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Land-Cover and Imperviousness Data for Regional Areas near Denver, Colorado; Dallas-Fort Worth, Texas; and Milwaukee-Green Bay, Wisconsin - 2001

By James Falcone and Daniel Pearson

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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)

2001 Land-Cover and Imperviousness Data for Regional Areas near Denver, Colorado; Dallas-Fort Worth, Texas; and Milwaukee-Green Bay, Wisconsin

By James Falcone and Daniel Pearson

Abstract

This report describes the processing and results of land-cover and impervious surface derivation for parts of three metropolitan areas being studied as part of the U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program Effects of Urbanization on Stream Ecosystems (EUSE). The data were derived primarily from Landsat-7 Enhanced Thematic Mapper Plus (ETM+) satellite imagery from the period 1999-2002, and are provided as 30-meter resolution raster datasets. Data were produced to a standard consistent with data being produced as part of the USGS National Land Cover Database 2001 (NLCD01) Program, and were derived in cooperation with, and assistance from, NLCD01 personnel. The data were intended as surrogates for NLCD01 data because of the EUSE Program's time-critical need for updated land-cover for parts of the United States that would not be available in time from the NLCD01 Program. Six datasets are described in this report: separate land-cover (15-class categorical data) and imperviousness (0-100 percent continuous data) raster datasets for parts of the general Denver, Colorado area (South Platte River Basin), Dallas-Fort Worth, Texas area (Trinity River Basin), and Milwaukee-Green Bay, Wisconsin area (Western Lake Michigan Drainages).

Introduction

As part of the U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program Effects of Urbanization on Stream Ecosystems (EUSE) study, statistics for several hundred Geographic Information System (GIS)-derived datasets, of which land-cover data were a key element, were calculated to characterize study watersheds in six metropolitan areas: Atlanta, Georgia; Raleigh, North Carolina; Denver, Colorado; Dallas-Fort Worth, Texas; Portland, Oregon; and Milwaukee-Green Bay, Wisconsin (U.S. Geological Survey, 2006a). Field collection of biological, chemical, and physical data occurred in 2003 and 2004, with analysis planned for the 2005-2006 time frame. A key requirement for characterizing the study watersheds and analyzing the field data for all six EUSE study areas was uniform land-cover data that (a) represented a time period as consistent as possible with field data, and (b) would be complete and ready for analysis by 2005. At the time of planning in 2002-2003, only one land-cover dataset, the National Land Cover Database 2001 (NLCD01; Homer and others, 2004), appeared to have the possibility of meeting these requirements. Discussions with representatives of the NLCD01 development program, however, indicated that, for three of the six study areas, NLCD01 data would not be available in time for analysis in 2005. Given that no other source of medium resolution (30 meter) land-cover data were or would be available for those three study areas for the correct time period, the decision was made for EUSE personnel to develop those land-cover and imperviousness datasets "in-house", using identical tools, methods, and standards as those being employed by the formal NLCD01 development teams. It was also envisaged that the final products could potentially be incorporated into the final NLCD01 and/or be used for other purposes beyond the EUSE study.

The three study areas comprised regions near Denver, Colorado (fig. 1), Dallas-Fort Worth, Texas (fig. 2), and Milwaukee-Green Bay, Wisconsin (fig. 3). The geographic extent of the land-cover and imperviousness datasets was primarily intended to cover the area of the EUSE study watersheds for each individual study, and does not necessarily cover all urban areas in the region, for example near Denver.

