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Analysis of ecosystem services at Mullins Creek on the University of Arkansas campus

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Analysis of Ecosystem Services at Mullins Creek on the University of Arkansas Campus

Honors Thesis

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Abstract

The University of Arkansas has been a site of population and urban growth since its inception in 1871. This urban development has caused extreme changes in land use, and with this has also come a change in ecosystem services provided by the area. Ecosystem services are benefits acquired by humans that are provided by functions are an ecosystem (Constanza et al., 1997). Constanza developed a method for quantifying ecosystem services. In this method, Constanza valuated ecosystem services for biomes. These service values were based on the economic value of the service provided, and were given in dollar per hectare-year.

A case study of Mullins Creek, an urban stream with its head waters located on the University of Arkansas campus, was the focus of this research project. Using delineation data from a previous research project on this stream, the watershed for Mullins Creek on campus was mapped in ArcGIS and the land use and land cover areas for the watershed found. The land use and land covers given in ArcGIS were converted to biomes as defined by Constanza. The geometric area for each biome in hectares was multiplied by the service value defined by Constanza, and a total dollar per year value for the watershed was calculated.

After the present ecosystem service value for the watershed was found, the pre-developed watershed was considered. The land use and land cover for this watershed was estimated using historical information regarding the university. The land use areas were acquired from ArcGIS and multiplied by the service value for each land area to receive the dollar per year service value of the pre-developed watershed.

With the present and pre-developed service values known, it was found that there was a significant loss in ecosystem service values since the university was founded. Therefore, a design for improvements was developed in order to recover some of the service values lost due to urbanization. A "possible" watershed was developed with land use changes suggested that would increase service value without drastically changing current infrastructure and function of the urban area. Green roofs and pervious pavements were two land covers considered. Green roofs were suggested for specific buildings within the watershed, and pervious pavement was suggested for specific parking lots. These specific locations were identified in ArcGIS and the new land use areas found. These areas were again multiplied by the service values for each land use, with green roofs considered grass/rangelands at 75% value, and pervious pavements as grass/rangelands at 50% value.

The calculated results showed that with the land use changes suggested, there would be a 7% increase in service value. An economic analysis was performed to calculate the actual cost of implementing the suggested land use changes, and the costs were much more than the service value received. These results should not be a deterrent in considering land use changes for ecosystem service increase. The values found are not explicit values, but should be used for comparisons of land use change over time.

Analysis of Ecosystem Services at Mullins Creek on the University of Arkansas Campus

1. BACKGROUND

The University of Arkansas, founded in 1871, is the flagship campus of the University of Arkansas system and is located in Fayetteville, Arkansas. The university's campus has changed dramatically since its inception nearly 150 years ago due largely to urban development. This development over time has been necessary because of increased population of Fayetteville and increased enrollment at the university. In its first few years, the school was known as Arkansas Industrial University. According to a photograph taken in 1882, the graduating class at that time was 13 (UA, 2009). In the 2008-2009 school year, student enrollment was approximately 19,000. This large change in human inhabitance has led to the need for increased housing and facilities on and off campus. For example, in the past six years, twenty new buildings have been erected on campus (Facilities Management Planning Group, FMPG, 2007).

The University of Arkansas campus originated on the hill surrounding Old Main, but over the years has expanded, currently covering 345 acres. Physical aspects of campus have changed along with the urban development. One main aspect that was drastically altered is Mullins Creek, also known as College Branch. The creek is a tributary to the West Fork of the White River, which is the source of water for many citizens of Northwest Arkansas (ADEQ, 2004). This creek begins atop the hill above Maple Street, near Reid Hall. The headwaters of the stream consist of various storm drains. The flows from these outlets come together and form a small stream that proceeds down the hill toward Maple Street. The stream once flowed above ground from this area all the way through the land that is now campus. However, several developments have caused much of the stream to be channeled underground (UACDC, 2005). Currently, the stream flows into a large floor drain approximately 10 feet from Maple Street, meeting several other storm drain outlets. The flows from these sources become subsurface and flow under Maple Street headed south. Many structures such as Donald W. Reynolds Razorback Stadium, The Willard and Pat Walker Pavilion, John McDonnell Field, and other buildings and paved areas such as parking lots are located above the subsurface stream. While underground, the stream serves as a catch-all for many storm outlets (Koehn). The stream resurfaces after flowing under Leroy Pond Avenue. A large culvert serves as the outlet structure for the stream, whose volume is significantly larger than the segment of stream above Maple Street. Mullins Creek then ambles through the Gardens park area, flowing under two foot bridges and then under Lady Razorback Road at Parking Lot 56. The stream grows as more storm drainage outlets pour into its waters, nearing Highway 62. The creek turns 90-degrees approximately ten feet from the highway, and flows parallel with it momentarily before turning again and exiting campus through a culvert under the highway (See Figure 1).

Figure 1. Aerial View Map of the Mullins Creek Watershed, Fayetteville, AR

1. 1 Ecosystem Services

An ecosystem is “an interacting system of biota and its associated physical environment” (NRC, 2005). Ecosystem services are defined as “benefits [that] human populations derive, directly or indirectly, from ecosystem functions” (Constanza et al., 1997). Ecosystem functions are the natural processes performed by the ecological aspects of an area. Ecosystem functions are influenced largely by the state, or heath, of the ecosystem itself. The United Nations developed a Millennium Ecosystem Assessment in which they included ecosystem service studies (Figure 2). This assessment included non-quantifiable constituents of well-being, such as freedom of choice. These constituents were derived from ecosystem services, which encompass all things humans depend on for survival (Millennium Ecosystem Assessment, 2000).

