

# Comparison of 7.5-Minute and 1-Degree Digital Elevation Models 61

ORIGINAL CONTAINS

FOR ILLUSTRATIONS

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**ABSTRACT:** We compared two digital elevation models (DEMs) for the Echo Mountain SE quadrangle in the Cascade Mountains of Oregon. Comparisons were made between 7.5-minute (1:24,000-scale) and 1-degree (1:250,000-scale) images using the variables of elevation, slope aspect, and slope gradient. Both visual and statistical differences are presented.

## INTRODUCTION

THE METHODS REQUIRED to assess the extent and distribution of natural resources often require that topographic factors be taken into account. This may be because these factors are directly influencing the resources of interest (vegetation patterns), or because topographic factors influence the data from Earth resources satellites.

In forested environments, for example, slope gradient and slope aspect are known to influence distribution of various plant species. The shading resulting from various slope and aspect combinations along with solar angle of incidence also influences the appearance of forest types on remotely sensed imagery. By accounting for topographic variables such as slope gradient, slope aspect, and elevation, we should be able to improve our capacity to conduct inventories of natural resources. Eby's (1987) study of the effect of sun incidence angle data, calculated from digital elevation data, is an example in the use of digital Landsat data. Stoszek (1977) and Miller and Heller (1978) both determined that topographic variables—including elevation, aspect and locations near ridgetops—could be used to predict infestations by the Douglas-fir tussock moth.

With Geographic Information Systems (GIS), topographic variables such as these can be developed from Digital Elevation Models (DEM) available in digital formats from the United States Geological Survey (USGS). Greenlee (1987) developed a method to extract drainage networks and other rasterized linework from a DEM for input into a vector GIS. Jenson and Dominique (1988) reported that DEMs can be useful for hydrologic applications such as delineating watersheds and developing overland flow path models. Their results indicated that the accuracy and detail of the hydrologic information was dependent on the resolution and quality of the DEM.

Two commonly used DEM formats are 1:250,000-scale (1-degree) Defense Mapping Agency (DMA) data and 1:24,000-scale (7.5-minute) DEM data. The DMA data are available for the whole of the conterminous United States, but DEM data are available only for selected areas where the USGS has collected data for developing and updating their 7.5-minute quadrangle sheets (U.S. Geological Survey, 1987). The 7.5-minute DEM data are more highly resolved (30 by 30 m per cell) than the 1-degree DMA data, at three arc-seconds (about 65 by 92 m for this mid-latitude area), but its limited availability invites the question of whether the resolution and accuracy of the DMA data, which is available over the entire United States, is adequate for inclusion with large area surveys incorporating satellite-acquired data.

We compared these two data forms on a USGS quadrangle-sized area in the Oregon Cascade Mountains. The study area chosen was the area covered by the Echo Mountain SE quadrangle (also referred to as Tamolitch Falls) within the McKenzie

River drainage east of Eugene, Oregon. The western two-thirds of the quadrangle is steep and deeply dissected, and the eastern portion is flatter. This area is typical of many forested mountains of the Pacific Northwest. The objective was to quantify the differences between slope gradient, slope aspect, and elevation images derived from the two digital elevation data forms.

## METHODS

The 7.5-minute data for the Echo Mountain SE quadrangle were read as elevations representing distance above mean sea level (MSL) in one-metre intervals with a minimum of 581 m and a maximum of 1747 m. The data were displayed as a level-sliced color image, with red colors as higher elevations and magenta for lower elevations (Plate 1).

Derived images of slope gradient and slope aspect were computed on the original 16-bit data (L.N. Brantley, personal comm.; see the Appendix for algorithms used). Eight sector aspects and a flat category were computed, and slopes were calculated in percent. Level-slicing was used to develop a color scheme for image representation of these two data sets.

The 1-degree data, a full scene of DMA data covering the area within 122 and 123 degrees west longitude and 44 and 45 north latitude, were read from tape to a disk file. A 151- by 151-pixel subset of the data covering the same area as in the 7.5-minute data was selected from the full scene with a 601-m minimum and a 1707-m maximum elevation.

Eighty observations, one from each of the two different elevation data sets, were obtained from a systematic sampling of the study area at points with a 1000-m spacing. A simple linear regression analysis was conducted to determine the relationship between the 80 elevations from the 7.5-minute data set and the 1-degree data set.

