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Quantifying Urbanization in Grand Traverse County, MI

Benjamin T. Roush
Western Michigan University

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CERTIFICATE OF ORAL DEFENSE OF HONORS THESIS

Benjamin Roush, having been admitted to the Carl and Winifred Lee Honors College in the fall of 2008, successfully completed the Lee Honors College Thesis on April 20, 2012.

The title of the thesis is:

Quantifying Urbanization in Grand Traverse County, MI

Dr. Charles Emerson, Geography

Dr. Lynne Heasley, Environmental Studies

Dr. Gregory Veeck, Geography

1903 W. Michigan Ave., Kalamazoo, MI 49008-5244
PHONE: (269) 387-3230 FAX: (269) 387-3903
www.wmich.edu/honors

Quantifying Urbanization in Grand Traverse County, MI

Benjamin Roush
Lee Honors College Thesis Project
Western Michigan University
Spring 2012 Semester
Lead Advisor: Dr. Charles Emerson
Co-Advisors: Dr. Lynne Heasley and Dr. Greg Veeck

ABSTRACT: Grand Traverse County, MI has witnessed population growth in the past thirty years, largely because of its popularity as a tourist destination and "wilderness" area in Michigan and around the Great Lakes basin in general. Accordingly, there has been human development and urbanization in the county, particularly around its major community, Traverse City. This paper seeks to quantify that urbanization. This will be done by classification of Landsat 5 – TM imagery collected in 1984 and 2010, utilizing the Gaussian maximum likelihood supervised classification method. After this process, changes in proportions of the various land use types in the county will be calculated. Spatial examination of urban expansion helps to objectively analyze the effects of human population growth on the environment. Furthermore, it visibly shows the effect of human processes on a landscape. There is also analysis and some discussion of other shifts in land use areas, such as forests and agricultural land. Furthermore, this paper examines the environmental effects of urbanization and policy measures required to protect environmental integrity. The study did find an increase in urbanized land in the county (2% increase as a proportion of the entire county, corresponding to a 21% increase in urbanized land), but not to the great extent that was expected considering the growth in tourism.

Introduction

Grand Traverse County, MI is a major tourist location, particularly for those in metropolitan Detroit and the Great Lakes region as a whole. It is located in the northwestern quadrant of the Lower Peninsula. The county has one major urban area, Traverse City, located at the base of the large peninsula jutting from the northern side of the county (Old Mission Peninsula). The eastern and western thirds of the county are largely forested, with interspersed wetlands. The southern third of the county is mostly dominated by cropland and pasture. The Old Mission peninsula has significant agricultural areas as well. Most of the crops on the peninsula are cherry or grape as the position of the peninsula between both arms of Grand Traverse Bay, a part of Lake Michigan, result in an ideal moderate climate. The cherry crops in the regions have led Traverse City to be known as the "Cherry Capital of the World." The county is approximately 490 sq. mi. (1,269 sq km) in area, with a permanent population of 86,986 (US Census, 2010), although population increases in summer months.

Figure 1: Grant Traverse Co.
Source: Michigan Economic
Development Corp.

There are a variety of attractions in the county, including sightseeing along the beautiful Grand Traverse Bay coastline, agricultural tourism, and winter sports like skiing. Visitors to the area, and the population of the county at large, see the area as a "wilderness haven" and a destination to enjoy the outdoors thoroughly. These factors taken all together have made the region an extremely popular tourist destination. As tourism has become more prevalent in the county in the last 30 years, human development and urbanization increased dramatically. Traverse City has seen this expansion in particular. This development includes the growth of

highway infrastructure and construction of new residential and commercial properties to account for the increase of people living in or visiting the area.

This paper seeks to quantify how much development has actually occurred in Grand Traverse County. Quantification involves using two LANDSAT 5-TM satellite images gathered in 1984 and 2010. The data collected has a 30m x 30m resolution. The images are then classified by land cover type using ENVI ™ software (ITT Exelis, 2011). The change in land cover area is calculated by tallying changes in pixel totals. This study revealed that quantitative analysis of urban expansion did yield an increase in developed land cover, but not to the great extent that increased in tourism would indicate. However, additional signs of development were noted when qualitatively analyzing the satellite imagery. A study of this kind can help policy makers and the general public better understand unbridled human development by objectively demonstrating the effects of urbanization on the landscape and the environment.

Specifically, this study also investigates the effects of increasing human development as it affects water resources and biodiversity. The study continues by focusing on the apparent paradox of continued development in an area that is known for its wilderness theme and culture and discusses policy measure necessary for protecting environmental quality.

Methodology

In order to obtain uniform characteristics in data analysis, the study collected only LANDSAT 5 – TM images. The USGS's Earth Explorer webpage provided the interface for image collection. Statistical criteria available for pre-processing of data were not deemed necessary and were thus not utilized. Grand Traverse County is located within path 22, row 29. Figured 2 demonstrates a full Landsat image. June and August ensured that vegetation cover was near full potential and were therefore of primary focus for data collection. With plentiful

vegetation cover, mistakes in classification between forested areas and grasslands would be far less likely. However, residential classification in some suburban developed areas would be relatively challenging. Images were collected from July 11, 1984 and June 17, 2010.

