Historical Land Cover Change and Growth Rate at Fort McCoy, WI Army Installation Base from 2004-2018

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Abstract

Military uses of GIS include applications such as mission command, intelligence, surveillance, reconnaissance, training area management, installation management, and mission support. Geospatial information plays a strategic role in cartography, battlefield management, terrain analysis, remote sensing, and military installation management. Fort McCoy is a United States Army installation on 60,000 acres between Sparta and Tomah, Wisconsin, in Monroe County. This study analyzes historical land cover change in Fort McCoy from 2004-2018. As a Total Force Training Center, Fort McCoy's primary responsibility is to support the training and readiness of military personnel and units of all branches and components of America's armed forces. This requirement has shown significant impact on land usage over time. Classifications for land use change include (a) complexes, (b) blacktop, (c) agricultural/green space, and (d) forested Lands. These classes were evaluated within the Fort McCoy main installation. NAIP, USGS aerial imagery, and Monroe County Wisconsin Land Information Office imagery were used for interpretation and data classifications. Results discovered land cover change in all four categories. Blacktop realized the largest increase between 2004 and 2018. Historical significance, local economic impact, and training capacities of Fort McCoy may help to explain land cover changes.

Introduction

Located in the heart of the Upper Midwest, Fort McCoy is the only U.S. Army installation in Wisconsin. The installation has provided support and facilities for the field and classroom training of more than 100,000 military personnel from all services each year since 1984. The Fort McCoy complex is situated on 60,000 acres, 46,000 of which are contiguous live-fire and maneuver areas. Fort McCoy provides reserve- and active-component forces with the networked, integrated, interoperable training resources required to support the Army's training strategies using a full spectrum of facilities, ranges, and training areas. From 1990 to the present day, new construction projects have served to modernize the post's infrastructure, facilities, and training areas (The Real McCoy, 2019).

In order to minimize maintenance costs and ensure the long-term utility of military training lands, it is necessary to inventory and classify the lands relative to their environmental condition and their ability to sustain various kinds and intensities of military training in the future (Warren, Diersing, Thompson, and Goran,

Rodriguez, C. 2019. Historical Land Cover Change and Growth Rate at Fort McCoy, WI Army Installation Base from 2000-2018. Volume 22, Papers in Resource Analysis. 16pp. Saint Mary's University of Minnesota University Central Services Press. Winona, MN. Retrieved (date) http://www.gis.smumn.edu

1989).

Spatial information has always been important to military commanders; an understanding of terrain, for example, is an essential military skill. GIS has a key role to play in creating, editing, analyzing, querying, and displaying geographical data in order to help the commander understand the influence of terrain on the conduct of the battle (Swann, 1999). Geographic Information Systems (GIS) play a pivotal role in military operations. As the operational picture and battlefield develop, everything is essentially spatial in nature.

The Department of Defense (DoD) is responsible for administering more than 25 million acres of federally owned land in the United States making it the fifth largest federal land managing agency. Often the factors affecting land condition are of different scales and their values are of different magnitudes (Mendoza, Anderson, and Gertner, 2002).

Different missions and focuses play an integral part in the asset and resource planning related to any such land usage and mission sets, from training considerations, environmental considerations, and organizational considerations. As stated by Swann (1999), asset and resource management have always been a problem.

Due to the nature and intensity of the activities occurring on many military training areas, management of those lands can be a complex problem. The scale of the problem is enormous. The number of buildings, the length of roads, complexity of infrastructure, and area of land involved are similar to that of a large local government user. With assets and resources for action and usage being often dispersed nationally and internationally, effective management is problematic (Swann, 1999).

In this study, the Fort McCoy military installation was analyzed using imagery spanning 18 years to identify land use change in the following classes: (a) complexes, (b) blacktop, (c) agricultural/green space, and (d) forested lands. The maximum likelihood classification tool and imagery interpretation was used to explore imagery to evaluate land use changes amongst the 2004 and 2018 years to explore changes in land use. Time periods selected were based on availability of finer resolution imagery, time periods of global military needs, and resource constraints.

Methods

Study Area

Fort McCoy is a United States Army installation on 60,000 acres between Sparta and Tomah, Wisconsin, in Monroe County (Figure 1).

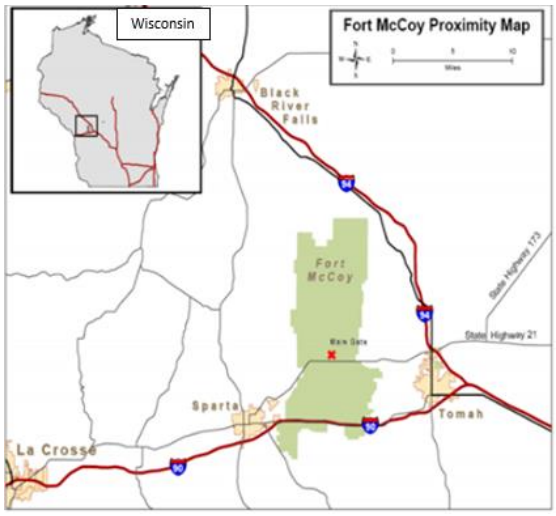

Figure 1. Fort McCoy study area located in west-central Wisconsin. Proximity of next major towns: 9 miles east of Sparta, WI, 12 miles west of Tomah, WI, 28 miles south of Black River Falls, WI.