For the 1-degree data, slope gradient and slope aspect images were derived, using the same methods described above *before* they were rescaled, rectified, and resampled to 30- by 30-m pixels. The resampling was conducted using a nearest neighbor routine which used the intensity of the closest pixel to determine the value of the output pixel. Slope gradient and slope aspect images were colored using the same scheme as with the 7.5-minute data.

A difference image was generated by subtracting elevations at each pixel location for the whole image area. Comparisons for both slope aspect and slope gradient variables were accomplished with an overlay analysis to generate a matrix of observations showing frequencies of coincidence of all classes.

## RESULTS AND DISCUSSION

The relationship between the elevations sampled from the 7.5-minute and the 1-degree data sets (before resampling) is

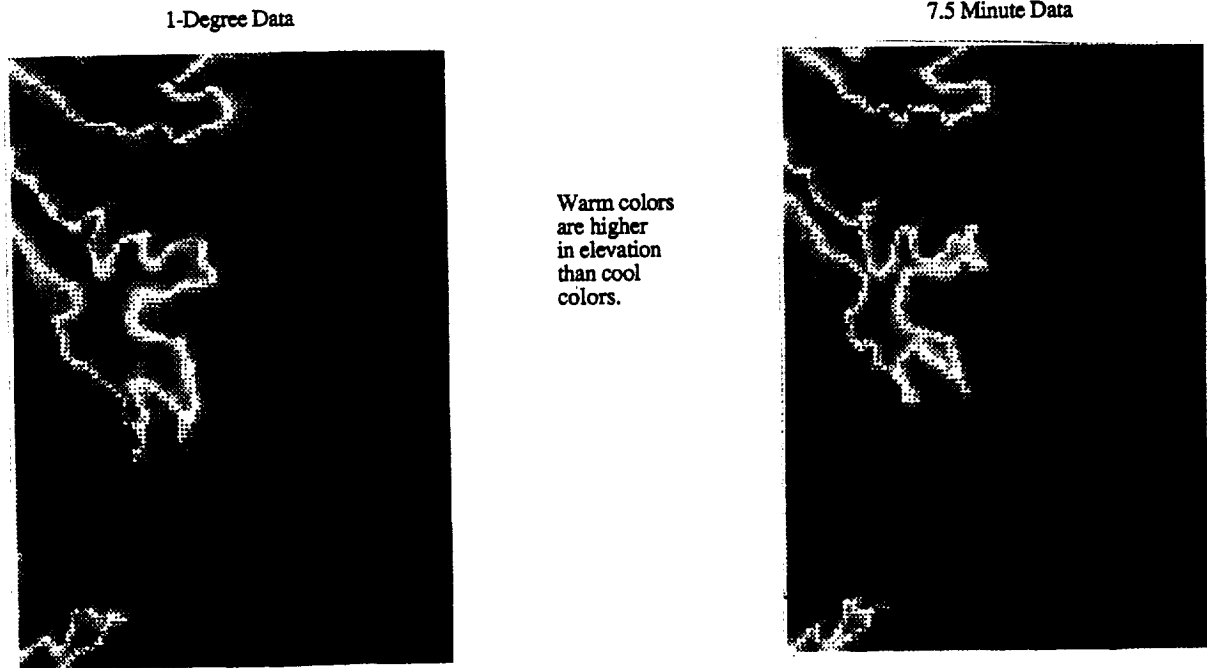


PLATE 1. Comparison images of 7.5-minute and 1-degree digital elevation models for the variable of elevation for the Echo Mountain SE Oregon Quadrangle.

shown in Figure 1. The relationship between these variables was found to be linear with a coefficient of determination of 84.3 percent. The slope, 0.99, and intercept, 36.9, were not significantly different from 1.0 and 0.0, respectively ( $P < 0.01$ ), indicating that there was no significant bias. The standard error was 30.6 m, and the residuals from the least-squares regression line appeared to be distributed randomly. By overlaying the elevation layers from the two different data sources, the mean elevation difference, on a pixel by pixel basis for the entire area, was calculated to be 31.0 m, with a standard deviation of 6.99 m. Most of the higher differences appeared to be associated with steeper slopes. A visual comparison of the 1-degree and 7.5-minute elevation maps suggest considerable correspondence of general patterns, but a greater amount of detail in the 7.5-minute image (Plate 1).