Figure 2: Full Landsat image. Source: USGS

Images were uploaded as individual bands. Bands 1 – 5 and 7 were then downloaded and stacked. Stacking used nearest neighbor resampling, and the band images were placed onto a UTM grid, zone 16N, in the WGS-84 datum. Only bands 1, 2, and 3 were used for land cover classification, as the 3-2-1, or the natural color combination provided adequate differentiation among land cover types. Furthermore, remote sensing studies of urban areas often use this band combination (Quinn, 2001; Lillesand et al., 2008). Table 1 gives the specific wavelengths for these bands. A shapefile of the Grand Traverse County boundary provided the clipping edge

when creating a specific image of the county. The Michigan Center for Geographic Information provided this boundary data. An example is shown in figure 3, and the other images can be found in Appendix I.

Table 1: Band Widths Used

Band Number	Wavelength (µm)
1	.45 - .52
2	.52 - .60
3	.63 - .69

Figure 3: Clipped Landsat image
Source: USGS

The method used for supervised classification was the Gaussian maximum likelihood algorithm. This type of classification uses both variance and covariance when determining pixel category (Lillesand et al., 2008). Classes included sand/bare ground, agriculture/grassland, forest/wetland, water, and human development (urban, suburban, roads, etc.). For the purposes of this paper, agricultural land, while technically anthropogenic in nature, will not be considered “developed” land cover. These classes were chosen to ensure focus on the urban regions of the county. Along these same lines, there was no need to differentiate between wetland and forests, or specific agriculture types. The primary purpose is simply to develop an accurate classification of human developed areas expanding into other land cover types. Sand was also an important land cover classification as confusion between it and human developed regions was a principle

conflict throughout the classification analysis process. As the county resides on the Lake Michigan coast, it was important to ensure the sand areas were not mistaken as urban, potentially leading to inflated human classification.

The training stage of classification called for at least 12 samples (but often more) of each land cover type. These samples were then converted to regions of interest (ROIs), which could be used by the software for final classification. All samples used the single-value collection method, with a scale factor of 255. Table 2 lists how many classification attempts were required for each image and table 3 describes the number of samples used to conduct each classification in each image.

Table 2: Attempted Classifications

Year	**Number of Attempted Classifications**
1984	2
2010	2

Table 3: Classification Samples

	# of Samples (Polygons)				
Year	Forest/Wetland	Sand/Bare Earth	Agriculture/Grassland	Developed	Water
1984	12	14	18	12	15
2010	15	15	21	15	15

Table 4: Pixels on Classification Samples

	# of Pixels in Samples				
Year	Forest/Wetland	Sand/Bare Earth	Agriculture/Grassland	Developed	Water
1984	4547	62	1009	965	2818
2010	2512	38	746	1030	1202

When the images were clipped, large regions of the ENVI display image were left "blacked out," meaning they are given a digital number value of 0. This occurred because of the irregular shape of the county in relation to ENVI's normally rectangular display environment. However, when classification occurs, these black-out regions are assigned to a class. Therefore, after classification, images were again clipped. After this occurred, a statistical analysis of the image was conducted. This analysis produced an output consisting of pixel counts for each classification. From these pixel counts, the area of each land cover can be calculated.

Issues and Concerns in Data Collection and Analysis

The primary difficulty in data analysis was ensuring accurate classification. Particular attention was required to differentiate between three land covers with extremely similar visual characteristics: sand/bare land, certain agricultural fields, and urban developments. In many cases, all three would appear similarly as bright white. In general, differentiation relied on context and user intuition. Such white regions near shorelines are likely sand (although some human development does reach directly to the shore), while white areas surrounded by other agricultural regions are likely also agricultural fields. While some of these agricultural fields may have been bare at the time the image was collected, it would be more accurate to classify them as agriculture as that is still their land use designation. These complex issues lead to the determination that supervised classification would be more accurate.

Another issue in classification included an apparent "dilution" of a developed area which was observed when trees covered suburban developments such as subdivisions. In these areas, tree land cover and developed land were both present in areas which should be strictly identified as developed (since trees do exist on developed lands). An example of this can be seen in figures 4a and 4b. Furthermore, water classification was sometimes difficult owing to shallow regions

and the presence of fog. Fog required another classification sample to ensure that the maximum likelihood classification scheme was not confused. Sand regions also required more refined classification designations, to make sure there were minimal amounts of confusion between the shallows and sand or beach.

