Comparison of Air Photo and Satellite Image Sources for Updating Land Cover and Land Use Maps

Robert F. Goodwin
William D. Hudson
Center for Remote Sensing and GIS
Michigan State University

June 2002

MICHIGAN STATE
UNIVERSITY

Introduction

The Center for Remote Sensing and Geographic Information Science (Center) is involved in an on-going study to develop and test various procedures and techniques for updating land cover/use maps. The IMAGIN (Improving Michigan's Access to Geographic Information Networks) organization, in cooperation with the Center, sponsored a work group to address land cover/use update issues. The work group met both in person and "electronically" (through a web-based bulletin board and e-mails) to produce an IMAGIN Working Paper, "Updating Land Cover / Use Data". A team of Center scientists, aided by graduate student assistants, has researched and tested a number of techniques identified by the work group. Included are; a complete update of the Michigan Land Cover/Use Classification System, issues related to image rectification, registration, transformation, mosaicking, and compression, and the development of software for semi-automated updating.

The Center has implemented these techniques in several areas within the state. To date, the Center has updated several counties including most of the counties within the Muskegon River watershed, Berrien County, and portions of Montcalm, Mecosta and Gratiot counties (Figure 1). Using similar classification rules and technical procedures, the Center has also assisted the Southeast Michigan Council of Governments (SEMCOG) in updating and backdating their land cover/use data.

Most of our updating to date has been accomplished using small scale, color infrared aerial photography. Table 1 summarizes an earlier, subjective comparison of several image types and scales. The current research endeavor involved a controlled comparison of a variety of imagery sources for updating land cover / use data. Our knowledge of imagery in general led us to speculate on the pros and cons of the different imagery types which we used to design a test to confirm or deny these. Anlaysis were conducted to compare; coverage, costs, resolution, frequency of updates,

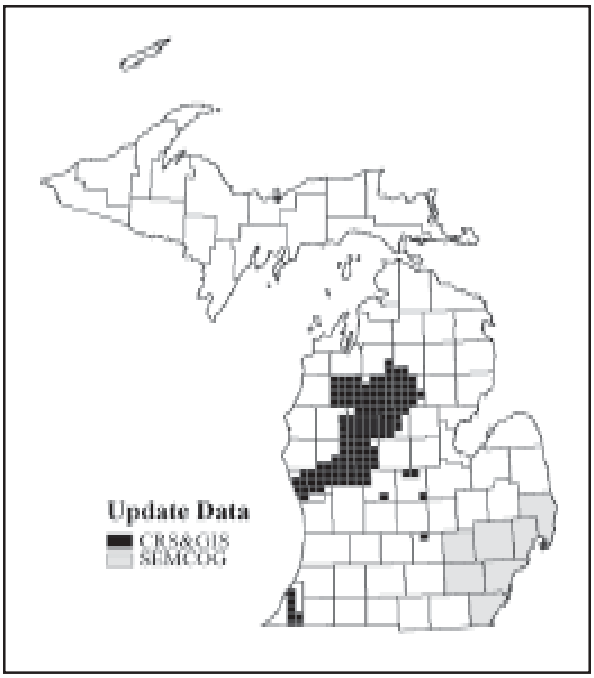

Figure 1. Areas updated using Center for Remote Sensing and GIS techniques

level of interpretability, and accuracy of mapping.

The project was designed to compare film (or satellite band selection) types, scales and resolutions for updating land cover / use maps. The key word here is ***updating***. It is generally accepted that updating is a much simpler task than starting from scratch. If land cover / use is known from a previous date, it is much easier to determine what it has become at a later date.

Williamstown Township, Ingham County Michigan (Figure 2), was our imagery test location. The decision to use Williamstown Township was influenced by its nearness to our offices, it's relatively rapid growth since 1978 (the year to be updated from), and the availability of several recent image sets.

The steps involved in our test included: determining film types and scales, acquiring imagery, preparing imagery (scanning, geo-rectifying and clipping), correcting base polygon data, updating base polygon data (Figure 3), and determining interpretation accuracy for each imagery set chosen. In addition to an interpretation test, we compared the date, availability and price for each imagery set, since these variables are often of paramount importance.

Table 1 Comparison of Several Image Types and Scales

Agency	MDNR	MDNR	MDNR	MDNR	USGS - NAPP	USGS - NAPP
Year	1998	1998	1978	1978	1998	1998
Scale	1:15,840	1:15,840	1:24,000	1:24,000	1:40,000	1:40,000
Film Type	BWIR	BWIR	CIR	CIR	CIR	CIR
d.p.i./resolution	402 / 1 m	201 / 2 m	610 / 1 m	305 / 2 m	1016 / 1 m	508 / 2 m
File Size (MB)	13	3.5	90	23	250	62
Scan time/image (minutes)	2.5	1	3	1	9	3
Interpretability	good	poor to average	very good	good	very good	good
# photos/twp.	~ 40	~ 40	~ 20	~ 20	6 - 8	6 - 8
Total Size/twp. (MB)	520	140	1800	460	1500 - 2000	370 - 500
Rectification Time/Photo (Cross-Validated Polynomial)	N/A	N/A	N/A	N/A	75 To 105 Minutes	60 To 90 Minutes
Time to Construct Mosaic	N/A	N/A	N/A	N/A	5 To 7 Hours	4 To 6 Hours

