

Patterns of Urban Sprawl in Edmonton: A Spatial Analysis Using FragStats Landscape Metrics

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Executive Summary

This report provides an analysis and evaluation of 1966 - 1976 land-use conversion trends in Edmonton from an urban planning perspective. By placing 14 FragStats metrics on 1966 and 1976 Canada Land-Use Monitoring Program (CLUMP) Edmonton land-use data and creating a transition matrix, the transformation of 13 different land-use categories can be presented with ArcGIS v10 software to show which land-use type was converted into another. Results of the data analyzed show an increase in the area covered by Urban Built-up Areas by 35,399 hectares with a simultaneous loss of 21,559 hectares of Cropland, 33,171 hectares of Improved & Unimproved Pasture & Range Land, and 11,770 hectares of Non-productive Woodland. By examining Total Area, Number of Patches, and Number of Disjunct Core Area metrics, trends of land-use conversion suggests the city will develop into a problematic urban sprawl. The report recognizes the fact that the analysis has limitations: the spatial files rely on aerial photo interpretation, and a portion of the study area is unmapped. The report finds that city planners must devise development strategies that focus more on redevelopment of urban areas instead of converting additional area into urban zones.

Introduction

From 1963 to 1981, Edmonton experienced a rapid urban redevelopment phase thanks to its strong economic position brought on by a housing boom and the emergence of the oil sands industry. Great Canadian Oil (Suncor) began production in 1967, and the 1967 Arab embargo of the United States drove oil prices high enough to make the oil sands profitable (Edmonton Heritage Council, 2017). Large-scale residential development consortiums moved into the Edmonton market, boosting the province's total construction by 50% (2017). While some of the old downtown neighbourhoods went through redevelopment, urban expansion accelerated in the form of malls, single use residential neighbourhoods, and newly created suburban communities such as Mill Woods.

According to City of Edmonton statistics, the city population grew by 80,329 (21.1%) between 1966 and 1976 (City of Edmonton, 2018). The increase in population compared to the increase in area dedicated to urban development is indicative of uncoordinated sprawl growth, which strains energy, education, healthcare, transportation, and sanitation services (Bhatta, 2010). Significant amounts of valuable croplands, woodlands, and pastures have been needlessly converted into urban areas. This analysis attempts to describe the inefficient qualities of urban expansion that have taken place in Edmonton from 1966-1976 in order to dissuade future development from exacerbating current problems due to excessive urban sprawl.

Methods

Edmonton land-use shape files were obtained from Canada Land Use Monitoring Program (CLUMP) files for the years 1966 and 1976 from GeoGratis – a website containing free geospatial data and materials. The land-use files record 15 different land-use types (Appendix A) though only 11 land-use types were selected for analysis due to size and relevance. Using ArcGIS v10 software, the vector files were converted into raster files with 100m resolution and exported as GeoTIFF files for FRAGSTATS use in calculating landscape metrics (Appendix B) of each land-use type. The two GeoTIFF rasters were combined using ArcGIS v10, joins were made between the attribute tables to identify land-use changes, and the combined table was exported as a .dbf file to create a transition matrix using Microsoft Excel to show changes in percentages.

The CLUMP class definitions (Appendix B) were reviewed to determine the classes that are most relevant to the analysis of urban sprawl. These classes are Total Area, Number of Patches, and Number of Disjunct Core Areas. The land-use types under consideration are Urban Built-up Areas, Cropland,

Improved & Unimproved Pasture and Range Land, and Non-productive Woodland. These land-use types were selected due to their economic and social value, significant size and rate of change related to Urban Built-up Area. Maps of Edmonton for 1966 and 1976 were created using the CLUMP vector data to provide an overview of land-use change.

Results

Between 1966 and 1976, changes noted in Total Area significant to the analysis of urban expansion (see Tables 1 & 2):

- The Urban Built-up Area type increased by 35,399 ha (64.4% of 1966 level)
- Cropland decreased by 21,559 ha (8% of 1966 level)
- Improved Pasture and Forage Crops decreased by 2392 ha (5% of 1966 level)
- Unimproved Pasture and Range Land decreased by 30,780 ha (41% of 1966 level)
- Non-productive Woodland decreased by 11,770 ha (62% of 1966 level)

The urban core of Edmonton expanded significantly in all directions (Map 2). To the east, urban areas and productive woodlands replaced unimproved pastures. Communities north of Edmonton underwent considerable development as well, replacing croplands (Map 2). New communities sprung up in the southwest and east, and expansions were added to Edmonton's airport (Map3).

Of the 35,399 ha converted to Urban Built-up Areas (see Table 3):

- 21,373 ha (7.5%) was converted from Cropland
- 477 ha (1.02%) was converted from Improved Pasture and Forage Crops
- 7425 ha (9.78%) was converted from Unimproved Pasture and Range Land
- 2071 ha (10.85%) was converted from Non-productive Woodland

Changes in landscape metrics for Urban Built-up Areas were noted as well: the Number of Patches increased from 133 in 1966 to 417 in 1976, while the Number of Disjunct Core Areas increased from 88 to 384 (see Tables 1 & 2).