Fort McCoy is located in Monroe County between the cities of Sparta and Tomah and roughly 30 miles east of La Crosse in west-central Wisconsin. The installation is

divided by State Highway 21. Since its creation in 1909, the post has been used primarily as a military training center (Figure 2).

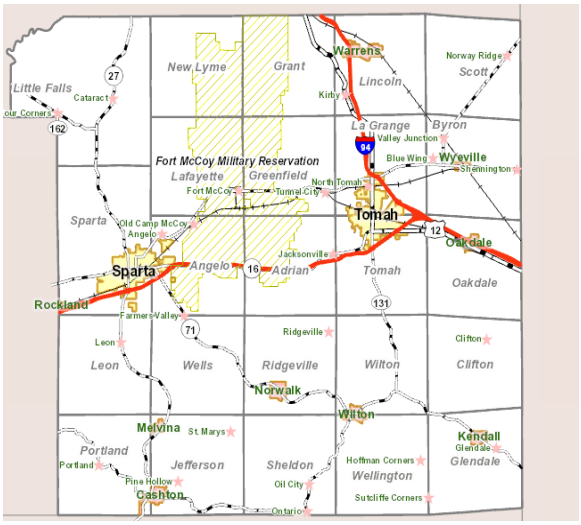

Figure 2. Fort McCoy military installation located in Monroe County, WI. The installation, which occupies a land area of approximately 60,000 acres, is divided by State Highway 21.

From 1990 to the present day, new construction projects have served to modernize the post's infrastructure, facilities, and training areas. The installation has provided support and facilities for the training of more than 100,000 personnel annually since 1984. Today, the post provides full-scale support to its customers at each juncture of its training triad — transient, institutional, and exercise (The Real McCoy, 2019).

Most of Fort McCoy's 1,000 buildings with 5 million square feet of area are within the triangular shaped Cantonment Area that covers approximately 2,600 acres. The Cantonment Area is surrounded by approximately 114,000 acres of maneuver area, 7,600 acres of impact area, 1,400 acres of ranges, and 640 acres in airfield of land owned by the government.

Work Flow

The analysis entailed a variety of processes from initiation to completion. According to Bangerte (2017), logical data flows focus on what happens in a particular information flow and what general processes occurred.

General work flow processes involved in analysis included data collection, data preparation, classification system establishment, classification tool identification, training sample creation, raster output analysis, raster to GRID conversions, class acreage change analysis, results, and discussion as to explanations for land cover changes (Appendix A.) ArcMap was used for classifications, conversions, and overall analysis of land cover changes.

Data Collection

Imagery Acquisition

Imagery for this study came from a variety of sources and was evaluated for image resolution and suitability for image classification. The Fort McCoy Public Affairs and Geographic Information Systems/Integrated Training Area Management office were contacted in attempts to obtain installation GIS and imagery/vector data. All installation procured data is treated as FOUO (For Official Use Only) and thus unavailable for general public distribution without the proper declassification. Consequently, ample public imagery sources were available and subsequently used for input data for the study.

Publicly available imagery included aerial imagery from the National Agriculture Imagery Program (NAIP) within the United States Department of Agriculture (USDA), U.S Geological

Survey (USGS) EarthExplorer, and the Monroe County Land Information Office (GIS Office).

Imagery downloaded came in digital ortho quarter tiles (DOQQs) or compressed county mosaics (CCM). Imagery came in either .tiff or .sid files depending on the downloading source.

Imagery resolution was evaluated to determine which imagery would produce the most accurate results. Monroe County and some NAIP imagery resulted in a two-meter resolution in comparison to the USGS collected imagery (below) consisting of one-meter resolution.

DOQQ imagery from USGS EarthExplorer was selected for analysis due to it being a more precise image for the study area with a better resolution amongst all three potential data sources evaluated.

Data Preparation

Satellite imagery gathered of the Fort McCoy (Figure 3) area included years 2004 and 2018.

Figure 3. Ft. McCoy area of interest/study area. Fort McCoy serves as a Total Force Training Center that supports the year-round training of Reserve, National Guard and active component U.S. military personnel from all branches of the armed services (Real McCoy, 2019).

Preparing, exploring, and later grouping the images into one image (mosaic) was an essential step to start the study in order to successfully run classification tools.