The visual correspondence of general pattern between the 1-degree and the 7.5-minute data sets was also apparent for both slope aspect and slope gradient images (Plates 2 and 3). Pattern heterogeneity was higher in the 7.5-minute data sets, probably due to the finer original pixel resolution. While the modes for aspect class comparisons occurred as expected (East with East, Southeast with Southeast, etc.) only 36 percent of pixels were in the same class in both images (Table 1). Sixty-seven percent of pixels were in the same or adjacent (East with Northeast, East and Southeast, e.g.) classes. In the slope gradient images, 29 percent of all pixels were in the same class in both images (Table 2), and gradients calculated from the 1-degree data were lower than those from the 7.5-minute data. The differences apparent in the images seemed to derive from a greater level of detail in the 7.5-minute than in the 1-degree data.

While we have noted anomalies in 1-degree data in other areas, of low relief, which create obvious artifacts in derived topographic images, no instance of this was found in the data used in this comparison in areas of mountainous terrain. This is true also of other 1-degree data sets we have used. For applications in mountainous terrain, 1-degree data seem an appropriate match for Landsat Multispectral Scanner data and for databases where data storage limitations may be of concern.

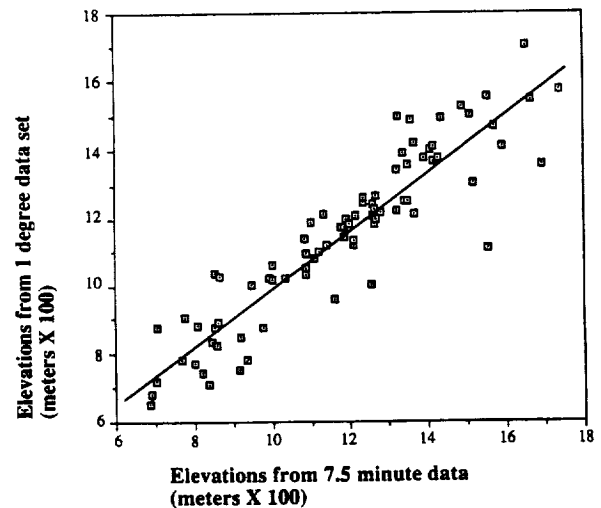


FIG. 1. Scatter diagram of elevations obtained from a 7.5-minute digital elevation model (x axis) and a 1-degree digital terrain model (y axis) on the Echo Mountain SE quadrangle area of the central Oregon Cascade mountains.

One final note has to do with the order of processing for digital terrain data sets. Resampling to adjust pixel size, rectification of images, and rescaling to different intervals resulted in different final image values depending on the order of processing. In some cases the differences were great. In this set of analyses, for example, we retained the 16-bit format as far along in the chain of processing as possible, and final images for slope and aspect yielded very different quantitative estimates of flat terrain. Because the original data are in one-metre intervals, and the algorithm for slope aspect determines a non-flat aspect for *any* unequal elevation, very few slope aspect "flat"