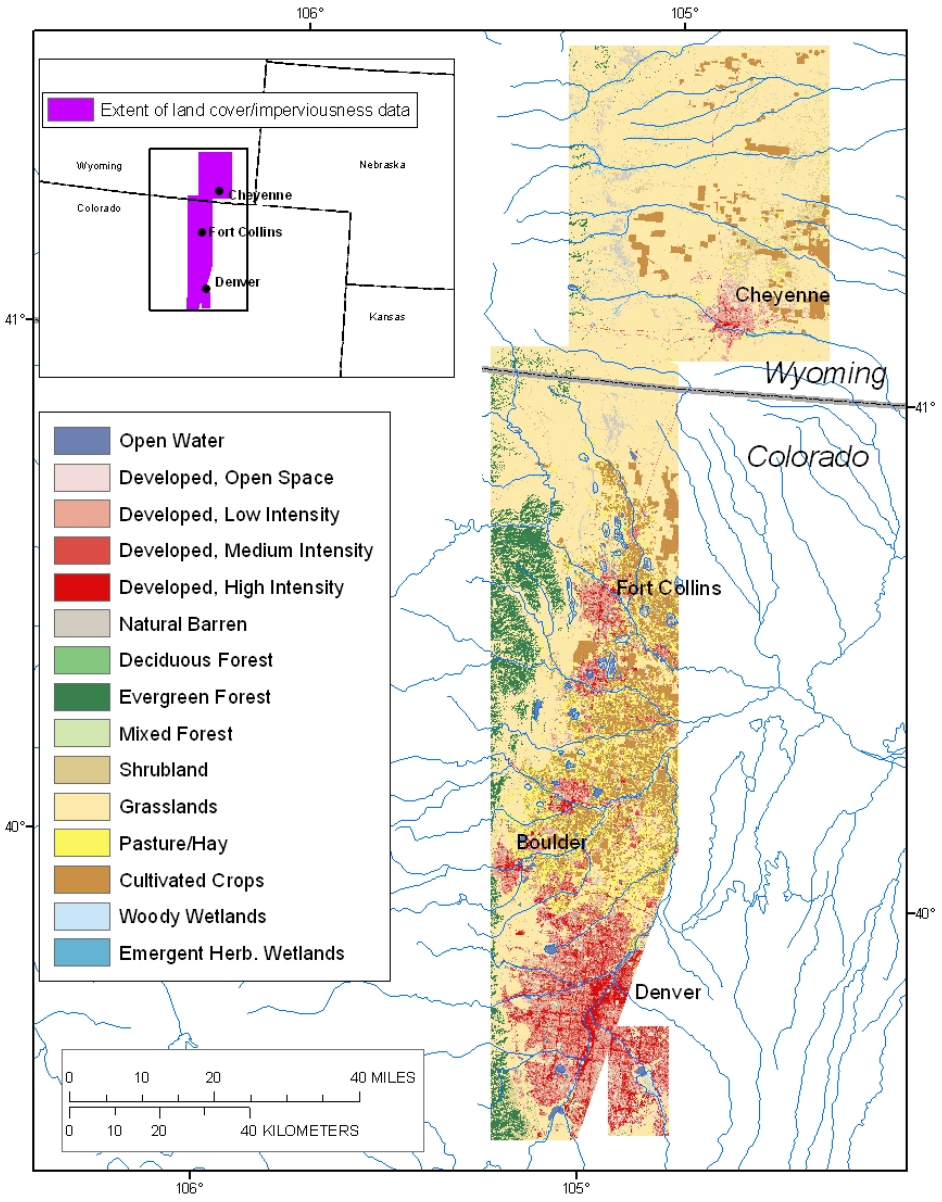

Figure 1. 2001 land-cover for National Water-Quality Assessment Program, Effects of Urbanization on Stream Ecosystems (EUSE) study, Denver, Colorado.

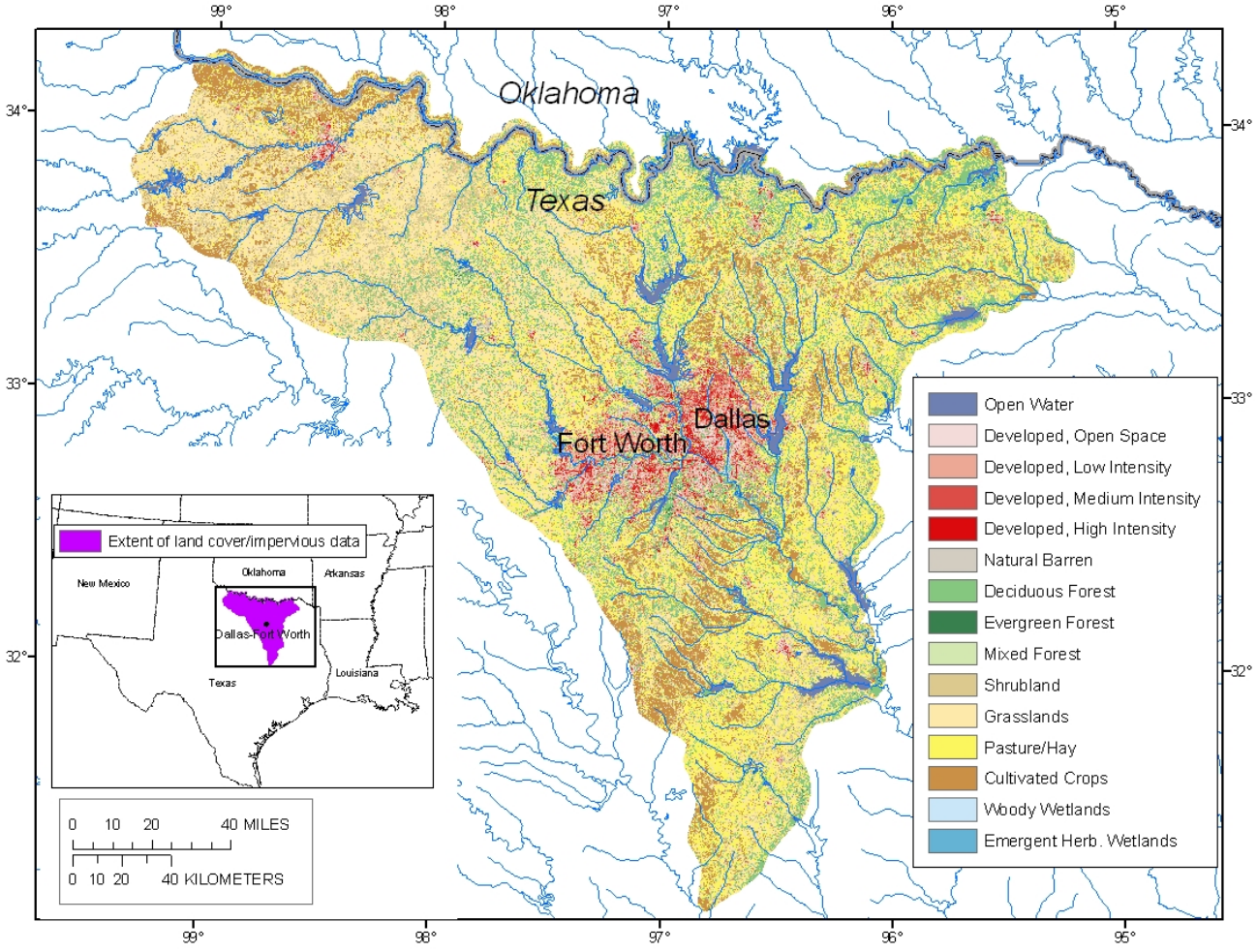

Figure 2. 2001 land-cover for National Water-Quality Assessment Program, Effects of Urbanization on Stream Ecosystems (EUSE) study, Dallas-Fort Worth, Texas.

