Quantifying seventy years of landuse change in the Winooski River Basin, northern Vermont

Formatted for:
Journal of Environmental Management

Draft- 2/5/09

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Abstract

We use random sampling and manual, point-based classification of aerial imagery to quantify land use change over the past seventy years in the 2,704 km^2 Winooski River Basin of northern Vermont. Thirty sets of aerial photographs taken at intervals of 12 to 29 years between 1937 and 2004 demonstrate that cultivated land has decreased by 23%, forested land has increased by 22%, and impervious surfaces have increased by 2%. These trends are consistent with the landuse history of New England, showing widespread reforestation as marginal agricultural land has been abandoned over the past century. We found that forested sites are more common in the upland parts of the basin; sites with more impervious area are more common in the lowlands and nearer to the interstate highways. Using a variety of tests, we validate this straightforward technique for determining landuse change over time and demonstrate its feasibility for analysis of aerial imagery elsewhere.

Keywods: Landcover, impervious, runoff, landuse analysis, aerial photograph

1.0 Introduction

Landscapes are dynamic, the result of both natural processes and human activity. Over only a human lifetime, significant changes in landuse occur including the reversion of farmland to forest and increases in developed areas (Wessels, 1997 and Albers, 2000). Quantifying landuse change is important for addressing many hydrologic questions integral to the way society approaches construction of infrastructure and development (Milly; et. al, 2008, Foley et al., 2005). For example, the runoff yields from impervious surfaces far exceed those of forests and have implications for water quality and storm water management (Forman, 1998). Understanding the history of landuse at a site can help explain both current and past problems, such as erosion and flooding, and provide guidance for the design of future infrastructure.

While the importance of these landuse changes is clear, quantification of landuse change over time is not as straightforward (Heckendorf, 1998, Verburg, 2009, Thornton, 2007). In many parts of the United States, federal, state and local governments contracted for aerial photography over regular time intervals starting in the late 1930s; these images are publically available in many regions (Neigh, 2008). Although the images are available, quantifying landuse change using unrectified, predominately monochromatic images of varying quality is uncertain REF. A common approach to landuse quantification using aerial photos involves digitization of the entire photograph, thus separating the image into polygons representing different landuse types (Mapedza, 2003). Polygons can be defined manually, a time consuming process, or through a number of developed automated techniques (Verburg, 2009, Neigh, 2008) which are of uncertain reliability when older or poorer quality aerial photographs are used REF.

Here, we demonstrate a widely applicable approach for quantifying land-use change over time using random point sampling and manual landuse classification. Using older, monochromatic imagery of variable quality, we demonstrate that this technique is both practical and accurate. Applying the point counting approach to the Winooski River Basin of northern Vermont, we show how the abandonment of farmland, the coming of the Interstate Highway, and subsequent suburbanization have all changed land-use patterns over the past 70 years.

2.0 Study Area

Until recently, Vermont's geology, topography, and varied landscapes strongly controlled the pattern human landuse (Jennison, 1989). Northern Vermont's landscape is dominated by the rugged Green Mountains, which consist of hard metamorphic rock and rise to elevations over 1400 m and form the headwaters of the 2,704 km^2 Winooski River Basin (USGS NWIS, 2008). The adjacent Champlain Valley to the west consists of sedimentary rocks and has a more subdued topography and richer, more productive farmlands (Doolan, 1996; Mehrtens, 2001). Glaciers covered the Green Mountains during the last glaciation and left behind substantial quantities of sediment in the form of stony, impermeable glacial till in the mountains, well drained sand and gravel along some valley walls, dense clay in many valley bottoms, and permeable, fertile alluvium near river channels (Doll, 1970). There is generally more exposed rock and less soil at higher elevations (Wessels, 1997; Doll, 1970).

The New England landscape has been used by humans since shortly after the glaciers receded; thus, an understanding of this history is important when considering recent landuse practices. Before European settlers arrived in North America, Native American society made use of the resources of the New England landscape(REF). Forests during this time were kept open, primarily by the collection of wood and underbrush to fuel heating and cooking fires REF, and some land clearing was done using fire (Pyne, 1982). By the late 1600's, much of northeastern North America was colonized. Expansion of settlement into Vermont was limited until the defeat of the Native Americans during the French and Indian War, which led to the "great swarming time" in the early 1700's when settlers rapidly moved across New England in the wake of newfound safety REF. During the 1700s, settlers logged land for building purposes, later burning brush and stumps for agriculture REF. This self-sufficient homestead period was successful for New England's new residents; by 1790 all of the official New England towns in existence today were already established (Wessels, 1997).

As agriculture changed over time, so did the human footprint on the landscape. "Sheep Fever" took hold in 1810 when about 4,000 sheep were imported into Vermont in the wake of new tariffs on wool to encourage domestic production (Wessels, 1997; Albers, 2000). This agricultural movement was so popular that by 1840 the initial population of 4,000 sheep had expanded to 1.7 million REF. This thirty year period of intensive agricultural growth necessitated rapid clearing of the land; 75% of the New England landscape was cleared during this time REF. This substantial clearing of the landscape for agriculture by the mid 1800's set the stage for future Vermont agriculture, development, and this study (Jennison, 1989). As economic factors changed, many marginal upland farms were abandoned, which led to reforestation. By 1850 50% of the farmers in Vermont had moved west (Eschele, 1975; Wessels, 1997). Farmers who stayed ran lowland dairy farms in the river valleys, which were dominated by richer alluvial soils that could better sustain agricultural use (REF).

3.0 Methods

We analyzed aerial photographs at thirty locations within the Winooski River Basin to derive land use changes over the past seventy years (Figure 1). These thirty sample locations were generated using the "random point generation" tool in the Hawth's Tools toolbar in ARC GIS. At each location, a 3 km X 3 km quadrat was established. Because land-use data are typically normally distributed REF, a sample size of thirty quadrats was used to represent the basin as a whole (Janke and Tinsley, 2005). For further analysis, we also divided the basin into two elevation classes around the mean basin elevation, *uplands* and *lowlands*, which allowed us to examine the trends at sites within each category.

