Site-Specific Management Guidelines

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SSMG-11

The Earth Model—Calculating Field Size and Distances between Points using GPS Coordinates

Summary

An ever-increasing number of farmers have global positioning system (GPS) receivers on their combines. When not harvesting, GPS receivers are useful for more than locating one's favorite fishing spot. They can be tools for determining the distance between two points or to accurately determine the acres in a field that is to be rented. The distance between two sampling points and the area of a field can be found using GPS coordinates and knowledge of the Earth Terrestrial Coordinate System. Because GPS latitude and longitude are in terrestrial coordinates, determining the distance in length measurements (feet, meters, yards, kilometers, and miles) rather than degrees, between two points is not trivial. The objective of this guideline is to provide a method that farmers, ranchers, or agricultural practitioners can use to calculate distances between points and to calculate the size of a field using Excel, a commonly available spreadsheet. A more detailed description for calculating distance and area is found in Carlson (1999), in which the mathematics and assumptions used to create the model used in this guideline are described. A Basic programming language computer program is also available in that paper.

Simplifying Assumptions

For purposes of these calculations we will go back to the middle ages and assume that the earth is flat. On a flat earth, a line of longitude is parallel to the next line of longitude and lines of longitude are perpendicular to lines of latitude. After study of **Figure 1**, it is clear that these assumptions are not true. However, calculations show that if distances are small (less than one mile on the earth surface), these assumptions result in errors of less than 16 inches in a mile at 45 degrees latitude. Errors are smaller close to the equator and larger as the poles are approached. Also important to note is the fact that there have been many analytical models to describe the earth. Most GPS receivers and our calculations use the WGS84 spheroid earth model. Constants for the major and minor axis for this model are 6,378,137.0 meters and 6,356,752.3142 meters, respectively.

Distance between Two Points

First, use a DGPS (differential corrected GPS) to determine the latitude and longitudes of two points on the earth surface and determine an approximate elevation. In the example, we have used a Trimble 132 DGPS receiver to determine the latitude and longitude of the ends of a 300 ft. tape (**Table 1**). GPS receivers report locations in both decimal degrees and degrees, minutes, and seconds. GPS data reported in degrees, minutes, and seconds must first be converted to decimal degrees.

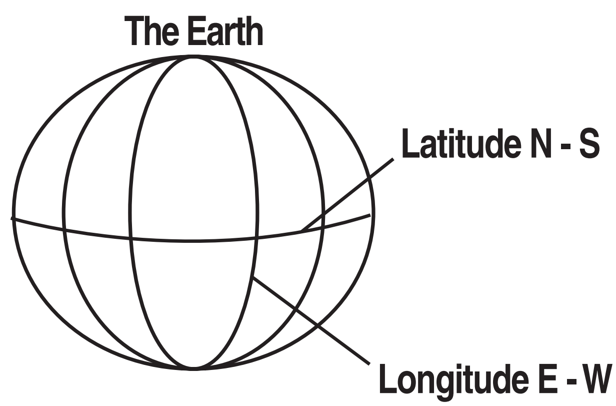

Figure 1. Latitude and longitude of the Earth. Distance between two adjacent integer (whole numbers such as 1 and 2, or 25 and 26, not 13.3 and 13.22 degrees) longitude lines are approximately 70 miles at the equator and converge to 0 miles at the North or South Poles.

Converting is best accomplished by using examples. Suppose you want to convert -96 degrees, 47.46732 minutes and 44 degrees, 27.66786 minutes into decimal degrees. This is accomplished by dividing the minutes by 60 and adding together as follows:

$$\text{Decimal degrees} = -(96 + (47.46732/60)) = -96.791122$$
$$44 + (27.66786/60) = 44.46113$$

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The same data may have been presented as -96 degrees, 47 minutes, and 28.0392 seconds and 44 degrees, 27 minutes, and 40.0716 seconds. Use the same procedure as above, but divide the seconds by 60*60 or 3600. The results are in units of decimal degrees.

Decimal degrees = -(96 + (47/60) + (28.0392/3600)) = -96.791122

Second, input the latitude and longitude information and appropriate equations into an Excel worksheet (**Table 2a**).

Table 1. Latitude, longitude, and elevations of the two ends of a 300 ft. tape.

