Using Remotely Sensed Imagery to Determine Impervious Surface in Sioux Falls, South Dakota

INTRODUCTION

The City of Sioux Falls, South Dakota has been acquiring hard copy aerial photography of the City and its growth areas since the 1930s and digital high resolution orthophotography and digital elevation models since 1998. Early Geographic Information System (GIS) uses of the digital orthophotography were limited. For mapping purposes, the imagery was displayed as a background. There was little analysis performed other than utilizing the imagery to fine tune vector layers. Over time, the uses of the orthophotography have evolved. No longer are the images used solely as an attractive background for non-scientific purposes. Instead, the orthophotography is distributed enterprise wide through various means and is used for high-end spatial analysis.

High resolution commercially available satellite imagery is also available for the City of Sioux Falls. The satellite imagery provides information from the infrared portion of the spectrum, a wavelength not covered by the aerial photography. A resolution merge between the satellite imagery and the aerial photography was performed, resulting in a data set with the higher resolution of the ortho photography but with the spectral coverage of the satellite imagery. This merged data set was used to analyze impervious surface area within the city, which was in turn utilized by City Engineering staff as an additional tool to determine the amount of stormwater runoff.

This poster focuses on the use of high resolution orthophotography, enhanced by infrared data derived from satellite imagery, and its feasibility and usefulness in determining the location and quantities of pervious versus impervious areas in the City of Sioux Falls. Methodology and results are discussed. GIS professionals, remote sensing professionals, urban planners, environmental professionals, and public works employees are the intended audience.

IMPERVIOUS COVER AND RUNOFF

A wide range in impervious cover is often seen for the same zoning category and land use assignments, and Sioux Falls is no exception. Impervious area associated with medium density single family homes can range from 10 percent to nearly 50 percent, depending on the layout of streets and parking. Further, site runoff increases as a result of site impervious cover.

Impervious is defined as the sum of roads, parking lots, sidewalks, rooftops, and other impermeable surfaces of the urban landscape. An impervious surface is an indicator of a more intensive land use. The infiltration of these areas is lowered to or near zero. The direct hydrological effect of impervious surfaces occurs as a change in the magnitude and velocity and volume of surface flow, and precipitation that would normally be part of natural infiltration instead falls on and flows over impervious surfaces. The runoff is then channeled and released via storm sewers directly in the receiving stream.

In the City of Sioux Falls, all real property within the city is charged an annual Storm Drainage Fee (SDF) (*formula below*), based upon the runoff weighting factor, the parcel area, and the unit financial charge (*Table 1*), which varies from year to year. The runoff weighting factor (RWF) is determined by the type of land use (*Table 2, abbreviated list*). The runoff weighting factor can also be determined by percentage of impervious area (*Table 3*).

Storm Drainage Fee = (Runoff Weighting Factor * Parcel Area * Unit Financial Charge)

or

$$SDF = (RWF * PA * UFC)$$

Table 2

LUC	LandUse	RWF
110	Single-family (lot area less than 30,000 square feet)	7.50
111	Single-family (lot area of 30,000– 60,000 square feet)	5.75
120	Duplex	7.50
140	Apartment building (1– 3 stories)	11.25
210	Apparel and textiles	17.00
220	Wood, furniture, fixtures	17.00
260	Electronic, scientific, optical	17.00
280	Chemical, petroleum storage	17.00
310	Food, agricultural processing, stockyards, rendering	17.00
330	Chemical, petroleum, rubber, and plastic	17.00
350	Primary metal, smelting	17.00
460	Utilities (gas, sewer, water, telephone, etc.)	17.00
580	Extensive retail– auto repair, body shop	18.75
610	Food store	18.75
620	Neighborhood commercial, hardware, drugs, laundromat, beauty shop, barbershop, neighborhood shopping center	18.75
640	Department store, discount store, regional shopping center	18.75
730	Nursing homes and hospitals	11.25
760	Day care centers	11.25
840	Restaurants, bars, lounges	18.75

Table 1

Effective Date	Unit Financial Charge
January 1, 2004	0.000354
January 1, 2005	0.000383
January 1, 2006	0.000413
January 1, 2007	0.000446
January 1, 2008	0.000477

Table 3

Percentage Impervious Area	Average Runoff to Rainfall Ratio (Rv*)	Runoff Weighting Factor (Rv × 25)
0	0.04	1
10	0.19	4.75
15	0.26	6.5
20	0.3	7.5
30	0.38	9.5
40	0.45	11.25
50	0.53	13.25
60	0.6	15
70	0.68	17
80	0.75	18.75
90	0.83	20.75
100	0.9	22.5

METHODOLOGY

? **Image Preparation**

? ? ***High resolution orthophotography*** (*Image 1*) acquired May 3, 2002 - The original resolution of 0.5-foot pixel was resampled to 2-foot.