Discussion

Urban areas are expanding at the expense of agriculturally productive areas, open range land, and unused woodlands. This has added considerably to losses of area for Non-productive Woodland, Cropland, and Unimproved Pasture and Range Land. These observations are supported by

documentation of Edmonton's suburban expansion through the 'land banking' system, a mechanism in which municipalities assembled land for the purpose of building self-contained suburbs and released parcels over time at below-market rates (Shields et al, 2015). The price of land was lowered, making low density housing more affordable, causing a spike in population growth. Land surrounding Edmonton was rapidly bought and sold off. Re-purposing Croplands for urban development reduces food security and limits opportunities for citizens to buy local produce. Development of Non-productive Woodland means the loss of aesthetically pleasing landscapes and puts further pressure on local wildlife by removing habitat zones. Both Woodlands also act as natural flood barriers by retaining excess rainwater and preventing extreme run-offs (European Environment Agency, 2016).

Selling land at below-market rates and building single-family residences lead to aggressively expansive suburban development and urban sprawl. Urban sprawl is characterized by uncoordinated, scattered suburban development that increases traffic problems, depletes local resources, and destroys open space (Ji et al, 2006). Evidence of urban sprawl in Edmonton is supported by FragStats statistics regarding the number of patches and disjunct core areas. FragStats metrics such as patch density have been used in the analysis of urban expansion in Bangalore (Sudhira & Ramachandra, 2007). The Number of Patches increased by 284 over the ten-year study period (Table 2). The increase in patch density of Urban Built-up Areas means that more urban areas are being created separate from each other. The Number of Disjunct Core Areas (Table 2) also increased by 296, suggesting that there is a large degree of spatial separation between the patches. Furthermore, the discrepancy between population growth and increase of Total Area of Urban Built-up Areas reinforces the theory of Edmonton's urban sprawl. A spread out population necessitates more roads, additional municipal services, schools and amenities paid for by a comparably smaller tax base than a dense urban core.

Recommendations

Edmonton should adapt a city planning strategy which emphasizes urban core revival and development. Stimulating the construction of higher density residential communities on zones already designated as Urban Built-up Areas will save money wasted on upkeep of additional roads, pipes, powerlines and services required for a dispersed population. More compact forms of urban expansion enhance accessibility and public transport, leading to "improved urban services that are responsive to the needs of different social groups, better environmental conditions, as well as improved economic opportunities and livelihoods" (UN Habitat, 2009, p. xxix). Urban planning should be inclusive of lower income residents and recognize and address current major environmental and resource issues. The

Edmonton municipal government should provide additional incentives for real estate developers to focus on inner city redevelopment where possible.

1966	Total Area (ha)		Percentage of landscape		Number of Patches		Total Edge (m)		Coefficient of Variation (Patch Area)		Shape Index - Mean		Total Core Area (ha)		Core Area Percentage of Landscape		Number of Disjunct Core Areas		
	Area	Percentage	Number	Percentage	Number	Percentage	Length	Area	Percentage	Mean	Standard Deviation	Mean	Standard Deviation	Area	Percentage	Number	Percentage	Number	Percentage
Water areas	19861	3.0825	337	1000600	599.7003	1.3198	13003	2.0181	238										
Cropland	284664	44.1805	579	11817300	1498.1967	1.6392	196305	30.467	1349										
Unimproved pasture and range land	75934	11.7851	2597	8727000	525.5473	1.4701	24261	3.7654	1922										
Improved pasture and forage crops	46750	7.2557	2132	5502800	186.3394	1.3557	11720	1.819	1547										
Productive woodland	28450	4.4155	843	2871600	263.1711	1.4933	10701	1.6608	670										
Swamp marsh or bog	11340	1.76	1144	1867200	218.2349	1.2831	1951	0.3028	365										
Non-productive woodland	19086	2.9622	517	1861000	339.773	1.5178	7816	1.2131	413										
Mines quarries sand and gravel pits	1681	0.2609	99	199400	154.1402	1.2398	508	0.0788	47										
Urban built-up area	19596	3.0413	133	555400	604.8148	1.2798	15708	2.4379	88										
Outdoor recreation	1735	0.2693	80	204400	132.3644	1.3764	563	0.0874	47										
Horticulture	23	0.0036	5	4200	89.7381	1.0286	0	0	0										
Unproductive land - rock	208	0.0323	14	40300	65.4976	1.7833	5	0.0008	2										
Total	509328	79.0489	8480	34651200	4677.5178	16.7869	282541	43.8511	6688										

