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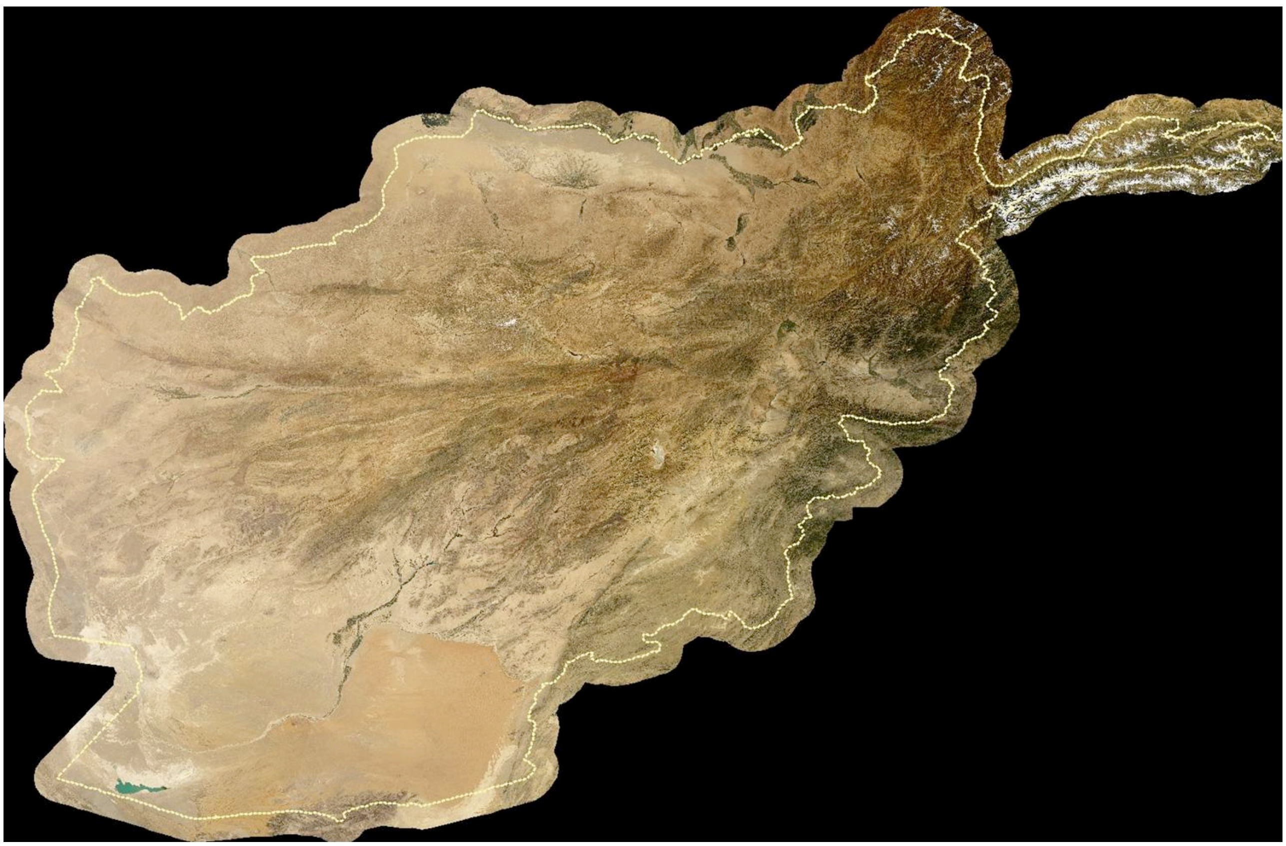
Natural-Color Image Mosaics of Afghanistan: Digital Databases and Maps

By Philip A. Davis and Trent M. Hare



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COVER
Landsat natural-color image mosaic of Afghanistan, with political boundary outlined.

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Introduction

In 2005, the U.S. Agency for International Development and the U.S. Trade and Development Agency contracted with the U.S. Geological Survey (USGS) to perform assessments of the natural resources within Afghanistan. The assessments concentrated on resources related to the economic development of the country, specifically oil and gas, coal, minerals, and water, as well as on earthquake hazards. All of these assessments require geologic, structural, and topographic information throughout the country at a finer scale and with better accuracy than those provided by existing maps, which were published in the 1970s by the Russians and Germans. The very rugged terrain, the large scale of these assessments, and the terrorist threat in Afghanistan indicated that the best approach to provide the preliminary assessments was to use remotely sensed, satellite image data, although this may also apply to subsequent phases of the assessments. Therefore, the first step in the assessment process was to produce satellite image mosaics of Afghanistan. This report discusses the production of two digital natural-color satellite image databases, as well as various versions of a countrywide, natural-color map.