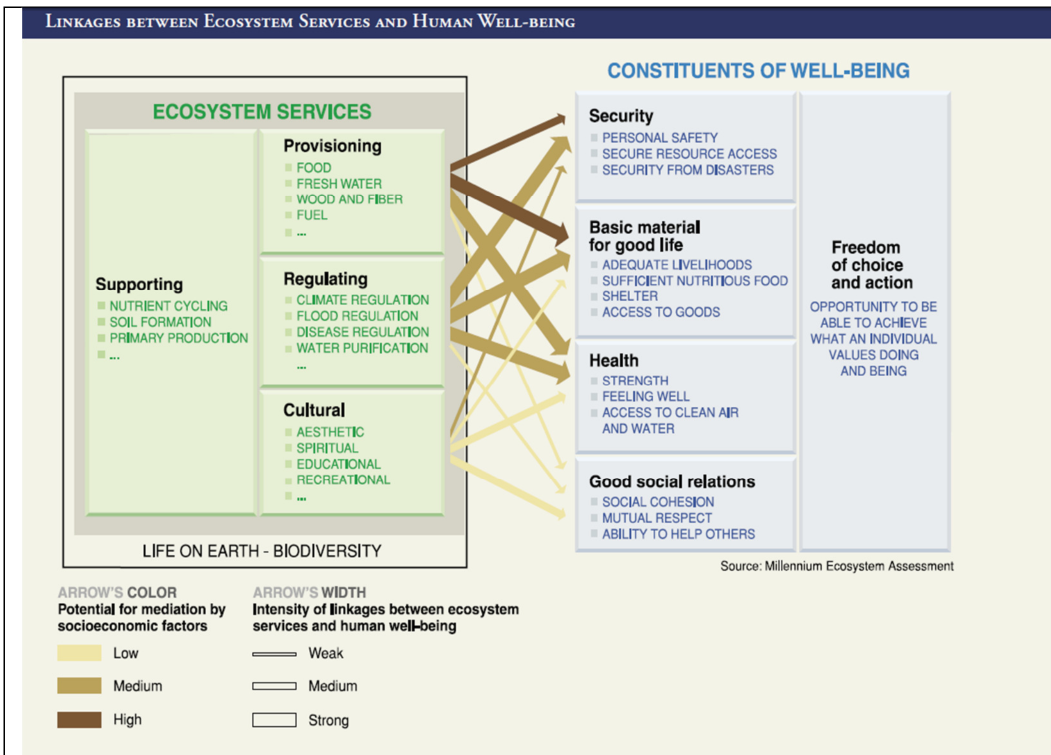

Figure 2. Ecosystem Services and Human Well-Being (Millennium Ecosystem Assessment, 2000)

There are a variety of ecosystem services that have been defined. A table of ecosystem services is given (Table 1).

An undisturbed environment allows an ecosystem to function properly. Disturbances such as urban development cause a decline in the ability of an ecosystem to provide its services. Therefore, an analysis of ecosystem services of an area can be useful in determining how much a biome has been affected by development. An analysis can also provide clues to how the development can be altered to regain services that had been lost.

Table 1. Ecosystem Services and Functions (Constanza et al., 1997)

ECOSYSTEM SERVICE*	ECOSYSTEM FUNCTIONS	EXAMPLES
Gas regulation	Regulation of atmospheric chemical composition	CO2/O2 balance, O3 for UVB protection, and SO_X levels
Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels	Green-house gas regulation, DMS production affecting cloud formation.
Disturbance Regulation	Capacitance, damping, and integrity of ecosystem response to fluctuations	Storm protection, flood control, drought recovery, and other aspects of habitat response
Water regulation	Regulation of hydrological flows	Provisioning of water for agricultural (e.g., irrigation) or industrial (e.g., milling) processes or transportation.
Water supply	Storage and retention of water	Provisioning of water by watersheds, reservoirs, and aquifers.
Erosion control and sediment retention	Retention of soil within an ecosystem.	Prevention of loss of soil by wind, runoff, or other removal processes, storage of silt in lakes and wetlands.
Soil formation	Soil formation processes	Weathering of rock and the accumulation of organic material
Nutrient cycling	Storage, internal cycling, processing, and acquisition of nutrients	Nitrogen fixation, N, P, and other elemental or nutrient cycles
Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds	Waste treatment, pollution control, detoxification
Pollination	Movement of floral gametes.	Provisioning of pollinators for the reproduction of plant populations.
Biological control	Trophic-dynamic regulations of populations.	Keystone predator control of prey species, reduction of herbivory by top predators.
Refugia	Habitat for resident and transient populations.	Nurseries, habitat for migratory species, regional habitats for locally harvested species, or over wintering grounds.
Food production	That portion of gross primary production extractable as food.	Production of fish, game, crops, nuts, fruits by hunting, gathering, subsistence farming, or fishing.
Raw materials	That portion of gross primary production extractable as raw materials.	The production of lumber, fuel, or fodder.
Genetic resources	Sources of unique biological materials and products.	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species (pets and horticultural varieties of plants).
Recreation	Providing opportunities for recreational activities.	Eco-tourism, sport fishing, and other outdoor recreational activities.
Cultural	Providing opportunities for noncommercial uses.	Aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems.
** Includes ecosystem goods and ecosystem services*		

1.2 Objectives

The purpose of this research is to analyze the ecosystem service value for the Mullins Creek Watershed using the Costanza Method of service value determination. This value will provide insight into the effect of urban development on the health of the stream and the ability of the stream and its surrounding area to provide adequate ecosystem services. The research conducted was purely theoretical; actual data describing the ecosystem and land use and land cover of the area would provide more accurate results.

The main objectives for this research project are below.

1. Examine Mullins Creek on the University of Arkansas campus and determine the present ecosystem services value for the Mullins Creek Watershed
2. Determine the ecosystem services value of the stream prior to urbanization of the area using historical land use data.
3. Specify possible changes in the watershed that would increase the ecosystem services value based on its past and present values.

