.6
12	EA031	Botanical Garden	0.4	0.8
13	EA040	Orchard/Plantation	0.4	0.8
14	EA050	Vineyard	0.4	0.6
15	EA055	Hops	0.7	0.9
16	EB010	Grassland	0.8	0.9
17	EB015	Grass/Scrub/Brush	0.6	0.7
18	EB020	Scrub/Brush/Bush	0.5	0.6
19	EB030	Land Use/Land Cover (Vegetation)	0	1
20	EB070	Brush	0.5	0.6
21	EC005	Tree	0.2	0.6
22	EC010	Bamboo/Cane	0.3	0.6
23	EC015	Forest	0.2	0.6
24	EC020	Oasis	0.2	0.6
25	EC030	Trees	0.2	0.6
26	EC040	Cleared Way/Cut Line/Firebreak	0.3	0.8
27	ED010	Marsh	0.1	0.8
28	ED020	Swamp	0.1	0.7
29	EE000	Miscellaneous Vegetation	0.1	0.9
30	EE010	Logging Area	0.3	0.8
31	EE020	Land devoid of vegetation	1	1
32	<Null>	Water	0	0

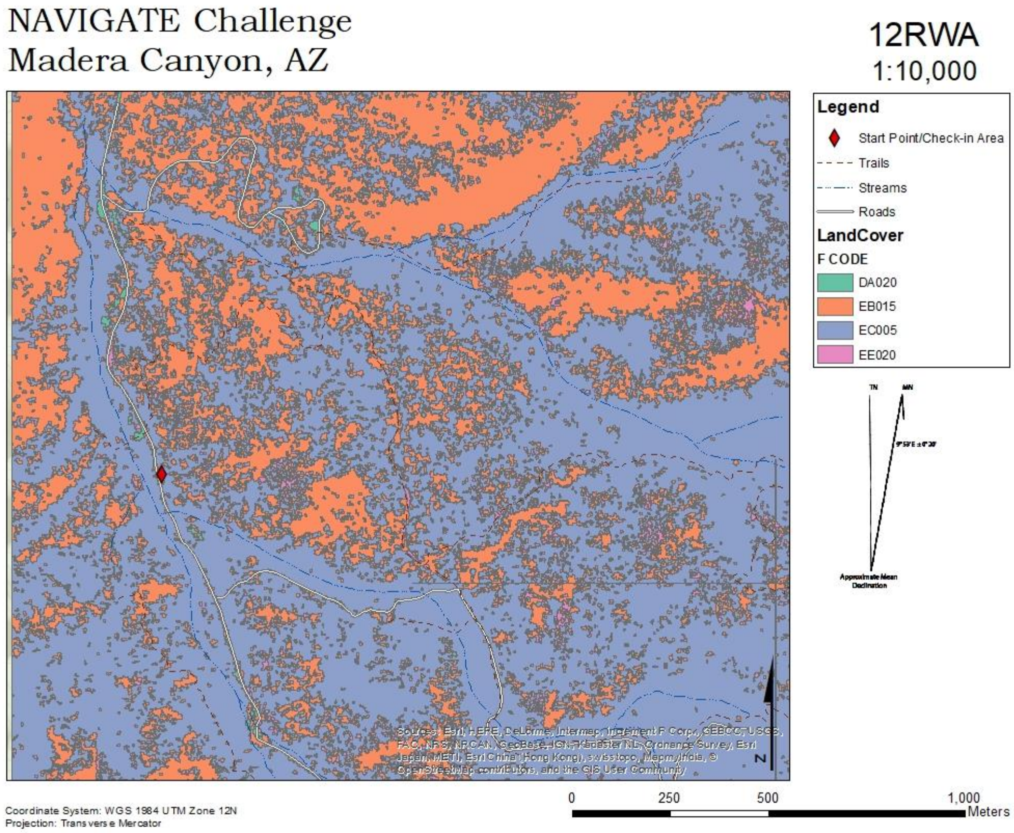

Figure 5 - Land Cover map generated by the unsupervised classification of NAIP imagery

Cross-Country Mobility Geoprocessing Tool

The Cross Country mobility tool was modified from a Cross-Country mobility geoprocessing script downloaded from ESRI's "Mature Support". This script was modified using python to include the data for the Madera Canyon Challenge area and be usable within the ArcGIS Pro v2.0 software platform. This allowed the geoprocessing tool to be shared as a geoprocessing package on ArcGIS online and be published as a geoprocessing service to be woven into ArcGIS's "Web app Builder".

The geoprocessing tool allows a user to input parameters that would impact movement over the terrain. These parameters include the weight of the individual, day or night visibility, dry or wet soil conditions, and maximum or minimum land cover. Once these parameters are entered the tool calculates the impact of area slope, area surface roughness, area vegetation, and area soils on movement speed.

The impact of slope on movement speed is determined by first using the reference table values for maximum and minimum movement speeds for day and night movement at the maximum slope that can be traversed in these conditions. (Table 4). Because the original formula was based on vehicle movement speed over terrain noted in Army Field Manual 5-33, the user's weight was first converted into tons by dividing the weight by 2,000. The maximum speed in the footmarch reference table was divided by the user's weight to obtain a variable referenced as in the field manual 5-0 as "speed over weight" (Department of the Army. 1995, 6-1). The script then used the following formula to generate a speed over each cell in the terrain.

$$(\,Maximum\ Slope\ percent - Slope\ Percent\ from\ DEM)/(Speed\ over\ Weight)$$

The slope raster was then added to a list called Cross Country mobility factor as f1. Surface curvature was calculated using the curvature tool and the DEM and was added to the list as f2.