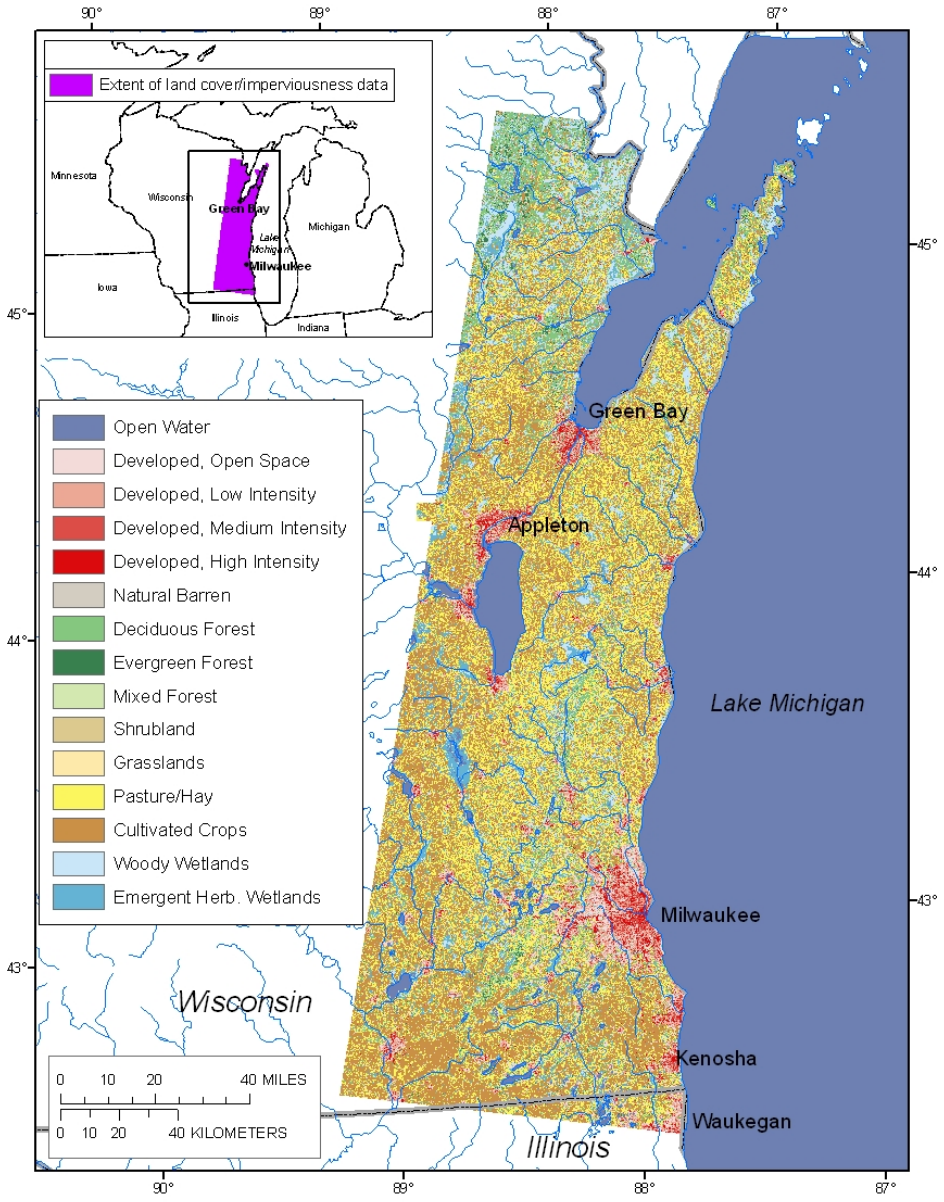

Figure 3. 2001 land-cover for National Water-Quality Assessment Program, Effects of Urbanization on Stream Ecosystems (EUSE) study, Milwaukee-Green Bay, Wisconsin.

Six separate products were produced as part of this effort: a land-cover and imperviousness dataset for each of the three areas shown in figures 1-3. Each product has a spatial resolution of 30 meters, corresponding to the underlying Landsat ground-sample distance. The land-cover data follow a modified Anderson Level II categorical classification (Anderson and others, 1976; Homer and others, 2004), where each pixel is coded according to the predominant land-cover type. Values in the imperviousness datasets are continuous. Each pixel has a value ranging from 0-100, representing the estimated percent anthropogenic impervious surface of that cell (fig. 4).

(a) (b)