The thirty quadrats are representative of the basin as a whole in terms of elevation; the mean elevation of the basin as well as the distribution of elevations closely matches those of the sampled quadrats (Figure 2). Within each quadrat, we established 300 random sampling points with a forced minimum distance of 50 meters between each; these 300 points were generated using the same random point generator used to select the quadrats (Figure 4). Three hundred sample points was chosen as a sample size based on accepted approaches in other point counting-based research, such as pollen-analysis (Velez et al., 2008; Lupo et al., 2006; Liu et al., 2007).

For each quadrat, we acquired digital aerial imagery or hard copy aerial photos from the University of Vermont Map Library and Williston, VT Natural Resource Conservation Service (NRCS) Image Library (TABLE 1). The earliest imagery is from 1937; but is not available for every site, so is supplemented with 1942 imagery for remaining sites. Hard copy photographs from 1937 or 1942, 1962, and 1974, were acquired for all quadrats, as well as digital 2003 digital imagery. Hard copy photos were scanned and georeferenced in ARC GIS to correct distortion, applying specific coordinates to the standard image format. We georeferenced each image by selecting points on the photograph that are still identifiable today, such as road intersections, bridges, and buildings. By linking these common points on the scanned imagery with previously rectified 2003 imagery, each older, scanned image was transformed to match the control points. The transformation of each image in this study was based on a minimum of ten control points (except for totally forested sites) and used a second order transformation to achieve an average RMS error of ten pixels or less. Forested sites were georeferenced using hydrologic and topographic features as control points. This is a less accurate approach, but at these sites near total forest cover at all time steps makes geo-referencing accuracy less important.

For each of the 300 random sample points within each 9 km^2 quadrat, landuse was classified into one of four categories using the aerial photographs (Figure 3). "Actively cultivated/ vegetation repressed" land consists of lawns, agricultural fields, grazed pastures, or any environment where tree growth is prevented. "Forested" defines any area where unrestricted tree growth is taking place. This includes forests, hedgerows, or abandoned farm fields at the point where succesional brush and shrub growth becomes visible on the aerial imagery. "Impermeable" describes roads, parking lots, buildings, or any other impermeable surface. Lastly, water describes any body of water. Using these definitions, we categorized all points in each quadrat, generating data for the sampled subpopulation (n=30, 270 km^2); we then extrapolated our findings across the 2,704 km^2basin.

4.0 Data and Results

Analysis of thirty randomly distributed sites across the Winooski River Basin revealed a changing landuse over time with a basin- wide increase in urbanization and forested land and a decrease in agricultural area. In 1937, the basin averaged 32% agricultural /repressed land, 7% impervious land, and 60% forested land. From 1937- 1962, average agricultural/repressed land dropped drastically to 15.8% while forest rose to 78.2% and impervious land dropped to 5.3%.

This 25 year period marked the period of most change in the basin, with slower changes to all categories of landuse between 1962 and 2003. During this time- though the pace had lessened- cultivated land continued to decrease while reforestation took its place with some additional increases in development. By 2003 this average had shifted to 9% agricultural /repressed land, 9% impervious land, and 82% forested land (Figure 4).

The pattern of land use and land use change in the Winooski Basin is not spatially homogeneous. Of the 30 sites, 5 were nearly 100% forested during all time steps and 11 sites contained over 10% impervious area by 2003. Heavily developed and heavily forested sites are clustered. The upland elevations contained all of the five unchanged, mostly forested sites. Uplands tended to be more forested, see more agricultural abandonment, and have less development. Conversely, lowland regions contained all 11 sites that in 2003 had more than 10% impervious surfaces; compared to the upland sites, lowland sites contain more land in active agriculture (Figure 5).

5.0 Precision, accuracy, reproducibility and comparison to other techniques

This is section is still growing pending further work…

We used several approaches to determine the precision, accuracy, and reproducibility of the manual-classification, point-counting technique we used for image analysis.

To test for reproducibility, we analyzed an image twice (the same analyst using the same procedure to categorize the same sample locations); the 21% vs 23% cultivated land, 70% vs 70% forested land, and 7% vs. 6% impermeable surfaces. The consistency between results of these two analyses show that when a single observer uses a set classification system, it is possible to be consistent in results.

To test for bias between different analysts, another individual (analyst 2) was asked to classify the points in the same image after explanation of the classification guidelines. The results, comparing the two analysts, were 31% vs 23% cultivated land, 64% vs 70% forested land, and 4% vs 6% impervious surfaces. It is important to note that the primary differences in these results are the distinction between forest and cultivated/repressed land. This is a result of different perceptions of the transition between field, brush, and trees and emphasizes the importance of consistency in the person making the classifications. For the rest of the study, one analyst (Hackett) did all delineations.

To compare different image analysis techniques, we analyzed one image using a variety of approaches (Table 3). First, we manually digitized the entire 3km X 3km sample site into the four land-use classes. The resulting land use distribution, using manual polygon generation (100% digitization), was very similar to the point-counted results (Table 2).

There are limitations to the precision of our method imposed by the number of observations in each land-use class. Land-use classes that are rare will have fewer counts and thus less precise determinations. (REF).

6.0 Discussion

Analysis of aerial photography demonstrates conclusively that the landscape of northern Vermont has changed significantly over the past 70 years with forests replacing farmland. Much of the early imagery, that from the 1930's and 1940's, reveals relatively open landscapes with many farms that have either been recently abandoned or are still in operation. At this time step, we find that vegetation is being repressed over more than 30% of the basin's land area; agriculture, in one form or another remains a major landscape use. By 1962, cultivated land represents only 17% of the basin land area, a significant decrease from the 30% it occupied only two decades before. In little more than 20 years, forests had taken back nearly half the cleared land. By 1974, vegetation was being repressed on only 11% of the Winooski River Basin and by 2003, less than 10% of the Winooski river basin was open land kept clear of forests FIGURE XX.

Other work completed in Vermont as well as historical evidence corroborates these results. In addition to farmland abandonment, changing practices in the dairy industry have led to a decrease in the grazing of cows in favor of bringing the food to them (Saterthwaite, 1975). As a result, even active farms have abandoned their pasture land, allowing it to begin succession. Additionally, automated analysis using detection of landuse by pixel identification of 2001 LANDSAT imagery of the Lake Champlain Basin (which includes the Winooski River Basin) indicates that the Winooski River Basin is 8.3% urban surfaces, 15.7% agricultural surfaces, and 75.9% forest (VCGI LANDSAT, 2001, Guer, 2007). These data are similar to our manually classified, point-counted results in terms of impervious surface but differ slightly from our results for cultivated/ repressed (15.7% vs 9%) and forest land data (75.9% vs 80%). Discrepancies in the latter two categories are likely the result of different classification definitions in terms of forest and brush compared to pasture and field.