? ? The color infrared portion of ***IKONOS imagery*** (*Image 2*) acquired May 20, 2002 at a resolution of 4-meters was projected to the City of Sioux Falls standard projection schema, UTM projection, Zone 14 North, spheroid GRS1980.

? **Resolution Merge**

? ? The high resolution orthophography was merged, or fused, (*Image 3*) with the IKONOS imagery using ERDAS Imagine 8.7. The merged image maintains the spatial resolution of the orthophography while also possessing the spectral qualities of the satellite imagery, thus enabling discrimination at a finer level of detail. The principal component method was chosen since it maintains the original scene radiometry (color balance) of the input multispectral data in the output file and creates an output image that may be more interpretable than the original data.

? ? ? The band histograms of the output image closely resemble those of the input multispectal image, the IKONOS color infrared image.

? ? ? One final benefit of this method is the output file tends to have the same data range as the input multispectral file.

Image 1 - High Resolution Orthophotography

Image 2 - High Resolution IKONOS

City of Sioux Falls - Sioux Falls, South Dakota

By Lauri B. Sohl
lsohl@siouxfalls.org

Projection
Universal Transverse Mercator
Software
ERDAS Imagine 8.7 and ArcGIS 9.1
Hardware
Dell Precision 650-Xeon 2.0 GHz with Windows 2000
Printer
HP DesignJet 800PS
Data source(s)
City of Sioux Falls, Includes Material © Space Imaging L.P.

Image 3 - Resolution Merged Image

Image 4 - Post-Classification

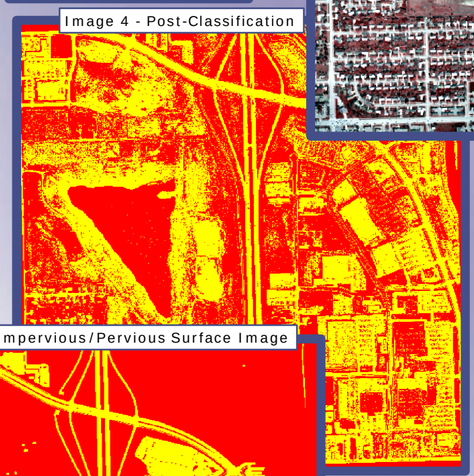


Image 5 - Impervious/Pervious Surface Image

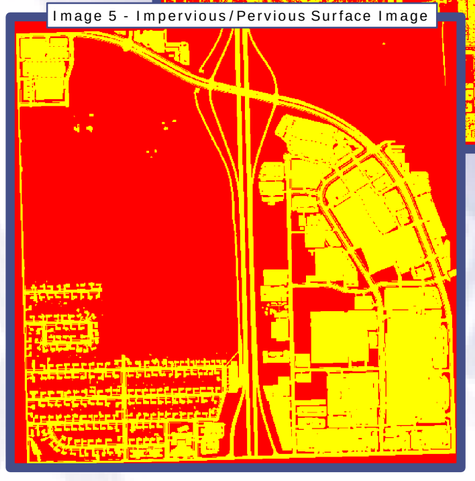


IMAGE CLASSIFICATION EVALUATION

? **Image Classification**

? ? Our goal is to classify impervious surface, thus partitioning the study area into vegetated or impervious pixels.

? ? I chose to implement a special purpose classification to identify pervious/impervious surface.

? ? ? No attempt was made to assure compatibility over distance or time, nor were specific land use categories identified. This study is geared towards Sioux Falls, South Dakota, our geographic area of expertise, and should not be applied directly elsewhere without special consideration of local conditions and data sources.

? ? ? The reason for a special classification are apparent. This is our first time utilizing high resolution satellite imagery to classify pervious/impervious surface. Previously, all identification was done en masse using land use by parcel or in rare occasions, a detailed site study.