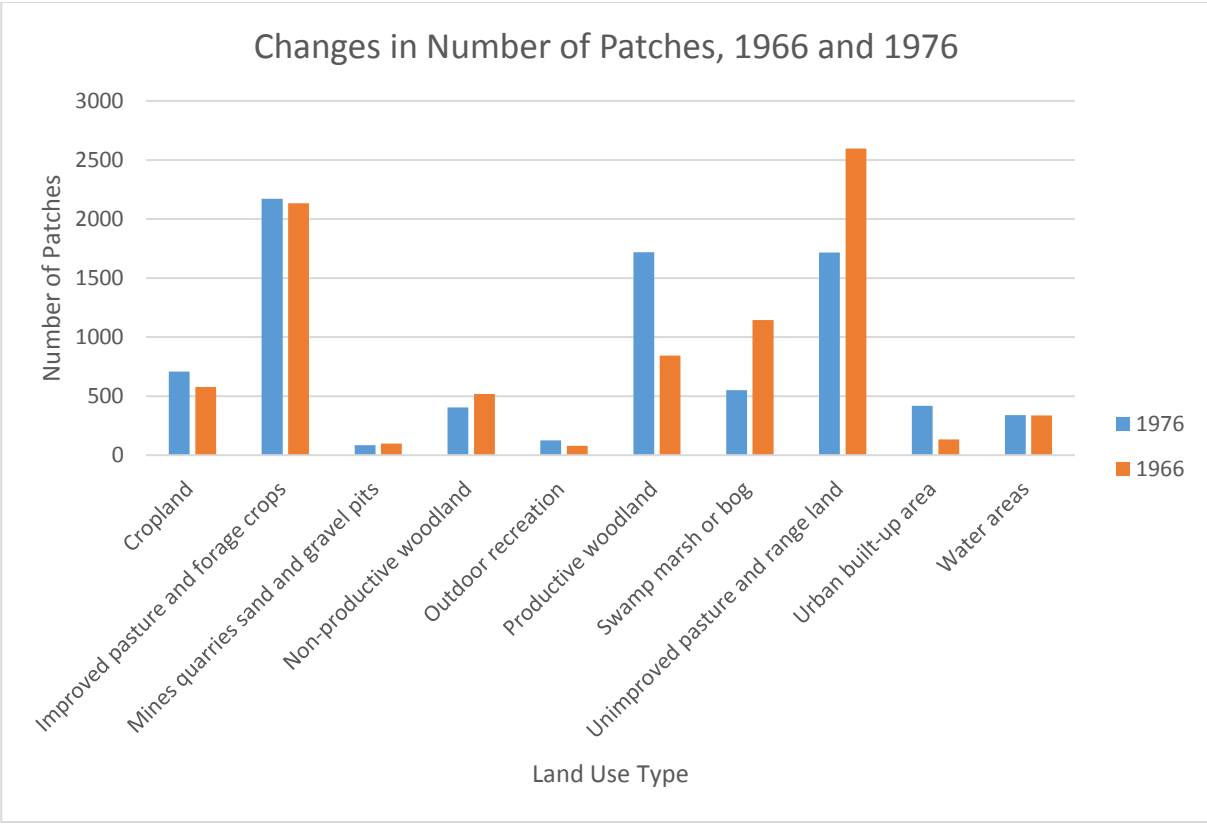
Table 1: FragStats metrics for 1966 land-use types. Note: Horticulture, though below 50 cells, is included due to its increased presence in 1976. Unmapped Areas and Unproductive Land – Sand have been excluded from the table.

1976		Total Area (ha)	Percentage of landscape	Number of Patches	Total Edge (m)	Coefficient of Variation (Patch Area)	Shape Index - Mean	Total Core Area (ha)	Core Area Percentage of Landscape	Number of Disjunct Core Areas
Water areas	19875	3.0866	340	1003800	602.0022	1.3189	13003	2.0194	238	
Cropland	263105	40.8601	709	9696500	1121.912	1.5205	190266	29.5482	928	
Unimproved pasture and range land	45154	7.0124	1715	4865600	281.4969	1.405	15687	2.4362	1183	
Improved pasture and forage crops	44358	6.8888	2170	5327500	169.2857	1.3403	10710	1.6633	1489	
Productive woodland	59439	9.2308	1718	6029300	414.5431	1.4841	22774	3.5368	1291	
Swamp marsh or bog	6228	0.9672	551	926500	197.1752	1.2636	1375	0.2135	219	
Non-productive woodland	7316	1.1362	403	905700	219.4666	1.374	2236	0.3472	203	
Mines quarries sand and gravel pits	3116	0.4839	84	262400	342.119	1.3176	1405	0.2182	61	
Urban built-up area	54995	8.5407	417	2373000	703.7032	1.4787	38268	5.943	384	
Outdoor recreation	4582	0.7116	126	378900	249.2571	1.3274	2152	0.3342	79	
Horticulture	750	0.1165	44	77800	131.8307	1.1377	255	0.0396	22	
Total	508918	79.0348	8277	31847000	4432.7917	14.9678	298131	46.2996	6097	