Table 4 - The movement speed and the maximum slope for day and night movement. (ESRI, 2016)

OBJECTID *	Visibility	Maximum Speed (miles/h)	Maximum Slope %
1	Day	1.242742	100
2	Night	0.621371	85

Movement speeds for vegetation, soils, and surface roughness were also determined based on ESRI's reference tables and FM 5-33. The vegetation reference values from the reference table were joined based on the f_code field in both tables. By joining the reference table to the mapped land cover feature class, it allowed for joining of the movement factor that each type of vegetation would incur. For example, a swamp incurred a .7 movement factor and grassland areas incurred a .9 movement factor. Similarly, the tool joined the soils layer and surface roughness layers to the corresponding reference tables and the movement factor for each of these reference tables were also added to the attributes of the respective features. Finally, in order to assign movement values to the entire area of interest, each of the input features was converted to a raster in the Cross Country mobility tool. The movement factors for each cell were added to the Cross Country mobility factor list. Final movement speed was calculated by multiplying all of the movement factors from the cross country mobility factor list together. A final test of the tool in ArcGIS Pro produced a raster that generated an estimated movement speed for the Madera Canyon competition area that varied from less than 1 mph to 6.74 mph for a 185 lb person (Figure 6).

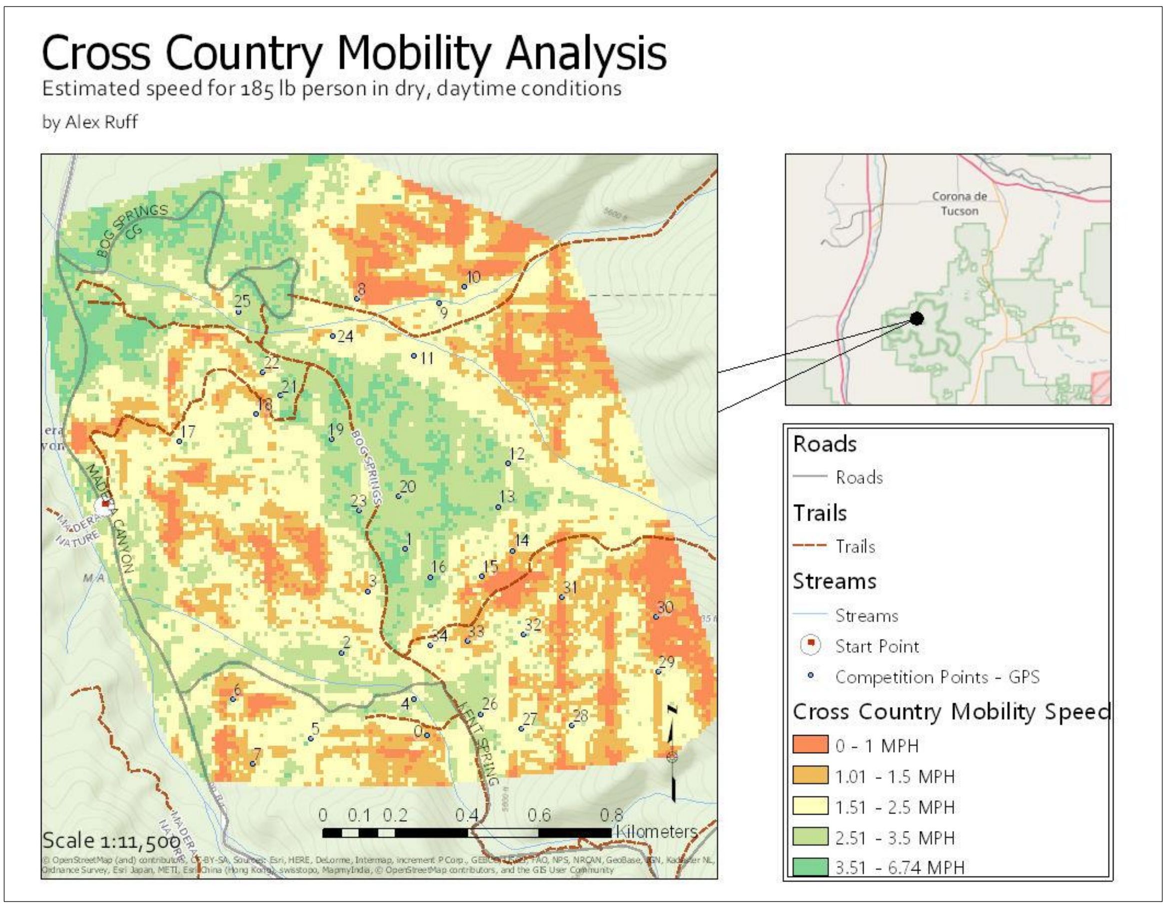

Figure 6 - Cross country mobility model for the land navigation event at Madera Canyon, Arizona.