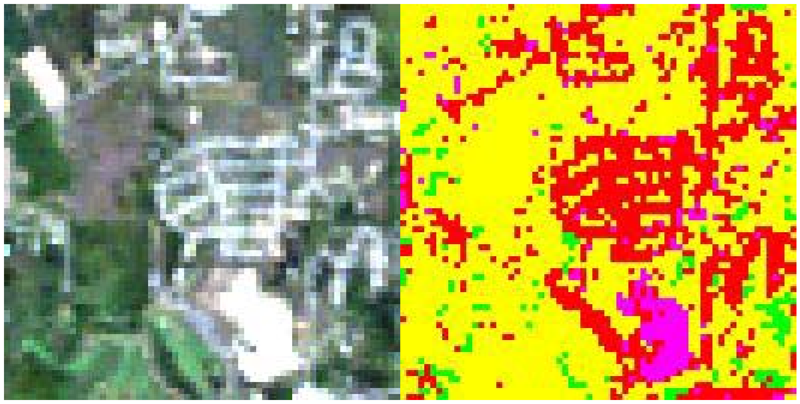

Figure 4 a & b: Here there is clearly a suburban area (red) that is only partially classified as such. The trees in the region are disrupting complete classification, actually causing agricultural or grassland classification (yellow). This image is from 6/17/2010 at 3x zoom.
Source: USGS

Furthermore, the project underutilized other bands available to Landsat, particularly band 4, which covers the near-infrared portion of the electromagnetic spectrum. While band 4 is highly useful in the delineation of different vegetation and vegetation borders, as the focus of this study was on urban areas, it was not deemed necessary for required classification. However, if it had been applied to the study, more accurate classification may have occurred. The lack of use of band 4, or any other band, however, does not discount the information and statistics gathered throughout the study.

Conclusion

The research conducted in this study determined the land cover of the county (table 5 and figure 5). This quantitative analysis did indicate a small increase in urban development, as predicted. Developed land accounted for 2.4% more of the entire county in 2010 than in 1984, or

an increase of approximately 34 square kilometers. This is a 21% increase in urban areas themselves, however. Sand and bare lands also increased by approximately 11 square kilometers. While it cannot be stated with certainty that these cleared lands are being used for human purposes, it is possible that they are in a “pre-development stage” such as a cleared area for future construction. These increased sand values could also stem from the decreasing water level that has been witnessed in the Great Lakes in the past years (GLERL, 2012). Another indication of human development, albeit not necessarily urbanization processes, is the decrease in vegetation. Forests land area decreased from approximately 531 sq. km to 457 sq. km. Also of highlight is the major increase in agriculture and grasslands witnessed in 2010. This is probably because of some misclassification of urban areas as grasslands, but also because of the deforestation, as shown in figure 6.

Table 5: Land Cover Data

1984	# of pixels	Percentage of land cover	Area (sq. km)
forest/wetland	590060	41.83	531.05
sand/bare	25520	1.81	22.97
ag/grassland	574290	40.72	516.86
developed	158890	11.27	143.00
water	61697	4.37	55.53
total	1410457		1269.41
2010			
forest/wetland	507664	35.99	456.90
sand/bare	38236	2.71	34.41
ag/grassland	609706	43.23	548.74
developed	193286	13.70	173.96
water	61565	4.36	55.41
total	1410457		1269.41