2. METHODOLOGY

2.1 Method for determining ecosystem services

Land cover is the actual material or vegetation covering the land. Land use of a region is the use of the land as defined by humans (VCGI, 1995). The land use and land cover of an area describes the biome of the region and its ecosystem. Constanza et al. (1997) developed a method of ecosystem service evaluation using the geometric area of a biome to calculate the dollar value of the ecosystem services. The valuation of the service is calculated in dollars per year, and is found by multiplying the area of a biome (in hectares) by that biome's ecosystem service coefficient. Coefficients were developed for each service provided by each ecosystem type. They were based on one of three economic values (Constanza et al., 1997). These were:

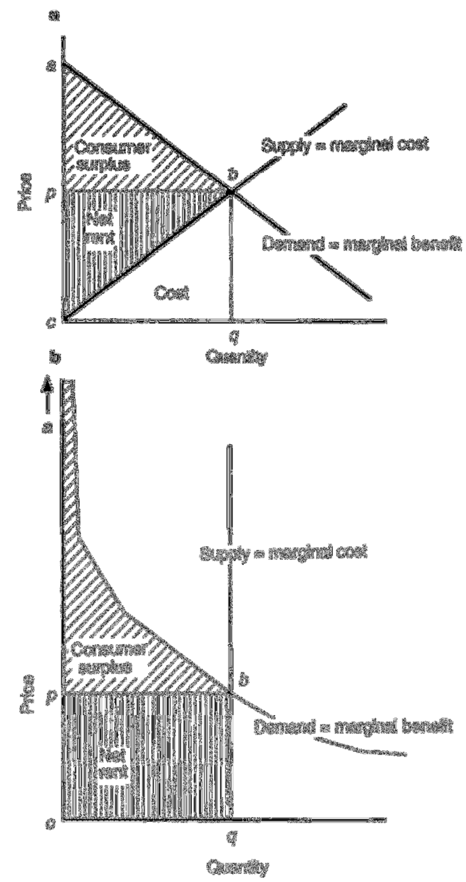

Figure 3. Supply/ Demand Curves for Normal Goods (a) and some Ecosystem Services (b) (Constanza et al., 1997)

1. Sum of consumer and producer surplus
2. Net rent (or producer surplus)
3. Price times quantity as proxy

   for the economic value for the service

Surplus is based on the "willingness-to-pay" of a product. If a product is purchased for less than the price a person would be willing to pay, there is a consumer surplus. If a product is sold for more than the producer is willing to sell it for, there is a producer surplus. Net rent, which can also be described as the producer surplus, is the area between the market price and the supply curve on a supply-and-demand curve (Figure 3).

The Constanza Method was chosen for use in this study due to its ability to approximate the service values of an area. Other studies have used this method, despite the fact that some have questioned it due to limitations. For example, a study performed in San Antonio, TX, used the method because it was the "most comprehensive set of first-approximations available for quantifying the change in the value of services provided by a wide array of ecosystems" (Kreuter et al., 2001). A study performed at Poyang Lake Basin in China also used the Constanza Method because of its comprehensiveness (Yang, 2008). Since this study is based on a conceptual understanding of the ecosystem services in the Mullins Creek watershed, the Constanza method was considered sufficient.

2.2 Current Ecosystem Service Evaluation

In order to determine the current ecosystem services of the Mullins Creek Watershed, area for each land-use category was calculated. Arial images of the watershed were acquired from Geostor, an online database for geographical information in Arkansas (www.geostor.arkansas.gov). In order to determine the land-use of the area, the Mullins Creek Watershed data was acquired. Research done previously by Keisha Koehn, a University of Arkansas student, determined the watershed of this water body by delineating based on the stream and the university's storm water pipe schematics. This information was made available by Ms. Koehn for public use. Data obtained from this research defined the watershed boundary for Mullins Creek. Further data was downloaded from Geostor. This data depicted the land use and land cover (LULC) for Fayetteville, AR when opened in ArcGIS. The software was then used to "clip" the LULC data with the watershed boundary. Therefore, the LULC data for the Mullins Creek Watershed could be explicitly known (Figure 4).

Geometric area for each LULC region was calculated in ArcGIS and exported to Microsoft Excel. In order to translate the LULC data given in ArcGIS into a biome as described by Constanza, the land use and land cover titles were compared to Constanza's and the aerial map of the watershed consulted. Both urban areas (Intensity 1 and 3) were found comparable to the Constanza urban biome. The areas labeled barren land were found to be vast areas of dirt with no vegetation. This was found comparable to the Constanza desert biome. The water: perennial LULC was found to be equal to the lakes/rivers biome. The herbaceous/woody/ transitional LULC was labeled with the Constanza grass/rangeland biome, as were both the warm season grasses LULC and the cool season grasses LULC. With the comparable biome for each LULC determined, Table 2 was created displaying the area of each biome, along with the ecosystem services available and the service value coefficients for each biome in terms of each service. The coefficients were totaled with units of U.S. \$ ha^{-1} yr^{-1}. In order to calculate the service of each biome in the Mullins Creek Watershed, the service value totals were multiplied by the biome areas (Equation 1). This gave a total service value for each biome in U.S. \$ yr^{-1}. The total service value coefficient for each ecosystem service was also calculated.

$$ESV = \sum A_k \times VC_k \qquad [1]$$

In this equation, ESV is the estimated ecosystem service value, A_k is the area in hectares, and VC_k is the value coefficient in dollar per hectare year.