	Latitude	Longitude	Elevation
Point 1	45.46491350	-95.90903233*	334.9 m
Point 2	45.46555306	-95.90976827	334.9 m

* Note that in the Western Hemisphere, to the west of Greenwich, England, longitude is many times expressed as a negative number. This distinguishes a latitude-longitude point from the same point in the Eastern Hemisphere. It also simplifies the mathematics of calculating distance. In the Southern Hemisphere, latitude becomes negative for the same reason.

When the equations and constants are input correctly, the Excel spreadsheet will have the values shown in **Table 2b**.

The distance between the two points is determined by converting the latitude/longitude values to values on an X/Y coordinate plane. Point 1 is at the origin (0,0), and point 2 is at the coordinates shown in B12 and B13 (71.08488298, 57.55806184). The distance between the points is solved using the equation:

$$\text{Distance} = ((0-71.08)^2+(0-57.6)^2)^{0.5}.$$

This value is in B15. The distance 91.465877 m can be converted to feet (300.0849 ft) by multiplying it by the conversion factor 3.28084 ft/m.

Calculation of Field Area

A second exercise is presented to give an example calculation of the area of a field. Again, the same simplifying assumptions (flat and no curvature of the longitudinal lines) are appropriate for calculation of an area that is small relative to the size of the earth…less than 1 section (640 acres).

Table 2a. Input, equations, and output of an Excel spreadsheet. Once the equations are input, distances between different points can be calculated by changing B1, B2, C1, C2, and C15.

	A	B	C
1	Point #1	Latitude point 1 (45.4649135)	Longitude point 1 (-95.9090323)
2	Point #2	Latitude point 2 (45.46555306)	Longitude point 2 (-95.9097683)
3	Determine true angle	=(ATAN((C14^2)/(C13^2)*TAN(B1*PI()/180)))*180/PI()	
4	Determine true angle	=(ATAN((C14^2)/(C13^2)*TAN(B2*PI()/180)))*180/PI()	
5			
6	Radius pt 1	=(1/((COS(B3*PI()/180))^2/C13^2+(SIN(B3*PI()/180))^2/C14^2))^0.5+C15	
7	Radius pt 2	=(1/((COS(B4*PI()/180))^2/C13^2+(SIN(B4*PI()/180))^2/C14^2))^0.5+C15	
8			
9	X - Y earth coordinates	=B6*COS(B3*PI()/180)	=B6*SIN(B3*PI()/180)
10	X - Y earth coordinates	=B7*COS(B4*PI()/180)	=B7*SIN(B4*PI()/180)
11			
12	X coordinate	=((B9-B10)^2+(C9-C10)^2)^0.5	
13	Y coordinate	=2*PI()*((((B9+B10)/2))/360)*(C1-C2)	6378137
14			6356752.3142
15	Distance meter	=((B12)^2+(B13)^2)^0.5	Elevation meters (334.9)
16	Distance feet	= B15*3.28084	
17			
18			
19			
20	Area of a triangle	=0.5*ABS(B17*C18-C17*B18+C17*D18-D17*C18+D17*B18-B17*D18)	
21	M^2 to ft^2	=(B20*10.76391)	
22	Ft^2 to acres	=(B21/43560)	

Table 2b. The values in the Excel spread sheet following input of values and equations shown in Table 2a.

	A	B	C
1	Point #1	45.4649135	-95.90903233
2	Point #2	45.46555306	-95.90976827
3	Determine true angle	45.27250514	
4	Determine true angle	45.27314475	
5			
6	Radius pt 1	6367650.922	
7	Radius pt 2	6367650.683	
8			
9	X - Y earth coordinates	4481143.389	4523973.05
10	X - Y earth coordinates	4481092.718	4524022.91
11			
12	X coordinate	71.08499298	
13	Y coordinate	57.55806184	6378137
14			6356752.31
15	Distance meters	91.46587729	334.9
16	Distance feet	300.0849088	

For our example, the four corners of a football practice field at South Dakota State University were located using a Trimble 132 receiver.