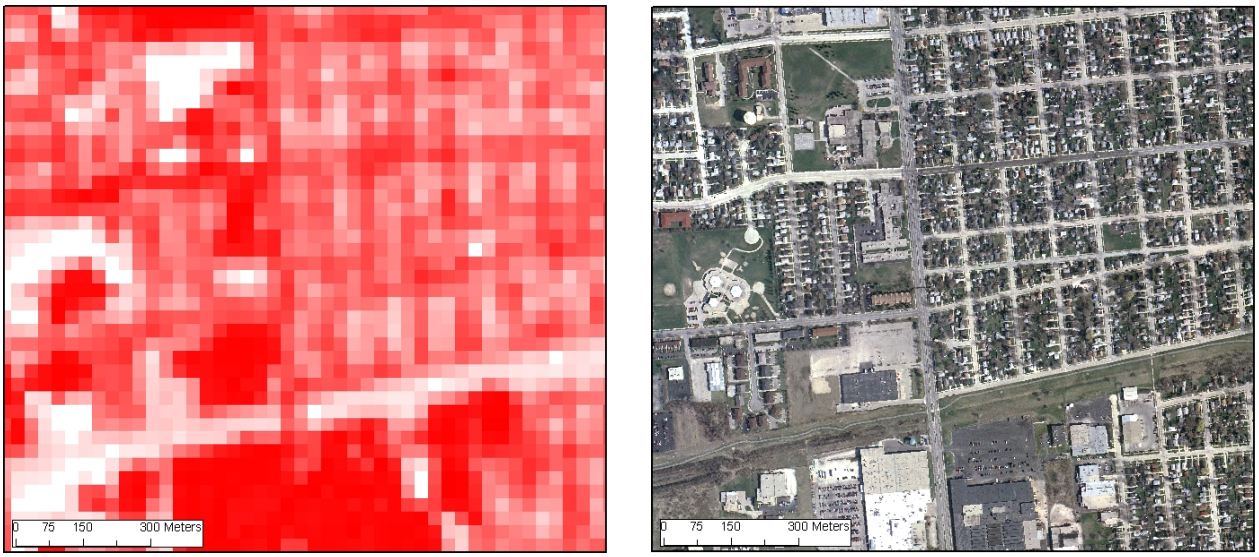

Figure 4. Sample derived impervious surface data (a), compared to high-resolution orthoimagery (b), for the same area.

Each 30-meter pixel of the impervious surface dataset represents an estimated value (0-100) of the percent impervious surface at that location. Values shown here are color-ramped from white (low imperviousness) to red (high imperviousness).

Methods

One of the goals for deriving these products was to be as consistent as possible with NLCD01 data being derived by the NLCD01 Program. The EUSE personnel who performed the derivation attended NLCD01 training at the USGS Earth Resources Observation and Science Data Center (EDC), and communicated regularly with NLCD01 personnel throughout the process. Derivation was performed using identical software tools as the NLCD01, which included several tools used in tandem: ERDAS/Imagine© (Leica Geosystems AG), Cubist© and See5© (Rulequest Reseach Pty Ltd), and ARC/INFO (ESRI Inc.). Additional specialized ERDAS add-on software for regression and classification was implemented by the USGS as part of the NLCD01 effort, and was also used in processing.

Source Imagery

Imagery was provided by the USGS EDC from the NLCD01 imagery archive (U.S. Geological Survey, 2006d). Derivation of land-cover and imperviousness datasets was based primarily on Landsat-7 ETM+ 30-meter imagery, but also included IKONOS 4-meter (Space Imaging, Inc.), and U.S. Department of Agriculture (USDA) National Agriculture Imagery Program (NAIP) 1-meter images used as training data for imperviousness regression (table 1). Additional high-resolution (1-foot to 1-meter) Digital Orthophoto Quads (DOQs) or other aerial photography available from the USGS Seamless Server (U.S. Geological Survey, 2006b) were also used frequently as a source of training data or for visual verification purposes.

At least three Landsat images were used for every Worldwide Reference System (WRS) Landsat path/row footprint, generally including a leaf-on, leaf-off, and an early spring or late fall image for each. The number of Landsat path/row footprints necessary for coverage of each study area varied: for Denver three WRS footprints were required (fig. 5); for Dallas-Fort Worth eight were required (fig. 6); and for Milwaukee-Green Bay two were required (fig. 7). For the Dallas-Fort Worth area data-mosaic scenes were delivered based on three time periods: leaf-on, leaf-off, and spring. For the Denver and Milwaukee-Green Bay areas, data were delivered as separate scenes. Landsat data were delivered in two formats: seven band terrain-corrected Digital Number (DN) spectral data and three band (brightness, greenness, wetness) Tasseled Cap transformed data.