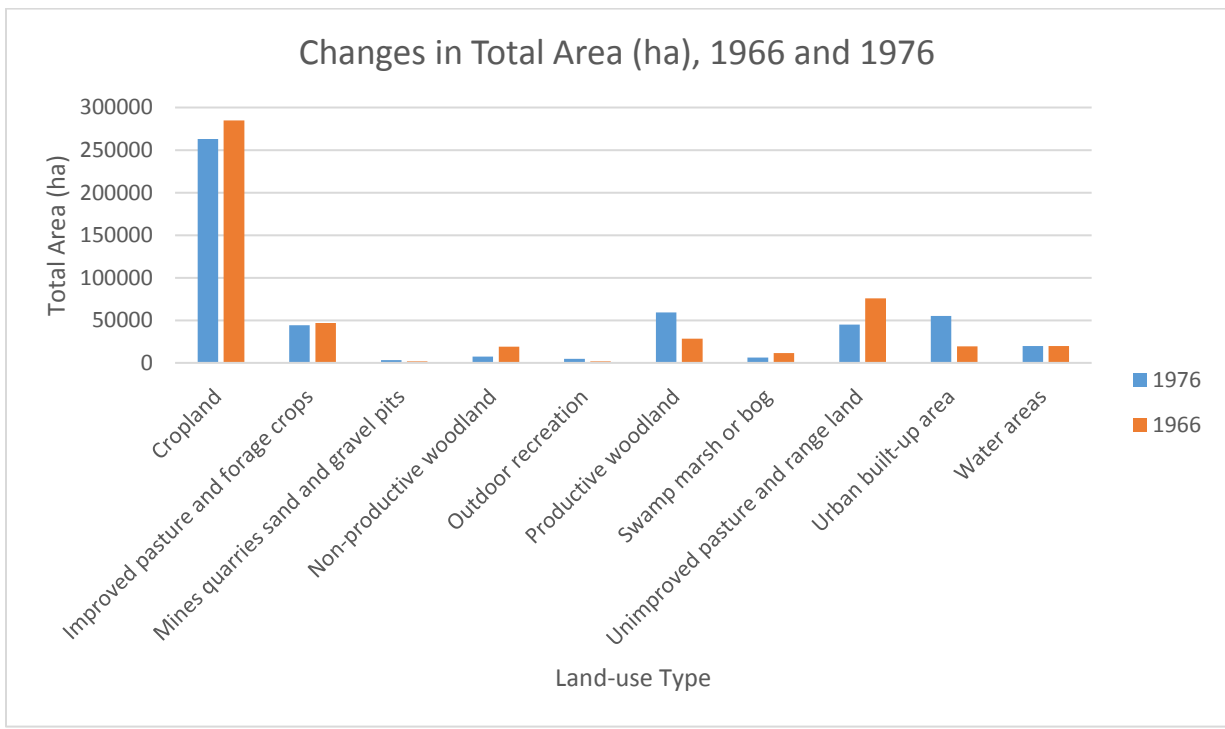
Table 2: FragStats metrics for land-use types, 1976. Note: Unmapped Areas, Unproductive Lands – Rock & Unproductive Lands – Sand are excluded from the table.

1976	1966											Grand Total (1966)
	Cropland	Horticulture	Improved pasture and forage crops	Mines quarries sand and gravel pits	Non-productive woodland	Outdoor recreation	Productive woodland	Swamp marsh or bog	Unimproved pasture and range land	Urban built-up area	Water areas	
Cropland	82.34%	0.22%	0.02%	0.70%	0.26%	0.22%	1.69%	0.38%	6.65%	7.52%		55.89%
Horticulture	34.78%	52.17%				4.35%				8.70%		0.00%
Improved pasture and forage crops	0.98%	0.01%	94.40%	0.13%	0.28%	0.09%	0.77%	0.16%	2.15%	1.02%	0.00%	9.19%
Mines quarries sand and gravel pits	4.34%		0.12%	42.59%	3.81%	5.35%	9.10%	0.18%	13.44%	21.06%		0.33%
Non-productive woodland	12.57%	0.05%	0.05%	0.27%	8.53%	2.30%	51.62%	0.46%	13.32%	10.85%		3.75%
Outdoor recreation	0.17%					85.42%			0.29%	14.12%		0.34%
Productive woodland	14.92%	0.04%	0.11%	0.39%	1.44%	2.07%	63.76%	0.27%	7.33%	9.67%		5.59%
Swamp marsh or bog	17.67%	0.04%	0.12%	0.07%	7.82%	1.04%	12.86%	28.17%	26.08%	6.06%	0.08%	2.23%
Unimproved pasture and range land	26.08%	0.09%	0.14%	0.25%	4.55%	1.55%	32.34%	2.27%	22.95%	9.78%	0.00%	14.92%
Urban built-up area	0.02%		0.01%	0.01%			0.01%			99.96%		3.85%
Water areas											100.00%	3.90%
Grand Total (1976)	51.72%	0.15%	8.72%	0.61%	1.44%	0.90%	11.66%	1.22%	8.88%	10.81%	3.91%	100.00%