Calculating Areas of a Field

In calculating areas, the simplifying assumptions discussed above are used. In our example you will need to: (i) use the spread sheet developed above; (ii) know the DGPS coordinates of the corners of the field in question; and (iii) use the triangle area equation, which is:

$$Area = .5*|x_1*y_2 - x_2*y_1 + x_2*y_3 - x_3*y_2 + x_3*y_1 - x_1*y_3|$$

Note that the | | lines are absolute value operators. This means that the calculation inside of the | | will be positive or converted to positive.

where x_i and y_i are the coordinates of the three points making the triangle.

To calculate acres:

Step 1: Use a DGPS to measure the corners of your test field. The latitude and longitude values of South Dakota State University football field are given in step 2

Step 2: Separate the field into two triangles (or as many triangles as are necessary to cover the entire field. Irregular fields can be approximated by a number of triangles). This is accomplished by identifying points i, ii, and iii as the corners for triangle 1 and the points ii, iii, and iv as the corners for triangle 2.

Input the longitude and latitude information into the F and G columns. When done, the spreadsheet should look like:

	F	G
1	44.3215242	-96.7779358
2	44.3210783	-96.7779332
3	44.3215143	-96.7767868
4	44.321080	-96.7767883

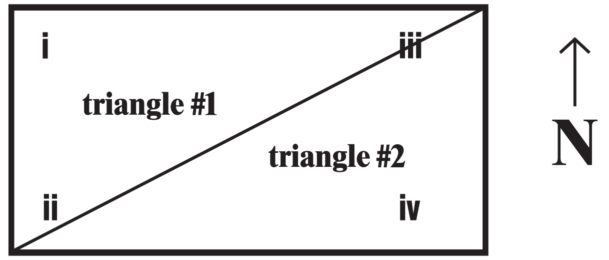

Figure 2. Practice football field divided into calculable triangles.

Select the smallest value in F1 through 4 (F2=44.3210783) and G 1 through 4 (G1= -96.7779358) and put these values in B2 and C2. These values will be defined as the origin on the X/Y coordinate system and the points are located in the southwest corner of the area being worked on.

The area in triangle 1 will be calculated in steps 3 through 6.

Step 3: Copy F1 and G1 to B1 and C1, respectively.

The X and Y coordinates for point 1 are in B12 and B13. Copy these points to B17 and B18. When copying these values you must copy the values, not the equation. This can be accomplished by using {paste special} and {values} commands.

Step 4: Copy F2 and G2 to B1 and C1, respectively.

The X and Y coordinates for point 2 are in B12 and B13; copy these values to C17 and C18. When copying these values you again must copy the value, not the equation.

Step 5: Copy F3 and G3 to B1 and C1, respectively.

The X and Y coordinates for point 3 are in B12 and B13. Copy these values to D17 and D18. When copying these values you must copy the value, not the equation.

When you are done the values in the spreadsheet should be:

	B	C	D
17	49.55035245	0	48.45022
18	0	0.207419129	91.6629606

Step 6: calculate the area for triangle 1 using the formula given above. This is accomplished by setting cell:

B20 = 0.5*ABS(B17*C18-C17*B18+C17*D18-D17*C18+D17*B18-B17*D18)

The value (2270.852m^2) in cell B20 represents the area of triangle 1. This value is converted to ft^2 by multiplying it by 10.76391ft^2/m^2. The 24,443.25 ft^2 is then converted to acres by dividing it by 43,560 ft^2/acre. Following these calculations the area of triangle 1 is 0.56114 acres.

Step 7: Repeat steps 2 through 5 for triangle 2. As defined under step 2, your new corner points are located at points ii(F2,G2), iii(F3,G3), and iv(F4,G4). Calculations are accomplished by copying F2 and G2 to B1 and C1; F3 and G3 to B1 and C1; and F4 and G4 to B1 and C1. When done correctly the spreadsheet will have the values:

	B	C	D
17		48.450221	0.188911406
18	0.2074192	91.6629606	91.62341041
19			
20	2203.991		

Following the calculations described above the number of acres contained in triangle 2 is 0.54462

Step 8. Determine total acres by adding the acres in 6 and 7 together. The total acres in the football field were 1.10576. ■

References

Carlson, C.G. 1999. What do latitude and longitude readings from a DGPS receiver mean? http://www.abs.sdstate.edu/plantsci/ext/pawg/earthmo1.htm. C.G. Carlson, Plant Science Department, South Dakota State University, Brookings, SD

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