Characteristics of Landsat ETM+ Satellite Image Data

We used Landsat Enhanced Thematic Mapper Plus (ETM+) data to construct the natural-color image mosaics of Afghanistan. The Landsat non-thermal-band data were previously calibrated to relative reflectance, matched scene to -scene to provide a consistent band-reflectance database throughout the country, and then mosaicked into seamless 1°-by-2° map tiles (Davis, 2006, 2007). One set of map tiles retained the original 28.5-m spatial resolution of the Landsat multispectral bands, and another set, at 14.25-m spatial resolution, was generated by a resolution-enhancement algorithm that combined the high-frequency morphologic information of the Landsat panchromatic band with the spectral information of the six Landsat nonthermal multispectral bands. These map tiles were constructed from orthorectified Landsat scenes that have a positional accuracy of 50 m (Kalluri and others, 2000). The original Landsat scenes were in Universal Transverse Mercator (UTM) map projection, using the WGS84 datum. Afghanistan has three UTM zones (41–43); zone 42 lies between long 66º and 72º E. The map tiles were also produced in this map projection so as not to degrade the positional accuracy of the data. The multispectral map tiles by Davis (2006) were used to construct natural-color map tiles and different versions of a countrywide natural-color image mosaic of Afghanistan.

Natural-color images depict the Earth's surface as seen by the human eye. Much of Afghanistan is semiarid to arid, and so much of the country appears as shades of red, brown, and yellow. Vegetation cover is restricted to irrigated agricultural areas along watercourses and to the high mountain areas in the northeast corner of the country, where scattered glaciers also occur. We produced this natural-color base map to provide assessment teams with a database that they could use to locate and display ancillary information but also as a positioning tool during fieldwork.

Natural-Color Calibration of Landsat Visible-Band Image Data

Calibration of the Landsat ETM+ maps by Davis (2006) was by relative reflectance and needed to be "grounded" with ground-reflectance data, but the difficulties in performing fieldwork in Afghanistan precluded ground-reflectance surveys. For natural-color calibration, which involves only the blue, green, and red Landsat color bands, we could use ground photographs, Munsell color readings of ground surfaces, or another image base that accurately depicts the surface color. Ground photography is the least reliable of these three approaches. On four separate field trips to north-central Afghanistan, we acquired ground photographs and Munsell color readings for various ground surfaces, but the field areas excluded the wide range of surface colors that occur in Afghanistan, especially in desert areas, and so we supplemented our ground color-sample data with a less direct source of color information.

The Moderate-Resolution Imaging Spectroradiometer (MODIS) satellite collects 36 spectral images at relatively low resolution (250–1,000 m per pixel), but the instrument's color bands allow accurate atmospheric corrections. The MODIS science team has provided ground-calibration sites that allow the sensor data to be calibrated to ground reflectance. The MODIS science team has prepared "true color" image mosaics for many countries in the world, including Afghanistan; they are posted on WeatherStreet.com's Web site (URL http://www.truecolorearth.com/). We obtained a "true color" image mosaic of Afghanistan from this Web site and registered it to our Landsat image mosaic so that we could determine the correspondence between the digital values of the blue, green, and red color bands in the MODIS "true color" mosaic with their respective digital values in the Landsat image mosaic (fig. 1). The relation between the MODIS and Landsat digital values is best modeled with a third-order polynomial, as we have also observed in "true color" calibrations for Ikonos satellite data. Although previous studies have determined a linear relation between the surface reflectance of Landsat visible bands and the Munsell blue, green, and red digital values for various surfaces (for example, Escadafal and others, 1989), the surface reflectances used did not exceed 40 percent (a digital value of 102 in our Landsat dataset), which is near the change from the linear trend at lower reflectances to a third-order polynomial at higher reflectances. In addition, closer examination of the data collected by Escadafal and others indicates that their "linear" relation between reflectance and Munsell digital value becomes less distinct with increasing reflectance and may actually be better modeled with a second- or third-order polynomial.