The finalized tool was then migrated to a server in order to allow access by users outside of the University of Arizona GIS Enterprise portal. The first step in this process involved hosting all reference tables, feature layers, and the Madera Canyon digital elevation model raster on a server with a static location. Following that, the geoprocessing script was edited to hardcode the location of the input parameter layer and reference tables on the server, allowing the tool to find and access the necessary parameters. The tool was then published as a service to a Portal for ArcGIS. Some user parameters were kept in as user inputs in order to allow the user to edit some of the necessary variables for the competition. These input parameters were weight, visibility, minimum or maximum vegetation cover, and wet or dry soil conditions. Once published, the tool was built into a web application using ESRI's "Web app Builder" (Figure 7). The web application was shared publicly and allowed a user to access the data and the analysis without logging into an ArcGIS online account. Competitors were emailed the link to the mobility tool web application 9 days prior to participating in the event.

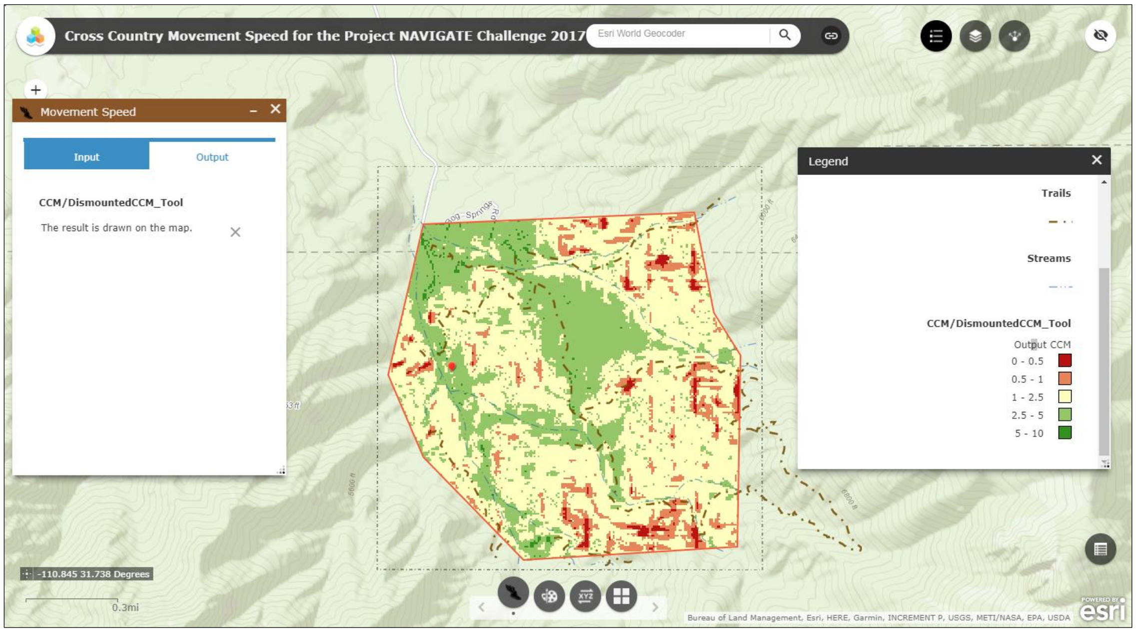

Figure 7 – The finished Cross Country mobility web application allows a user to select parameters such as weight, visibility, and vegetation density. The resulting raster demonstrates the movement speed over the terrain in miles per hour.

Land Navigation Course

A land navigation course was created within the Madera Canyon wilderness that encompassed roughly 1 square mile. This land navigation course was designed to have three levels of competition, individual with a map and compass, team with a map and compass, and team with a GPS unit and map. Thirty-five points were laid out in the wilderness by using a 3 ft wooden engineering stake, and engineering tape with the name of an Arizona peak labeled (Fig. 6). Each stake was marked using a GPS receiver and the Military Grid Reference System (MGRS) coordinate was collected from each stake. Each point location was given a point value based on distance from the start point, elevation and where they were located in the Cross-country mobility raster. Competitors in the individual map and compass category were charged with finding 6 pre-selected locations and return as fast as possible. Team entries in the map and compass category were given 10 points and their corresponding point value and had to collect as many points within the 2-hour time frame. GPS team entries were given all 35 locations on a map and each point's corresponding point value. Team GPS entries were given 2 hours to collect as many points as possible.

Figure 8 - Points were labeled with Arizona mountain peaks using engineering tape and a 3 ft engineering stake.

University of Arizona students, community members, and staff were invited to participate in the Land Navigation competition which was held on November 18th, 2017. University of Arizona students in the Marine Corps ROTC were given the event as a mandatory training exercise and a US Army recruiting station in Tucson, AZ also signed up to participate. Paper maps were created and provided to all competitors in 1:25,000 scale and 1:10:000 scale using ArcMap and ArcGIS Pro. In order to make the competition as military relevant as possible all coordinates for the map and compass competitors were given in MGRS and MGRS grid lines were added. The USGS Topo basemap was used (Figure 7) due to the similarity to maps that would be used in other military training. Paper maps for the GPS category were given every point on the map and were provided with a 1:10,000 scale map (Figure 8). Competitors were emailed the link to the mobility tool 9 days prior to participating in the event and encouraged to use it for route planning.

On the morning of the competition, each competitor was asked if they had used the tool as they were checking into the event. Scorecards from the event were collected and analyzed following the competition. Each scorecard included the number of points that were correctly found, the start time, and time that the competitor returned to the start point. A total of 51 participants competed in the competition. However, only 27 scorecards could be identified to a participant or were determined legible enough for analysis.