Figure 2. Williamstown Township, Ingham County Michigan

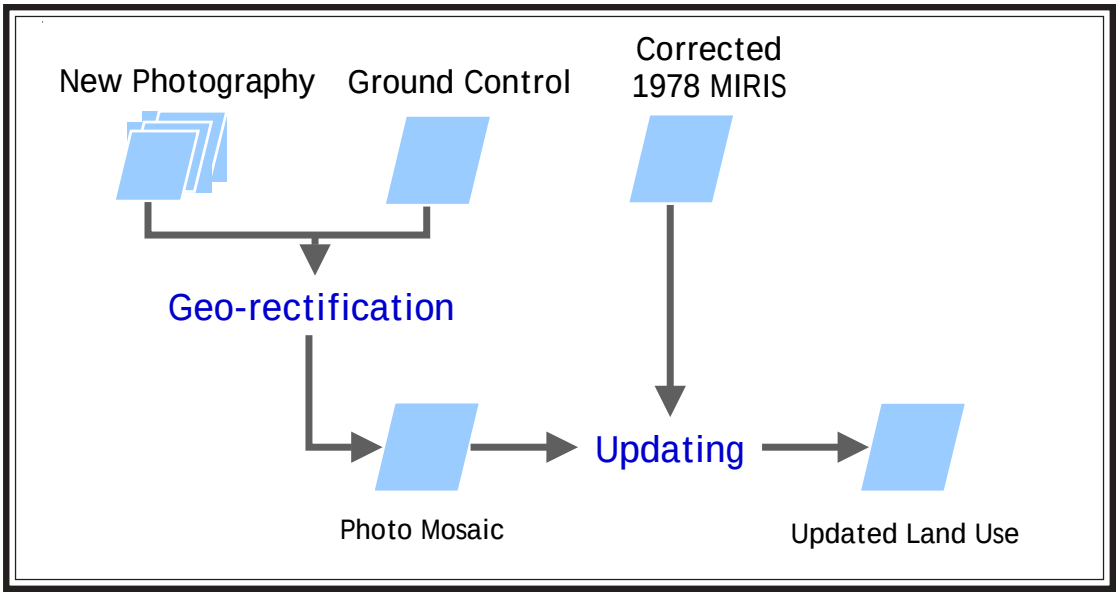

Figure 3. The Center process for updating land cover/use maps, in general, is shown here. Scanned imagery is first geo-rectified using a ground control source, GPS points for instance. The resulting geo-rectified imagery is seamed into a mosaic. The base polygon data is then overlaid onto the photo mosaic and updated.

Imagery Selection and Acquisition

Imagery was selected based upon its potential availability over a large portion of the state and included both aerial photography and satellite data. Film based aerial photos included black-and-white (infrared), true color, and color infrared (Figure 4). Multi-spectral satellite data included 30-meter Landsat data (Figure 5) and one and four-meter IKONOS data (Figure 6). The six data sets tested are summarized in Table 2.

The 1998/99 National Aerial Photography Program (NAPP) color infrared (CIR) photography was ordered from the U.S. Geological Survey (USGS) through their website (http://earthexplorer.usgs.gov). Due to their superior resolution, compared to paper prints, diapositive aerial photographs were obtained. 1978 CIR and 1999 black-and-white infrared (BWIR) aerial photographs were acquired, on loan, from the Michigan Department of Natural Resources (MDNR). Once again, diapositives were used. 2000 Landsat 7 ETM multi-spectral imagery was purchased from the Basic Science and Remote Sensing Initiative at Michigan State University via their website (http://www.landsat.org). The 2000 AirphotoUSA digital true color imagery was obtained through a reseller of the company's data. IKONOS multi-spectral imagery could not be obtained in time for our test; however, samples were given to us for comparison, courtesy of Space Imaging. Lastly, the Kodak CITIPIX true color imagery was ordered online (http://kei.kodak.com/). Only one digital image was ordered for comparison because coverage at this time did not include Williamstown Township.

Table 2. Imagery sets tested in Williamstown Township, Ingham County

Imagery Dataset	Year	Spectral Type	Scale
Michigan DNR	1999	B&W Infrared	1:15,840
National Aerial Photography Program	1998/99	Color Infrared	1:40,000
AirphotoUSA	2000	True Color	Digital - 1-meter resolution
LandSat 7 ETM	2000	Multi-spectral	Digital - 30 meter resolution
IKONOS	---	Multi-spectral	Digital - 1,4 meter resolution
Kodak CITIPIX	1999	True Color	Digital - 0.15 meter resolution

A

B

C

Figure 4. The three basic film types tested; A - black-and-white (infrared), B - true color, and C - color infrared

Figure 5. Landsat ETM, 30-meter, false-color composite (4,3,2) of Williamstown Township