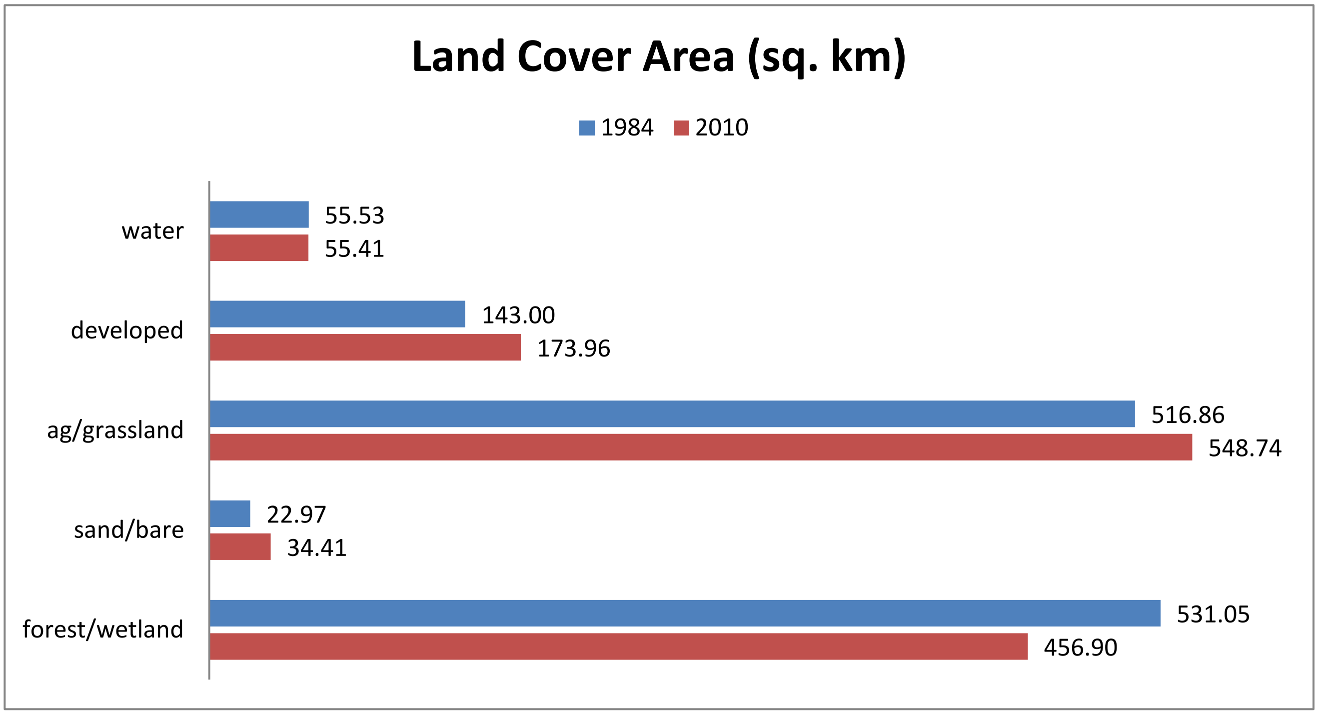

Figure 5: Comparisons of land cover in 1984 and 2010

Figure 6: Example of deforestation between 1999 and 2010
Source: USGS

While there is not a large quantitative change in developed lands, qualitative and subjective visual examination of the natural images does show that urban developments have expanded markedly between 1984 and 2010. This is particularly true when examining regions to the west, southwest, and east of Traverse City (shown as the major developed area in the center of the county), shown in figure 7. The sinuous nature of modern housing developments is more

than clear in these areas. For a complete examination, Appendix I has each natural color and classified image.

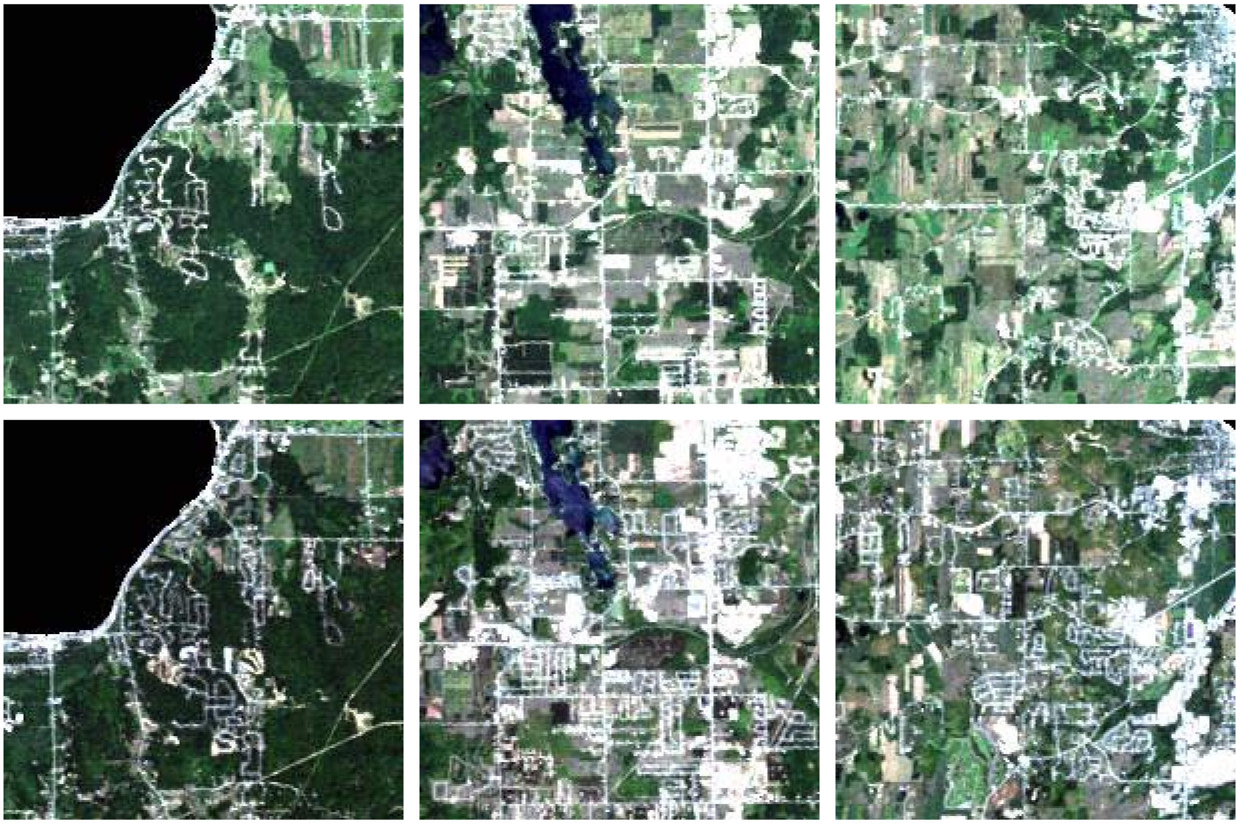

Figure 7: The images from the upper row are from 1984, while the lower row's images are from 2010. Development here is more than clear qualitatively. Source: USGS

Comparing urbanization to changes in population also helps to obtain a more clear understanding of the effects of urbanization. Figure 8 shows changes in population in Grand Traverse County and Traverse City between 1984 and 2010. Population of the county at large is shown to increase, while the city itself experiences a decreased population. This is likely explained by increased interest in developed areas outside the city proper (such as more suburban and exurban subdivisions). The connection between increasing urbanization and population growth reinforces that population changes do have visible effects on the landscape, namely

expansion of urban lands at the expense of other land types. Any future research on this subject should involve the development of a regression model linking population and land use change.