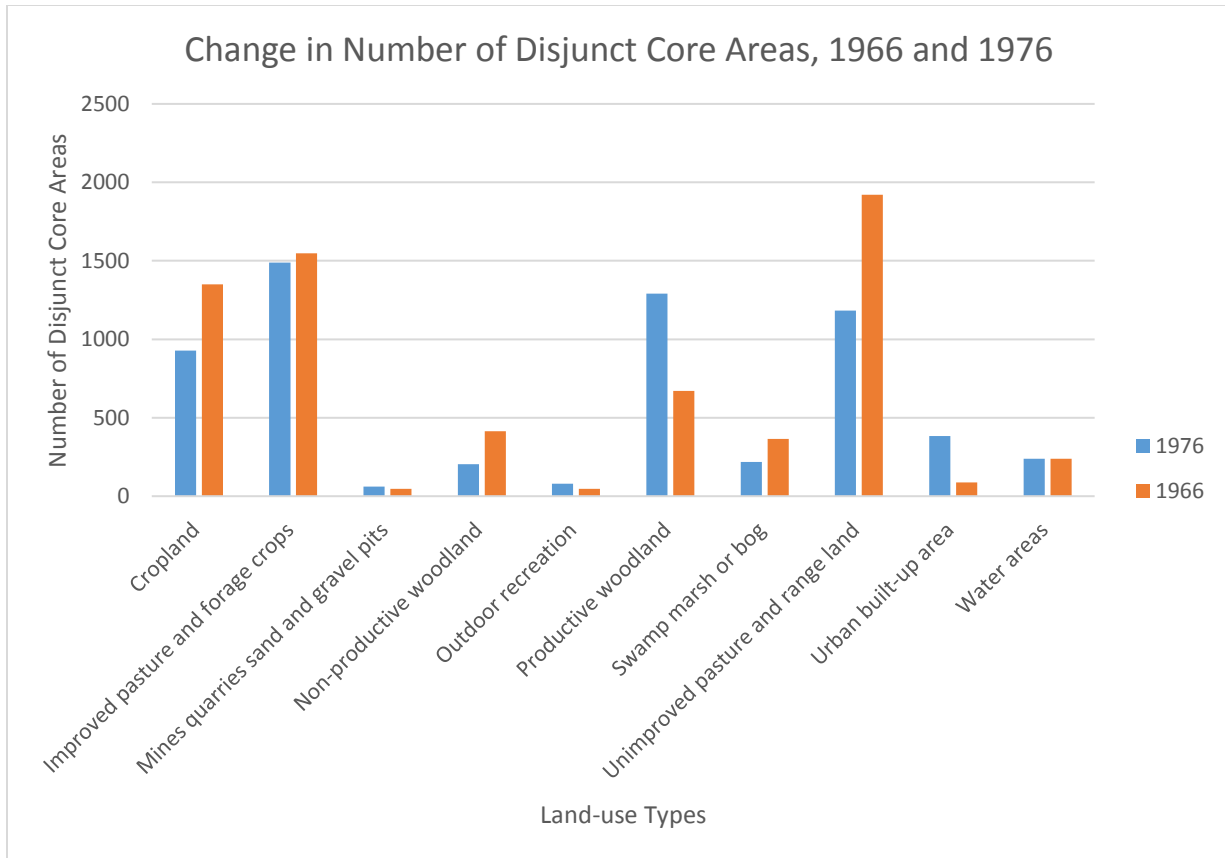
Table 3: Transition Matrix for 11 land-use types, Edmonton, 1966 – 1976. Note: Unmapped Areas, Unproductive Lands – Rock and Unproductive Lands – Sand have been excluded.



Graph 1: Changes in the number of patches, 1966 to 1976.



Graph 2: Changes in total area, measured in hectares, from 1966 to 1976.



Graph 3: Changes in the number of disjunct core areas, from 1966 to 1976.

Appendix A

Cropland: Land used for annual field crops such as grain, oilseeds, sugar beets, tobacco, potatoes, field vegetables and canning crops. Associated fallow, and land being cleared for field crops, are also included.

Horticulture: Horticulture, poultry and fur operations. Land used for intensive cultivation of vegetables and small fruits, includes market gardens, nurseries, flower and bulb farms and sod farms. Large-scale commercial fur and poultry farms are also included because of their specialized agricultural nature.

Improved Pasture and Forage Crops: Land used for improved pasture or for the production of hay and other cultivated fodder crops, including land being cleared for these purposes.

Mines, Quarries, Sand and Gravel Pits: Land used in the past or present for the extraction of earth materials.

Non-productive Woodland: Land covered by scrub growth.

Outdoor Recreation: Land used for private or public outdoor recreational purposes. Some examples are: golf courses, parks, beaches, summer cottage areas, game preserves and historic sites.

Productive Woodland: Wooded land with trees having over 25% canopy cover and being over 20 feet in height approximately. Artificially restocked areas, or plantations are included regardless of age. Much cut-over and burned-over land is included.

Swamp, Marsh or Bog: Open wetlands except those which frequently dry up or show evidence of grazing or hay cutting.