RESULTS AND DISCUSSION

Views of Web Applications and GIS Products

A total of 3 paper maps and 2 web applications were generated for the land navigation event. The paper maps contained information on the start point, contour lines, and the trail and stream network to assist with terrain association and identifying points. A total of 250 paper maps were produced in 1:25,000 scale for those individuals that were only using a map and compass (Figure 10), and 100 copies of a 1:10,000 maps were created to include the locations of each point on a map. Each GPS unit competition team was given a 1:10:000 scaled map with the points located (Figure 11). The links to the two web applications were deployed on social media (Facebook and Twitter) on November 9th, 2017, were hosted on a University of Arizona website, and were emailed to participants five days prior to the event. One web application showed a 3D representation of the competition area, and the second application contained the Cross-Country

Mobility tool. The Cross Country Mobility tool web application had been viewed a total of 120 times prior to the start of the competition (Figure 12).

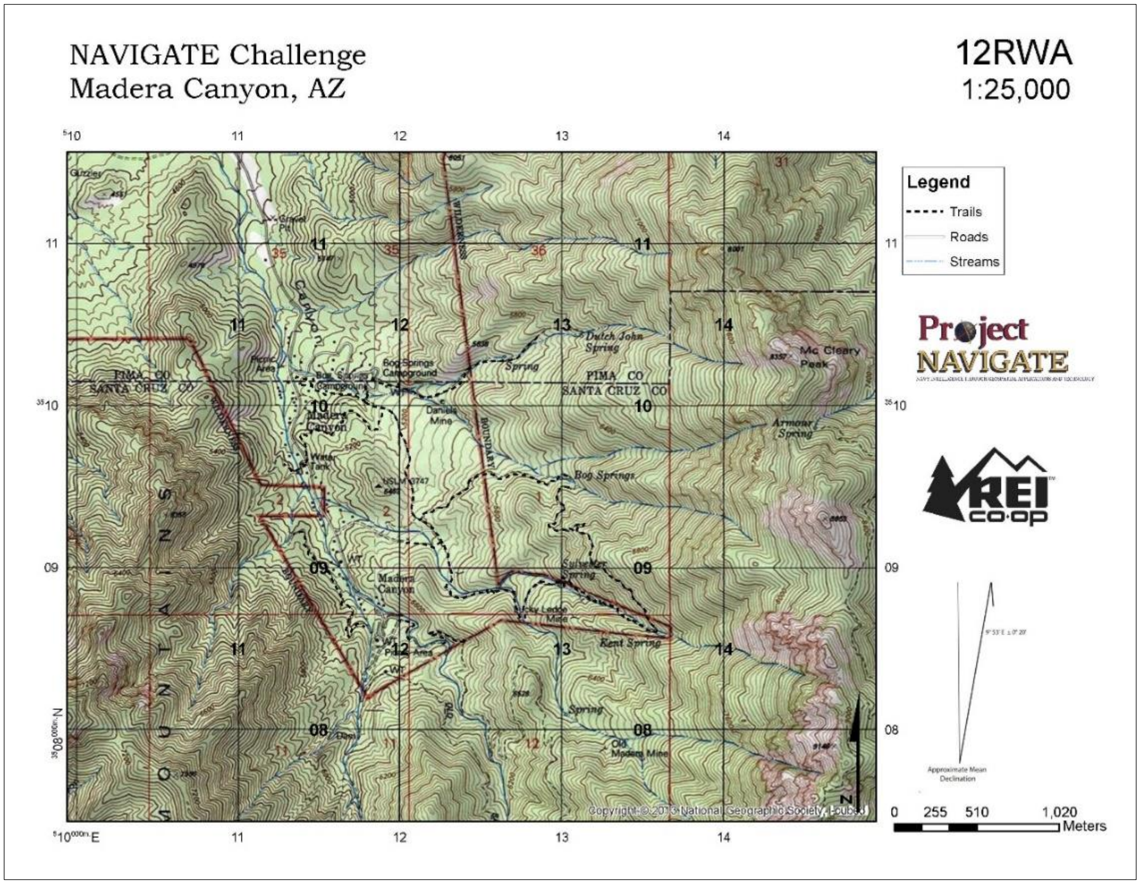

Figure 9- Map used for map and compass individuals and map and compass teams in the Land Navigation competition.