Table 6: Population and Household Change in Traverse City and Grand Traverse County. Source: US Census

Population	Traverse City	Grand Traverse County
1980	15516	54899
1990	15116	64273
2000	14383	77654
2010	14482	86986
Households		
1980	5747	19176
1990	6202	23965
2000	6383	30396
2010	6598	35328

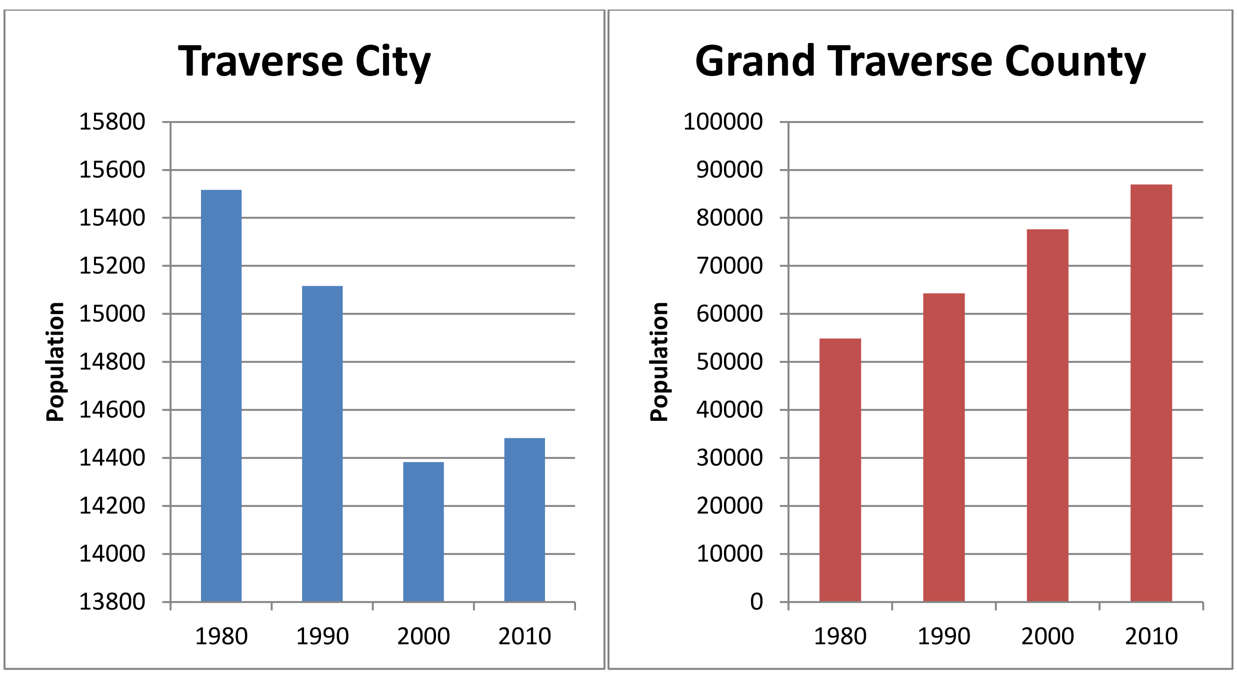

Figure 8: Population change in Traverse City and Grand Traverse County. Source: US Census

The reasoning behind the specific locations of urbanization should also be the subject of further research. For example, there is clear development to the southwest of Traverse City between 1984 and 2010 (see figures A3 and A4 in Appendix I). This development can reasonably be attributed to the fact that US Highway 31 passes through the area, and as a major transportation route, businesses would flourish in the area. However, the complicated tax code and development incentives in a county probably also play an important role in development focuses outside city borders themselves. Linkages between suburban sprawl and these factors must be investigated.

Discussion

While the spatial extent of increased urbanization is seemingly low, the ramifications of such human development can still be great. The following section will describe some of the problems that are associated with increasingly urbanized areas.

Effects on Watershed Health and Quality

Urbanization has a negative impact upon water bodies. In Grand Traverse County, the major fluvial system is the Boardman River. In general, urban developments include impermeable surfaces such as parking lots, other transportation networks, and buildings. Such structures allow for surface run-off that can contain a variety of harmful substances. One specific issue is the development of highways. Highways are causes of run-off pollution during their use, but are also a threat to aquatic systems during their construction. Highway run-off can include substances such as zinc, phosphorus (from local fertilizer activity), and oil and gasoline residues. Such compounds have obvious and immediate negative effects on the ecological strength of aquatic systems. Furthermore, highway development can increase sedimentation and erosion rates in fluvial systems, which is particularly important as the Grand Traverse County

government often dumps sand on roads for traction during icy conditions (Wheeler et al., 2005). The Boardman River, in 2000, had approximately 600 distinct locations where erosion had become problematic, with 150 different locations in which sedimentation had already been remediated (Great Lakes Commission, 2000). Human activity can also threaten stream integrity via waste pollution such as E. coli, along with addition of cholesterol or pharmaceutical products like steroids and antibiotics. Such additions to watersheds have the potential for wide-ranging ecosystem affects, and in the case of E. coli, can affect public use of natural resources such as beaches, which then can also have negative economic effects.