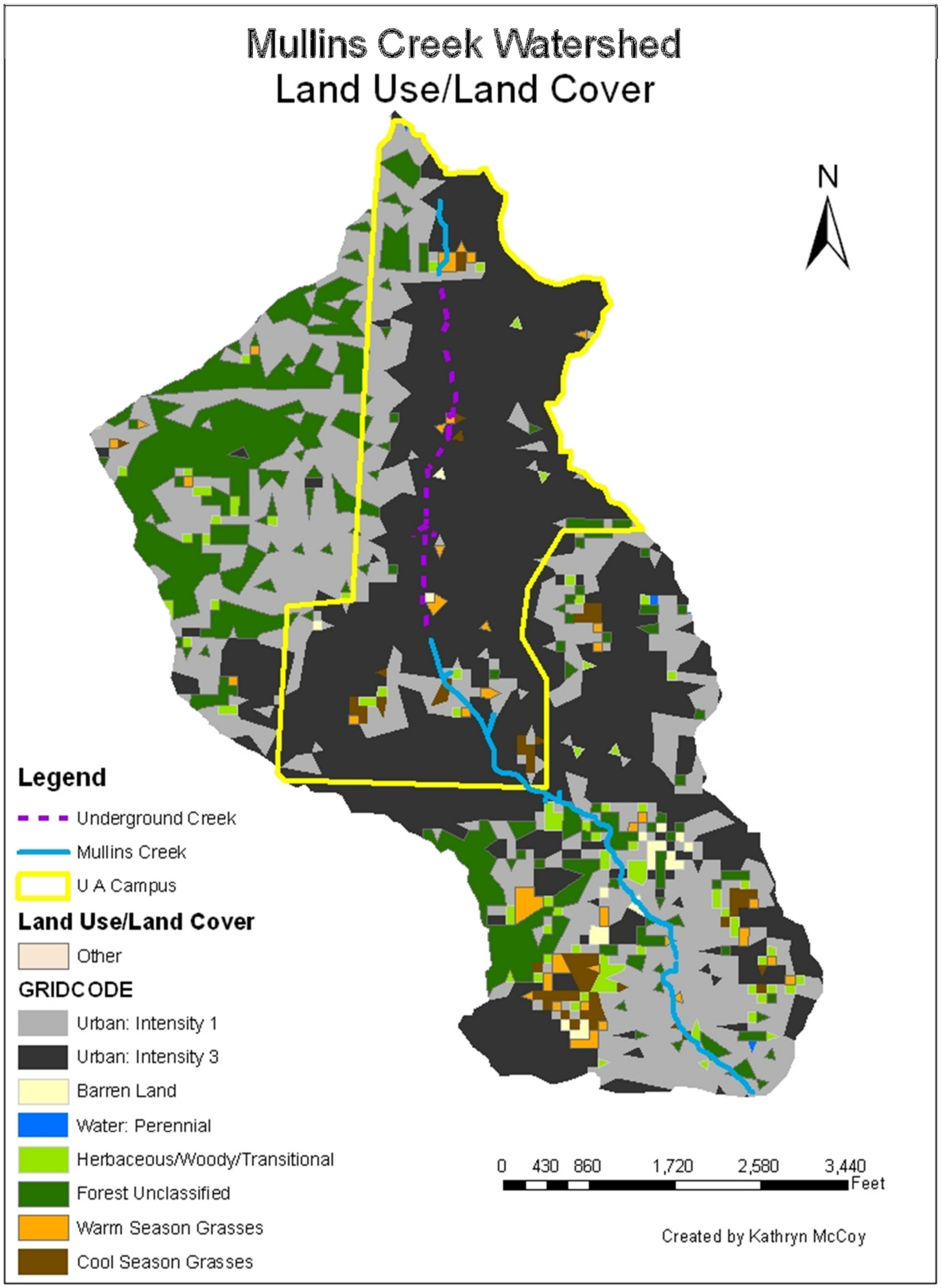

Figure 4. Current Land Use/Land Cover for the Mullins Creek Watershed

Table 2. Ecosystem Service Values for Mullins Creek Watershed, Present-Day

Land Use/ Land Cover		Urban: Intensity 1	Urban: Intensity 3	Barren Land	Water: Perennial	Herbaceous/ Woody/ Transitional	Forest Unclassified	Warm Season Grasses	Cool Season Grasses	
Constanza Biome		Urban	Urban	Desert	Lakes/Rivers	Grass/Rangeland	Forest	Grass/Rangeland	Grass/Rangeland	TOTALS
Area (m^2)		1047679	1500856	20124	1775	69541	487189	43406	49247	3219817
Area (hectare)		105	150	2	0	7	49	4	5	322
Ecosystem Services and Values (Constanza Method) ($ ha^{-1} yr^{-1})	Gas Regulation					7		7	7	21
	Climate Regulation					0	88	0	0	88
	Disturbance Regulation						2			2
	Water Regulation				5445	3	2	3	3	5456
	Water Supply				2117		3			2120
	Erosion Control					29	96	29	29	183
	Soil Formation					1	10	1	1	13
	Nutrient Cycling						361			361
	Waste Treatment				665	87	87	87	87	1013
	Pollination					25		25	25	75
	Biological Control					23	2	23	23	71
	Habitat									0
	Food Production				41	67	43	67	67	285
	Raw Material						138			138
	Genetics Resources					0	16	0	0	16
	Recreation				230	2	66	2	2	302
	Cultural						2			2
Total Value per ha ($ $ha^{-1}yr^{-1}$)		0	0	0	8498	244	916	244	244	10146
Total Value ($ yr^{-1})		0	0	0	1508	1697	44627	1059	1202	50092

2.3 Past Ecosystem Service Evaluation

The evaluation of present-day ecosystem services for Mullins Creek was conducted to quantify the services available in the current condition of the creek and its watershed. In order to increase the ecosystem service value for this area, land use changes could be made to the region. In order to determine a course of action, an evaluation of ecosystem services was performed for the area in a pre-developed condition. To perform this evaluation, the pre-developed condition of the area was estimated using historical information about the university. With the university being founded in 1871, information available dates back to this time. According to the Preservation Master Plan, the phase of development from 1875-1924 involved development in the area directly surrounding Old Main (Ruby Architects, Inc. et al., 2009). The assumption is therefore made that little to no development existed in the area surrounding Mullins Creek. With this assumption, the land use and land cover map created for present-day Mullins Creek was altered. LULC of Urban: Intensity 3, which includes most impervious urban areas such as parking lots and buildings, was assumed to be herbaceous areas for pre-development. Urban Intensity 1, urban areas which include pervious cover such as manicured lawns, was assumed to be forested area for pre-development. The site map was adjusted in ArcGIS to display these assumptions (Figure 5). The geometric areas exported to Excel were also adjusted, with the urban areas assumed as stated. The same method was used to classify the biome for each LULC as was used for the present-day ecosystem services. The service values for each biome and the total watershed in past conditions was calculated (Table 3).