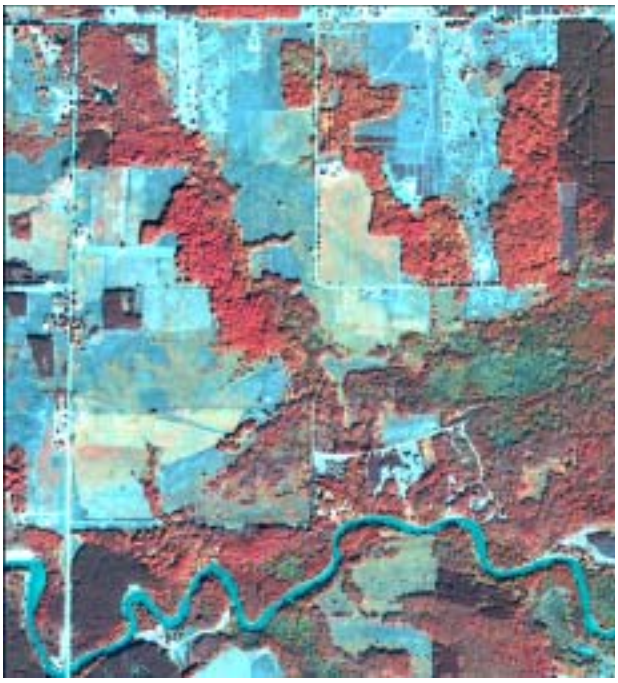

Figure 6. IKONOS, 1-meter, pan-sharpened, false-color composite (courtesy of Space Imaging)

Imagery Preparation

All analog data sets (aerial photos) were scanned, orthorectified into the Michigan GeoRef coordinate system, and clipped to the extent of Williamstown Township, plus 500 meters. The 500-meter buffer was intended to provide interpretation clues to those polygons adjacent to the township boundary. The 1998 NAPP aerial photos were scanned at a pixel resolution of 1-meter x 1-meter (1016 dots per inch). The 1978 MDNR aerial photos were also scanned at a 1-meter x 1-meter pixel resolution (610 dots per inch), while the 1999 MDNR aerial photos were scanned in at a 0.5-meter x 0.5-meter pixel resolution (800 dots per inch). Global Positioning System (GPS) points (ground control points), taken at various road intersections throughout the Township, provided the horizontal control during orthorectification. A Trimble Pro XRS GPS receiver was used to obtain sub-meter accuracy for each. A standard USGS 30-meter Digital Elevation Model (DEM) provided vertical control. For each analog image set the scanned aerial photos were orthorectified into blocks within the Orthobase module of ERDAS Imagine 8.5. After orthorectification, all "Orthos" were seamed into a township mosaic. Lastly, each township mosaic was clipped to the extent of Williamstown Township, plus 500 meters.

To prepare the Landsat 7 digital imagery, the general area of Williamstown Township was clipped out from the complete initial Landsat image. The clipped area was then geo-rectified in ERDAS Imagine 8.5 using a second order polynomial model, the previously orthorectified 1998 NAPP mosaic provided the ground control. After geo-rectification, the image was further clipped to the extent of the township, plus 500 meters.

Since the 2000 AirphotoUSA imagery was already orthorectified, is was simply clipped to the extent of Williamstown Township, plus 500 meters, and re-projected into the Michigan GeoRef coordinate system using ERDAS Imagine 8.5.

1978 Land Cover/Use Polygon Data

The initial land cover/use data was the 1978 polygon data compiled by the MDNR. Created in the late 1970's as part of the MDNRs Current Use Inventory, the classification system used was a subset of the comprehensive Michigan Land Cover/Use Classification System. This data set was created by digitizing polygons from un-rectified 1978 color infrared aerial photographs. As a result of digitizing from un-rectified aerial photographs, polygon boundaries are typically not perfectly coincident with the cover/use they represent when overlaid onto geo-rectified imagery. A more accurate initial land cover/use data set was created by overlaying the 1978 polygon data onto a orthorectified 1978 mosaic and correcting any gross errors or omissions. Each polygon was checked individually and edited if necessary. Changes were made in nearly 18% of the township and are summarized in Appendix Table 1. The subsequent "cleaned" 1978 polygon data represented the initial land cover/use polygon data for use while updating (Figure 7).

Updating

The next step in the project was to update the "cleaned" polygon data to the dates represented by the various geo-rectified imagery sets. Four interpreters were given a different image mosaic each, along with a copy of the initial land cover/use polygon data in ArcInfo coverage format. Within ArcEdit, each interpreter overlaid the initial land cover/use polygon data onto his or her image mosaic and updated each polygon's shape and land cover/use attribute, if necessary. During the process all interpreters were allowed to use any ancillary data source available, except each other's imagery set. Plat books, topographic maps, and atlases were all available. In addition, where stereo viewing was possible (1999 MDNR, 1998/99 NAPP), the interpreters were urged to use that capability. The multi-spectral characteristic of the Landsat 7 imagery allowed the interpreter the advantage of viewing several band combinations to determine land cover/use (Figure 8).

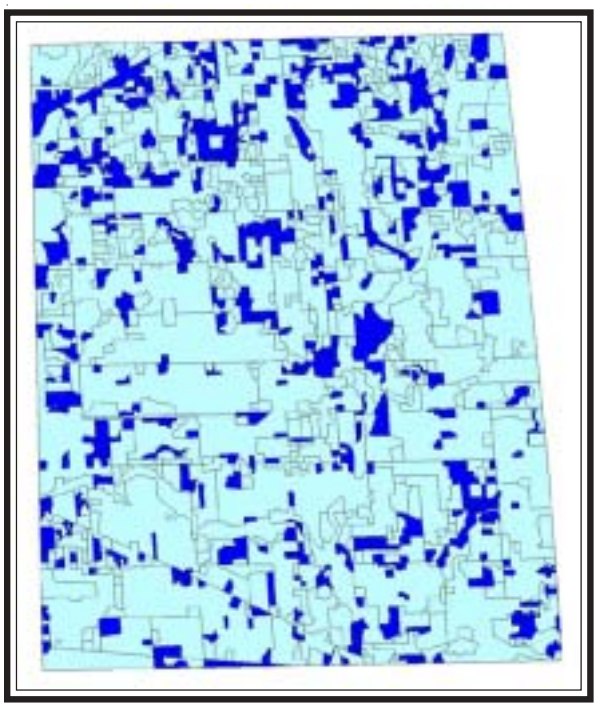

Figure 7. Polygons in dark blue represent changes made to original 1978 base data to create a "cleaned" coverage

A

B

C

Figure 8. Landsat 7 imagery is multi-spectral and can therefore be viewed in several band combinations, which help to delinate land cover more easily. Band combinations A - 3,2,1 (True Color), B - 4,3,2 (Standard false color composite) and C - 5,4,3 ("Easter-egg" composite).