? ? Unsupervised classification (*Image 4*) was utilized to classify the image with merged resolution.

? ? ? This method was chosen since the spectral characteristics of the study area were well understood, and the simple thematic classification being analyzed (vegetated vs. impervious) allowed for readily identifiable spectral clusters representing one of the two information classes.

? ? After classification, these classes were designated as pervious or impervious through the manual interpretation (*Image 5*) of spectral cluster locations compared to the source merged data set.

? ? ? Spectral confusion is common in both supervised or unsupervised classification, with some spectral clusters representing multiple surface types.

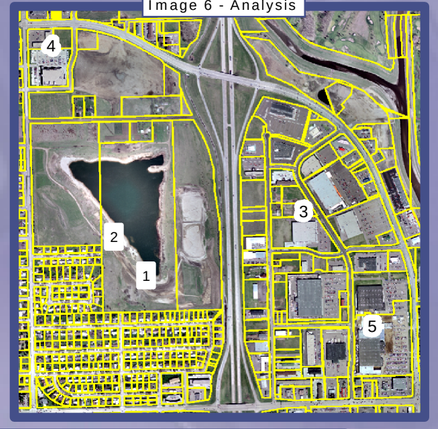
? ? ? This results in some areas of the initial classified image being mislabeled. Manual identification, delineation, and separation of spectrally confused features served as a simple and effective way of separating out these mislabled features and was used to "clean up" the initial classification product.

? ? ? On-screen digitizing is practical for our needs but may not be an efficient method when dealing with regions or larger areas.

Table 4

Area	Type	Land Use Code	*Old* Runoff Weighting Factor	*Old* Storm Drainage Fee	Percentage Impervious	*New* Runoff Weighting Factor	*New* Storm Drainage Fee	Difference
1	Residential	110	7.5	$40.23	25%	7.5	$40.23	**$0.00**
2	Residential	110	7.5	$72.74	12%	4.75	$46.07	**$26.67**
3	Auto Parts Store	580	18.75	$2,373.35	59%	13.25	$1,677.17	**$696.18**
4	Grocery Store	610	18.75	$1,936.45	82%	18.75	$1,936.45	**$0.00**
5	Discount Store	620	18.75	$4,726.74	91%	20.75	$5,230.93	**($504.19)**

Image 6 - Analysis



ASSESSMENT AND CONCLUSION

Since a consistent methodology was used throughout the process, impervious and pervious surface results from both the high resolution aerial photography and satellite imagery can be compared with a high degree of accuracy. To evaluate the classified merged image, a vector layer (*Image 6*) consisting of planimetric layers was overlayed upon the high resolution orthophotography. This layer consists of numerous impervious features, including: building footprints, bridges, concrete pads, driveways, parking lots, and roads.

The initial comparison of storm drainge fees calculated by the old method, using the land use code to determine the runoff weighting factor, and an alternative method, using the percentage of impervious area to determine the runoff weighting factor, was enlightening. *Table 4*, above, demonstrates 5 randomly chosen parcels of varying land uses. Of these 5, 2 of the parcels would have the same runoff weighting factor using either method, 2 of the parcels would have a lower runoff weighting factor, resulting in a lower storm drainage fee, and one parcel was found to have a higher runoff weighting factor, resulting in a higher storm drainage fee.

Initial results demonstrated that by merging the spectrally detailed IKONOS image with the higher spatial resolution aerial photography creates an outstanding image to utilize for visual and programmatic classification. City Engineers commented on the impervious designations that they could make by analyzing the merged image manually or by utilizing it within other software. In addition, after classification, the image became even more useful. By using a large number of classes, there were few classes with the ubiquitous shadow (undetermined) class.

The advancements in high resolution satellite imagery and client technology provide local governments with a cost-effective solution to determine impervious and pervious surfaces as input to storm drainage fee calculations.

Further research will include thresholding the Normalized Difference Vegetation Index (NDVI) on the Ikonos image, pre-merge, to determine a spectral stratum containing all impervious pixels (buildings, roads, sidewalks). The NDVI image enhancement technique measures the amount of vegation biomass that exists for a given pixel.since the NDVI normalizes for the effects of shadows, which reduces the differential spectral response of the shadowed portions of the imagery.