Our field studies were conducted after our MODIS-to-Landsat calibration was performed. During fieldwork, we recorded Munsell colors (Munsell Color, 1975; Goddard and others, 1995) for more than 100 rock and soil surfaces. Our fieldwork was not intended for this purpose, nor could fieldwork be conducted in many parts of Afghanistan, and so our Munsell color samples do not cover the wide range of colors that occur within Afghanistan. We extracted blue, green, and red digital values from the MODIS-calibrated Landsat data for the sites that we sampled in the field. We converted the Munsell color samples to blue, green, and red digital values by using a Munsell conversion program (URL http://colorpro.com/info/software/munsell.htm). The relation between the MODIS-calibrated Landsat blue, green, and red digital values and those derived from the Munsell color samples is plotted in figure 2. The red and green digital values correspond quite well, but the blue digital values in the MODIS-calibrated Landsat data are lower than the ground-surface Munsell digital values. We performed a linear least-squares regression analysis on the blue digital values (fig. 2) and applied the resulting equation to the Landsat blue digital values and displayed it with the MODIS-calibrated Landsat green and red digital values. The resulting color-composite image had too much red in many areas of Afghanistan. Therefore, we applied a transformation halfway between the MODIS calibration and the Munsell calibration, which produced much better results. This hybrid calibration replaced the subtle green tint in the MODIS-calibrated images of alluvium and deserts with more realistic shades of gray, yellow, and red and more closely matched the colors of the outcrops that we sampled and photographed during our field studies in the Khamard District of the Bamian Province.

Production of Natural-Color Landsat Image Mosaics and Maps

We applied the hybrid MODIS-Munsell natural-color transform to the Landsat 28.5- and 14.25-m-spatial-resolution image data that were produced as 1º-by-2º map-tile mosaics in UTM projection by Davis (2006). The resulting natural-color map tiles were then reprojected to the WGS84 geographic reference system by using a second-order polynomial transformation and more than 5,000 grid-control points for the 28.5-m-spatial-resolution data and more than 20,000 grid-control points for the 14.25-m-spatial-resolution data -to retain the 50-m positional accuracy of each dataset. Each map tile overlaps adjacent tiles by at least 100 pixels. The digital map files begin with the map-tile name, which starts with the letter "Q" (for quadrangle) and four digits that designate the lower-left-corner latitude and longitude coordinates of the 1º-by-2º map tile (fig. 3). The map-tile index is followed by the map's resolution and coordinate system ("UTM" for Universal Transverse Mercator projection or "GEOG" for WGS84 geographic coordinates) and the designation "NC" (for natural color). For example, the two filenames for map tile Q3460 in this report are Q3460_14m_UTM_NC.tif and Q3460_28m_GEOG_NC.tif.

All of the 28.5- and 14.25-m-spatial-resolution map tiles for Afghanistan (in both UTM projection and WGS84 geographic coordinates) are stored as losslessly compressed, embedded geotiff files (with associated world files) that can be downloaded from the USGS Projects in Afghanistan's Web site (URL http://gisdata.usgs.net/website/afghan/). Only the 14.25-m-spatial-resolution UTM and 28.5-m-spatial-resolution WGS84 geographic geotiff datasets are provided on these DVD–ROMs to decrease the number of discs needed.

In addition to the natural-color map tiles, we also constructed a countrywide natural-color map of Afghanistan at 1:850,000 scale as a Portable Document Format (PDF) file. This scale conforms to that of the geologic map of Afghanistan recently published by Doebrich and Wahl (2005). At the start of this project, the USGS Afghanistan geospatial team decided to project all map data at a scale 1:500,000 or larger in Transverse Mercator (TM), using a WGS84 datum, a central meridian of long 66º E., a reference latitude of 34º N., a scale factor of 0.9996, and a false easting and northing of zero. This map projection retains more positional accuracy than do WGS84 geographic coordinates. Therefore, all of the UTM map tiles were reprojected to this TM projection and then mosaicked into a single image file. Country and province borders, major cities, and roads were obtained from the Afghanistan Information Management Service's Web site (http://www.aims.org.af/) and superposed on the countrywide natural-color image mosaic. This image map was then converted to a PDF file at 300 dots per inch (dpi), or about 72 m per pixel, for ease in printing.

We also produced three higher-resolution image mosaics of the map at 600 dpi, which provides 35.985 m per pixel, the highest resolution allowed by most plotters. All three of these image mosaics maintain positioning information in JPEG2000 format. The first image mosaic (afghan_naturalcolor_600dpi_fullversion) contains all of the map information contained in the lower-resolution (300 dpi) PDF file, the second image mosaic (afghan_naturalcolor_600dpi_provinces) contains only the country border and province borders and names, and the third mosaic (afghan_naturalcolor_600dpi_country) contains only the country border.