Imagery had to be mosaiced for the study area before classification tools could be run successfully (Figures 4 and 5). A mosaic is a combination or merge of two or more images. Mosaicking the imagery made the process streamlined only using one image as the raster input and made a variety of clustered images into a standardized image set for each year, creating an easier method of visualizing the study area as one image instead of multiple images.

Input imagery data sources were mosaiced together using ESRI's ArcGIS raster dataset tools. The Mosaic tool merges multiple existing raster datasets into a single existing raster dataset.

Figure 4. 2018 USGS imagery mosaic used for the study area.

Figure 5. 2004 USGS imagery mosaic used for study area.

Classification System

Military land often serve a variety of additional uses such as: timber production, agriculture, livestock grazing, off-road vehicle recreation, and hunting. In light of the potential cumulative effects of larger-scale and more intense military training, coupled with other uses, the military community has become increasingly aware of the need to maintain or improve the condition of its lands (Warren and Bagley, 1992).

The Land Condition Trend Analysis (LCTA) program is the Army's standard for land inventory and monitoring, employing standardized methods of natural resources, data collection, analyses, and reporting designed to meet multiple goals and objectives within owned lands (Anderson, Guertin, and Price, 1996).

Standard LCTA methodology was used in combination with the Anderson classification system (Anderson, Hardy, Roach, and Witmer, 1976) to create the following classes (a) Complexes, (b) Blacktop, (c) Agricultural/Green Space, and (d) Forested Lands (Table 1).

Maximum Likelihood Classification

Maximum likelihood classifier (MLC) is the most widely adopted parametric classification algorithm (Manandhar, 2009). An MLC was chosen due to errors in object classification within unsupervised classification. Rozenstein and Karnieli (2011) state training maximum likelihood classifiers are more properly applied to an area for which one is more familiar with, and as such, creating classifiers with knowledge of the area provided rationale in utilizing MLC for this study.

Table 1. Image class descriptions.

Class	Description
Forested Lands	Areas characterized by tree cover. Includes areas with deciduous, evergreen, and/or mixed forest types.
Complexes	A group of similar buildings or facilities i.e barracks, training facilities, administrative buildings, etc.
Agricultural/ Green Space	Areas characterized by vegetation managed for production of food, feed, or fiber. Includes pasture, hay, row crops, small grains, fallow, open fields and recreational land.
Blacktop	Areas characterized by a constructed material including low/high density land surfaces such as roads and parking lots that repel rainwater and do not permit it to soak into the ground (i.e roads, parking lots, highways, gravel lots).

Training Samples

Maximum image classifications require training classifiers to assign pixels or objects to a given class using training samples. Representative training samples for all land cover types (classes) identified in the image had to be attained before conducting land change assessments.

Histogram analysis was used for training sample grouping (Figure 6 and Figure 7). Due to the histograms following a normal distribution, having similar peaks, and overlaps between samples created, they were merged into their respective identified classes and used to create separate signature files for each year of imagery. Training samples that had close peaks and overlap between identified samples were merged and saved as a

signature file and used as input for the maximum likelihood tool for classification output.

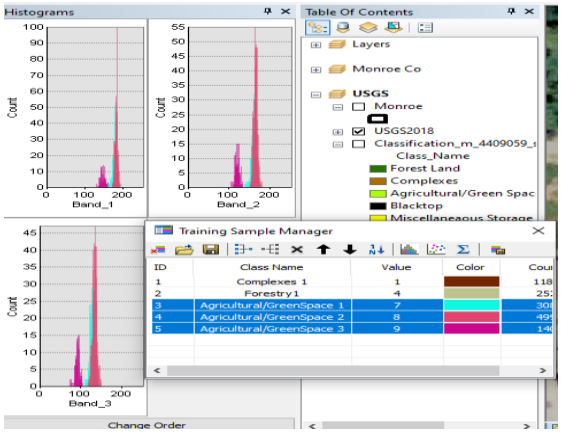

Figure 6. Agriculture class histogram example merged into one class due to overlap training samples.

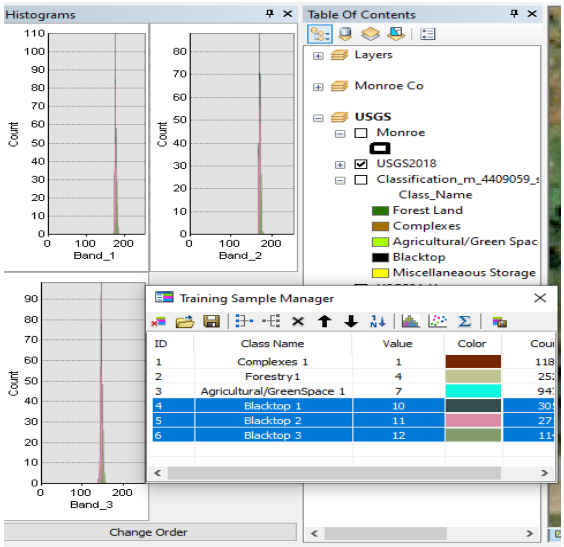

Figure 7. Blacktop training sample histogram class analysis.