Interpretation Accuracies

To determine the accuracy of each interpreter's updated polygon coverage, and thus the imagery set, a "truth" map was developed for comparison. Using the updated land cover/use polygon data from the most recent imagery set (2000 AirphotoUSA image mosaic), approximately 60% of the polygons were field checked. The "truth" map (coverage) was compiled based on observations of current land cover/use and references to the 2000 AirphotoUSA image mosaic (actual changes between 1978 and 2000 are summarized in Appendix Table 2). To find the differences, or areas of disagreement, a "union" was performed within ArcInfo between the truth map and each updated land cover/use polygon coverage. A query was then run on the resulting "union" coverage to determine where disagreement between the "truth" map and each updated coverage existed. The polygon disagreement acreages were then tallied to give a "rough" idea of accuracy. A sample of between 72 and 123 disagreement polygons from each union was further investigated to determine if they were in disagreement due to change, subjectivity or interpretation error.

It is important to note that all polygons below the minimum mapping unit (2.5 acres) were ignored when tallying acreages. The reasoning is that every interpreter will digitize "like" boundaries somewhat differently, resulting in areas that agree in theory but not in exact space. Consider the following example: a crop polygon is separated from a pasture polygon by a hedgerow. In this example, one interpreter includes the hedgerow in his or her crop polygon. Another interpreter decides to include the hedgerow with the pasture polygon. Neither choice is a mistake, just a subjective call. Since a hedgerow is too thin to be mapped, it could be placed into either. When a union is performed in this example, a small polygon, that is the width of the hedgerow, results where there is disagreement due to boundary placement.

Results

Interpretation accuracies for all imagery sets ranged from 89 to 93 percent. The actual interpretation accuracy between 1998/99 NAPP, 1999 MDNR and 2000 AirphotoUSA was virtually the same, with less than 3% separating all three. The 1999 MDNR set was most accurate with an accuracy of 92.23% (Appendix Table 3), while the 1998/99 NAPP and 2000 AirphotoUSA sets were 89.31% (Appendix Table 4) and 91.08% (Appendix Table 5) respectively.

When checking the samples of disagreement polygons, there appeared to be a tendency for the interpreters to confuse hayland with pasture and large maintained residential yards on both the MDNR black and white infrared imagery and the AirphotoUSA true color imagery. With the NAPP color infrared imagery there was little problem separating the three but there was confusion between shrubland and forestland, most likely due to it's spring date. The finer resolution of the 1999 MDNR seemed to make up for its lack of color in some circumstances. One example was the ability to identify fences separating pasture from other land cover/use categories. The very coarse resolution of the Landsat 7 imagery was determined to be a severe impediment. While its multispectral nature helped identify certain large areas very well, the coarse resolution resulted in inclusion of incorrect land cover/use areas or exclusion of correct ones.

As shown in Table 3, the 1998/99 NAPP photography is the oldest, and therefore the most dated imagery. If updating is going to occur in an area experiencing rapid growth, then this, or similarly dated imagery, may not be the best choice. NAPP photography is on a 7-year cycle, so the next mission will probably not be available until at least 2005 (Table 5). On the other hand, NAPP photography is very inexpensive compared to other sets. Many areas in the Michigan have had Digital Ortho Quarter Quads created from NAPP phtography and are available from the Center for Geographic Information (http://

www.michigan.gov/cgi) free of charge.

The 1999 MDNR photography was more expensive to acquire than NAPP imagery, but it too is available for the entire state. The Upper Peninsula of Michigan was flown in 1997; the northern Lower Peninsula in 1998 and the southern Lower Peninsula in 1999. It too is becoming dated for areas experiencing rapid growth but may work fine for areas which are not growing rapidly.

The biggest drawback to using datasets such as AirphotoUSA and Kodak CITIPIX is their availability. Because AirphotoUSA, Kodak CITIPIX and others like them only photograph areas where there will be a return on their investment, they will always be limited in coverage. It is unlikely that sets such as these will ever be available in the Upper Peninsula or large areas of the northern Lower Peninsula. If you are in an area covered by the 2000 AirphotoUSA set, imagery can be acquired for a relatively inexpensive cost, and since it is already orthorectified, there will be considerable cost savings. License restrictions apply to this set. The 1999-2001 Kodak CITIPIX imagery is the most expensive of all compared sets but it also has the best resolution by far. During the test we determined that the increased resolution of the 1999 MDNR imagery helped in some circumstances, but overall it did not seem to increase accuracy significantly. The even better resolution of the Kodak CITIPIX set may therefore not contribute significantly to interpretation accuracy when updating land cover/use.