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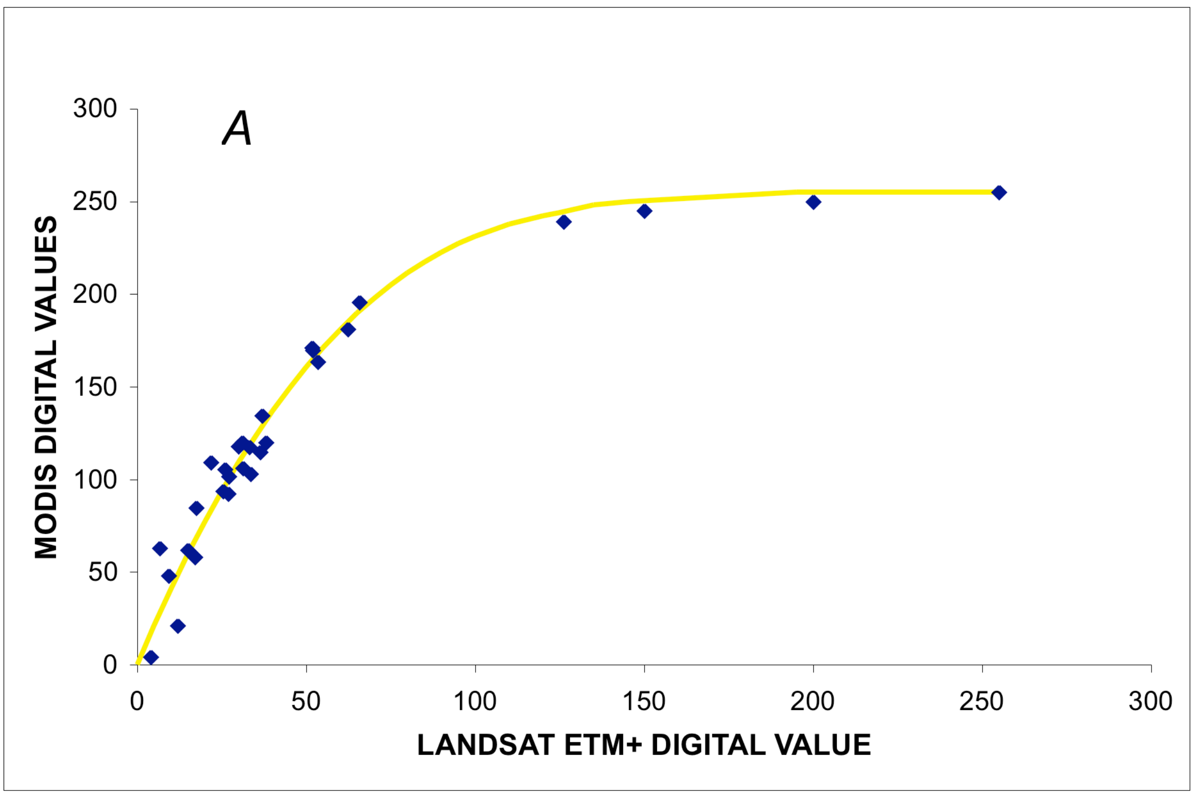

Figure 1. Digital values of blue (*A*), green (*B*), and red (*C*) color bands in Moderate-Resolution Imaging Spectroradiometer (MODIS) satellite "true color" mosaic versus respective digital values in Landsat Enhanced Thematic Mapper Plus (ETM+) image mosaic. Yellow curve is third-order-polynomial fit to data.