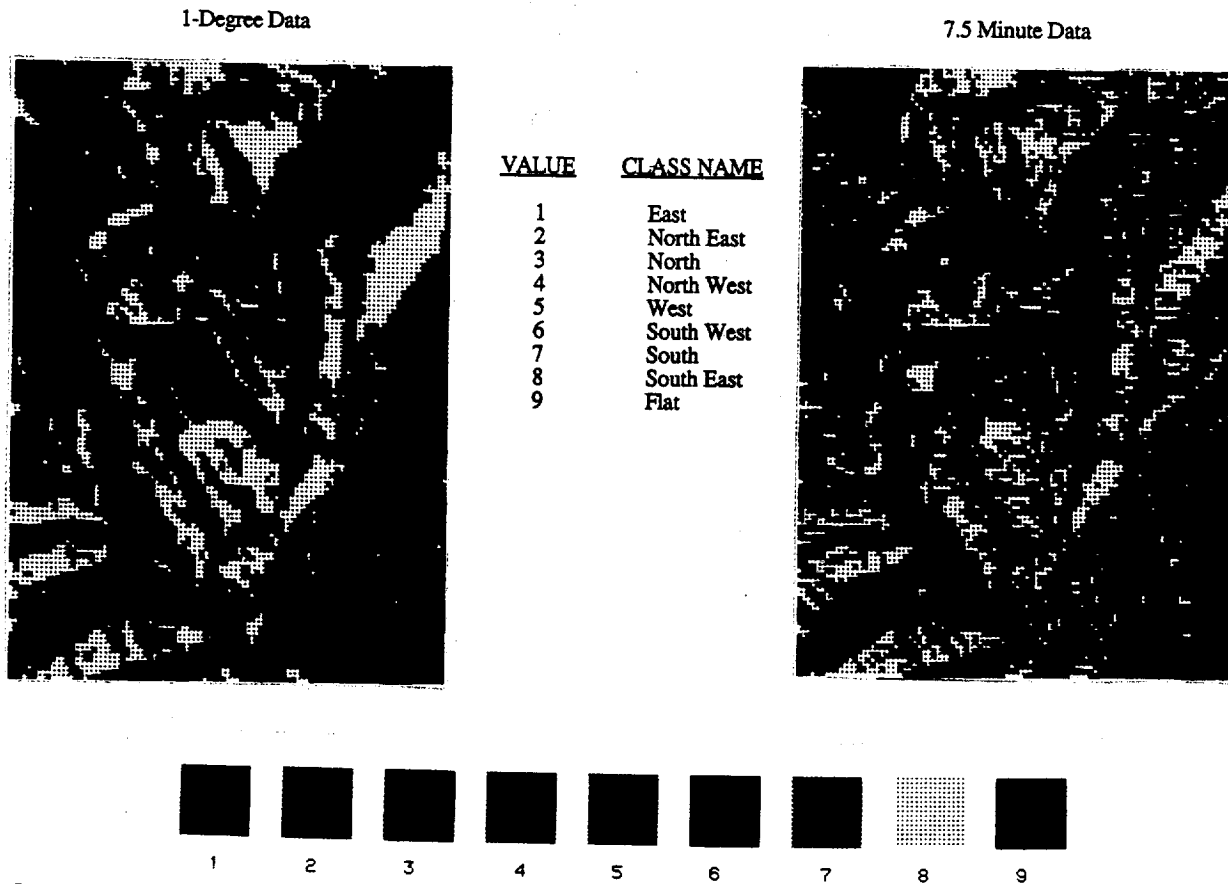


PLATE 2. Comparison images of 7.5-minute and 1-degree digital elevation models for the variable of slope aspect for Echo Mountain SE Oregon quadrangle.