As with the Kodak CITIPIX imagery, the IKONOS imagery was not tested for interpretation accuracy. Although IKONOS could not be tested for interpretation accuracy over Williamstown Township, samples were obtained for areas in Wexford County and Monroe/Wayne Counties Michigan. A limited test of this imagery in Wayne County indicated that it is very similar to most of the photographic data sets tested and would therefore probably provide similar accuracies for updating land cover/use. This high-resolution satellite imagery, along with the Quickbird satellite imagery (http://www.digitalglobe.com), is taken on request so is available, theoretically, anywhere at anytime. This on-demand service results in very up to date imagery, which is useful in areas experiencing rapid growth. IKONOS imagery is also multi-spectral, allowing for the user to view the image either in true color, color infrared, or black-and-white. This imagery is on the higher end of the price scale but comes orthorectified if you so desire. Landsat 7 satellite imagery is very inexpensive and available for several dates almost anywhere in the world.

Table 3. Date and Availability

Imagery Dataset	Date	Availability
Michigan DNR	Summer 1999	Entire State
National Aerial Photography Program	Spring 1998/99	Entire State
AirphotoUSA	Fall 2000	Lansing, Detroit, and Grand Rapids metro areas
LandSat 7 ETM	Fall 2000	Entire State
IKONOS	-	Any Location
Kodak CITIPIX	-	Lansing, Detroit, and Grand Rapids metro areas

Table 4. Price per Township (based on ordering an entire county)

Imagery Dataset	Hardcopy	Referenced	Orthorectified
Michigan DNR	$500 - $1000	n/a	n/a
National Aerial Photography Program	$60 - $150	n/a	$45 - $60*
AirphotoUSA	n/a	n/a	$360
LandSat 7 ETM	n/a	$50 - $600 per scene	n/a
IKONOS	n/a	n/a	$400 - $4800**
Kodak CITIPIX	$1,200	$2,000	$9,000

** Digital Ortho Quarter Quads available from the MDNR or USGS.*

***$400 for archived data at lowest precision. $4800 for non-archived data at highest precision.*

Table 5 Acquisition cycle

Agency/Company	Date Acquired	Acquisition Cycle
Michigan DNR	1997, 1998, 1999	Every 10 Years
National Aerial Photography Program	1998, 1999	Every 7 Years
AirphotoUSA	2000	Every 2 Years
LandSat 7 ETM	Continuously	Continuously
IKONOS	On Demand	On Demand
Kodak CITIPIX	1999, 2000, 2000	Every 2 Years

Because it is multi-spectral, it is very useful for coarse delineation of land cover areas.

Conclusions

Of the four sets tested for interpretation accuracy, three were virtually identical. The fourth set, Landsat 7, was too coarse to compare directly with the other three sets tested for interpretation accuracy. Although Landsat 7 imagery did not compare well with the other sets tested here, it could possibly be used for intermediate "monitoring" updates that would take little time compared to more extensive updates using finer resolution imagery.

The fact that three of the sets tested nearly identically has important implications, since removing accuracy from the decsion allows the user to choose imagery based on date, availability and price alone. Users need to determine if the date an image set was acquired has any implications. If the area in question is experiencing rapid growth, such as Williamstown Township, or there is a need to have imagery taken a specific time of year, such as springtime, the date of the imagery is very important (Figure 7). In addition, if an imagery set is not available for the area in question, another imagery set will have to be used, such as one of the statewide sets. Perhaps the most important aspect of imagery is the cost. Dwindling budgets may force the use of a less expensive dataset or delay the project till a cheaper alternative can be found.

Several key observations were made after (and during) this project. First, to test interpretation accuracy more precisely, all interpreters should have initially been given the same updated polygon boundaries and instructed to simply interpret the delineated land cover/use. Instead, four interpreters were each updating and digitizing the same land cover/use polygon boundaries differently – the result of the inherent subjectivity in determining boundary placement in the natural environment. This resulted in large acreages of disagreement, most of which consisted of polygons below the minimum mapping size. Also, to avoid change on the landscape, it would have been ideal to have the interpreters using imagery sets all taken within the same year. This was impossible to accomplish, however, due to the the uncoordinated nature of aerial photography acquisition. Lastly, had the interpreters visited the general area beforehand, they probably would have increased their interpretation accuracy immensely. For example, had they visited a nearby township to Williamstown Township, they would have noticed the abundance of horses and subsequent pasture in the area and would have been looking for that condition when interpreting. It is often standard practice to visit the area you intend to interpret before the actual interpretation begins, but this test abstained from visiting the area beforehand to avoid tainting the interpretation accuracy from the imagery alone.

This test, although designed to look at various imagery sets, could not possibly compare all of the imagery that exists in Michigan at the present time. However, many of the large and publicly available datasets have been addressed. Many local governmental units contract for their own imagery, which may or may not be available to the general public. Contacting a county's planning department is a good place to start. For additional information on sources of imagery within the state of Michigan, visit the Michigan State University Aerial Archive at http://www.crs.msu.edu/archive.htm or call 517-355-3771.

Figure 7. Older, outdated imagery can be a problem in areas experiencing rapid growth. This example shows an area in Williamstown Township, Ingham County Michigan. On the left is a NAPP image from March, 1999 showing an area under development. On the right is a AirphotoUSA image from October 2000 showing the same area with the circles representing new houses constructed since March, 1999.