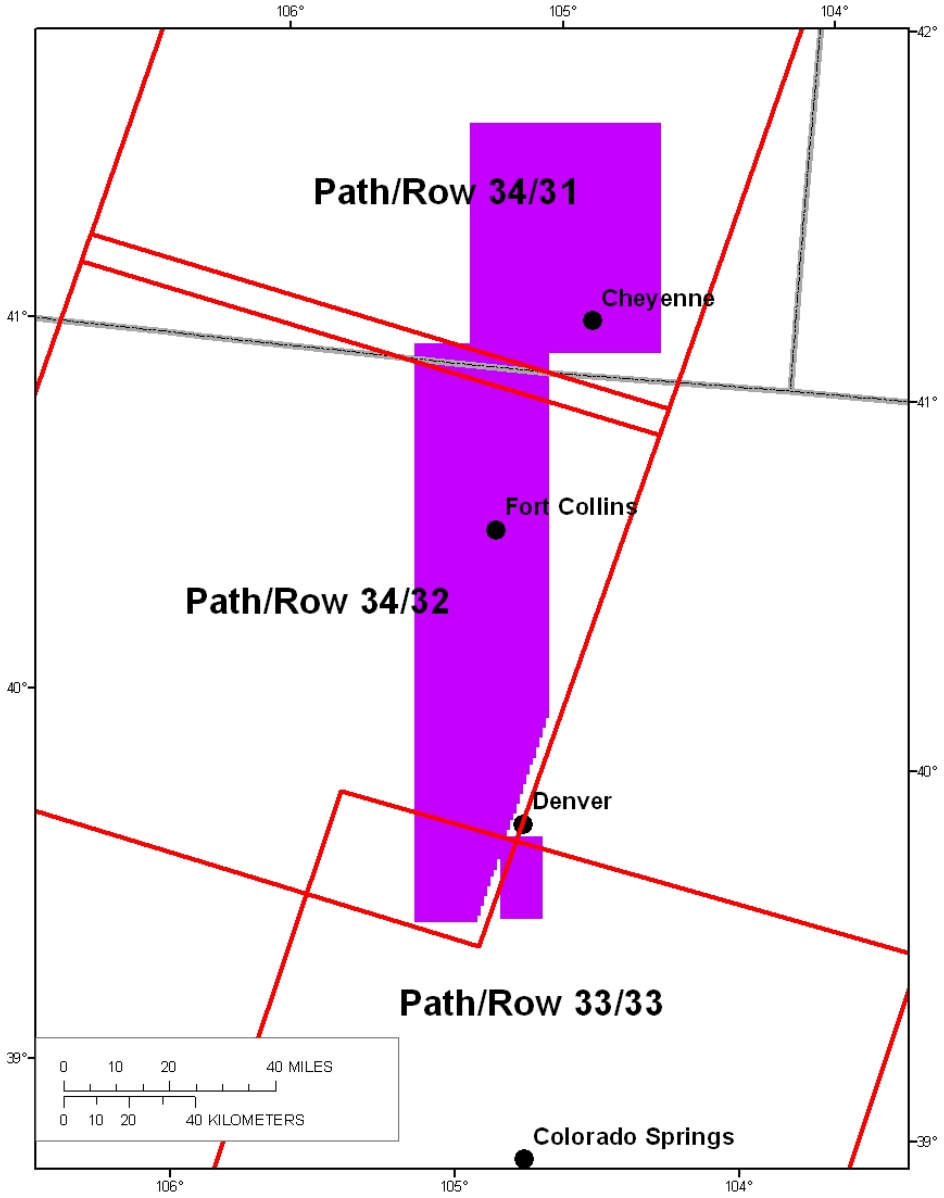

Figure 5. Landsat path/row footprints for Denver coverage.

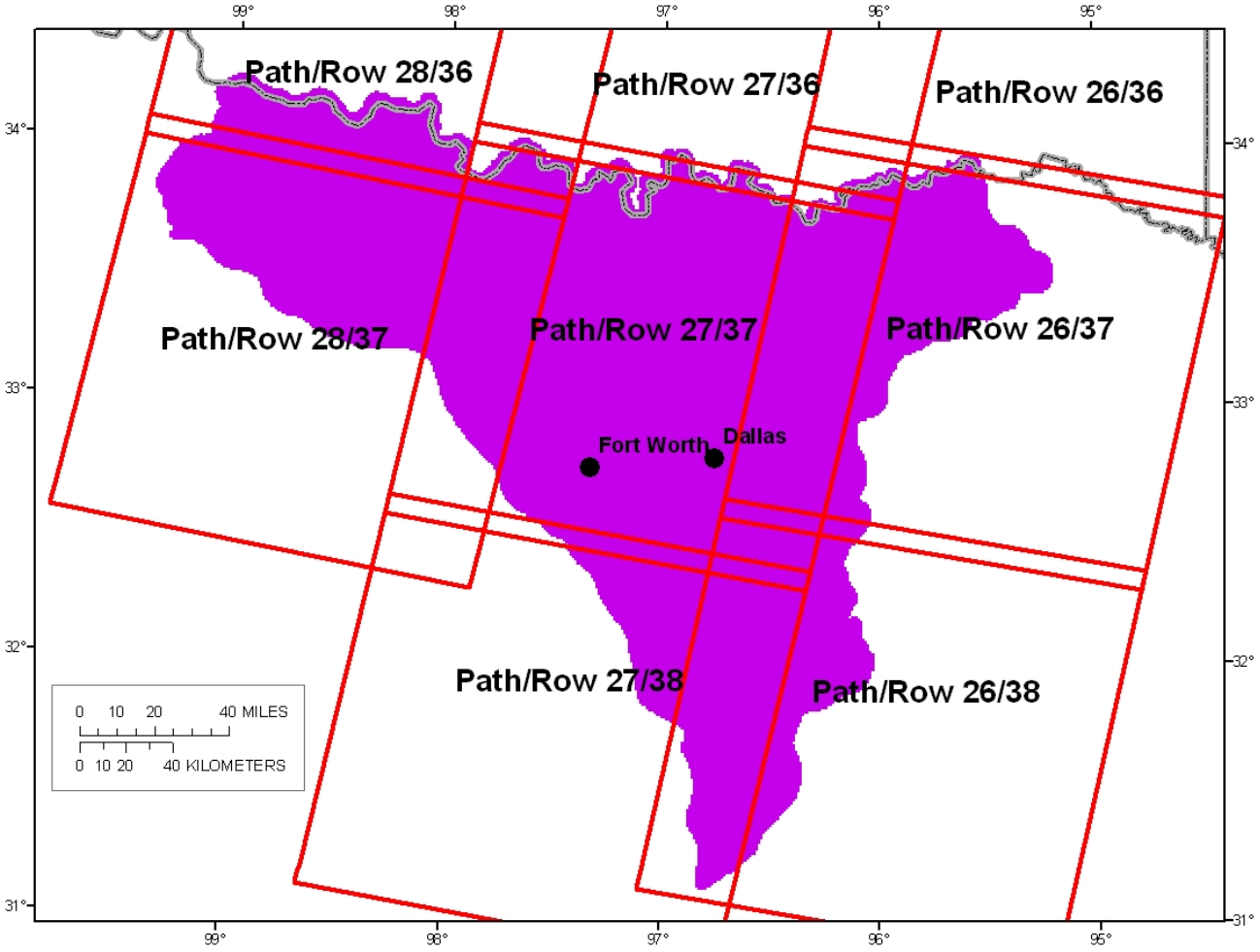

Figure 6. Landsat path/row footprints for Dallas-Fort Worth coverage.