Analysis

Maximum likelihood classifications were conducted for each respective mosaic image of the study area. Classification area was defined by creating a polygon around the area of interest defined by what is called the Cantonment Area (Figure 8).

A polygon was drawn encompassing the study area of the Cantonment Area for land cover analysis characterized by zones of development within the general triangular base structure. The polygon was used as the processing extent dimensions for the classification tool in raster outputs, but does not encompass the maneuver, impact, ranges, and airfield areas.

Figure 8. Polygon used as the processing extent for classification tool.

A maximum likelihood classification was conducted on the raster bands and produced a classified raster output clipped to the study area polygon encompassing approximately 1,987 acres. (Figure 9).

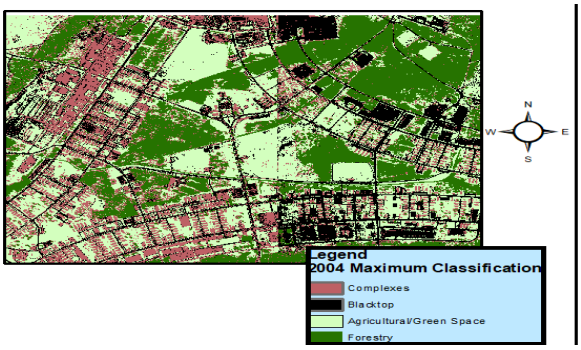

Figure 9. Raster output for the 2004 study area consisting of approximately 1,987 acres. Maroon = complexes, black= blacktop, light green= agricultural/green space, dark green= forestry.

While the classification process utilized the study area polygon, the output extend for a raster is defined by the

rectangular extent of the polygon as shown in Figure 9. The final analyzed area contains land fully operated by the Fort. The size of the maximum likelihood classification results is approximately 4% of all the total land contained within the Fort McCoy property.

Landcover area changes were evaluated by determining changes in area between both images of 2004 and 2018 after classifications were calculated.

Calculating Areas

Maximum likelihood outputs were converted to integer grid formats to be able to determine area changes in square meters for each land class (Figure 10).

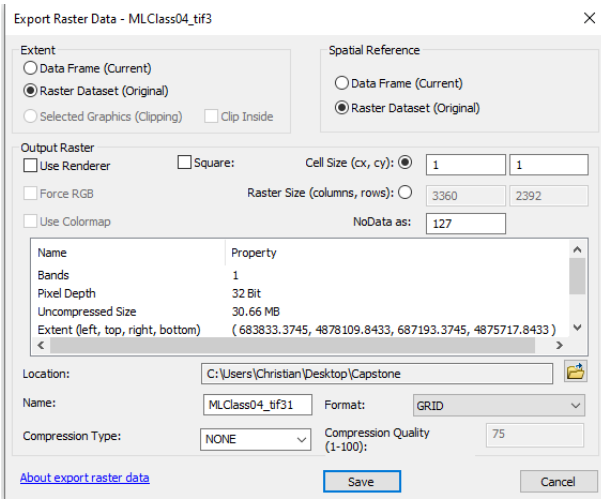

Figure 10. Export raster to GRID integer format data export process.

Changes in land area were evaluated for 2004 and 2018. Using the count field in the value attribute table for each raster dataset, area totals in square meters were calculated for each land use category and subsequently converted into acres as land parcels typically use acres for defining parcel size and ownership.

Calculating class conversions between the years was conducted through converting raster data to features. Each raster was converted using the Raster to Polygon tool. Amount of change between each land cover classification was calculated by using the Union tool and Dissolve tool. The Union tool was run to create overlapping features from both polygon feature datasets and the Dissolve tool was run to merge like attributes using the class attribute for both years.

Results

Land Cover Change Analysis

The acreage for each land cover class was calculated for all four categories along with percentage of change from 2004 to 2018 in an area of approximately 1,987 acres (Table 2).

Table 2. The amount, in acres, of each land cover classification and percent change between 2004 and 2018.

Class	2004 Acreage	2018 Acreage	Percent Change
Forested Lands	572.51	421.31	-26.41%
Complexes	353.91	282.75	-20.10%
Agricultural/Green Space	656.23	756.83	15.33%
Blacktop	403.38	524.77	30.09%

All classes saw change over the 14-year span. From 2004 to 2018, blacktop realized the greatest increase of 30%. Agricultural/green space lands increased by 15%, complexes saw a decrease of land by 20%, and forested lands saw a decrease of land by 26%. Differences in land cover classes are reflected in Appendix B and Appendix C.

