Why are there differences in Geographical Information System's (GIS) acreage numbers?

The question is often asked, "Why are GIS acreage numbers inconsistent?" This is a good question to ask, but the answer might not be so simple. There are many reasons there are different acreages for a given section, allotment, or any other defined area on the ground; there is also equally apparent inconsistency in linear measures. In searching for a national standard for generating metrics from a GIS, differing numbers have become an important issue.

The discussion that follows is about numbers generated using GIS software. The problems discussed here should not be attributed to surveyed acres, i.e., land metrics generated by a registered surveyor.

One would imagine that a GIS computer system would consistently arrive at the same numbers for a given polygon. This would be true if all elements in that GIS remained the same. If another GIS calculated metrics for that same polygon and had identical elements, the acreage would be the same. But identical systems and elements, as discussed below, are often not the case.

There are three major elements that contribute to inconsistent metrics from a GIS.

1) The type, accuracy, and version of the digital representation.

   - The type of representation, raster or vector, can greatly change the metrics of a given polygon. Raster representations of polygons and linear features give very different results than the vector representation of the item on the ground. Depending on the cell size in a raster, acres could be entirely different or closely resemble the vector version of the same feature. Similarly, the quality of digitizing, point spacing, registration of source materials, transformation creep, etc., can greatly affect metrics in a GIS.

   - Another reason for different acreages is a question of version. One might ask; is one version newer than another? Have there been updates to the data? Is the data on a different computer system using different software? One office's version of the data may be the same, but other factors may cause variations, such as topologic tolerances and map projections. Even the computer chips can result in miniscule variations in results. This is why metadata is so important.

2) The formula and conversion factors used.

   - The formula for computing metrics is probably consistent within a version of a GIS. For example, ArcGIS calculates square units or length units consistently, regardless of program module. Brand X GIS may use an entirely different method for deriving acres or miles from a GIS feature.

   - The conversion factors can also lead to different numbers. For example, the conversion factor from square meters to acres using the U.S. Survey foot results in slightly less acres than the numbers derived from using the Imperial foot conversion factor for meters to acres.

- Another fundamental problem is "machine precision." Geographic coordinates are either stored in floating point numbers or converted to floating points prior to any projection calculation. Floating point numbers differ in their representation (precision, accuracy, range) from machine to machine. Moreover, projection (and thus length and area) computations use transcendental functions, for which rounding is necessary.

3) The map projection used.

   Another important source of variation in acreage and miles figures can be attributed to map projection. A map projection is set of mathematical factors designed to minimize spatial distortion as we flatten the Earth to display on a screen or print on a plotter, but there are many different map projections, each with its own distortions in shape and distance. **Acres and miles calculations reflect these differences in distortion due to projection.** ArcGIS computes the square units or linear units using that data set’s assigned map projection. The term “map acres” or “GIS acres” is very apt for that reason. Acreage and miles calculations are very much a product of the “planar representation” or “map” in which the data is stored.

   Problems in resolving differences due to map projection are many. First, there is no standard map projection that meets all needs. There are many uses for geographic data and many types of maps. It follows, then, that there are many different map projections, each one meeting different needs. For example, data stored in a nationwide system might use “USA Contiguous Albers Equal Area Conic,” whereas a Forest Reserve may use “NAD 1983 UTM Zone 11.” Acres calculated from these two projections are slightly different for the same area on the Earth.

   Second, there are legal reasons map projections differ from state to state. For example, Oregon’s legislated map projection is different than Idaho’s legislated map projection. Given that, one might find variations, however tiny, in the acreages generated in each system.

So we, in the Bureau of Land Management (BLM) GIS, are not alone in the plight of standardizing acres and miles numbers. It’s a problem facing everyone who uses a GIS to calculate acres and miles. One might say that it is nearly impossible to have consistent acres and miles figures for a given parcel of land from a geographic information system, yet that is what the users of GIS data expect, ignoring that the devil is in the details.

One might ask if there is a solution to these problems. I can propose that there are short term and long term possibilities:

For the foreseeable future, there should be metadata narratives developed to accompany acres and miles computed using a GIS. This metadata should include the methods used, conversion factors, map projections, etc. There should also be a general disclaimer stating the data is not survey quality and was computed using a geographic information system.

For numbers generated within an agency or community, there should be a limited number of map projections used, each with a defined purpose and application and limitation. For example, acres generated on a national basis might be different than numbers developed and used locally, because they may have different purposes. This is allowable as long as the metadata states the methods used in developing the numbers and the possible pitfalls.
In response to a question about which is the best or most accurate projection, the answer is based on what the user intends.

In the long term, it may be possible to perform area and length calculations based on spherical or geodesic geometry. This is not an entirely new idea. The formulas for determining distances and areas on an oblate sphere are available and documented; they are just not implemented in a commonly used GIS. Perhaps the next generation geographic information systems will perform computations based on how the feature lies on the Earth, instead of how it lies on the map.