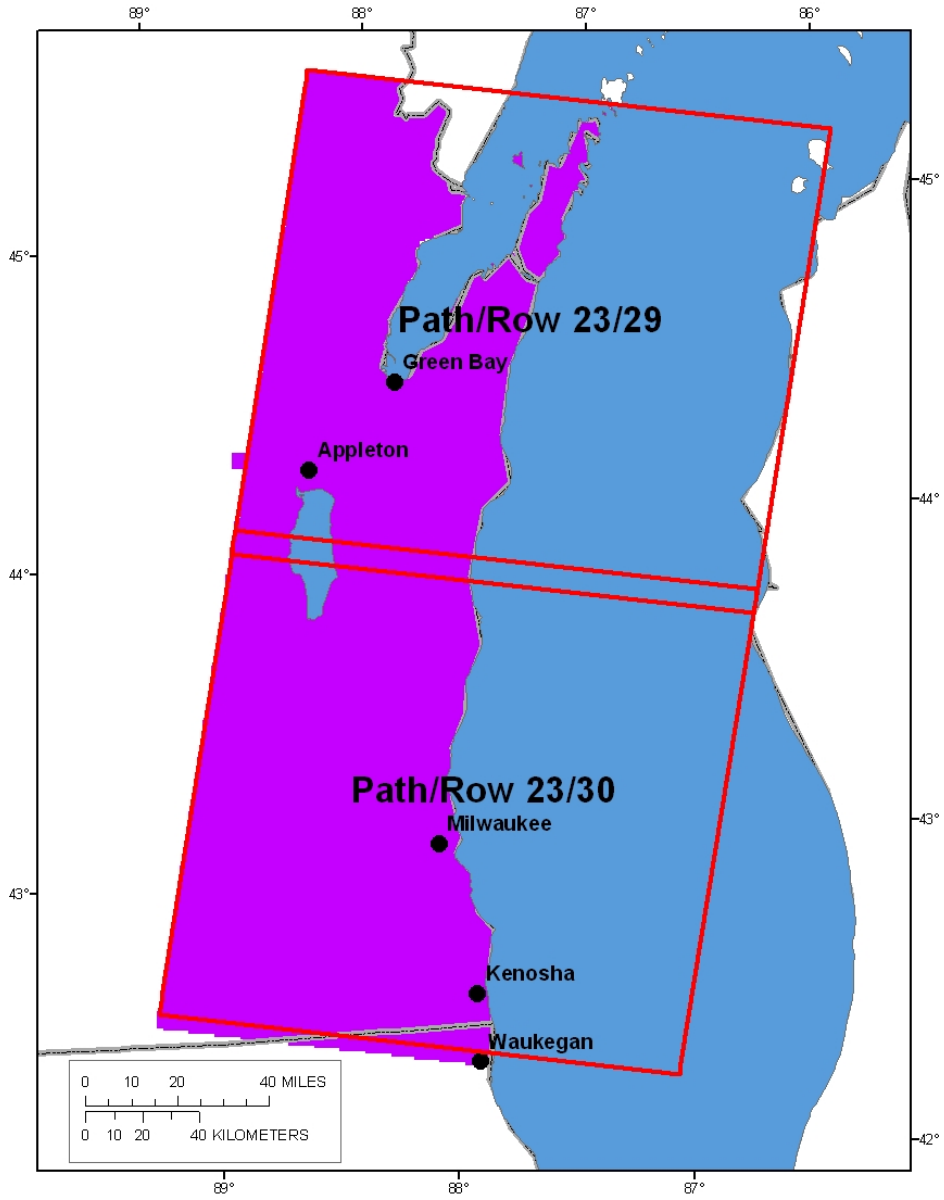

Figure 7. Landsat path/row footprints for Milwaukee-Green Bay coverage.

Land-Cover Processing

The land-cover datasets were derived according to the method described by Homer and others (2004), which consists of decision tree classification based on reference point training data. In some areas the decision tree classification was supplemented by other methods of supervised and unsupervised classification, which also incorporated ancillary data, such as wetlands, roads, streams, and elevation data. Merging the results of the decision tree classification with results of other classifications was found to be beneficial for some land-cover types.

The general steps were as follows:

1. Training points were recorded for known land-cover locations. Spectral values of the Landsat imagery and/or Tasseled Cap layers were extracted at those locations.
2. A decision tree that modeled rules for determining final land-cover, based on the spectral values of the input points was built using the See5© software.
3. The decision tree model was applied to the entire Landsat imagery.
4. Areas of error were examined and masks were created to improve the classification, for example, in areas of known water, forest, or barren land, based on additional supervised or unsupervised classifications and ancillary data. These included modeling against other sources of data of known accuracy. For example, in Milwaukee-Green Bay, parts of the study area overlapped Wisconsin State land-cover data (WISCLAND; Wisconsin Department of Natural Resources, 2006) and/or National Oceanic and Atmospheric Administration Coastal Change Analysis Program data (NOAA C-CAP; National Oceanic and Atmospheric Administration, 2006), which provided additional information about wetlands and other land-cover types.
5. The process was iteratively rerun with modified training data and/or masks.
6. Urban classes were created primarily from the completed imperviousness layer.
7. Final results were compared and verified against National Land-cover Dataset 1992 (U.S. Geological Survey, 2006c), high-resolution imagery or DOQs, and other data sources.