In 2018, the majority of land cover from 2004 were forested lands losing about 39% to agricultural/green space; complexes losing 38% to blacktop, agricultural/green space losing 16% to blacktop, and blacktop losing about 17% respectively. Table 3 represents class changes between 2004 and 2018.

Table 3. The comparison of land cover classification changes, in acres lost, between unique classes between 2004-2018.

2004 Class	2018 Class	Acreage Lost
Agricultural/Green Space	Blacktop	110
	Complexes	86
	Forested Lands	70
Blacktop	Agricultural	70
	Complexes	62
	Forested Lands	18
Complexes	Agricultural	72
	Blacktop	138
	Forested Lands	52
Forested Lands	Agricultural	226
	Blacktop	24
	Complexes	43

Accuracy Assessment

The classification process was straightforward; however, the result can be incorrect if training samples were not well chosen. New signature files were created for each year set but errors could have still taken place. Image resolution in earlier time periods and interpretation of the area, can be subjective and also could have added to the potential inaccuracy of the study.

Image resolution in between time periods differed with images used. The tiling format of the 2018 NAIP imagery was based on a 3.75' x 3.75' quarter quadrangle with a 300-pixel buffer on all four sides using 4 band colors and 32-bit pixels and a .6 x .6 cell size as compared to the 2004 NAIP imagery based on a 3.75' x 3.75' quarter quadrangle with a 360 meter buffer on all four sides using only 3 band colors with 24 bit pixels and 1 x 1 cell size.

The limited number of identified classes in this study did seem to cause some issues but not impact classification categories in repeated attempts to refine classes. Reject fraction for both classifications were set at 0.0 which means that every cell was classified into the assigned four categories.

Discussion

The study showed an increase and decrease in land cover classes occurred over the study period. The greatest increase was 30% (blacktop), and greatest decrease being forested lands by 26%. This analysis did have some challenges and limitations, and due to the probability of error, the findings should be used as a generalization of the growing and changing area as well as the general trend of each of the classes appearing to be fluctuating on Fort McCoy. While four classes were chosen in the study area, it is possible a more detailed approach could have examined further, refined classes. For instance, a more representative sample for general study areas as stated by the Mississippi River Regional Planning Commission (2013) should successfully include 15+ classes (Appendix D). As a result, having a limited number of classifications does not fully incorporate all land uses in the area.

According to the Fort McCoy Natural Resources Conservation Team an analysis of internal mission encroachments was done to increase the amount of maneuver acreage on Fort McCoy. This effort resulted in an additional 1,203 acres by reducing the wetland buffer zone from 50 to 25 meters, and additional 23,910 acres by reducing indirect live fire restrictions on certain firing areas, adding 8,911 acres by reducing smoke and obscurant buffer zones, and an additional 538 acres through the removal of airfield restrictions. As a result of this partnership, the installation reduced the environmental and safety restrictions on 34,562 acres without adding additional risk to the environment, personnel, property or training, while maintaining compliance with state and federal laws.

This could be evident to the results

produced in the reduction of forested lands and complexes to be able to create more movement space. Agricultural/green space increased by 15% and according to Monroe Country, agricultural/green space and forested lands are increasingly being sold to owners who do not use the land for farming or for forestry, but instead use it for residential construction. This has caused an increase in concern about development pressure of Fort McCoy according to the Army Public Health Center (2016).

Both Fort McCoy and the surrounding communities have grown in the past decade. The towns surrounding Fort McCoy are dominated by its' presence, since Fort McCoy takes up very significant portions of their land area. In the Town of Grant, for example, Fort McCoy covers 11,195.63 acres, 48.20% of the town's territory. In the Town of New Lyme, Fort McCoy covers 38.6% of the town's territory, and in the Town of Lafayette, it covers 52.03%.

According to the Army Public Health Center (2016), Monroe County has experienced steady growth from 2000-2010 at over 9 percent. The Wisconsin state average during this same time was 6 percent.

The land cover changes occurring on Fort McCoy appear to be influenced by the local economies, ever-changing department of defense needs, and the response to new emerging global defense threats. Since the beginning of the wars in Iraq and Afghanistan, Fort McCoy has realized increases in troops and training areas. In recent years, troops have been mobilized throughout the world and individual soldiers are spending more time training at military facilities.

As stated by the Mississippi River Regional Planning Commission (2013), Fort McCoy has grown and adapted to changing military requirements for decades seeing increases – doubling and tripling in some categories – in personnel, expenditures, and activities; Fort McCoy is the largest employer in Monroe County and has an enormous impact on the local economy (Fort McCoy accounted for an estimated $1.31 billion in economic activity in fiscal year 2011).