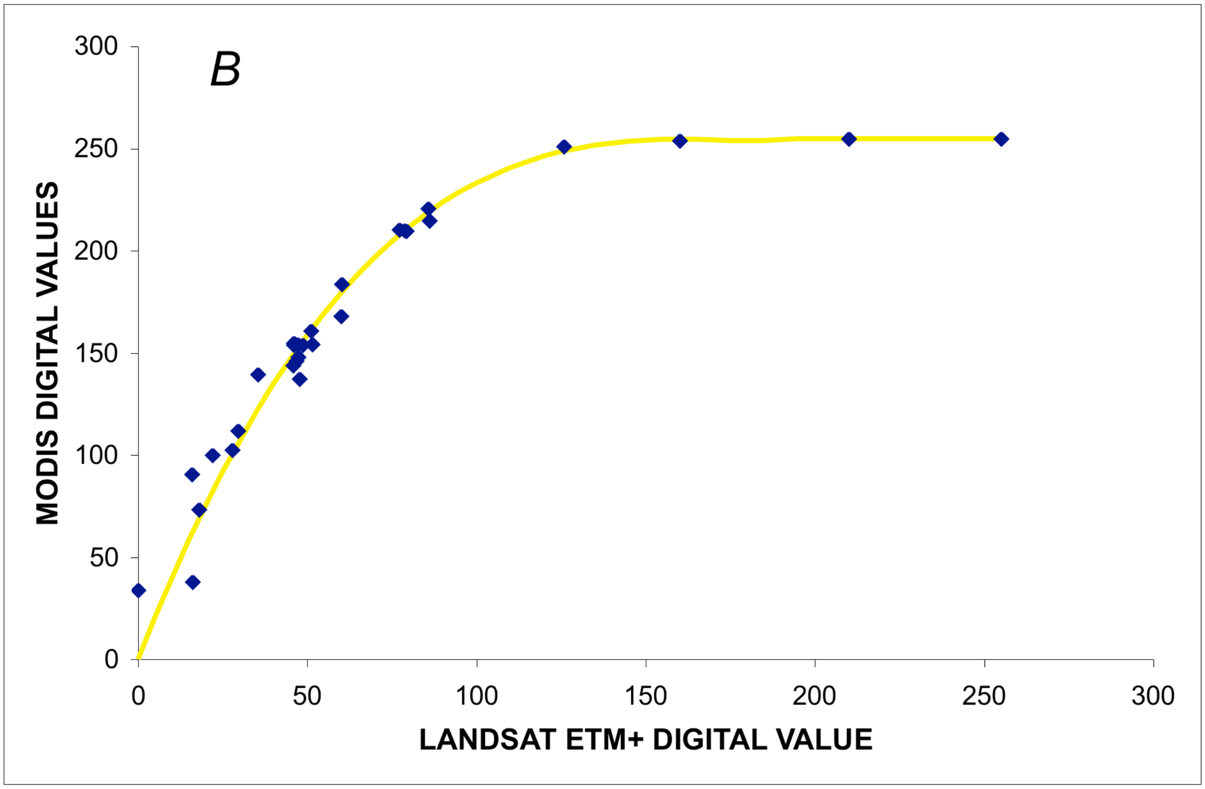

Figure 1 (B)