The pattern and intensity of land-use change is not spatially homogeneous. Differences between upland and lowland sites are consistent basin-wide. All five of the forested sites that changed little between 1937-2003 are located in the upland elevation category. Conversely, in 2003 all of the sites with more than 10% impervious surfaces were located in the lowland elevation category. Trends in land use over time differ between the uplands and the lowlands. Four of the five sites which experienced over 10% net reforestation are in the lowlands (Figure 6). Such lowland reforestation probably reflects the opportunity for cleared land to reforest; most of the upland sites were already forested by 1937. These data support the historical record which suggests that topography plays a strong role in human- landscape interaction and land use (Jennison, 1989). The thinner soils and steeper slopes of the uplands resulted in early abandonment and reforestation there; easy accessibility, gentler topography, and more fertile soils kept farms longer in the lowlands and now facilitate development in the lowlands.

In addition to elevation, proximity to the Interstate Highway is associated with differences in contemporary land use and the intensity of land-use change. Five of the seven analysis sites within 600 meters (the ecological “road effect zone” of Forman, 2000). and eight of the twelve sample sites within 5 km of the Interstate Highway have the greatest site level proportions of impervious surfaces in the Winooski River Basin in 2003. A relatively high percentage of impervious area appears to be related to development, particularly that associated with the construction, catalyzed by the presence of the Interstate Highway (Figure 7). Additionally, of the six sites that experienced a decrease in forested land over the last seventy years, four of them are within 600 meters of Interstate 89, and five of the six are within 5 km. While the location of the highway is elevation controlled (most of Interstate 89 is in the lowlands), there is clearly an additional association with highly developed sites being proximal to the highway.

Our data suggest there are specific trajectories of land-use change. While some sites exhibit simple changes over time such as a consistent increase in forested area and a decrease in cultivated area, other show more complex, yet consistent trajectories. At five out of the thirty sample sites, the data show an initial increase in forested land followed by a decrease between the 1972 and 2003. This trajectory only occurs in the lowlands, and four of the five sites are within 600 meters of the Interstate Highway. Additionally, these four lowland sites are also among those sites which showed the greatest increase in impervious area. Unlike the previous widespread farm abandonment in the late 1800's when abandoned farms were reforested, today many former farms become housing tracts and commercial developments (REF). Another trajectory exhibited at four sites, is an initial decrease in cultivated/cleared area, followed by a later increase (Figure 8). Three of these four sites are in the lowlands and two of the four are within 500 meters of the highway. This trend is probably linked to development which not only adds impervious surfaces but cleared land as well (REF).

Several cultural forces of the last two centuries still drive land use change in the Winooski River basin. Early settlement, transport, and agricultural patterns, largely the result of topography and the location of rich, tillable land, caused much of northern Vermont's population to occupy the lowlands (Satterthwaite, 1975). The shift from sheep to dairy farming in the mid to late 1800s, along with the railroad, river, and road right of ways, all conspired to concentrate people in the lowlands along deep valleys (Eschele, 1976). Simultaneously, the abandonment of cultivated fields and pastures in the uplands in favor of the valleys prompted the start of Vermont's reforestation during the mid 1900's (Wessels, 1997). The construction of the Interstate Highway system along the Winooski River continued this pattern during the 1960s and allowed those with the financial means to live in suburbs as the ease of commuting increased (Alig et al; 2004, Rose, 1979). The trend of development being more common and widespread in the valley sites found in this study supports this history. Along with suburbs has come extended development including large box stores and associated parking areas, focused near highway access points (Wassmer, 2002; Liebs, 1995), Vermont's expression of the sprawling, "galactic city" (Lewis, 1995). Although the population in Vermont decreased for decades following the crash of sheep farming in the mid 1800s, for much of the last century, it has been increasing at first slowly and then much more rapidly (Wessels, 1997; Albers, 2000). Together, these forces have resulted in an increase in impervious surface from the construction of roads, homes, and businesses.

The pattern and tempo of landscape change we quantified are similar to those observed elsewhere in New England, but differ from the national average. We measured an increase in forested area over the past seventy years, with a decrease in crop land and a slight increase in average impervious area. This trend is common to much of New England, which as a whole has been reforestating since the 1950’s and in the early 1990’s was estimated to be 60-85% forested (Foster, 1992), similar to the 80% we measured for the Winooksi Basin in 2003. Urban area across New England has also been on the rise, estimated at about 12% (Alig, 2003), again, a value similar to what we measure 9% for the Winooksi Basin in 2003. However there are departures from the regional average. Maine has been reforesting and is now 90% forested, with only 2.5% urban area (Platinga, 1999). Nationally, land-use is trending the opposite direction. The USDA estimated in 1997 that 11 million acres of forest and cropland- 1 million acres per year of forest- had been lost nationwide since 1992, and the country has been experiencing a net loss of forest land since the 1950’s (Kline et al., 2004). Nationally, landuse was calculated to be 33% forest and 67% nonforest- of which 65.5 million acres (or 2.7%) was classified as urban (Alig, 2003).

There are several important environmental implications of our findings. Reforestation of active agricultural lands, so prevalent in the uplands, is beneficial in several ways. The return of trees reduces sediment yield and nutrient export potentially improving water quality (Forman and Alexander, 1998, Atasoy et al., 2006). Changing vegetation has also caused the hydrology of these areas to change; flood runoff is reduced by increased infiltration and total annual water yield drops as evapotranspiration increases (Juckem et al., 2008, Forman and Alexander, 2008). Additionally, while the increase in impervious area is small on a basin scale, some sites experienced much greater increases in developed area. The implications of impervious areas on the landscape extend beyond hydrology, to specific impacts in terms of pollutants and habitat fragmentation (Forman, 2000). Of global importance, is the increase is the rapid and significant sequestration of carbon in reforesting areas as biomass and soil carbon increase (Harmon, et al., 1990, Keeton, 2007).