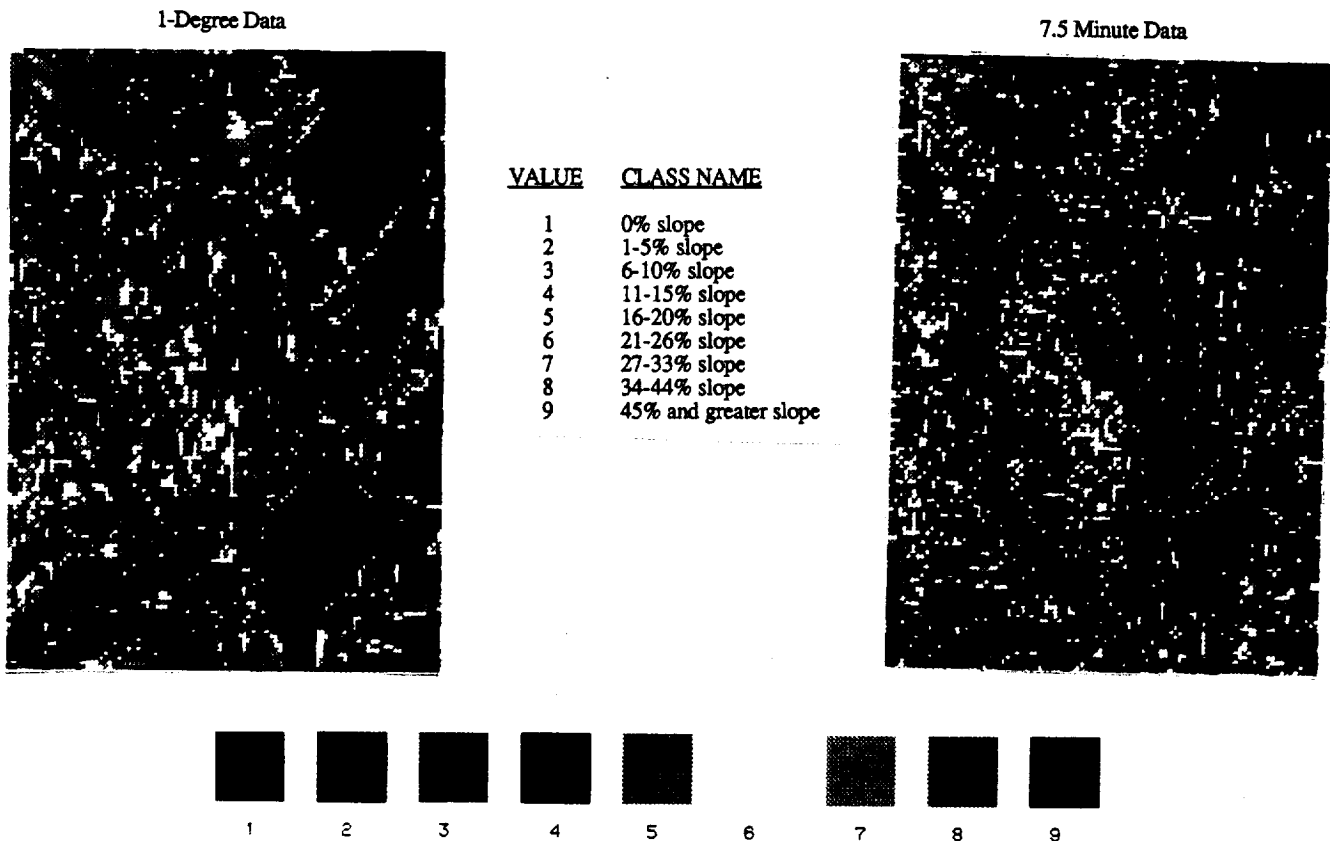


PLATE 3. Comparison images of 7.5-minute and 1-degree digital elevation models for the variable of slope gradient for Echo Mountain SE Oregon quadrangle.

TABLE 1. A COMPARISON OF SLOPE ASPECTS DERIVED FROM 7.5-MINUTE AND 1-DEGREE DIGITAL ELEVATION MODELS (DEM). NUMBERS ARE COUNTS OF COINCIDENT OCCURRENCE FOR THE ENTIRE ECHO MOUNTAIN SE QUADRANGLE.

1-degree DEM Aspects	7.5-minute DEM Aspects									
	E	NE	N	NW	W	SW	S	SE	Flat	TOTAL
E	8030	2689	686	497	524	651	888	2777	10	17403
NE	4886	7667	3191	808	744	637	556	1375	25	20526
N	1516	2905	7285	2557	927	470	462	799	17	17408
NW	576	569	1805	4921	2980	833	689	498	35	13739
W	470	241	728	2573	6383	2710	1236	525	254	17730
SW	1026	565	392	1027	4561	9924	3130	1131	28	31708
S	1518	384	188	437	1378	4821	6635	3337	4	23523
SE	5697	1087	426	480	788	1337	3340	9567	12	24071
FLAT	630	463	398	340	422	361	615	531	40	4161
TOTAL	24349	16570	15099	13640	18607	21744	17551	20540	425	170269
AGREEMENT	33%	46%	48%	36%	34%	46%	38%	47%	9%	36%

TABLE 2. A COMPARISON OF SLOPE GRADIENT CLASSES DERIVED FROM 7.5-MINUTE AND 1-DEGREE DIGITAL ELEVATION MODELS (DEM). NUMBERS ARE COUNTS OF COINCIDENT OCCURRENCE OVER THE ENTIRE ECHO MOUNTAIN SE QUADRANGLE