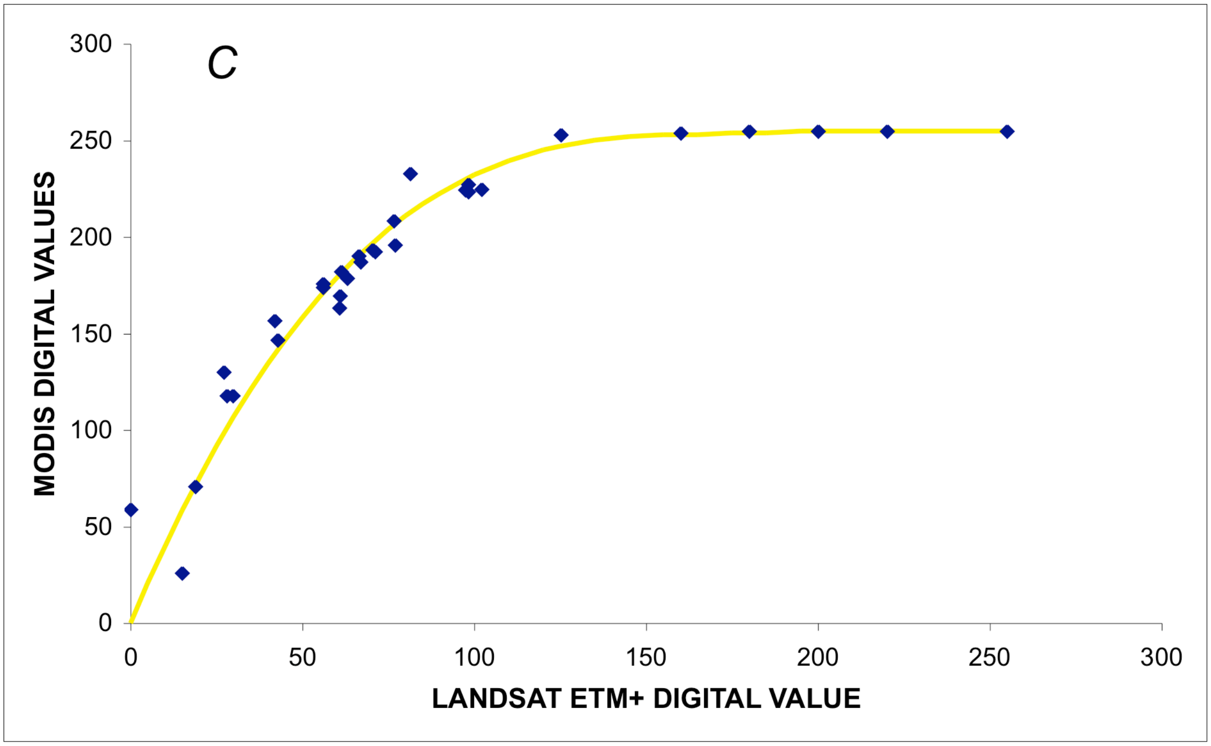

Figure 1 (C)

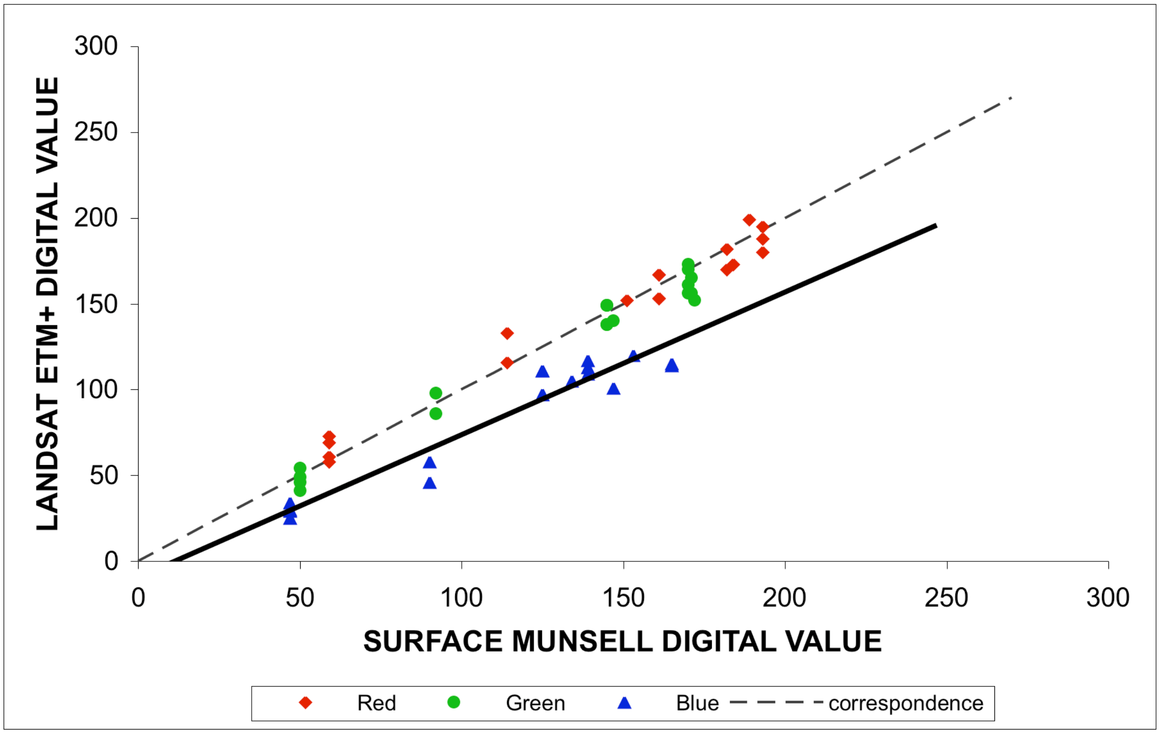

Figure 2. Digital values of red (diamonds), green (dots), and blue (triangles) color bands in Landsat Enhanced Thematic Mapper Plus (ETM+) image mosaic versus respective digital values in ground-surface Munsell (Munsell Color, 1975; Goddard and others, 1995) color samples. Dashed curve, one-to-one correspondence; solid curve, linear least-squares regression of blue-band data.

Figure 3. Map-tile scheme for Afghanistan project on natural-color image base. Each 1°-by-2° quadrangle is designated by its lower-left-corner latitude and longitude.