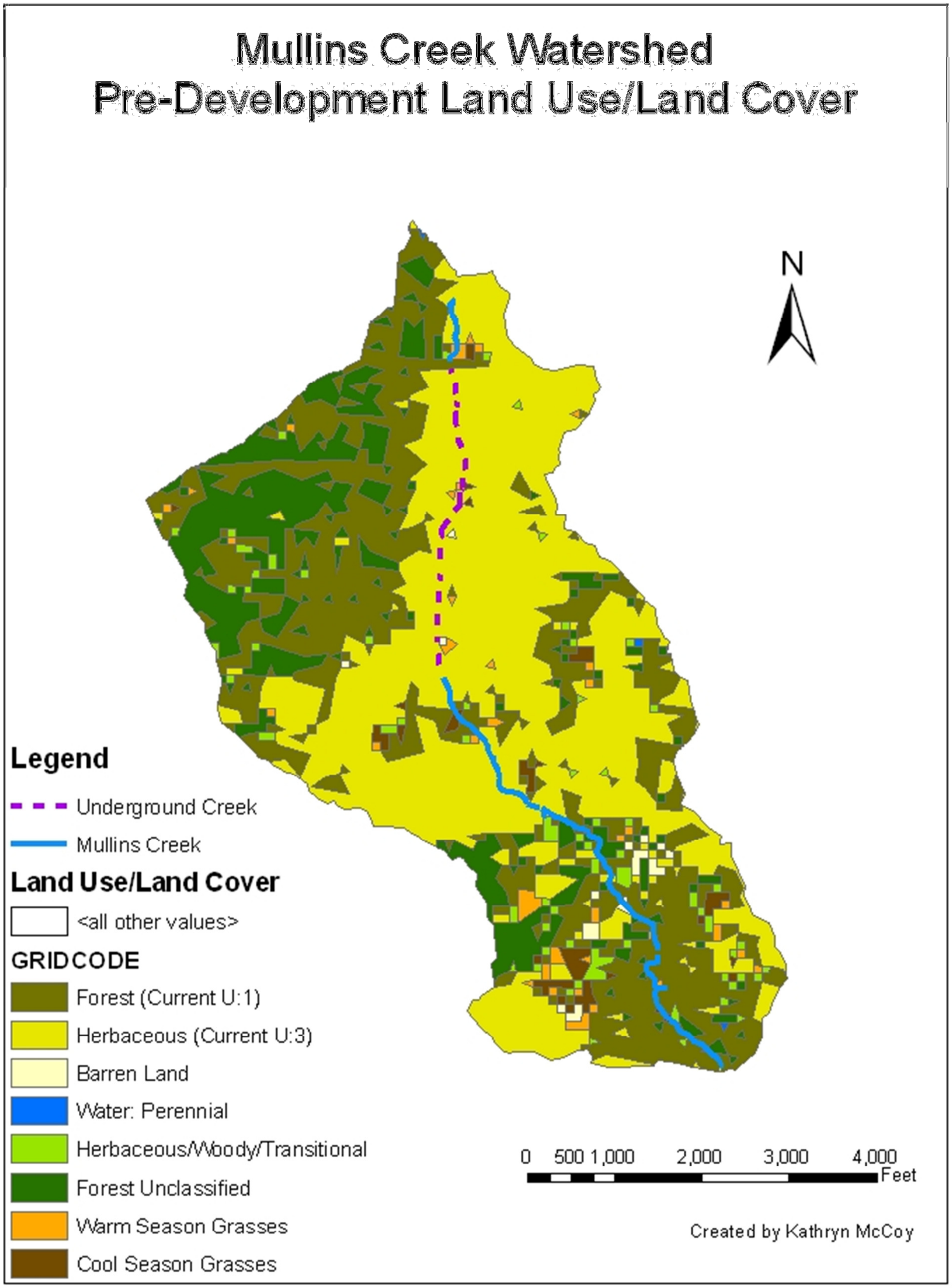

Figure 5. Pre-Development Land Use/Land Cover for Mullins Creek Watershed

Table 3. Land Use and Land Cover for Pre-Developed Mullins Creek Watershed

	Land Use/ Land Cover	Barren Land	Water: Perennial	Herbaceous/ Woody/ Transitional	Forest Unclassified	Warm Season Grasses	Cool Season Grasses	
	Constanza Biome	Desert	Lakes/Rivers	Grass/Rangeland	Forest	Grass/Rangeland	Grass/Rangeland	TOTALS
	Area (m^2)	20124	1775	1570396	1534868	43406	49247	3219817
	Area (hectare)	2	0	157	153	4	5	322
Ecosystem Services and Values (Constanza Method) ($ ha-1 yr-1)	Gas Regulation			7		7	7	21
	Climate Regulation			0	141	0	0	141
	Disturbance Regulation				2			2
	Water Regulation		5445	3	2	3	3	5456
	Water Supply		2117		3			2120
	Erosion Control			29	96	29	29	183
	Soil Formation			1	10	1	1	13
	Nutrient Cycling				361			361
	Waste Treatment		665	87	87	87	87	1013
	Pollination			25		25	25	75
	Biological Control			23	2	23	23	71
	Habitat							0
	Food Production		41	67	43	67	67	285
	Raw Material				138			138
	Genetics Resources			0	16	0	0	16
	Recreation		230	2	66	2	2	302
	Cultural				2			2
	Total Value per ha ($\$ ha^{-1} yr^{-1}$)	0	8498	244	969	244	244	10199
	Total Value ($\$ yr^{-1}$)	0	1508	38318	148729	1059	1202	190815

2.4 Suggestions for Ecosystem Services Improvements

In order to create a design for the watershed that would increase its ecosystem service value, the values for the present-day watershed and the pre-developed watershed were compared (Table 4).