Appendix Table 1. Acres Changed Between Original 1978 and Cleaned (Corrected) 1978
Williamstown Township
Ingham County

Old 1978 \ New 1978	11	12	13	14	17	19	21	22	23	24	29	31	32	41	42	43	51	52	53	61	62	Total Orig 1978	Loss	%Loss
11	1829.5	3.8			1.3	0.6	82.8	2.9	11.7	1.6	72.5	239.3	33.8	60.8	7.5					14.4		2362.5	533.0	22.6
12	8.5	154.2	6.0				0.8				4.2	20.4										194.1	39.9	20.6
13			0.0																			0.0	0.0	0.0
14				20.2										20.9	2.3							43.4	23.2	53.5
17					8.1							29.3		10.3								47.7	39.6	83.0
19				4.7		79.2						9.7		10.1								103.7	24.5	23.6
21	67.7		3.2				8891.2	22.9	5.9	116.4	62.6	723.5	9.3	27.4	0.6					5.7	3.5	9939.9	1048.7	10.6
22	1.6							38.9				5.3										45.8	6.9	15.1
23																						0.0	0.0	0.0
24							29.2			38.8		90.8	23.3									182.1	143.3	78.7
29	14.9						4.8	2.2			4.6	10.1	4.4	7.7								48.7	44.1	90.6
31	54.1				4.2		70.5			37.4		1772.9	59.6	11.7	3.7					13.8	11.9	2039.8	266.9	13.1
32	4.1											28.3	129.2	138.2				1.9		9.9		311.6	182.4	58.5
41	9.7					4.7	1.9					1.3	13.7	2084.1	4.5					0.6		2120.5	36.4	1.7
42												15.4		1.6	61.4							78.4	17.0	21.7
43																						0.0	0.0	0.0
51																						0.0	0.0	0.0
52																		36.2				36.2	0.0	0.0
53																						0.0	0.0	0.0
61	0.7						3.0			2.5		39.6	121.3	330.4	5.6			1.6		304.3	25.8	834.8	530.5	63.5
62	5.4						21.0				4.2	149.2	5.7	21.1	1.9			3.0		280.2	455.9	947.6	491.7	51.9
Total New 1978	1996.2	158.0	9.2	24.9	13.6	84.5	9105.2	66.9	17.6	196.7	148.1	3135.1	400.3	2724.3	87.5	0.0	0.0	42.7	0.0	628.9	497.1	**Total Acreage**		**19336**
Gain	166.7	3.8	9.2	4.7	5.5	5.3	214.0	28.0	17.6	157.9	143.5	1362.2	271.1	640.2	26.1	0.0	0.0	6.5	0.0	324.6	41.2	**Total Unchanged**		**15908.7**
%Gain	8.4	2.4	100.0	18.9	40.4	6.3	2.4	41.9	100.0	80.3	96.9	43.4	67.7	23.5	29.8	0.0	0.0	15.2	0.0	51.6	8.3	**Total Changed**		**3427**
%Net Gain/Loss	**-14.2**	**-18.2**	**100.0**	**-34.6**	**-42.6**	**-17.4**	**-8.2**	**26.8**	**100.0**	**1.6**	**6.3**	**30.4**	**9.2**	**21.8**	**8.1**	**0.0**	**0.0**	**15.2**	**0.0**	**-11.9**	**-43.6**	**% Changed**		**17.70%**

Note: Many errors were the result of the 1978 Interpreter interpreting from local knowledge at a later date than that represented by the photo. This resulted in a different LULC than what the 1978 photography showed and needed to be fixed.

Old 1978 \ New 1978	1	2	3	4	5	6	Total Orig 1978	Loss	%Loss
1	2116.1	176.5	332.5	111.9	0.0	14.4	2751.4	635.3	23.1
2	87.4	9217.5	866.7	35.7	0.0	9.2	10216.5	999.0	9.8
3	62.4	107.9	1990.0	153.6	1.9	35.6	2351.4	361.4	15.4
4	14.4	1.9	30.4	2151.6	0.0	0.6	2198.9	47.3	2.2
5	0.0	0.0	0.0	0.0	36.2	0.0	36.2	0.0	0.0
6	6.1	30.7	315.8	359.0	4.6	1066.2	1782.4	716.2	40.2
Total New 1978	2286.4	9534.5	3535.4	2811.8	42.7	1126.0	**Total Acreage**		**19336**
Gain	170.3	317.0	1545.4	660.2	6.5	59.8	**Total Unchanged**		**16577.6**
%Gain	7.4	3.3	43.7	23.5	15.2	5.3	**Total Changed**		**2758**
%Net Gain/Loss	-15.6	-6.5	28.3	21.3	15.2	-34.9	**% Changed**		**14.30%**

Appendix Table 2. Acres of Change between 1978 and 2000 - *Level 2 MIRIS-2000*
Williamstown Township
Ingham County