As Grand Traverse County is situated on arguably the greatest freshwater systems in the world, it is imperative that continuing developments account for water pollution to ensure protection of the vital natural resource that is the Great Lakes. Citizen activism in promoting cleaner waterways, as well as the construction of buffer strips in highly sensitive areas can help to remediate such pollution (GLEC, 2009). Urbanization can also have an effect on water security. Increasing urbanization means greater stresses on local water resources. It is important that human processes, whether domestic or industrial, account for proper water management through conservation practices. These practices can range from no-flush toilets to tertiary treatment applications in sewage facilities to intensive remediation in areas where construction may threaten groundwater quality (MLUI, 2005).

Potential Loss of Biodiversity

Human development, by its very nature, causes destruction of habitat. The potential damage from habitat loss depends on the rate at which development occurs and the sensitivity of the region in which the expansion is occurring. Also problematic is the continual nature of habitat lost to urban developments. Once human structures are constructed, it is highly unlikely

that an area will return to a natural ecosystem. Development also fragments habitat, destroying some ecological connections. Furthermore, urbanization leads to a local homogeneity of species. Diversity greatly decreases as standardized suburban and urban species come to dominate an area, pushing normally native species away from areas where they once inhabited (McKinney, 2002). The extent of such ecological changes is currently unknown in the developing regions around Traverse City, but such loss of diversity is a clear issue to be monitored by natural resource specialists.

In order to guard against a loss of biodiversity and habitat destruction, it important to conserve as much land as possible (McKinney, 2002). This is often much easier said than done, however, with economic concerns often taking the forefront to ecological issues, especially in regions that are not normally considered by the general public to be in danger, such as the nominally resilient mixed forest ecosystems of the Midwest. It is also important that preserved areas are relatively large. A set of small reserved properties will not be adequate in maintaining normal ecosystem interactions. The development of previously used lands that are currently manifested as brownfields is also part of the solution to conserving natural habitat. When such properties are used for new human development, it limits the amount natural habitat destruction elsewhere (MLUI and Mawby, 2005). Furthermore, the type of homogeneity previously described can be resisted by reintroduction of native species in developed areas. This would help to, at least to some extent, allow for native ecosystem function (McKinney, 2002).

Example of Pollution from Agro-Industry

As previously stated, cherry agriculture is a primary (and quintessential) economic sector in Grand Traverse County. The processing of cherries, however, does come with environmental effects. The Williamsburg Receiving & Storage Co. maraschino cherry plant north of Traverse

City exemplifies pollution from agricultural product processing. The plant produced large amounts of contaminated wastewater, as well as odors that were detrimental to the standard of living of the residents in the area. A lawsuit, filed by Northern Michigan Environmental Action Council, in conjunction with local citizens, resulted in legal enforcement of a greater environmental standard for the plant. All wastewater produced had to be transported to local waste treatment facilities for complete sanitation. Furthermore, mechanical devices were installed to remove the significant unpleasant odors (Reisig, 2007). Such agricultural pollution must be considered as a component of human development's effect in a region, especially as more of these sites may be expected with a growing economy and increasing development.

Boardman River Dam Removal

In some cases, small human infrastructure developments can have large impacts on the environment. Such is the case with dams. Dams normally are known as detrimental to the aquatic health of a region by changing hydrological patterns, particularly through increased temperature in areas upstream, and via increased sedimentation behind the dam itself. In August 2011, a formal proposal to remove the Brown Bridge Dam on the Boardman River was presented publicly. This represents a major step toward remediating past human effects on the natural ecosystem. The plan consists of removing the dam in a controlled fashion and allowing the stream to retake its original path, which is believed to still be intact, with only minor changes in morphology. After this, native vegetation will be planted around the new channel in an effort to speed return to standard ecosystem function. Once the stream is in place, it is believed that wetlands will develop, allowing for the complete return to environmental competence (Inter-Luve and AMEC, 2011).

Grand Traverse County's Environmental Dichotomy

The pollution risks from urbanization have been explained and it is evident that continual development, all other variables being equal, leads to the increasing threats on ecosystem and natural resource sustainability. However, the entirety of Grand Traverse County is not threatened equally. Certain regions may not be experiencing the same rates of urbanization. The large forested areas in the eastern areas of the county are protected as the Traverse City State Forest Area. Furthermore, Long Lake, in the west of the county, is reported to have superior water quality and a protection plan to ensure that these high standards continue (GLEC, 2009). Citizens in these environmentally sound regions may not see the importance of environmentally-conscious policy in urban regions and not take seriously attempts to implement such policy. This apparent change in threat factor between urban and rural areas may potentially cloud the importance of environmental policy in the region as a whole. It is important that the county, and indeed the northern lower peninsula of Michigan in general, recognize that environmental policies must be pursued for the protection of natural resources and their sustainable use. Although urbanization is not spreading rapidly to all areas of the county, all must understand the importance of urbanization's effects.