Table 4. Comparison of ecosystem service values for present and past conditions

Land Use /Land Cover	Urban: Intensity 1	Urban: Intensity 3	Barren Land	Water: Perennial	Herbaceous/ Woody/ Transitional	Forest Unclassified	Warm Season Grasses	Cool Season Grasses	
Constanza Biome	Urban	Urban	Desert	Lakes/Rivers	Grass/ Rangeland	Forest	Grass/ Rangeland	Grass/ Rangeland	TOTALS ($ yr^{-1})
Present Condition	0	0	0	1508	1697	47209	1059	1202	52674
Past Condition	0	0	0	1508	38318	148729	1059	1202	190815

From this comparison, the present condition value was found to be much less than the pre-developed (past) condition.

The improvement design was generated by considering the “possible” condition of the watershed. The “possible” condition is the condition to which the watershed can be improved while maintaining necessary development structures. Improvements can be achieved by designing more serviceable land use and land cover conditions than currently exist. The design process began with identification of locations within the watershed where the land use and land cover could be altered. A visual comparison of the past and present watershed land use/land covers was created (Figure 6). From this comparison, the largest land use/land cover area change between the past and present watersheds was the decrease of forests and herbaceous land with the increase of urban development. Therefore, the area of concentration for land use improvements will be the urban land use areas (Urban: Intensity 1 and Urban: Intensity 3).

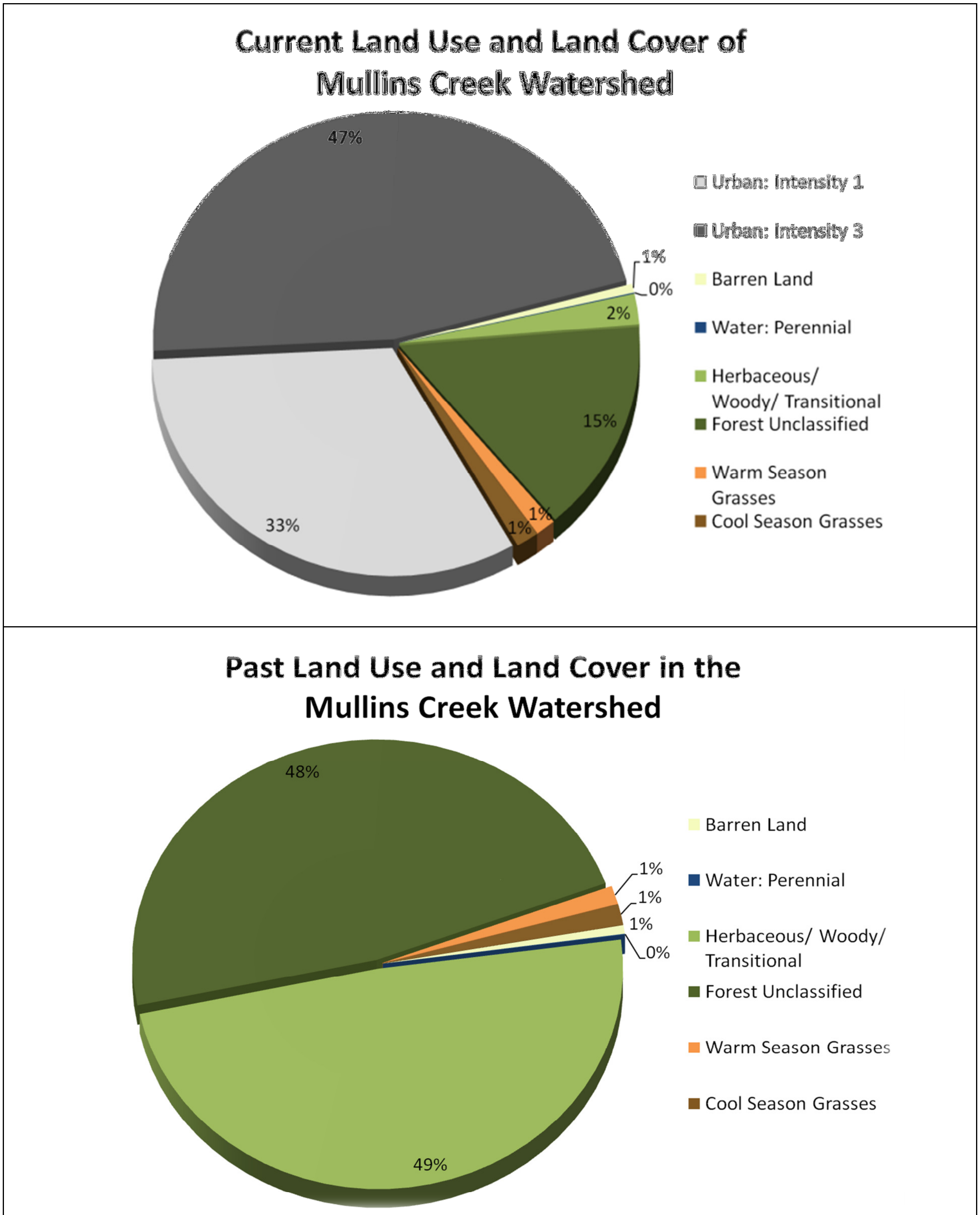

Figure 6. Comparison of Land Use/Land Covers in the Past and Present Watersheds

The Urban: Intensity 1 LULC consists of residential areas, where impervious and pervious cover are intermixed. Rooftops, driveways, roads, and sidewalks comprise the impervious area, while the pervious cover consists mainly of manicured lawns and gardens. The Urban: Intensity 3 LULC consists of larger impervious areas such as parking lots and building complexes. In order to provide more serving land use/land covers, the impervious components were redesigned while maintaining their functions, which are necessary for the function of urban civilization.