Imperviousness Processing

The impervious data were derived according to the protocol described by Yang and others (2003), which consists of regressing Landsat imagery (30-meter pixel) against high-resolution (1-meter or 4-meter) imagery for which percent imperviousness has been derived as reference. The general steps taken were as follows:

1. IKONOS images, 1-meter DOQs, or NAIP images were used as reference data against which Landsat imagery would be regressed. Reference data for the extent of the high-resolution images were classified as impervious or pervious, and then were resampled to 30-meter resolution, so that each 30-meter pixel represented a “truth” value of percent imperviousness for that pixel, for the extent of the high-resolution image(s).
2. An image mask that removed areas of known 0 percent imperviousness (for example, water bodies, contiguous forest, or agriculture), was created for the extent of the Landsat scene(s). The creation of the image mask was based on a variety of classification methods, including supervised and unsupervised classifications, and the inclusion of ancillary data from other sources, including roads, railroads, and urban areas of interest.
3. A regression from the high resolution-derived source data was applied against spectral and Tasseled Cap layers of the Landsat imagery using the Cubist© software to obtain a percent imperviousness for each pixel in the entire scene.
4. The resulting imperviousness dataset was reviewed for accuracy, then the classification model was iteratively modified and re-applied, to include modifications to the image mask.
5. Final results were compared and verified against high-resolution (1-foot) color imagery available for parts of the study areas.

Data Format

The data are provided as tarred raster datasets in Arc Grid format. Data may be “untarred” using WinZip© (Windows) or the “tar” command (Unix). Untarring the data will create a separate directory for each dataset in which the Grid is contained. Data characteristics of all datasets are as follows:

Cellsize: 30 meters
Data type: Unsigned 8 bit integer
Projection: Albers Equal Area
Units: Meters
Spheroid: GRS1980
Datum: NAD83
Projection Parameters:

29 30 00	1st standard parallel
45 30 00	2nd standard parallel
-96 00 00	Central Meridian
23 00 00	Latitude of projection's origin
0,0	False easting, False northing

The land-cover datasets follow the same attribute scheme as NLCD01 classes (Homer and others, 2004), minus classes not present in the study areas, namely Perennial Ice/Snow, and Alaska-only classes. These dataset classes are as follows:

Class 11 – Open Water
Class 21 – Developed, Open Space
Class 22 – Developed, Low Intensity
Class 23 – Developed, Medium Intensity
Class 24 – Developed, High Intensity
Class 31 – Barren Land
Class 41 – Deciduous Forest
Class 42 – Evergreen Forest
Class 43 – Mixed Forest
Class 52 – Shrub/Scrub
Class 71 – Grassland/Herbaceous
Class 81 – Pasture/Hay
Class 82 – Cultivated Crops
Class 90 – Woody Wetlands
Class 95 – Emergent Herbaceous Wetlands

Detailed class descriptions may be found at *http://www.mrlc.gov/nlcd_definitions.asp*.

Imperviousness datasets have data values ranging from 0-100, in whole integers, representing the percent impervious surface for each pixel.

Accuracy Assessment

Accuracy assessments were performed on the impervious data layers for each of the six study areas in the EUSE study being evaluated in 2005-2006, to determine their comparability. The accuracy assessments included the three impervious datasets described in this report, as well as three additional datasets provided by the NLCD01 Program for Atlanta, Georgia; Raleigh, North Carolina; and Portland, Oregon.

For each of the six study areas, 60 150-meter by 150-meter reference plots were randomly selected and delineated, and impervious surfaces manually digitized from 2002 high-resolution (1-foot) color orthophotoimagery (fig. 8). The percent impervious surface for each plot was calculated, and compared to values in the corresponding imperviousness dataset being assessed. Table 2 summarizes these results.

Figure 8. Sample 150-meter by 150-meter reference plot for accuracy assessment of percent impervious surfaces.

Green shaded areas are digitization of impervious surfaces (here, 70.2 percent of plot area).

Formal accuracy assessment was not performed on the land-cover datasets, because of the difficulty of obtaining consistently derived reference data for all land-cover types. Accuracy assessment of the three NLCD01 products used in the EUSE study (Atlanta, Raleigh, and Portland), likewise was not available.

Use of Data

Although these data have been used by the U.S. Geological Survey, U.S. Department of the Interior, no warranty expressed or implied is made by the U.S. Geological Survey as to the accuracy of the data. The act of distribution shall not constitute any such warranty, and no responsibility is assumed by the U.S. Geological Survey in the use of these data, software, or related materials. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Acknowledgments

Grateful recognition to Jon Dewitz and Collin Homer from the NLCD01 Program for help and guidance through the development of these datasets, and to Steven Sobieszczyk for the tremendous help in imperviousness accuracy-assessment evaluation.

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Anderson, James R., Hardy, E.E., Roach, J.T., and Witmer, R.E., 1976, A land use and land-cover classification system for use with remote sensor data: U.S. Geological Survey Professional Paper 964, 41 p.

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Wisconsin Department of Natural Resources (WDNR), 2006, WDNR - Land-cover Data (WISCLAND): Wisconsin Department of Natural Resources, accessed August 2006 at URL http://www.dnr.state.wi.us/maps/gis/datalandcover.html.

Yang, Limin, Huang, Chengquan, Homer, Collin, Wylie, Bruce, and Coan, Michael, 2003, An approach for mapping large-area impervious surfaces: synergistic use of Landsat-7 ETM+ and high spatial resolution imagery, Canadian Journal of Remote Sensing, v. 29, no. 2, p. 230-240.