In 2004, Fort McCoy employed over 3,200 personnel, and that number grew to 3,971 in 2011 and continues to increase. As stated by the Mississippi River Regional Planning Commission (2013), during this same period the total expenditures at Fort McCoy increased from $266.5 million to $409.6 million, and the estimated economic impact of Fort McCoy on the local economy increased from $613.0 million to $1.31 billion.

Fort McCoy contributes to the strength of its held area through its economic importance. Federal investment provides a level of stability against economic hard times in small, rural communities.

Conclusions

Land cover changes are continually occurring due to a variety of reasons including land purchases, eminent domain, new zoning, and joint planning efforts the study area and the land surrounding it can be can be expected to follow the general flux of this trend as more land is acquisitioned, expanded upon, and developed as the trends seems to suggest.

Historically, large military installations represent high economic multiplier effects in the local economy. According to the Mississippi River Regional Planning Commission (2013), the estimated economic impact of Fort McCoy on the local economy in FY 2011 was $1.31 billion; in FY 2002, it was

$357.8 million, which is 27.0% of the 2011 number (Appendix E). Appendix E from the Mississippi River Regional Planning Commission (2013) shows the economic impact from 2001-2010 that Fort McCoy has on the local communities.

According to Department of Defense Instruction 3030.03, it is DoD policy to work toward achieving compatibility between military installations and neighboring civilian communities by a joint compatible land use planning and control process conducted by the local community in cooperation with the local military installation.

The expansion and significant land cover increases can be attributed to the continued growth of the local community, the symbiotic relationship between Fort McCoy and local communities, and the ever changing economic and global environment.