1978 \ 2000	11	12	13	14	17	19	21	22	23	24	29	31	32	41	42	43	51	52	53	61	62	Total 1978	Loss	%Loss
11	1950.0	29.3				3.9					6.1			6.8								1996.1	46.1	2.3
12		151.4	6.7																			158.1	6.7	4.2
13		6.0						3.2														9.2	9.2	100.0
14				24.9																		24.9	0.0	0.0
17	1.6				8.1							3.9										13.6	5.5	40.4
19						84.5																84.5	0.0	0.0
21	756.9	12.5		14.4		58.5	6200.2	9.6	4.1	118.7	28.0	1487.4	197.9	108.0	68.9			5.0		12.8	22.0	9104.9	2904.7	31.9
22	10.0					1.8	6.9	7.7				19.0	1.8	16.0	2.1					1.5		66.8	59.1	88.5
23									17.6													17.6	0.0	0.0
24	5.4						52.3	6.9		18.6	2.2	54.4	7.0	9.0	13.8					27.0		196.6	178.0	90.5
29	53.2	6.4	4.6								71.1	2.6	3.2	4.8	2.2							148.1	77.0	52.0
31	503.1	55.5					395.0	1.6		77.1	0.3	816.7	455.0	493.1	133.5					165.6	38.6	3135.1	2318.4	73.9
32	46.1	7.1					6.0					8.7	64.5	261.0	6.8							400.2	335.7	83.9
41	33.8	1.8				1.1	5.9						7.5	2658.7	6.7					8.7		2724.2	58.0	2.1
42															87.5							87.5	0.0	0.0
43																						0.0	0.0	0.0
51																						0.0	0.0	0.0
52																		42.7				42.7	0.0	0.0
53																						0.0	0.0	0.0
61	4.7					2.4						4.9		146.0	6.0			4.5		456.4	4.0	628.9	172.5	27.4
62	1.2						7.6							43.4						110.1	334.7	497.0	162.3	32.7
Total 2000	3366.0	270.0	11.3	39.3	8.1	152.2	6673.9	29.0	21.7	214.4	107.7	2397.6	736.9	3746.8	327.5	0.0	0.0	52.2	0.0	782.1	399.3	**Total Acreage**		**19336.3**
Gain	1416.0	118.6	11.3	14.4	0.0	67.7	473.7	21.3	4.1	195.8	36.6	1580.9	672.4	1088.1	240.0	0.0	0.0	9.5	0.0	325.7	64.6	**Total Unchanged**		**12995.3**
%Gain	42.1	43.9	100.0	36.6	0.0	44.5	7.1	73.4	18.9	91.3	34.0	65.9	91.2	29.0	73.3	0.0	0.0	18.2	0.0	41.6	16.2	**Total Changed**		**6341**
% Net Gain/loss	39.8	39.7	0.0	36.6	-40.4	44.5	-24.8	-15.0	18.9	0.8	-18.0	-8.0	7.4	26.9	73.3	0.0	0.0	18.2	0.0	14.2	-16.5	**% Change**		**32.8**

Acres of Change between 1978 and 2000 - *Level 1 MIRIS-2000*
Williamstown Township
Ingham County

1978 \ 2000	1	2	3	4	5	6	Total 1978	Loss	% Loss
1	2266.4	9.3	3.9	6.8	0	0	2286.4	20	0.9
2	923.7	6543.9	1773.3	224.8	5	63.3	9534	2990.1	31.4
3	611.8	480	1344.9	894.4	0	204.2	3535.3	2190.4	62.0
4	36.7	5.9	7.5	2752.9	0	8.7	2811.7	58.8	2.1
5	0	0	0	0	42.7	0	42.7	0	0.0
6	8.3	7.6	4.9	195.4	4.5	905.2	1125.9	220.7	19.6
Total 2000	3846.9	7046.7	3134.5	4074.3	52.2	1181.4	**Total Acreage**		**19336**
Gain	1580.5	502.8	1789.6	1321.4	9.5	276.2	**unchanged**		**13856**
% Gain	41.1	7.1	57.1	32.4	18.2	23.4	**changed**		**5480**
% Net Gain/Loss	**40.2**	**-31.4**	**-4.9**	**30.3**	**18.2**	**3.8**	**% Changed**		**28.3**

Appendix Table 3. Acres of Disagreement between Truth and MDNR
Williamstown Township
Ingham County

MDNR \ TRUTH	11	12	13	14	17	19	21	22	23	24	29	31	32	41	42	43	51	52	53	61	62	Loss
11		18.1				3.9				10.4	9.7	110.3	19.7	35.5	3.0			3.6				214.2
12	2.6		11.3																			13.9
13		6.0																				6.0
14																						0.0
17																						0.0
19												3.1										3.1
21	68.0	3.0		14.4		3.5				112.0	9.6	320.0	7.6	37.7	4.8					4.2	11.1	595.9
22												35.7		3.6	16.6							55.9
23		5.2								5.9	14.5											25.6
24	32.1						70.1					97.6	13.7	10.5	4.0							228.0
29	28.1	6.4												4.7								39.2
31	128.0	14.4			8.1		70.7			31.3			229.5	63.9	2.5			5.0		59.2	43.2	655.8
32	8.8									9.6		82.3		237.7	47.5					125.2		511.1
41	20.0						21.1					9.4	26.0		41.0					19.2	5.9	142.6
42	3.4												9.0	6.7								19.1
43																						0.0
51																						0.0
52												3.4									2.7	6.1
53																						0.0
61												4.9	7.5	120.8	6.0						50.8	190.0
62							7.6							9.2						69.1		85.9
Gain	291.0	53.1	11.3	14.4	8.1	7.4	169.5	0.0	0.0	169.2	33.8	666.7	313.0	530.3	125.4	0.0	0.0	8.6	0.0	276.9	113.7	
% Net Gain/loss	76.8	39.2	5.3	14.4	8.1	4.3	-426.4	-55.9	-25.6	-58.8	-5.4	10.9	-198.1	387.7	106.3	0.0	0.0	2.5	0.0	86.9	27.8	