It is important to consider the scale at which our data are gathered. Averages presented in this paper reflect 9km^2 areas, which are taken together to derive average landuse for the Winooski River Basin. These data provide an important overview of basin-scale change but underestimate the magnitude of change at smaller scales, particularly those of importance for local hydrologic impacts including flashy run-off from large impermeable areas such as parking lots and the increased interconnectivity of impermeable surfaces. While the data we present are of limited utility at local scales, they clearly indicate basin-wide trends in land use and are consistent with regional data generated by other means.

The method we propose should be widely applicable. Multiple time-steps of aerial photography are widely available as is the capability to georeference them using semi-automated geographic information systems. The manual-classification, point-counting method that we demonstrate in this paper produced data that compare well with those generated by other methods. Data for the Winooski River Basin are consistent with findings elsewhere in New England, again suggesting the method we propose is robust.

There are limitations to any point counting method. Observer bias can be significant but can be overcome by using a single observer and a detailed classification scheme. Classification categories that are found rarely on images with have only small numbers of counts; thus, fractional uncertainties for these categories will be higher than for categories occupying larger portions of the landscape. Uncertainties can be reduced by increasing the number of points counted, but this can be quite time consuming as uncertainty decreases as the square of the number of counts.

6.0 Conclusions

The dynamics of landscape change are complex, dependent on past history, and important for managing the current and future landscapes. We show that the magnitude and trajectory of land use change over time can be quantified using point counting and manual classification of historical aerial photographs. Using a representative random set of 9,000 sample points scattered equally among 30 sample quadrats and analyzed for 4 different time steps representing more than 70 years of change, we show that reforestation dominates the overall history of the Winooski River Basin, Vermont. Considering subpopulations of the sample set shows that landscape history differs between upland and lowland sites and between areas near and far from the Interstate Highway system. The method we present is easily adaptable to other landscape and can, at low cost and with minimal technology, provide a quantitative view of landscape change from which planners, scientists, and historians can all benefit.

7.0 Acknowledgements

Vermont EPSCoR for GRA funding, the UVM Landscape Change Program, Bill Gill and the UVM map room, Dr. Donna Rizzo, Lance Besaw, Matt Jungers, Lee Corbett, Luke Reusser, Jamie Russell, and Carol Cady.

8.0 References

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Figure Captions

Figure 1. The Winooski River Basin with 30 random sample sites overlain on map generated from Vermont Center for Geographic Information. Sample sites are 3km by 3km square and were randomly generated using Hawth’s Tools in Arc GIS 9.3. The basin is divided into uplands and lowlands around the mean elevation of 397.5 m.

Figure 2. Histogram of elevations across the Winooski River Basin as compared to a histogram of elevations off all 30 sample sites. Elevation data derived from USGS National Elevation Dataset 7.5’ VT DEM, scale 1:24,000 provided by Vermont Center for Geographic Information.

Figure 3. A sample 3km by 3km quadrat with 300 randomly generated sample points overlain on top of aerial imagery for site 18. Aerial imagery from Vermont Center for Geographic Information, 2003 NAIP digital aerial imagery

Figure 4. Landuse percentages over time in the Winooski River Basin. Data are the grand mean of 30 sample sites within the basin for each time step .

Figure 5. Landuse percentages over time in the uplands and lowlands of the Winooski River Basin. Histograms are representative of mean landuse in the lowland (A) and upland (B) elevation sample sites at each time step.

Figure 6. Aerial images of site 24, near Jericho, Vermont. A. 1937 Image (image ID: 2-37) shows mostly rural cleared in the center of the image. B. 2003 image shows that much of this cleared land has been abandoned and reforested. The bar graph for this site shows the changing percentage of forested land over time.

Figure 7. Site 20 in Colchester Vermont. A. 1937 image (image ID: 1-23, 1-33) shows an abundance of cleared land with urban area in the lower left of the image. B. the 2003 image,

shows that some cleared land ahs reforested and urban area has increased, spreading upwards through the image. The bar graph for this site shows the changing percentage of impervious surface space over time.

Figure 8. Site 18. A. 1962 image (Image ID:48-110) showing the central Winooski River Basin before construction of Interstate 89. B. 2003 image. The 1962 aerial photograph shows agricultural land as well as reforestation, which was interrupted by the highway and cleared land associated with it.

Table 1. Inventory of aerial photographs used for analysis.

Table 2. Percent landuse over time at 30 sites in the Winooski River Basin.

Table 3. Percent landuse at site 18 in 1962 using replicates of different analysis techniques