Urban Built-up Area: Land occupied by cities, towns, and villages, or by isolated units away from settlements such as manufacturing plants, rail yards, and military camps. Parks and other open spaces within built-up areas are also included.

Unimproved Pasture and Range Land: Areas of natural grasslands, sedges, herbaceous plants and abandoned farmland whether used for grazing or not. Bushes and trees may cover up to 25% of the area. Intermittently wet hay lands (sloughs or meadows) are included as long as the land is utilized. Within some grassy, open woodlands, bushes and trees may exceed 25% cover if the area is actively grazed and no other use dominates.

Unproductive Land – Rock: Rock barrens, badlands, alkaline flats, gravel bars, eroded river banks, mine dumps. Unproductive land which does not support vegetation.

Appendix B

Landscape: An area of land containing a mosaic of patches or landscape elements; an area of land containing a mosaic of habitat patches.

Percentage of Landscape: A fundamental measure of landscape composition; specifically, how much of the landscape is comprised of a particular patch type.

Patch: Landscapes are composed of a mosaic of patches, a term that refers to the basic elements or units that make up a landscape. Patches represent relatively discrete areas of relatively homogeneous environmental conditions where the patch boundaries are distinguished by discontinuities in environmental character states from their surroundings.

Edge: The boundaries between patches; the edge buffer represents the distance at which the "core" or interior of a patch is unaffected by the edge of the patch. Edge effects must be viewed from an organism-centered perspective because edge effects influence organisms differently; some species have an affinity for edges, some are unaffected, and others are adversely affected.

Total Edge: The length of edge can be summarized at the patch level as the perimeter of the patch.

Coefficient of Variation (Patch Area): A simple measure of variability; used for comparing variability among landscapes by measuring relative variability about the mean (i.e., variability as a percentage of the mean), not absolute variability. Thus, it is not necessary to know mean patch size to interpret the coefficient of variation.

Shape Index – Mean: measures the complexity of patch shape compared to a standard shape (square) of the same size.

Core Area: Core area is defined as the area within a patch beyond some specified depth-of-edge influence (i.e., edge distance) or buffer width; the primary significance of core area in determining the character and function of patches in a landscape appears to be related to the 'edge effect'.

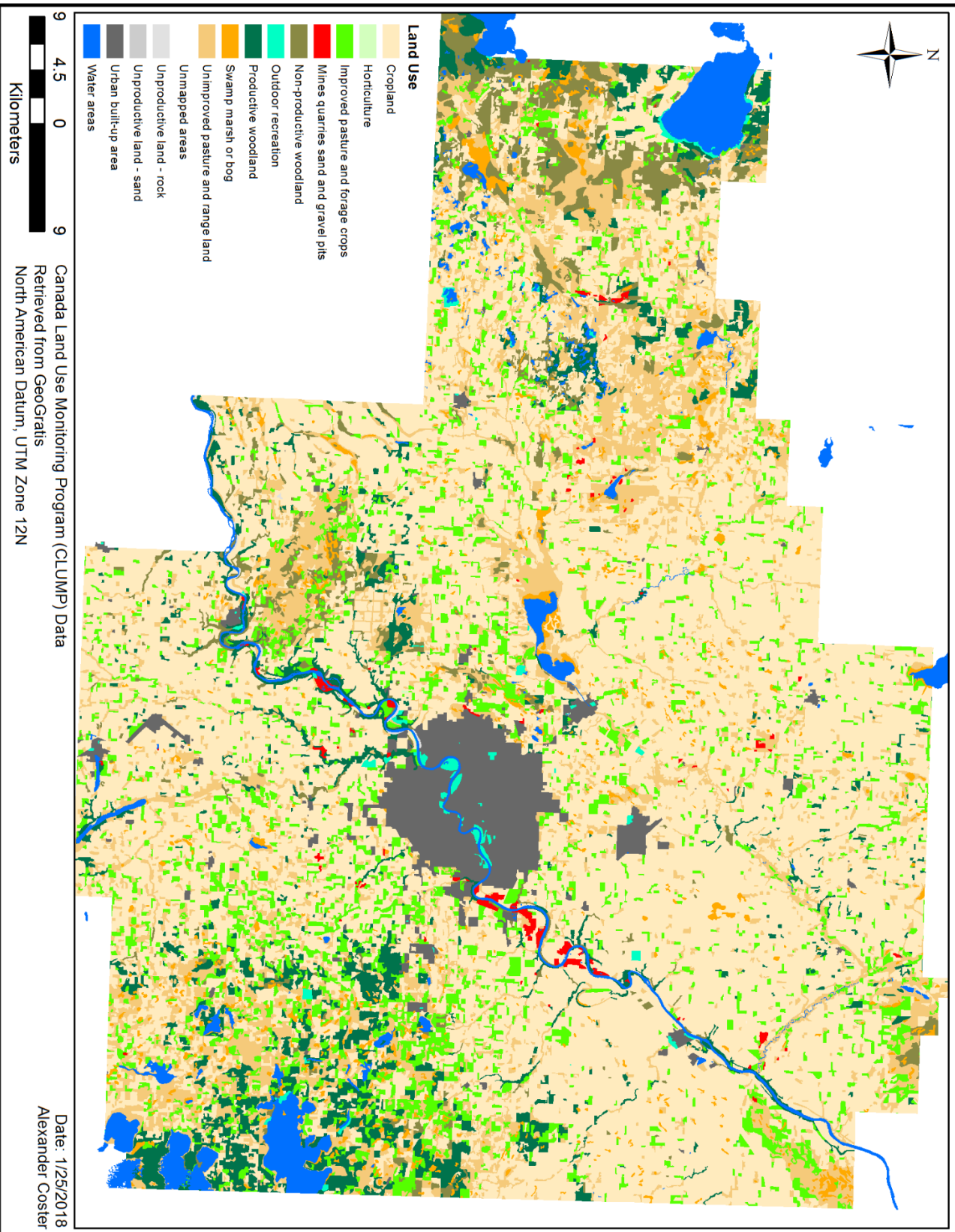
Total Core Area: total core area at the class and landscape levels.