1-degree DEM (percent)	7.5-minute DEM slopes (in percent)									TOTAL
	0	1-5	6-10	11-15	16-20	21-26	27-33	34-44	>44	
0	2314	2313	1798	1225	810	630	440	507	678	10715
1-5	565	3026	2967	1922	1201	808	708	845	1459	13501
6-10	398	2538	3775	2842	1686	1206	911	912	1346	15614
11-15	297	1545	2310	2184	1746	1612	1219	1079	1330	13322
16-20	217	609	1100	1381	1448	1724	1502	1299	1244	10524
21-26	296	479	901	1301	1683	2581	2670	2400	2564	14875
27-33	240	320	729	1221	1550	2629	3229	3314	3479	16711
34-44	250	243	570	996	1457	2440	3688	5245	6714	21603
>44	222	384	808	1240	1607	2459	3576	8015	21866	40177
TOTAL	4799	11457	14958	14312	13188	16089	17943	23616	40680	157042
AGREEMENT	48%	76%	25%	15%	11%	16%	18%	22%	54%	29%

pixels resulted. In slope gradient determinations, rounding can result in zero percent calls without absolute equality in the elevations used in calculations, and the zero percent classes were greater: 10,715 zero percent slopes versus 4161 "flat" aspects in the 1-degree data, and 4,799 zero percent slopes versus 425 "flat" aspects in the 7.5-minute data. Users of digital terrain data should carefully consider and check each step in their processing to ensure meaningful results. The methods of production can effect the kinds of artifacts that occur and the accuracy of the results.

We have concluded that, in our applications in wildlife habitat analysis, 1-degree DEM data are preferable to our developing our own digital elevation data for the extensive areas for which 7.5-minute data are not available. We suggest, however, that additional comparative research be conducted involving both types of DEMs for a variety of terrain types. The results reported in this paper may or may not be indicative of DEM differences found in other areas, but the comparison techniques in this paper can be applied to other areas with different topographic profiles.

#### ACKNOWLEDGMENTS

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#### APPENDIX

Computations of slope gradient and slope aspect (source, L.N. Brantley, personal comm.):

consider the 3- by 3-pixel matrix of elevations around the point (x,y) -

	x-1	x	x+1
y-1	a	b	c
y	d	e	f
y+1	g	h	i

where a,b,c, etc., are the elevations at the indicated points.

Computation of average x and y elevation changes:

$$\Delta x_1 = c - a$$

$$\Delta y_1 = a - g$$

$$\Delta x_2 = f - d$$

$$\Delta y_2 = b - h$$

$$\Delta x_3 = i - g$$

$$\Delta y_3 = c - i$$

$$\Delta x = \frac{\Delta x_1 + \Delta x_2 + \Delta x_3}{3}$$

$$\Delta y = \frac{\Delta y_1 + \Delta y_2 + \Delta y_3}{3}$$

$$\frac{-\pi}{8} < \theta < \frac{\pi}{8}$$

aspect = E

$$\frac{\pi}{8} < \theta < \frac{3\pi}{8}$$

aspect = NE

$$\frac{3\pi}{8} < \theta < \frac{5\pi}{8}$$

aspect = N

$$\frac{5\pi}{8} < \theta < \frac{7\pi}{8}$$

aspect = NW

$$\frac{7\pi}{8} < \theta < \pi$$

aspect = W

$$\text{or } -\pi < \theta < \frac{-7\pi}{8}$$

aspect = W

$$\frac{-7\pi}{8} < \theta < \frac{-5\pi}{8}$$

aspect = SW

$$\frac{-5\pi}{8} < \theta < \frac{-3\pi}{8}$$

aspect = S

$$\frac{-3\pi}{8} < \theta < \frac{-\pi}{8}$$

aspect = SE

(1) Computation of slope gradient:

let  $s$  = cell size

$$\Delta e = \sqrt{\Delta x^2 + \Delta y^2}$$

if  $\Delta e \leq s$ , percent slope =  $\Delta e/s \cdot 100$

if  $\Delta e > s$ , percent slope =  $100 + [(1 - s/\Delta e) \cdot 100]$

(2) Computation of slope aspect:

if  $\Delta x = 0$  and  $\Delta y = 0$ , aspect = FLAT,

otherwise

$$\theta = \tan^{-1} \left[ \frac{\Delta y}{\Delta x} \right]$$

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