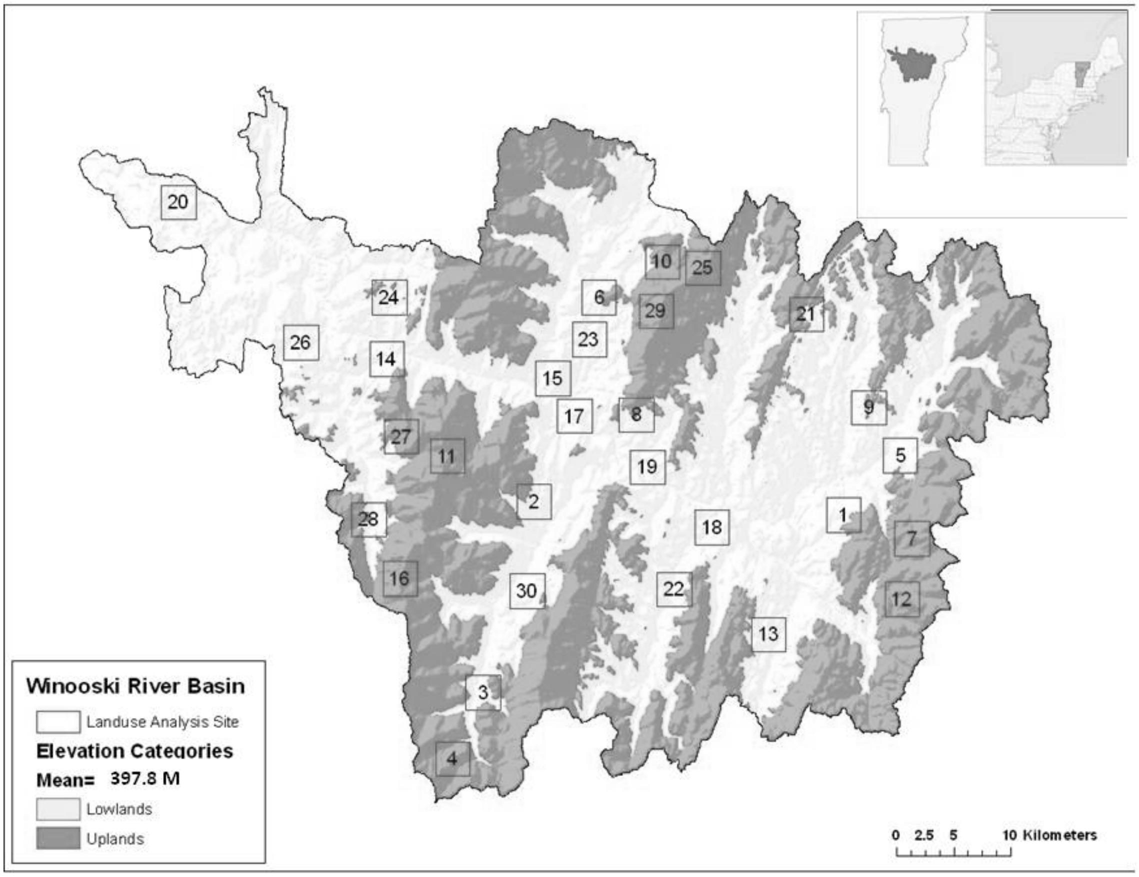


Figure 1.

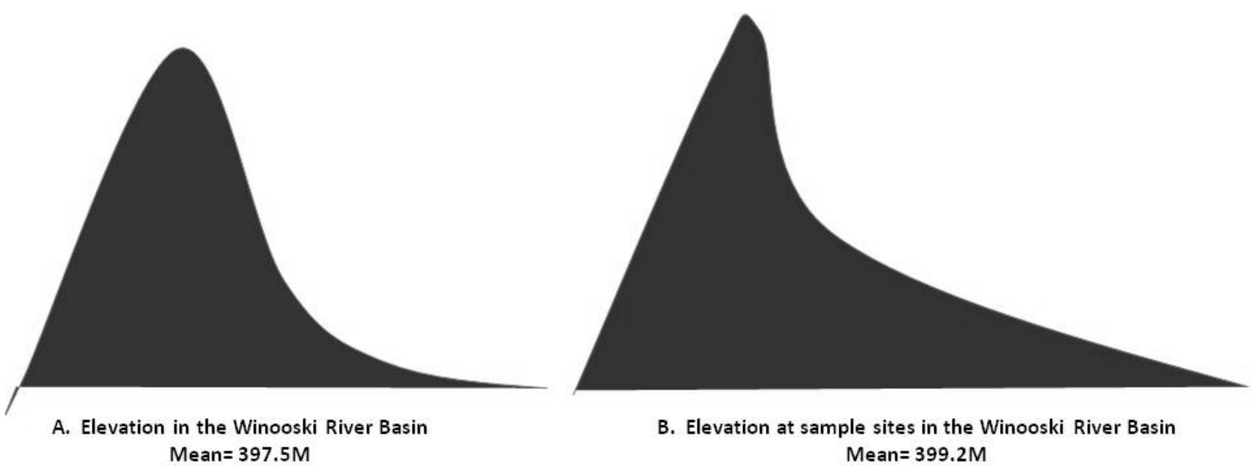


Figure 2.

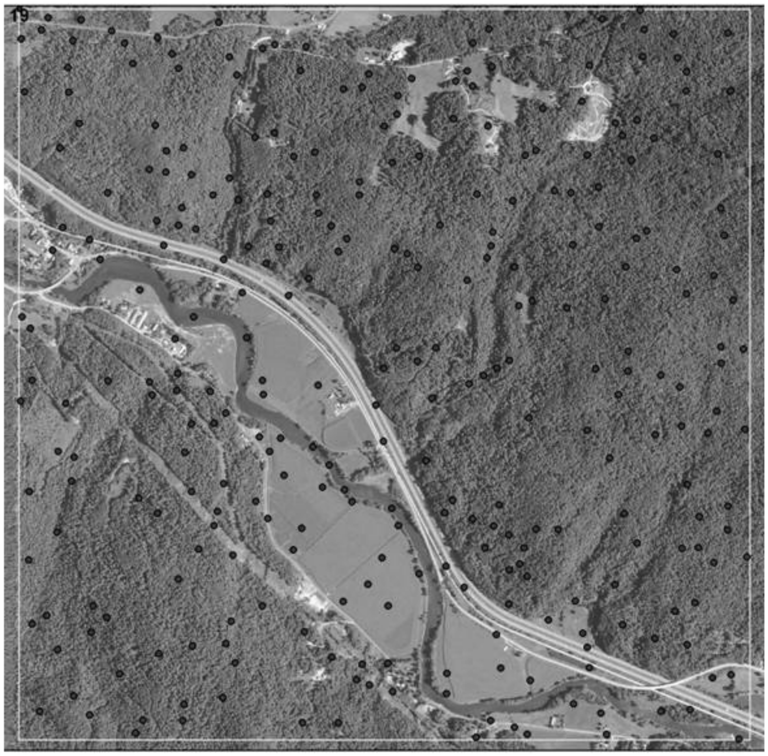


Figure 3.