2.4.1 Rooftops

Conventional rooftops were converted to green roofs where applicable. Green roofs are not possible on all structures. Sloped roofs, which are common in residential areas, do not accommodate green roofs. However, many of the buildings on campus have flat roofs, which have the capability to house green roofs.

A green roof is a rooftop covered with vegetation (EPA, 2009). Research has demonstrated that green roofs have many advantages. Green roofs would increase the pervious area available to capture storm water. Precipitation can be captured by the green roof media, which includes vegetation and soil. While this small layer of vegetation will not provide all the services that a natural grassed area would provide, the green roof would still have the capacity to provide many ecosystem services. One service green roofs would supply is climate control. They can reduce the possibility of heat islands. A heat island can occur when an area has a large amount of "heat-absorbing" structures, which can increase ambient temperature to unsafe levels. Heat islands can be avoided by increasing the amount of vegetation in the area, which naturally absorbs heat.

Biodiversity can also be increased by implementing green roofs. Impervious areas with little to no vegetation have little prospect of providing habitat to small creatures, but green roofs have the ability to reestablish this habitat. Rooftops are generally inaccessible to humans and therefore would be relatively undisturbed. Research conducted on green roofs found that following the roofs' establishments, 18% of arachnids and 11% of beetles identified in the green roof habitat were either rare or endangered (Getter, 2006).

Another ecosystem service provided by green roofs is nutrient cycling. Plants and soil take in nutrients and pollutants that may be found in runoff. Also, plants are a vital part of the carbon cycle, which is essential to ecosystem function.

Green roof costs are greater than conventional roofs initially. However, green roofs have the potential for cost and energy savings due to the natural roof protection they provide. The cost of a green roof depends on the type of roof implemented and the vegetation type. An extensive roof, which consists of short-growing plants, is $8 to $20 per square foot. Intensive roofs, which are made of larger plants, can be $15 to $20 per square foot (GLWI, 2009). The cost of green roofs is outweighed by the life expectancy, which is approximately 40 years with significant maintenance required after about 20 years (Paladino, 2004).

2.4.2 Pervious Pavements

Conventional pavement materials, such as concrete and asphalt, are impervious and therefore create larger volumes of runoff which can carry parking lot and road chemicals such as oil and tar to streams. In contrast, pervious pavements have been found to provide the equivalent of many ecosystem services. Firstly, pervious pavements allow water to infiltrate, which reduces runoff volumes and assists in recharging groundwater. This is an essential part of the water regulation service provided by natural biomes. By allowing infiltration of stormwater to occur, pervious pavements also have the potential for high pollutant removal rates, which is a component of the waste treatment ecosystem service (EPA, 2004).

The heat island effect produced by many urban areas can also be reduced with pervious pavements. A heat island is a region of high temperatures created by the heat absorption of paved surfaces. The difference in temperature between urban and rural areas due to a heat island has been as large as 27°F in some locations (EPA, 2009). Pervious pavements are normally of lighter color than conventional pavements, which means they are more likely to reflect light rather than absorb it as heat. There is also less space to store heat in pervious pavements due to the void spaces. By reducing the heat island effect, pervious pavements are providing the climate regulation ecosystem service. Vegetation such as trees has the ability to grow more easily near pervious pavements because air and water can better reach the roots (Tennis et al., 2004). Increasing the amount of vegetation in an area, many services such as climate regulation, water regulation, nutrient cycling, refugia, and biological control are increased.

The cost of replacing conventional pavement with pervious pavement varies. Much of the cost would be directed toward removing the existing pavement. The actual installation cost of pervious pavement can be equal to or cheaper (up to 25%) than the conventional pavement "when all construction and drainage costs are taken into account" (CASQA, 2003). Other literature has suggested that the initial cost may be higher than conventional pavement, but pervious pavements have advantages that over time are money-saving. For example, the implementation of pervious pavements would decrease the need for large stormwater draining systems that are used with conventional systems to control runoff. The pricing of pervious pavement per area varies depending on the type of material used. The cost per square foot ranges from $0.50 to $4.00 (Toolbase, 2008). Life expectancy of pervious pavement is not yet quantifiable, but systems as old as 20 years have been found to be in good working condition (StormwaterPA, 2009).

2.4.3 "Possible" Ecosystem Services of Mullins Creek Watershed

The watershed was reviewed for urban land use sections that could be altered to house more serviceable land uses, such as green roofs and pervious pavements. The aerial view and LULC map for the current watershed were compared, and a "possible" map created (Figure 7). Large paved areas such as Lot 56 and Lot 44 ("The Pit") were altered to a pervious pavement land cover, which was related to the grass/rangeland biome at 50%. This was estimated in order to calculate the service value as the Constanza biome at 50% service. Buildings that have the potential to be converted to green roofs were also altered and related to the grass/rangeland biome at 75% service value. Using these assumptions, the possible watershed ecosystem service value was calculated (Table 5). A pie chart of land use percentages was also created (Figure 8).