Public Reaction to Urbanization and Environmental Threats

The potential damages of urbanization are not unknown to many throughout the Grand Traverse County. There are a variety of private and public organizations that work as watch-dogs to ensure that human development in the county is done so in a manner that ensures the environmental longevity of the region. Such groups include the Traverse City based Michigan Land Use Institute, the Watershed Center – Grand Traverse Bay, the Michigan Environmental Council, and the Sustain Our Great Lakes initiative. These organizations show that there is

public support for protecting natural resources and maintain ecological integrity. Furthermore, there are municipal, county, state and federal agencies that monitor environmental quality. In fact, the government of Grand Traverse County in 1992 implemented a plan to curb soil erosion and runoff. The regulation includes penalties for non-compliance, including the authority to stop a development. It also creates a permitting process to ensure that new developments keep run-off and sedimentation rates within reason for compliance with federal environmental standard (Grand Traverse County, 1992).

The struggle between economic development and protection of the environment from said development is seemingly indefinite, but it is important to note in Grand Traverse County there is a constituency that understands the importance of environmental health and integrity. A significant problem is the potential that people will lose touch with the "need to preserve nature" and with environmental knowledge in general if an urban area becomes too great (McDaniel and Alley, 2005). This is probably not the case, given the relatively small urban area of Traverse City when compared with other cities, even in the state of Michigan and because of the region's connection with "wilderness" in public perception. Overall, it is important that citizens, regulators, and scientists alike understand that development is not in and of itself dramatically bad. However, it is important that development is monitored and regulated as to prevent the disrespect and destruction of the environment and natural resources on which all human civilization depends.