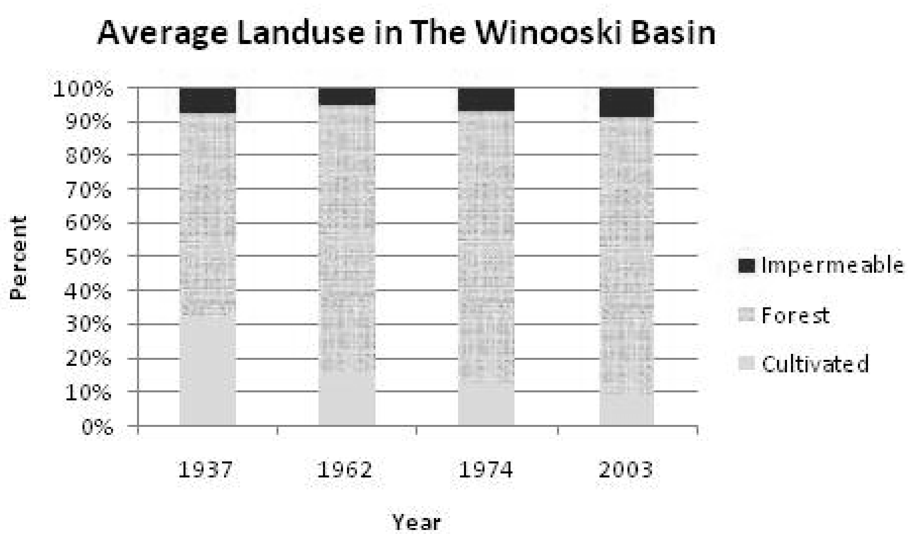
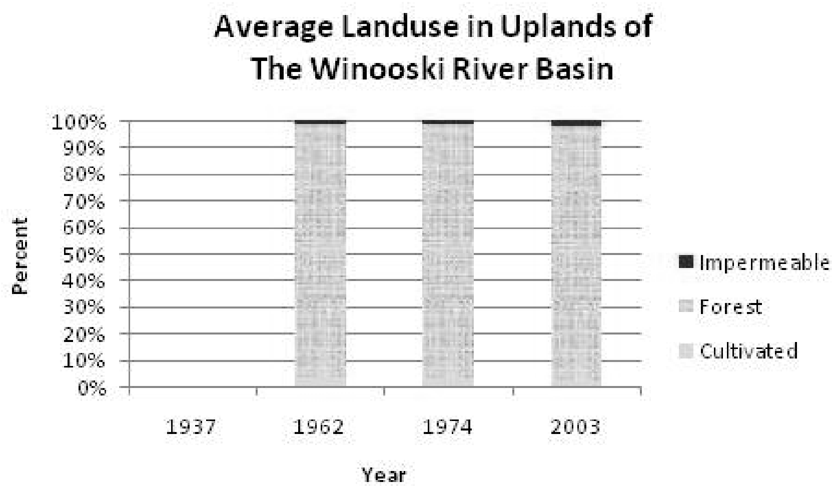


Figure 4.


Average Landuse in Uplands of
The Winooski River Basin
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
1937
1962
1974
2003
Year
Impermeable
Forest
Cultivated

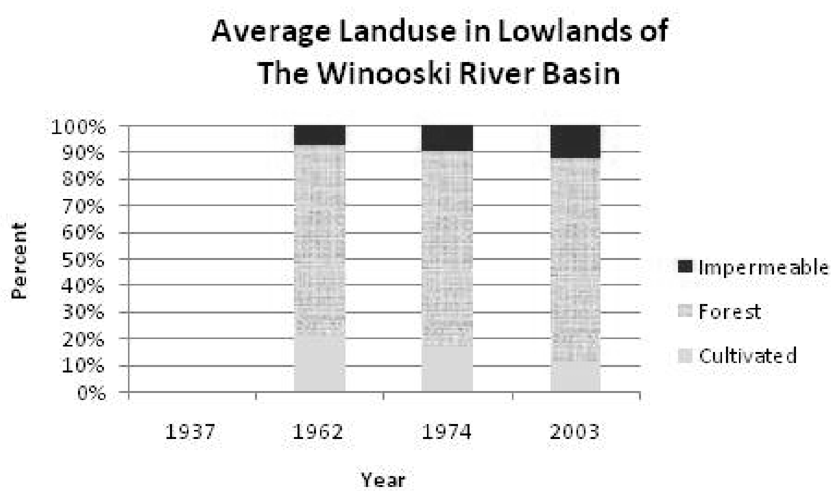

Average Landuse in Lowlands of
The Winooski River Basin
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
1937
1962
1974
2003
Year
Impermeable
Forest
Cultivated

Figure 5.