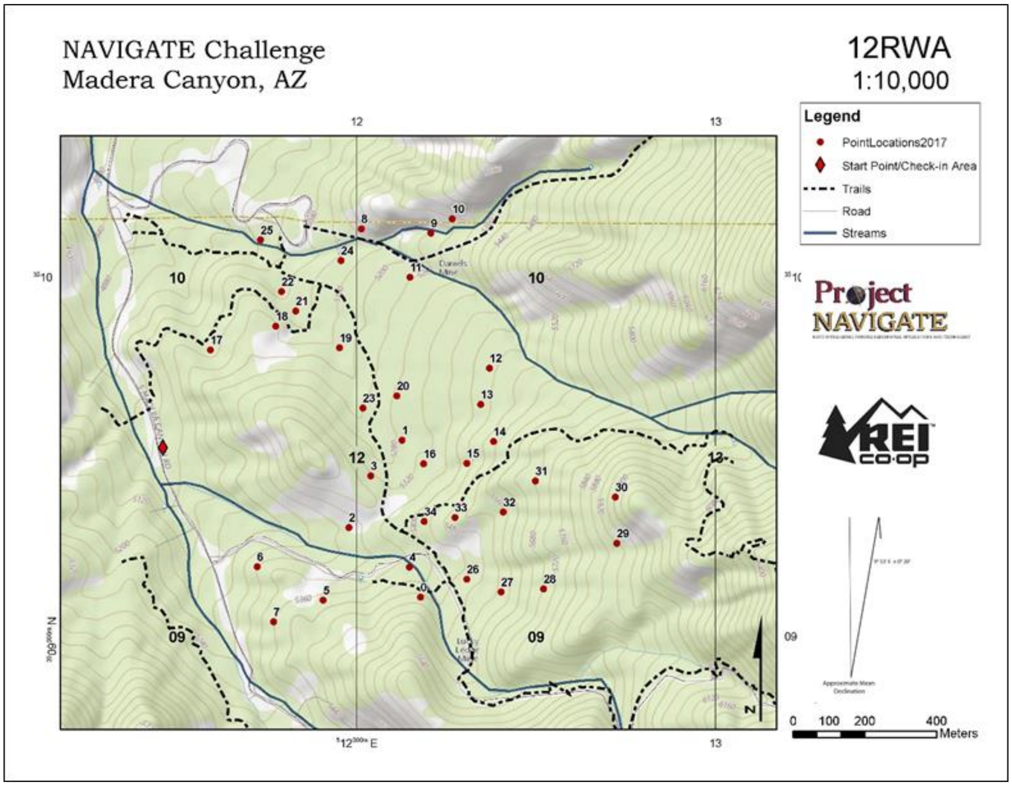

Figure 10- Map used for GPS unit teams

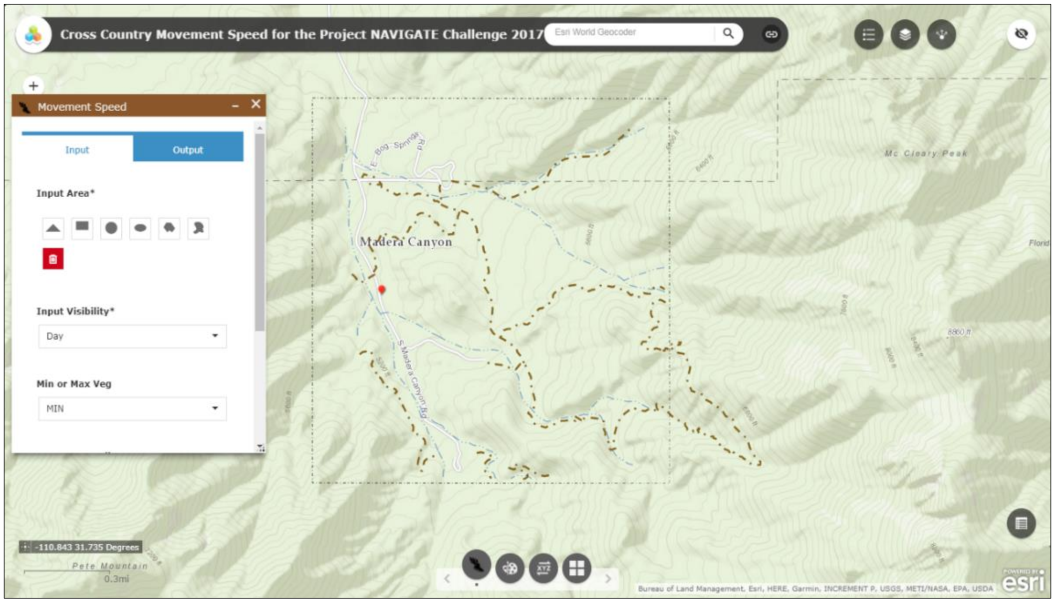

Figure 11 - Cross Country mobility web application showing the movement speed over the terrain.