Acknowledgements

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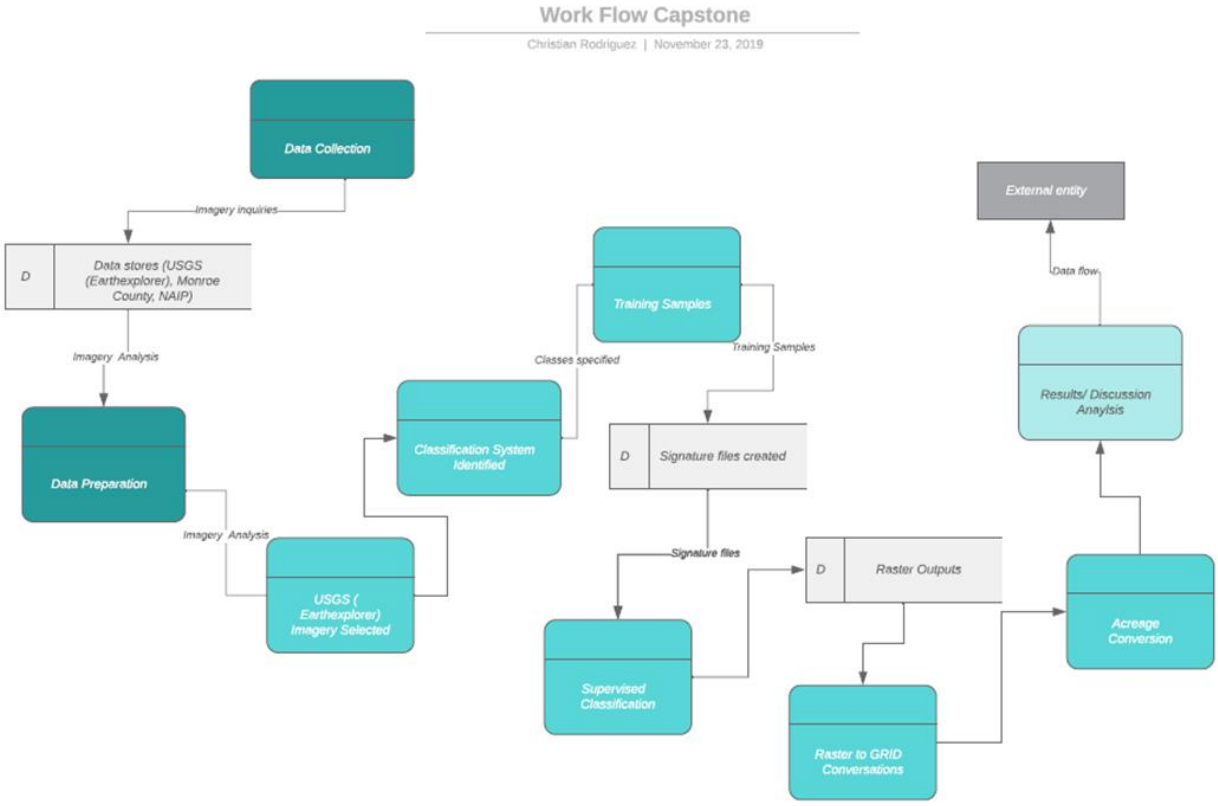
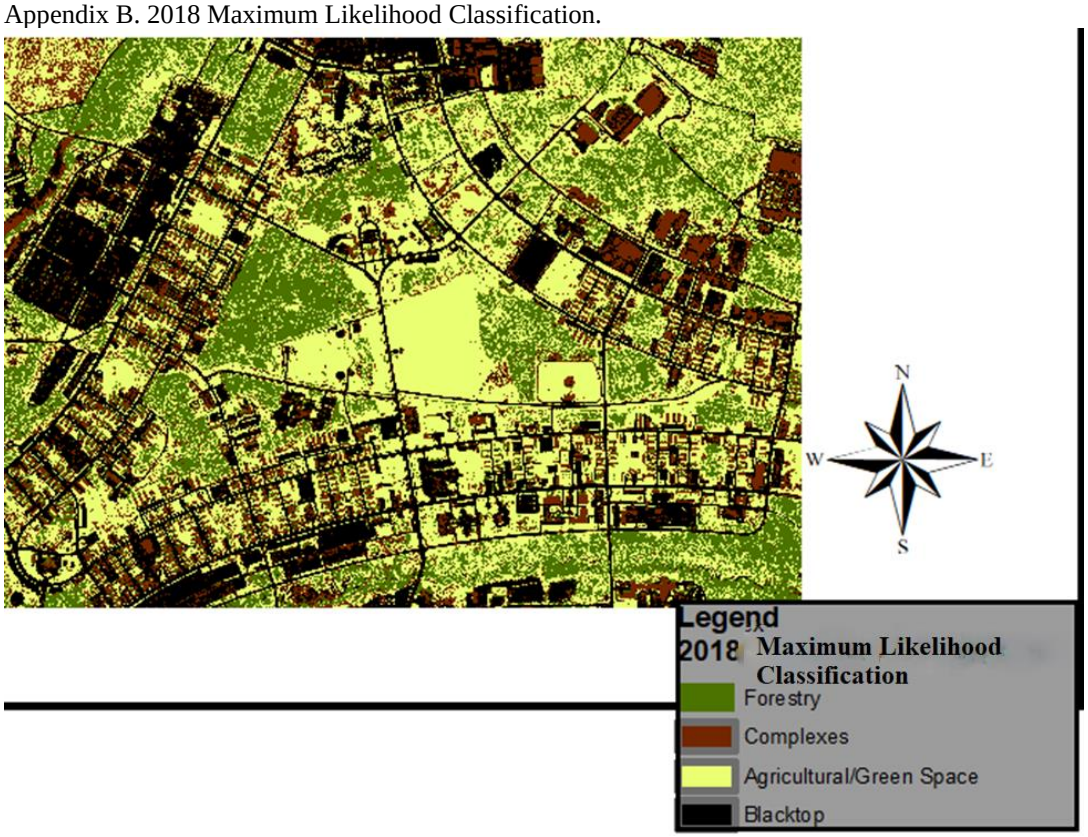
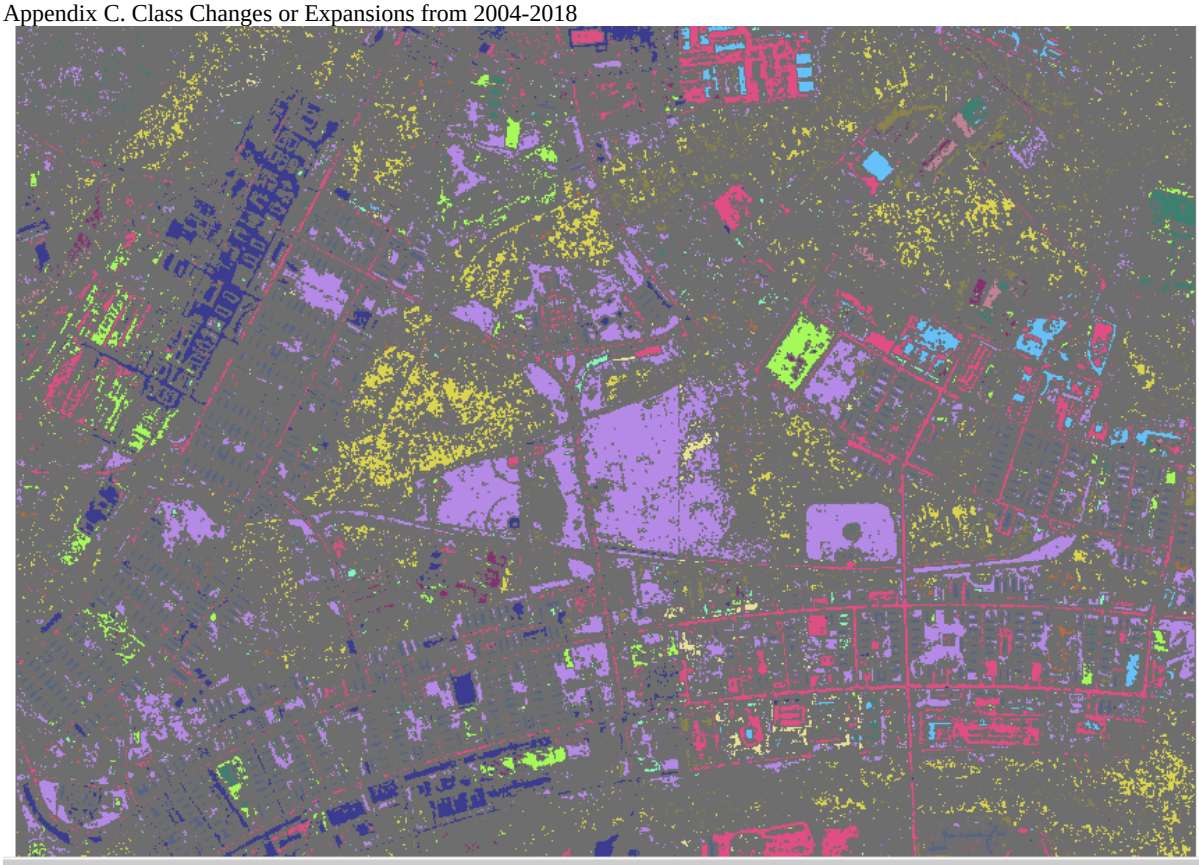
Appendix A. Work Flow Chart.