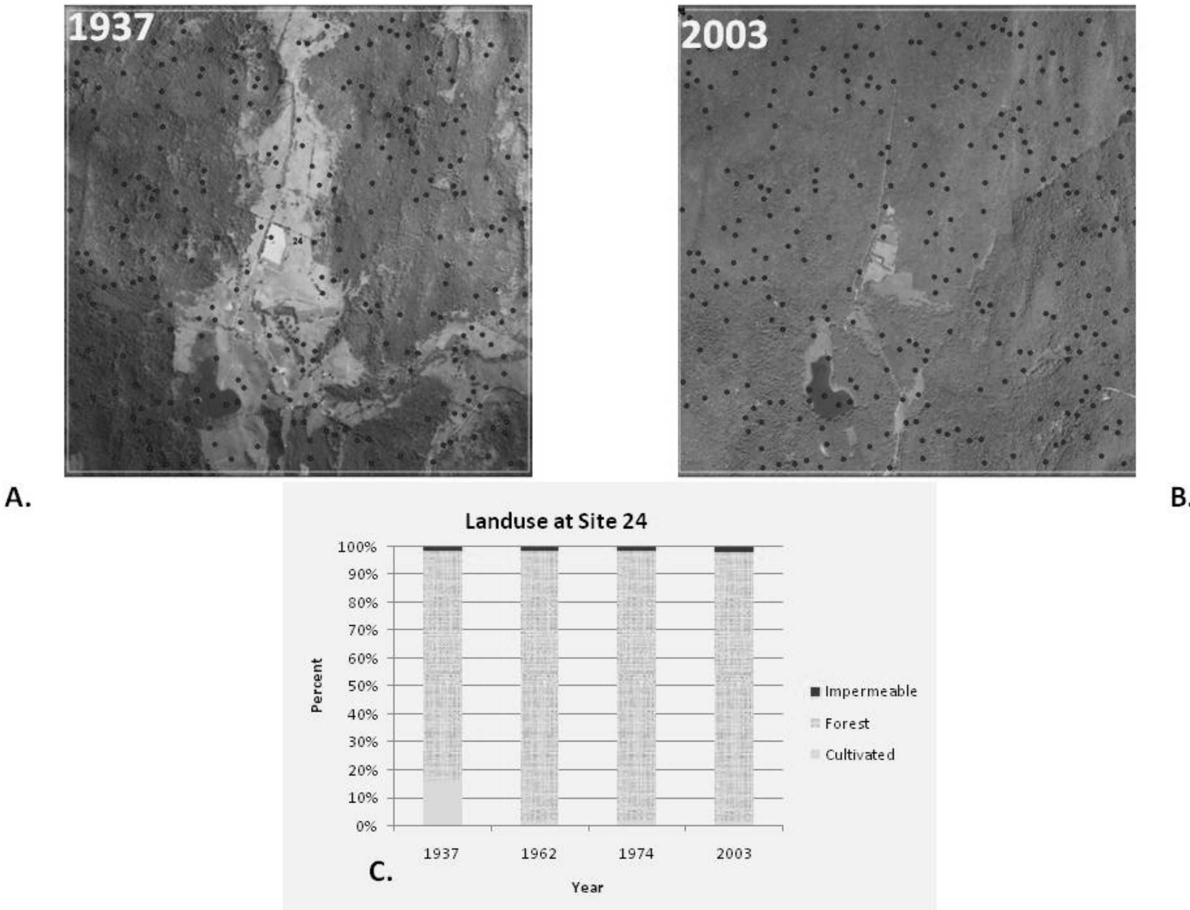

1937
2003
A.
B.
Landuse at Site 24
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
1937
1962
1974
2003
Year
Impermeable
Forest
Cultivated
C.

Figure 6.

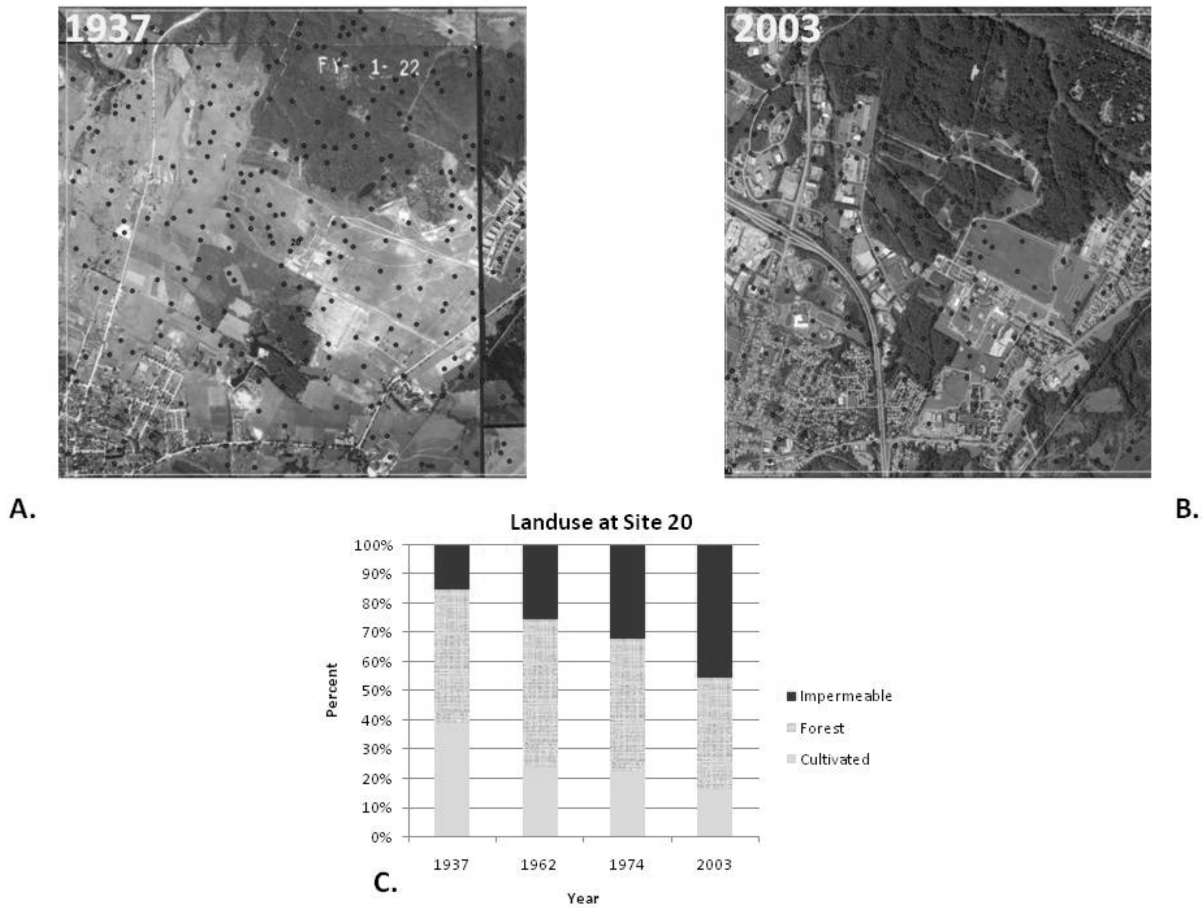

1937
FY- 1- 22
A.
2003
B.
Landuse at Site 20
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
1937
1962
1974
2003
Year
Impermeable
Forest
Cultivated
C.

Figure 7.