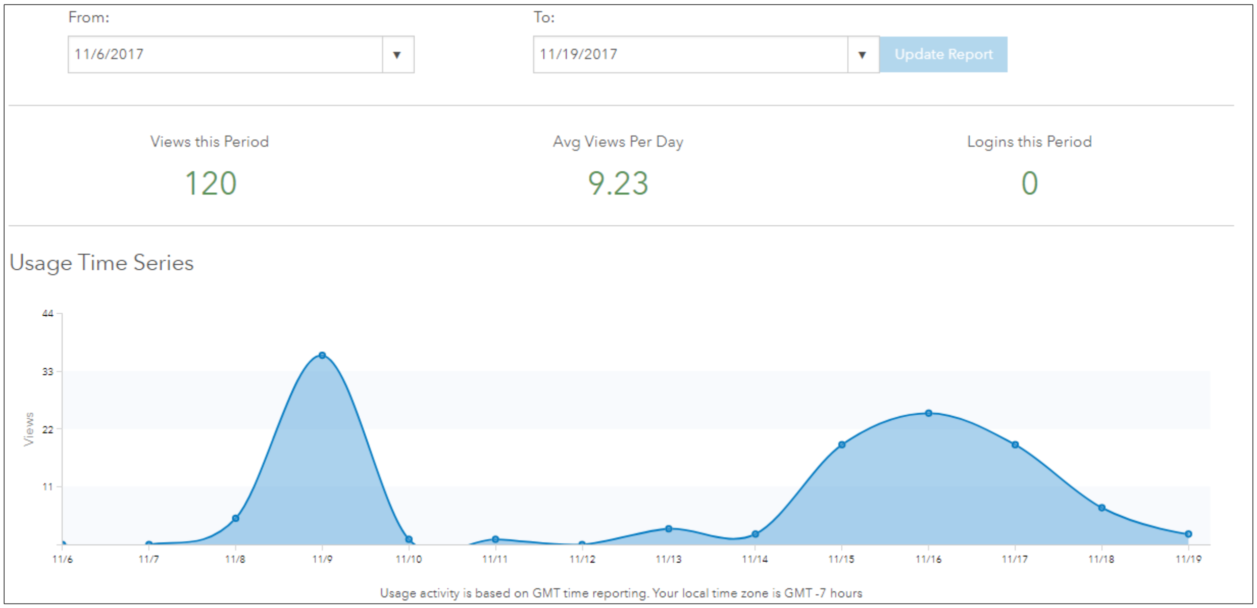

Figure 12- The number of times that the cross-country mobility web application was viewed prior to the competition on November 18th.

Land Navigation Results

The land navigation competition was held on November 18, 2017. Of those participants, 67% stated that they used the web application and Cross-Country mobility tool prior to the competition (Figure 12), and 73% of participants were part of the target audience of ROTC students (Figure 13). Of the participants that were part of the University of Arizona's ROTC program 61% stated they had used the mobility application (Table 5).

Competitors were scored on time and the number of points found. The average scores and time to completion were collected from scorecards after the event. Of the 27 usable scorecards, 17 were from competitors that had admitted to using the cross country mobility application while 10 were from individuals that did not utilize the mobility application. The average time to complete the competition was 2 hours. Those participants that used the mobility map completed the course with an average time of 2 hours and 2 minutes, while those that did not use the mobility application completed the course in 1 hour and 48 minutes (Figure 14). The average number of points collected by those individuals that had used the mobility map was 1.94 with a standard deviation of 1.25. By contrast, the average number of collected points by those that did not use the cross-country mobility application was .9 with a standard deviation of 1.10 (Figure 15).

Table 5 - Number of participants that stated they used the cross-country mobility web application prior to the land navigation competition.

	Total	Used the Mobility Application	Did not Use the Mobility Application
ROTC Participants	36	22	14
Non-ROTC Participants	15	12	3
Total	51	34	17

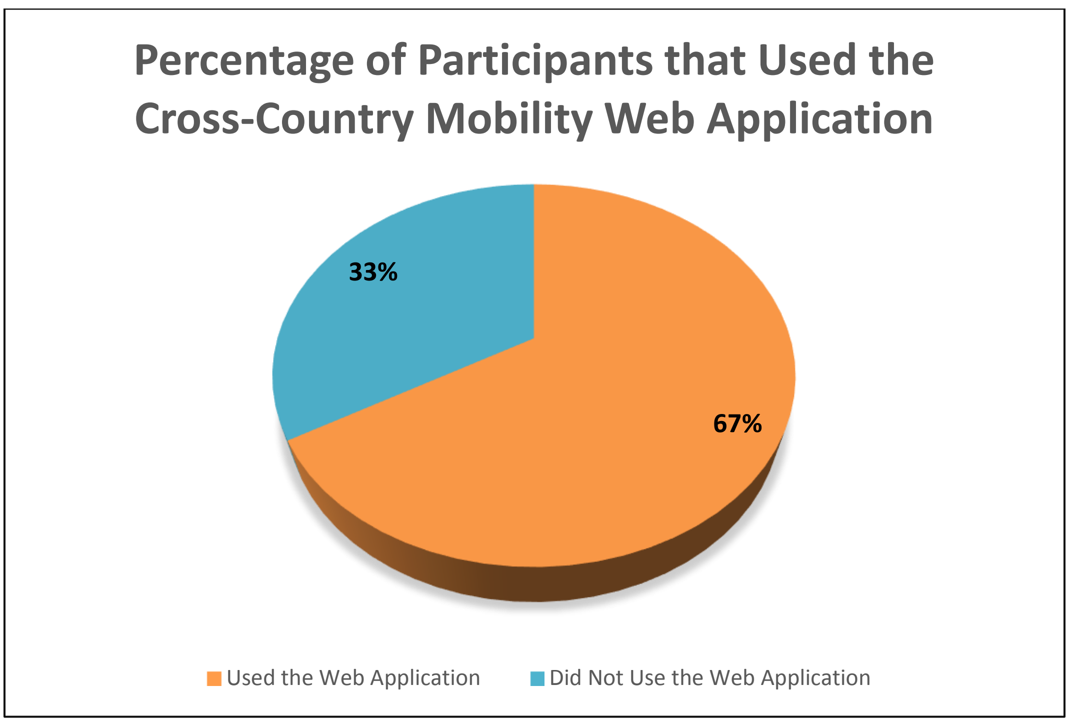

Figure 13 - The percentage of overall participants that used the web application.