Appendix B. 2018 Maximum Likelihood Classification.



Appendix C. Class Changes or Expansions from 2004-2018



Appendix D. Mississippi River Regional Planning Commission Classification Classes.

Monroe County Existing Land Use

Land Use	Acres Within 3 Miles	Acres Within 5 Miles
Agriculture/Open Space	39,595	76,660
Commercial	855	1,652
County	549	2,595
County Forest Crop	3,325	3,472
Cranberry	471	563
Federal	59,701	59,716
Forested	47,450	69,943
Manufacturing	241	471
Open Water	514	983
Residential	3,793	7,952
State	2,077	2,972
Wetlands	1,572	4,009

Source: Monroe County Land Information Office

Jackson County Existing Land Use

Land Use	Acres Within 3 Miles	Acres Within 5 Miles
Agriculture	34	1,333
Commercial	33	33
Cranberry Marsh	211	230
Farmstead	6	39
Forest Agriculture	1,227	2,691
Open Space/Pasture	1,871	4,674
Parks and Recreation	35	35
Platted Lands	69	136
Public/Institutional	3	6
Residential	240	536
Transportation	300	635
Utilities	1	1
Wooded Lands	11,060	29,531
Water	154	316

Source: Jackson County Land Information Office

Appendix E. Mississippi River Regional Planning Commission Fort McCoy Economic Impact 2001-2010.

Fort McCoy's Economic Impact

Fort McCoy Employment/Economic Impact Comparison - Fiscal Year 2001-2010 *(The Government's fiscal year runs from Oct. 1 – 30 Sept.)*

	2001	2002	2003*	2004*	2005*	2006*	2007*	2008*	2009*	2010*	2011
Employees	2,245	2,260	3,283	3,129	3,050	3,410	3,278	4,190	4,303	4,014	3,971
Civilian	1,615	1,620	1,657	1,415	1,350	1,460	1,524	1,604	1,687	1,732	1,443
Contract	265	398	624	869	1,100	1,400	1,251	1,464	1,366	1,200	1,261
Military	365	242	1,002	845	600	550	503	1,122	1,250	1,082	1,267
Payroll	$68,380,523	$78,024,615	$92,722,101	$78,159,343	$81,798,227	$88,630,445	$89,076,283	$159,376,739	$188,963,432	$194,886,413	$197,444,098
Civilian	$54,551,399	$61,987,630	$59,919,183	$45,824,447	$54,854,929	$63,981,180	$65,552,080	$ 69,500,651	$ 85,211,520	$96,842,207	$97,636,160
Military	$13,829,124	$16,036,985	$32,802,918	$32,334,896	$26,943.298	$24,649,265	$23,524,203	$ 89,876,088	$103,751,912	$98,044,206	$99,807,938
Total Expenditures	$145.3 M	$155.5 M	$266.5 M	$243.6 M	$231.0 M	$280.4 M	$299.2 M	$ 352.3 M	$ 442.4 M	$429.6 M	$409.6M
Economic Impact (The area Gross Multiplier Index increased from 2.3 to 3.2 in FY 04)	$334.1 M	$357.8 M	$613.0 M	$779.4 M	$739.3 M	$897.3 M	$957.4	$1.127 B	$1.416 B	$1.375 B	$1.31B
Number of Personnel Supported for Training	145,437	138,203	130,950	127,608	102,191	107,668	112,703	127,919	105,736	111,348	134,645
New Construction FY 1990-2011											$285.4M