Number of Disjunct Core Areas: a single patch may actually contain several disjunct patches of suitable interior habitat, and it may be more appropriate to consider disjunct core areas as separate patches; patches are disjoined and distinct from one another.

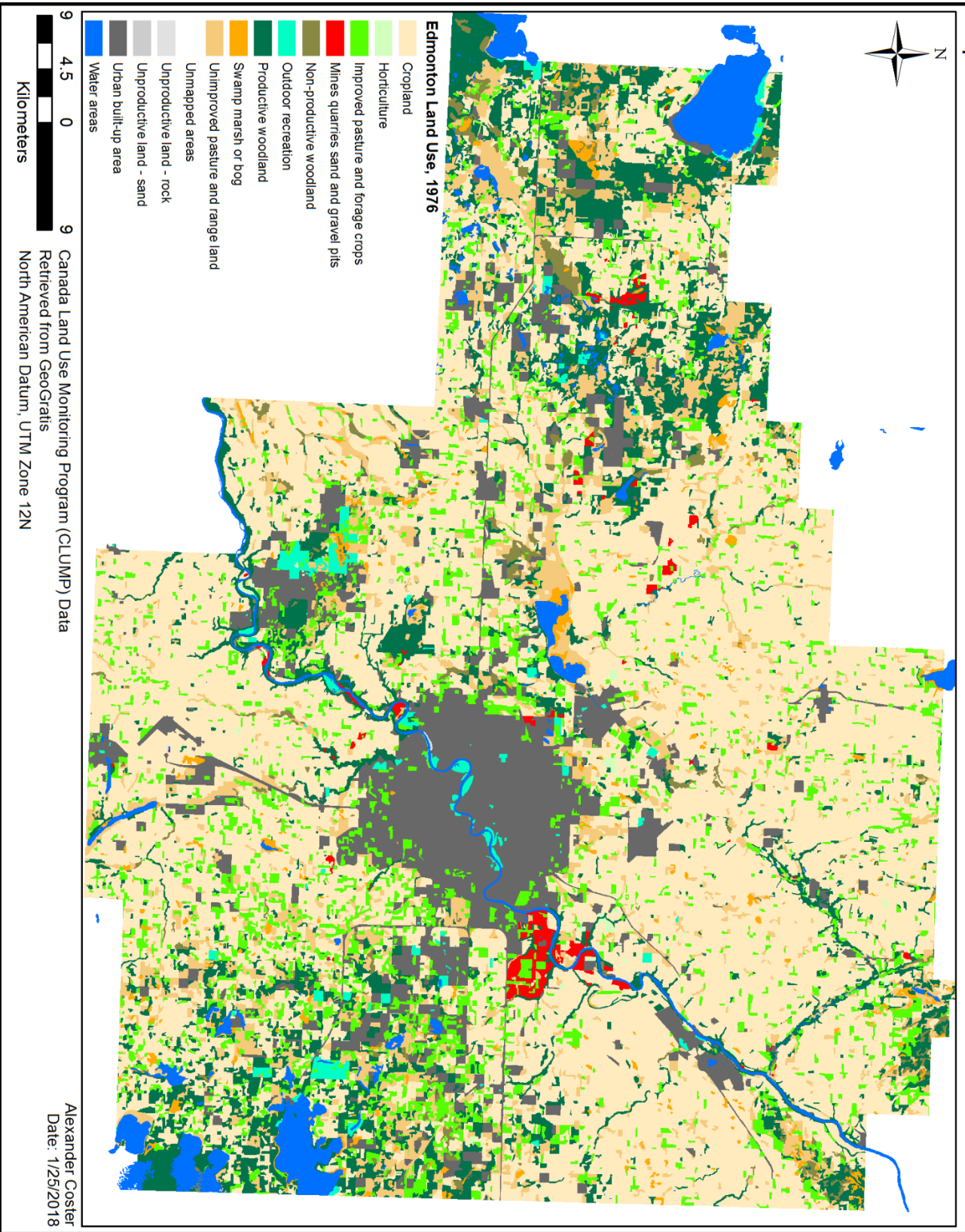
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Map 1 Edmonton Categorized by Land Use Type, 1966