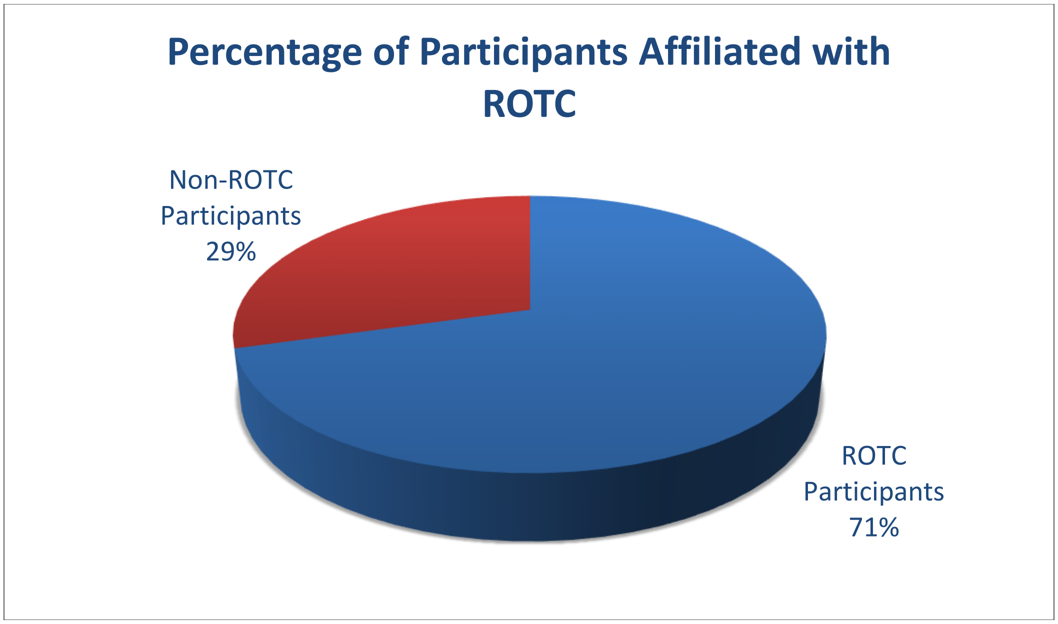

Figure 14 - The percentage of participants that were affiliated with The University of Arizona's ROTC program.

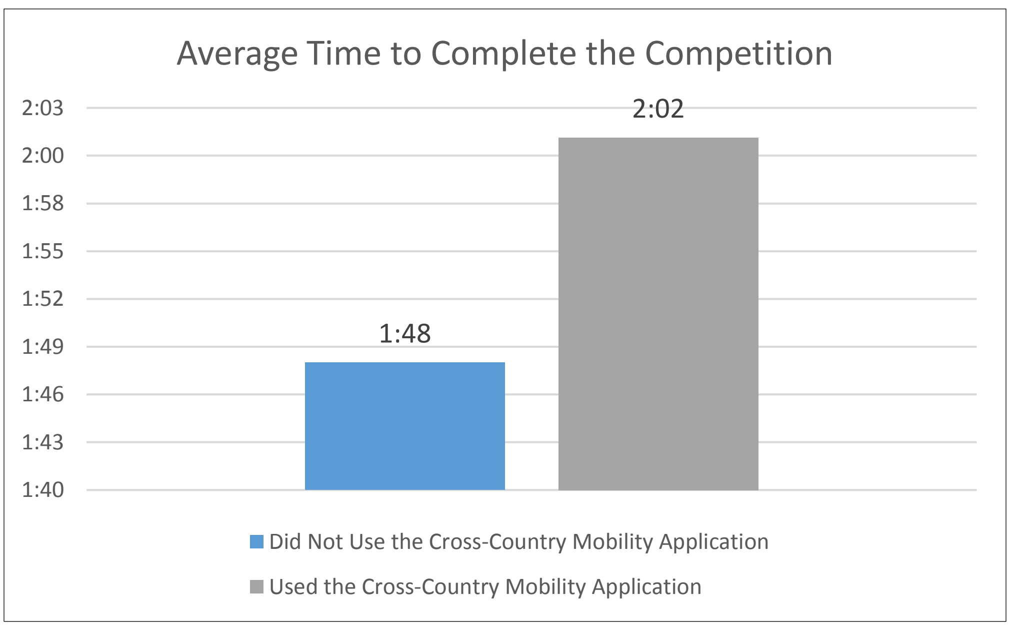

Figure 15 - The average time it took competitors to find points and return to the start for those that used the web application and those that did not.