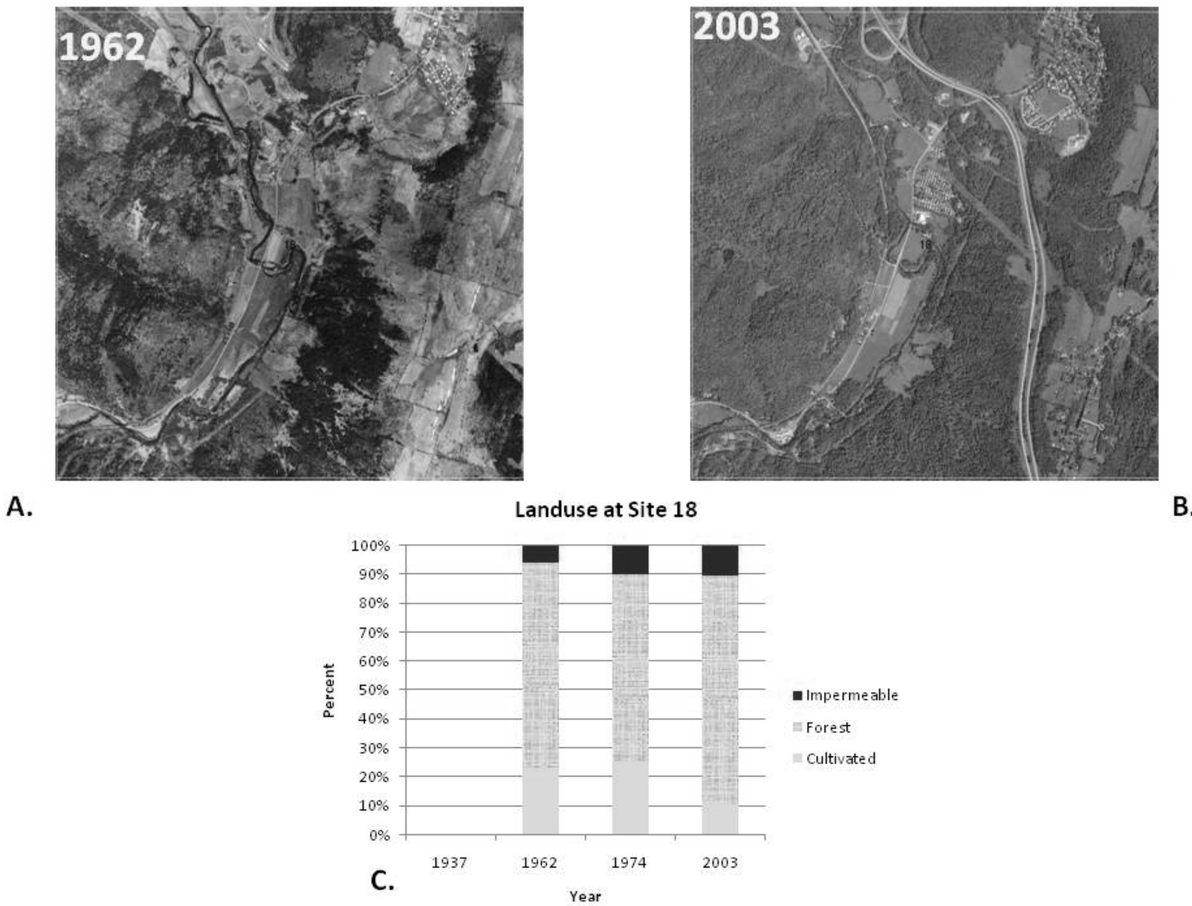

1962
2003
A.
B.
Landuse at Site 18
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
Impermeable
Forest
Cultivated
1937
1962
1974
2003
Year
C.

Figure 8.

Table 1.

Site	1937	1942	1962	1974	UTM[1,4]
1			47-158	16-146	
2			25-261, 19-124	13-118, 13-214	
3			23-97, 21-236	13-57	
4			23-101		
5			48-20, 42-64	16-218, 18-44	
6			49-23, 46-214	14-125, 14-46	
7			42-61	16-213	
8			44-251, 14-208	14-130, 14-208	
9			48-22, 17-153	16-220, 16-141	
10			51-89	14-216	
11			50-31	12-132	
12			42-57, 48-13	16-211	
13			44-22, 36-187	26-24, 26-122	
14	2-33		18-105	12-44, 12-128	
15			29-118, 49-28	14-42, 13-208	
16			50-81, 50-82	12-138	
17			49-29	14-40	
18			48-110	26-28, 15-50	
19			44-254	14-205	
20	1-23, 1-33		20-188, 20-189	4-106	
21			47-65	16-61	
22			44-261, 40-26	14-199	
23			49-26	14-126, 14-44	
24	2-37		18-109	12-125	
25			53-237	15-37	
26	2-19, 1-57		24-161, 24-47	5-137	
27			50-74	12-132	
28			18-96, 24-165	12-037	
29			44-246	14-213	
30			25-257	13-114	

[1]UTM coordinates indicate location at top left corner of sample site

[2]All hard copy aerial photographs were scanned from original monochromatic imagery

[3]2003 imagery from digital conglomeration of Vermont imagery (VCGI)

[4]still need to enter UTM corrdinates

Table 2.

	1937			1962			1974			2003		
Site	**C/R**	**F**	**I**	**C/R**	**F**	**I**	**C/R**	**F**	**I**	**C/R**	**F**	**I**
1				47	48	5	45	49	6	25	69	6
2				13	82	5	8	85	8	4	86	10
3				16	79	5	11	79	10	9	79	13
4				0	100	0	0	100	0	0	100	0
5				24	72	4	16	78	5	15	80	5
6				13	86	1	4	91	5	6	86	7
7				9	91	1	8	92	2	5	93	2
8				9	87	4	9	87	4	5	88	7
9				24	72	4	22	74	4	14	81	5
10				4	93	2	1	96	3	3	91	6
11				0	100	0	0	100	0	0	100	0
12				4	95	1	4	95	1	2	97	1
13				29	67	4	27	65	8	11	75	14
14	32	58	5	19	69	8	19	66	11	17	66	13
15				20	71	8	18	73	8	17	69	13
16				6	93	1	6	93	1	6	93	1
17				23	58	17	13	62	23	15	61	23
18				23	70	6	25	64	10	13	93	13
19				13	78	6	11	79	8	14	77	8
20	39	46	15	24	51	25	22	46	32	16	39	45
21				8	88	4	6	89	4	3	91	5
22				12	81	7	8	84	8	7	85	8
23				38	48	10	28	56	12	23	60	15
24	16	81	2	1	95	2	1	95	2	1	94	2
25				0	100	0	0	100	0	0	100	0
26	39	55	6	33	60	7	27	64	9	16	69	15
27				6	59	2	4	94	2	2	96	2
28				11	85	4	5	89	6	3	90	7
29				0	100	0	0	100	0	0	100	0
30				40	44	15	29	52	17	22	60	19

[1]C= Cultivated/repressed, F= Forest, I= Impermeable

Table 3.

Analysis Technique	% Agriculture	% Forest	% Impervious
300 Point (1)	23	70	6
300 Point (2)	21	70	7
500 Point (1)	26	67	6
500 Point (2)	24	68	6
Polygon (1)	*	*	*
Sampler 2 (1)	31	64	4
Automated (1)	*	*	*

*Analysis remains to be completed…