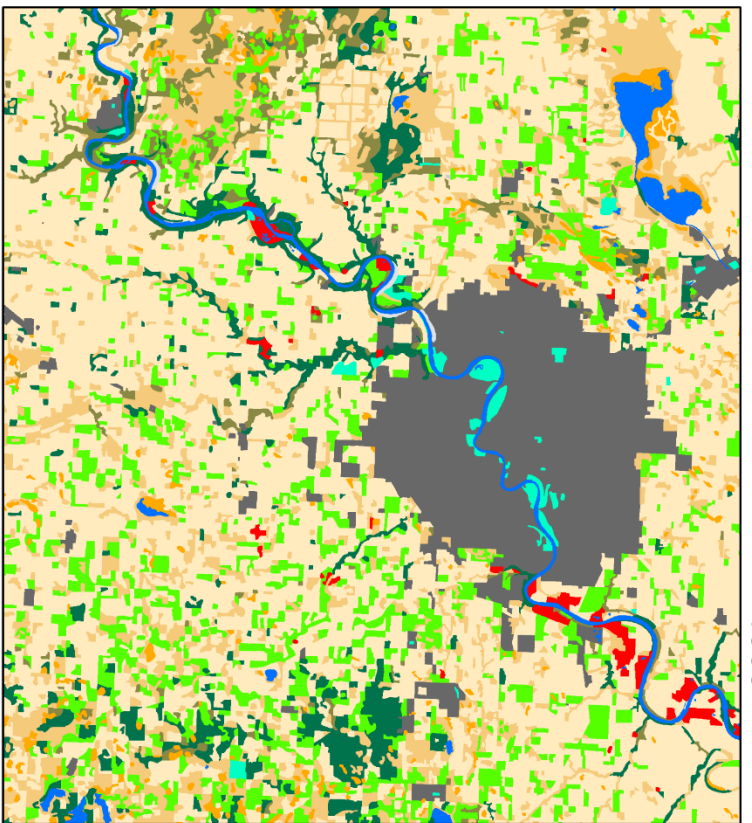
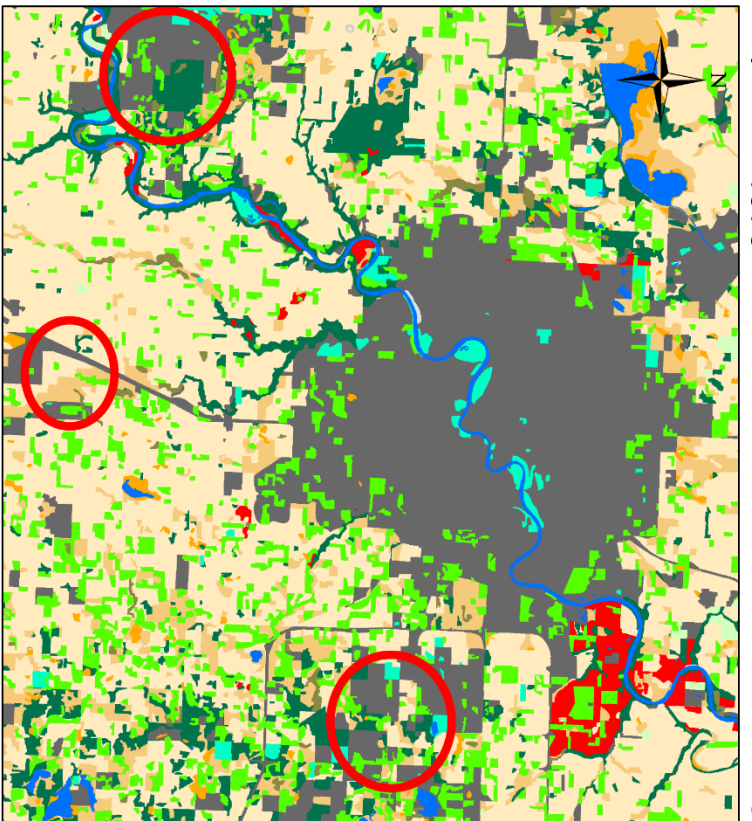
Map 2 Edmonton Categorized by Land Use Type, 1976



Map 3 1976

Extent of Urban Expansion in Edmonton

1966



Edmonton Land Use, 1976

- Cropland
- Horticulture
- Improved pasture and forage crops
- Mines quarries sand and gravel pits
- Non-productive woodland
- Outdoor recreation
- Productive woodland
- Swamp marsh or bog
- Unimproved pasture and range land
- Unmapped areas
- Unproductive land - rock
- Unproductive land - sand
- Urban built-up area
- Water areas

Canada Land Use Monitoring Program (CLUMP) Data
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North American Datum, UTM Zone 12N