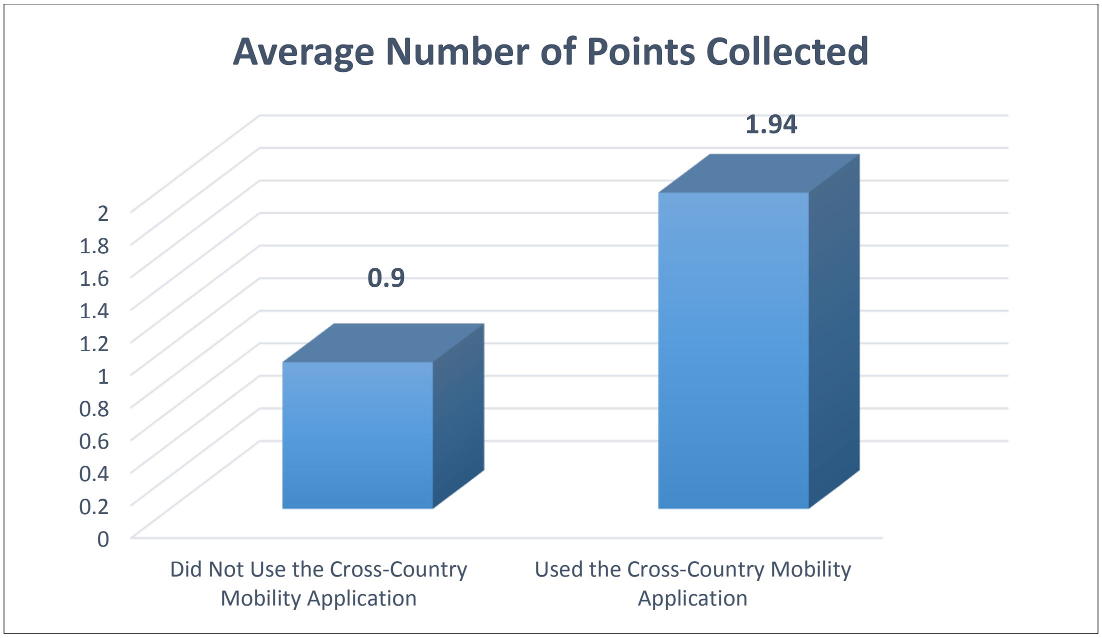

Figure 16 - The average number of points that were correctly found for those that used the online mobility tool and those that did not.

CONCLUSIONS

The objective of this project was to engage University of Arizona ROTC students with military applicable GIS content without burdening those students with additional coursework that may hinder a student's participation. This was met through the following objectives a) provide a future military officer in ROTC with spatial information that was previously unavailable to them in order to help them make a decision regarding terrain, and b) provide an opportunity for those officers to use that geospatial information in an informal setting. In order to meet these objectives, an interactive web application that provided movement speed over the terrain in Madera Canyon, Arizona, and a land navigation competition was developed to be introduced to ROTC students at the University of Arizona and those outside of the ROTC program. This project helped solve the difficulty of providing students with an opportunity to use GIS without increasing their course load by creating an informal competition which challenged individuals to analyze terrain and provided them an online tool to help them perform this analysis.

The objective to provide an informal educational opportunity for military officers training in ROTC was considered a success based on the reach and engagement of 51 individuals, of which 36 were future military officers. This objective was further evaluated by the number of times that the cross-country mobility web application was viewed prior to the navigation competition as well as by the number of ROTC students that stated they used the web application. The Cross-County mobility web application was viewed 121 times prior to the competition, suggesting that the web application had been viewed beyond the 51 participants. The cross-country mobility tool could have reached a larger ROTC audience and was only utilized by 61% of the ROTC participants.

The use of the GIS products to help make a decision regarding terrain was evaluated through time to complete and the total number of correct locations found. Although the average time to complete the course was 16 minutes longer with those that had used the mobility application than those that had not, the scores and number of points found were higher within the group that had used the application. This suggests that the web application assisted in providing information in point locations to those that were competing, but may not have helped them complete the course in a shorter time. However, the number of points was determined to be the more important success criteria considering that the highest number of points was the overall objective for competitors. To determine if using the web application provided a significant impact on point value, an unpaired t-test was run comparing the non-web app users and the web app users' point values. The two-tailed P value results for this test equaled .0516 suggesting that the web application was not quite statistically significant.

Qualitative results on the web application's ability to improve a user's score or add value to a participant's route planning were conducted through an anonymous survey sent out a week following the event. Only 8 participants responded to the survey, but comments provided some information on how the web application was used. One participant indicated that application was useful by stating, "The online map was helpful in planning". Two other participants may have indicated why the point value was lower than expected stating, "Maybe use larger wood sticks next time" and "make it easier to see points".

An assumption was made in this study that the cross-country mobility analysis provided an accurate reflection of movement speed across the terrain. Further studies may determine the accuracy of this model and refine the calculations used to derive the movement raster. A proven accurate model of movement speed hosted in a web application for additional land navigation locations or outdoor trails may be more capable of engaging military students and outdoor enthusiasts, which would further disseminate GIS content and analysis. This project could be expanded to analyze how users interacted with the online mobility tool, and if the time spent on the mobility tool changed their time or point collection scores.

Further extensions to this project could investigate and attempt to quantify an improvement in spatial thinking in participants that used the Cross-Country mobility application and participated in the corresponding land navigation challenge. Spatial thinking being defined as understanding space (e.g., distance between points in kilometers), representation (e.g., 2D map representation of the 3D terrain), and reasoning (e.g., using cross-country mobility speed to determine route) by the National Academy of Sciences (Committee, 2006, p. 12). Although it may be fairly evident that the challenge and mobility application test a user's ability to think spatially, an improvement in this domain from participation in a one-off exercise is unknown.

Evaluating and improvement in spatial thinking could be conducted through pre- and post- tests that evaluate spatial thinking abilities. This measurement tool may be based on Lee and Bednarz's "Spatial Thinking Ability Test" (Lee and Bednarz, 2011, 15-26) and could lead to improvements in the course, web application, or both.

The military's need to use space and have leaders that can analyze terrain may never change. However, as technology advances and GIS applications become more ubiquitous in the military landscape it may be integral to prepare and train our nation's future military officers on how to use GIS to perform terrain analysis, be capable of identifying the analysis that GIS can provide, and also understand its limitations. This can be done at the early stages of an officer's training by weaving contextualized and informal GIS instruction into existing military training such as land navigation.

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