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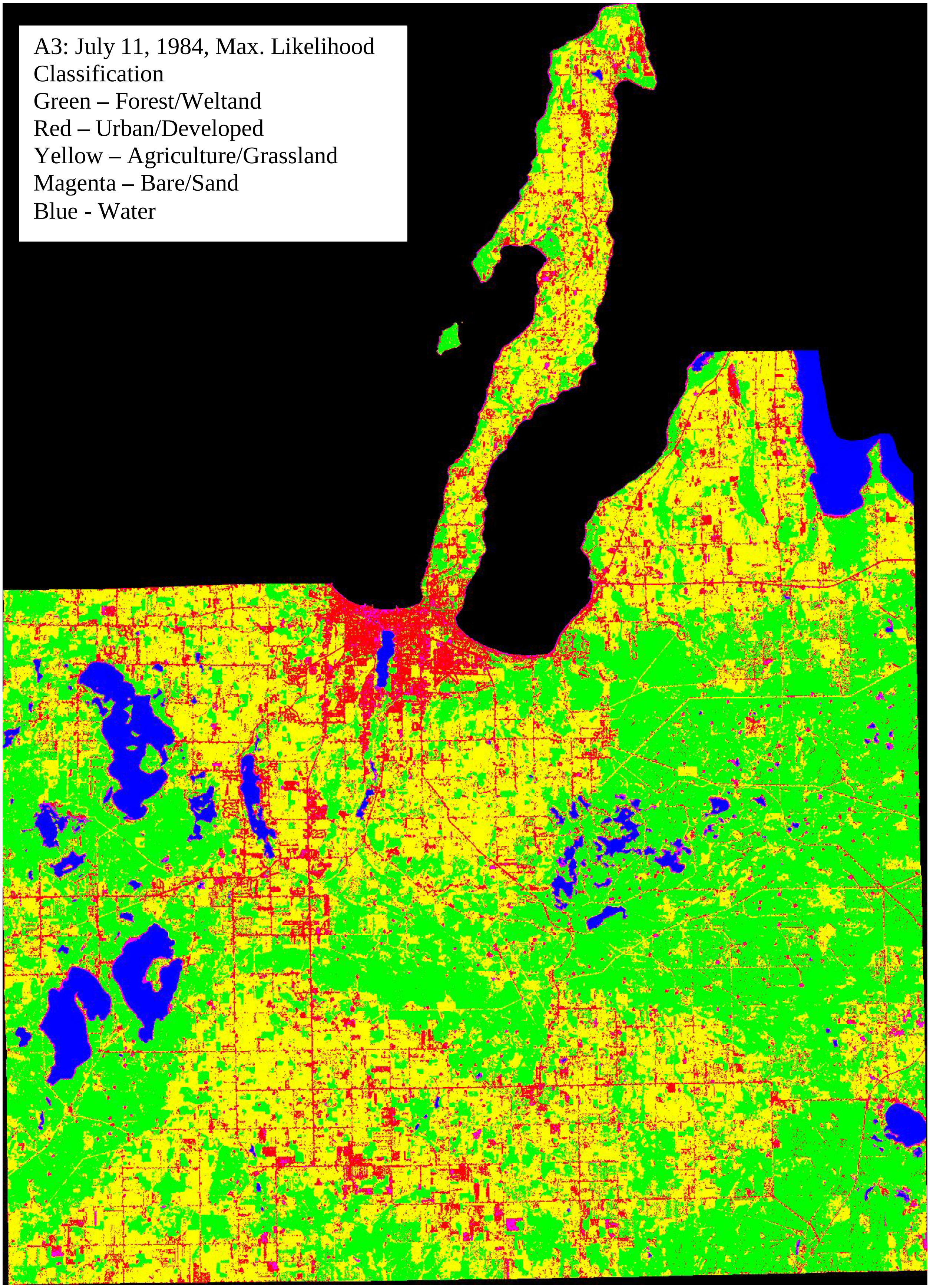
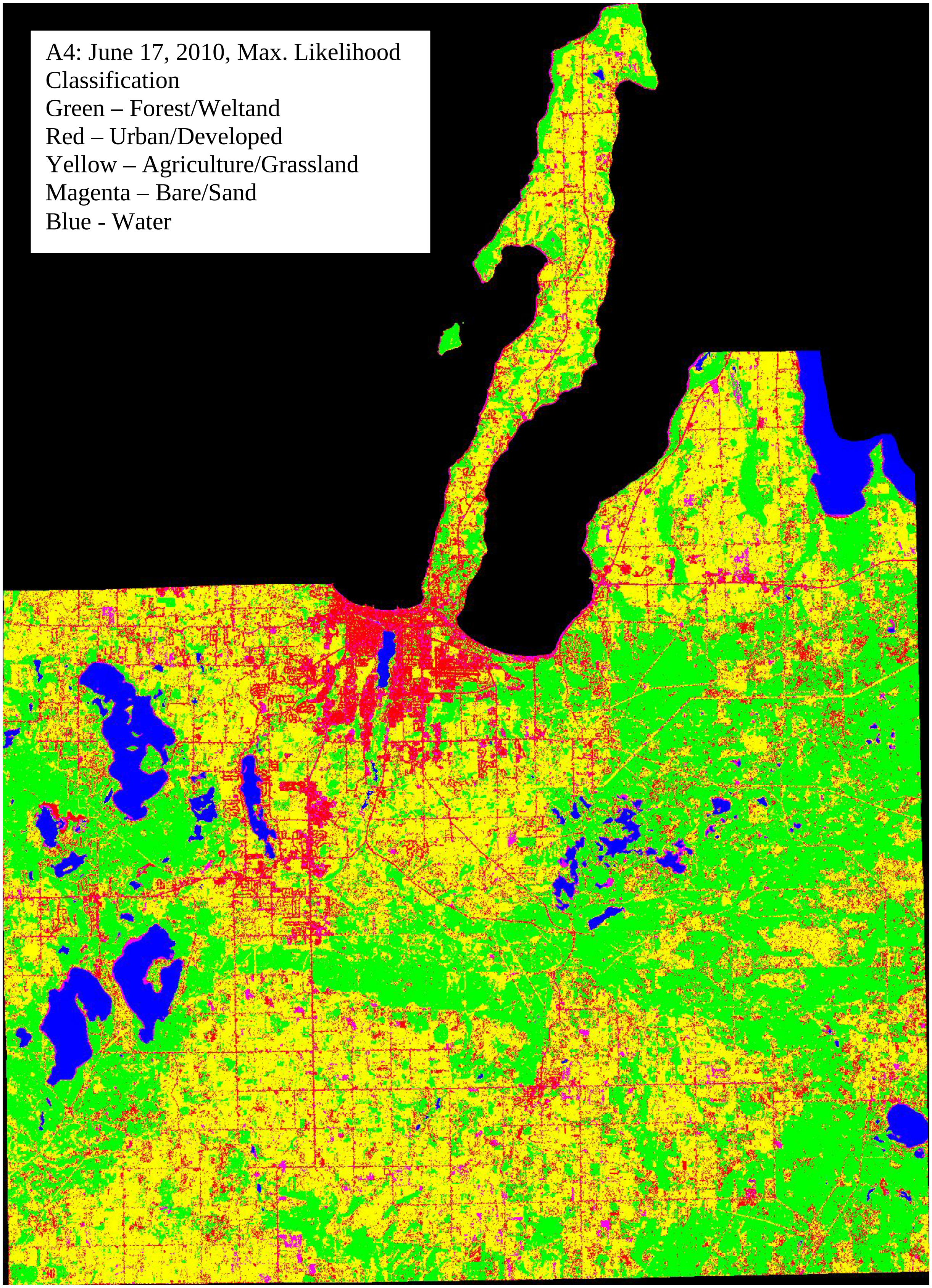
Appendix I


A1: July 11, 1984, natural color
Source: USGS


A2: June 16, 2010, natural color
Source: USGS


A3: July 11, 1984, Max. Likelihood
Classification
Green – Forest/Weltand
Red – Urban/Developed
Yellow – Agriculture/Grassland
Magenta – Bare/Sand
Blue - Water



A4: June 17, 2010, Max. Likelihood Classification