Table 1. Source imagery.

Area	Image Type	Location	Image Date	Spatial Resolution	Number of Spectral Bands
Denver, Colorado	Landsat-7	Path/Row 34/31	04/04/02	30 meters	7
	Landsat-7	Path/Row 34/31	06/23/02	30 meters	7
	Landsat-7	Path/Row 34/31	07/09/02	30 meters	7
	Landsat-7	Path/Row 34/31	08/10/02	30 meters	7
	Landsat-7	Path/Row 34/31	10/13/02	30 meters	7
	Landsat-7	Path/Row 33/33	10/16/00	30 meters	7
	Landsat-7	Path/Row 33/33	04/13/02	30 meters	7
	Landsat-7	Path/Row 33/33	06/16/02	30 meters	7
	Landsat-7	Path/Row 34/32	11/06/99	30 meters	7
	Landsat-7	Path/Row 34/32	04/17/01	30 meters	7
	Landsat-7	Path/Row 34/32	06/23/02	30 meters	7
	Landsat-7	Path/Row 34/32	08/26/02	30 meters	7
	IKONOS	Boulder area	06/06/00	4 meters	4
	IKONOS	Cheyenne area	05/07/02	4 meters	4
Dallas-Fort Worth, Texas	Landsat-7	Path/Row 26/36	10/13/99	30 meters	7
	Landsat-7	Path/Row 26/36	06/15/02	30 meters	7
	Landsat-7	Path/Row 26/36	02/23/02	30 meters	7
	Landsat-7	Path/Row 26/37	10/13/99	30 meters	7
	Landsat-7	Path/Row 26/37	06/15/02	30 meters	7
	Landsat-7	Path/Row 26/37	02/23/02	30 meters	7
	Landsat-7	Path/Row 26/38	09/29/00	30 meters	7
	Landsat-7	Path/Row 26/38	07/19/00	30 meters	7
	Landsat-7	Path/Row 26/38	02/23/02	30 meters	7
	Landsat-7	Path/Row 27/36	10/20/99	30 meters	7
	Landsat-7	Path/Row 27/36	06/22/02	30 meters	7
	Landsat-7	Path/Row 27/36	04/03/02	30 meters	7
	Landsat-7	Path/Row 27/37	10/25/01	30 meters	7
	Landsat-7	Path/Row 27/37	05/21/02	30 meters	7
	Landsat-7	Path/Row 27/37	04/03/02	30 meters	7
	Landsat-7	Path/Row 27/38	10/25/01	30 meters	7
	Landsat-7	Path/Row 27/38	05/21/02	30 meters	7
	Landsat-7	Path/Row 27/38	01/13/02	30 meters	7
	Landsat-7	Path/Row 28/36	10/16/01	30 meters	7
	Landsat-7	Path/Row 28/36	06/10/01	30 meters	7
	Landsat-7	Path/Row 28/36	03/09/02	30 meters	7
	Landsat-7	Path/Row 28/37	09/30/01	30 meters	7
	Landsat-7	Path/Row 28/37	06/10/01	30 meters	7
	Landsat-7	Path/Row 28/37	02/02/01	30 meters	7
	NAIP	Tarrant county	09/30/04	1 meter	4
	NAIP	Denton county	10/26/04	1 meter	4
	NAIP	Jack county	09/25/04	1 meter	4
	NAIP	Clay county	09/25/04	1 meter	4
	NAIP	Grayson county	10/29/04	1 meter	4

	NAIP	Kaufman county	10/26/04	1 meter	4
Milwaukee-Green Bay,	Landsat-7	Path/Row 23/29	10/24/99	30 meters	7
Wisconsin	Landsat-7	Path/Row 23/29	05/19/00	30 meters	7
	Landsat-7	Path/Row 23/29	09/08/00	30 meters	7
	Landsat-7	Path/Row 23/30	10/24/99	30 meters	7
	Landsat-7	Path/Row 23/30	05/03/00	30 meters	7
	Landsat-7	Path/Row 23/30	07/09/01	30 meters	7
	Landsat-7	Path/Row 23/30	09/11/01	30 meters	7
	IKONOS	Milwaukee area	05/05/02	4 meters	4
	IKONOS	Green Bay area	05/22/02	4 meters	4
	IKONOS	Waukegan area	08/09/02	4 meters	4

Table 2. Accuracy assessment results for impervious surface datasets.

Area	Reference data mean percent impervious surface (n = 60) (digitized)	Evaluation dataset mean percent impervious surface (n = 60)	Mean difference (percent)	Root Mean Square Error (RMSE)
Denver	46.63	48.55	1.92	10.15
Dallas-Fort Worth	47.90	36.60	-11.30	14.72
Milwaukee-Green Bay	48.78	47.21	-1.57	7.01
Atlanta (NLCD01)	47.77	38.58	-9.19	13.56
Raleigh (NLCD01)	42.93	29.58	-13.35	15.50
Portland (NLCD01)	52.01	52.37	0.36	8.53

Data Files

File Name	Brief Description	Tar file size
den01_lc.tar	Denver 2001 land-cover	4.8 MB
dfw01_lc.tar	Dallas-Fort Worth 2001 land-cover	36.2 MB
mgb01_lc.tar	Milwaukee-Green Bay 2001 land-cover	18.9 MB
den01_is.tar	Denver 2001 imperviousness	3.8 MB
dfw01_is.tar	Dallas-Fort Worth 2001 imperviousness	13.7 MB
mgb01_is.tar	Milwaukee-Green Bay 2001 imperviousness	8.8 MB