Acres of Disagreement	2792.4
Total Acreage > 2.5 ac.	18355.6
Percentage Error	**15.2**

Appendix Table 4. Acres of Disagreement between Truth and NAPP
Williamstown Township
Ingham County

TRUTH

NAPP	11	12	13	14	17	19	21	22	23	24	29	31	32	41	42	43	51	52	53	61	62	**Loss**
11		28.9				3.9	6.9			2.8	13.7	24.2	11.1	61.5	5.3					5.9		164.2
12				4.7																		4.7
13		17.3						6.7														24.0
14																						0.0
17																						0.0
19		4.1										9.7										13.8
21	64.7			14.4		3.8		12.0		116.5	13.3	536.2	22.2	42.6	7.7						16.8	850.2
22																						0.0
23																						0.0
24	37.4						110.1					105.1	8.3	13.4								274.3
29	34.2						3.6															37.8
31	211.4				8.1		52.1			33.1			477.1	212.3	30.5			5.0		115.4	23.7	1168.7
32	6.3													8.6						14.7		29.6
41	17.2						10.4				3.7	20.2	111.5		19.9					170.5	27.0	380.4
42	3.6							6.9				8.1	6.3	9.9							5.3	40.1
43															4.1							4.1
51																						0.0
52																					4.5	4.5
53																						0.0
61												2.7		41.3							40.9	84.9
62	3.4						5.5					60.5	8.1	20.1						120.9		218.5
Gain	378.2	50.3	0.0	19.1	8.1	7.7	188.6	25.6	0.0	152.4	30.7	766.7	644.6	409.7	67.5	0.0	0.0	5.0	0.0	427.4	118.2	
% Net Gain/loss	214.0	45.6	-24.0	19.1	8.1	-6.1	-661.6	25.6	0.0	-121.9	-7.1	-402.0	615.0	29.3	27.4	-4.1	0.0	0.5	0.0	342.5	-100.3	

Acres of Disagreement	3299.8
Total Acreage > 2.5 ac.	18386
Percentage Error	**17.9**

Appendix Table 5. Acres of Disagreement between Truth and AirphotoUSA
Williamstown Township
Ingham County

APUSA \ TRUTH	11	12	13	14	17	19	21	22	23	24	29	31	32	41	42	43	51	52	53	61	62	Loss
11		4.9								8.8				6.3								20.0
12										6.7												6.7
13		18.9						8.6														27.5
14																						0.0
17																						0.0
19																						0.0
21	8.6											41.8	17.7							2.5		70.6
22																						0.0
23																						0.0
24							77.3					14.0										91.3
29						4.9																4.9
31	80.5	8.4		14.4			69.0			175.7			35.4		3.5						11.2	398.1
32												4.1			4.8					89.0		97.9
41													16.9							8.4		25.3
42													6.0									6.0
43																						0.0
51																						0.0
52																						0.0
53																						0.0
61																						0.0
62																				35.8		35.8
Gain	89.1	32.2	0.0	14.4	0.0	4.9	146.3	8.6	0.0	191.2	0.0	59.9	76.0	6.3	8.3	0.0	0.0	0.0	0.0	135.7	11.2	
% Net Gain/loss	69.1	25.5	-27.5	14.4	0.0	4.9	75.7	8.6	0.0	99.9	-4.9	-338.2	-21.9	-19.0	2.3	0.0	0.0	0.0	0.0	135.7	-24.6	

Acres of Disagreement	784.1
Total Acreage > 2.5 ac.	19151
Percentage Error	**4.1**

Acres of Disagreement between Truth and Landsat 7 ETM
Williamstown Township
Ingham County

TRUTH

LANDSAT	1	11	12	13	14	17	19	21	22	23	24	29	31	32	41	42	43	51	52	53	61	62	Loss
1								29.3					6.3										35.6
11			92.7		12.4		57.5	284.5	6.9		109.5	22.2	1151.2	216.3	194.5	115.9			5.0		78.9	41.2	2388.7
12				6.7																			6.7
13			6.0						3.2														9.2
14																							0.0
17							4.6						3.9										8.5
19																							0.0
21		117.9							5.5		63.6	8.9	233.8	13.3	36.7						4.2	2.7	486.6
22		5.0											23.8		14.3								43.1
23								4.0															4.0
24								13.4	6.9				39.0	4.6	7.9	13.8							85.6
29		51.0	6.4	4.6									2.6	3.2	4.8								72.6
31		29.8						207.0			15.3			413.9	339.6	66.0					122.6	33.6	1227.8
32		14.4						2.5					10.9		236.8								264.6
41		4.7						25.3						7.5		6.7					8.7		52.9
42															4.6								4.6
43																							0.0
51																							0.0
52																							0.0
53																							0.0
61													4.9		132.9	6.0			4.5			4.0	152.3
62								7.6							43.4						103.1		154.1
Gain	0.0	222.8	105.1	11.3	12.4	0.0	62.1	573.6	22.5	0.0	188.4	31.1	1476.4	658.8	1015.5	208.4	0.0	0.0	9.5	0.0	317.5	81.5	
% Net Gain/loss	-35.6	-2165.9	98.4	2.1	12.4	-8.5	62.1	87.0	-20.6	-4.0	102.8	-41.5	248.6	394.2	962.6	203.8	0.0	0.0	9.5	0.0	165.2	-72.6	

Acres of Disagreement	4996.9
Total Acreage > 2.5 ac	18784.3
Percentage Error	**26.6**