Table 5. Possible Ecosystem Service Values for Mullins Creek Watershed

Land Use/ Land Cover		Urban: Intensity 1	Urban: Intensity 3	Barren Land	Water: Perennial	Herbaceous/ Woody/ Transitional	Forest Unclassified	Warm Season Grasses	Cool Season Grasses	Pervious Pavement	Green Roofs	
Constanza Biome		Urban	Urban	Desert	Lakes/ Rivers	Grass/ Rangeland	Forest	Grass/ Rangeland	Grass/ Rangeland	Grass/ Rangeland (50%)	Grass/ Rangeland (75%)	TOTALS
Area (m^2)		1030750	1268944	20030	1775	69484	485546	41902	47566	148080	109925	3224002
Area (hectare)		103	127	2	0	7	49	4	5	15	11	323
Ecosystem Services and Values (Constanza Method) ($ ha^{-1} yr^{-1})	Gas Regulation					7		7	7	4	5	30
	Climate Regulation					0	141	0	0	0	0	141
	Disturbance Regulation						2			0	0	2
	Water Regulation				5445	3	2	3	3	2	2	5460
	Water Supply				2117		3			0	0	2120
	Erosion Control					29	96	29	29	15	22	219
	Soil Formation					1	10	1	1	1	1	14
	Nutrient Cycling						361			0	0	361
	Waste Treatment				665	87	87	87	87	44	65	1122
	Pollination					25		25	25	13	19	106
	Biological Control					23	2	23	23	12	17	100
	Habitat									0	0	0
	Food Production				41	67	43	67	67	34	50	369
	Raw Material						138			0	0	138
	Genetics Resources					0	16	0	0	0	0	16
	Recreation				230	2	66	2	2	1	2	305
	Cultural						2			0	0	2
Total Value per ha ($ $ha^{-1}yr^{-1}$)		0	0	0	8498	244	969	244	244	122	183	10504
Total Value ($ yr^{-1})		0	0	0	1508	1695	47049	1022	1161	1830	2013	56279

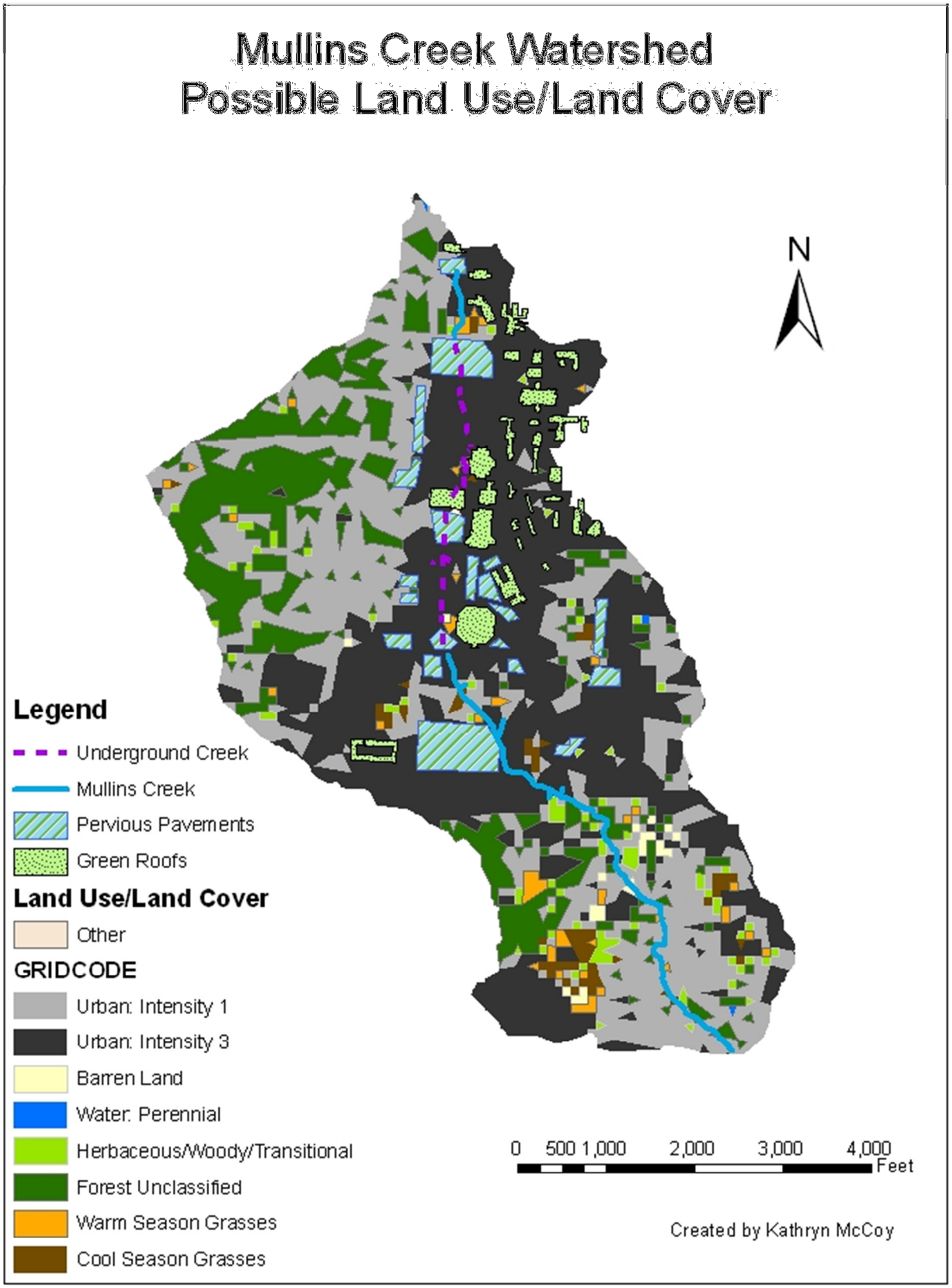

Figure 7. "Possible" Land Use/Land Cover of the Mullins Creek Watershed

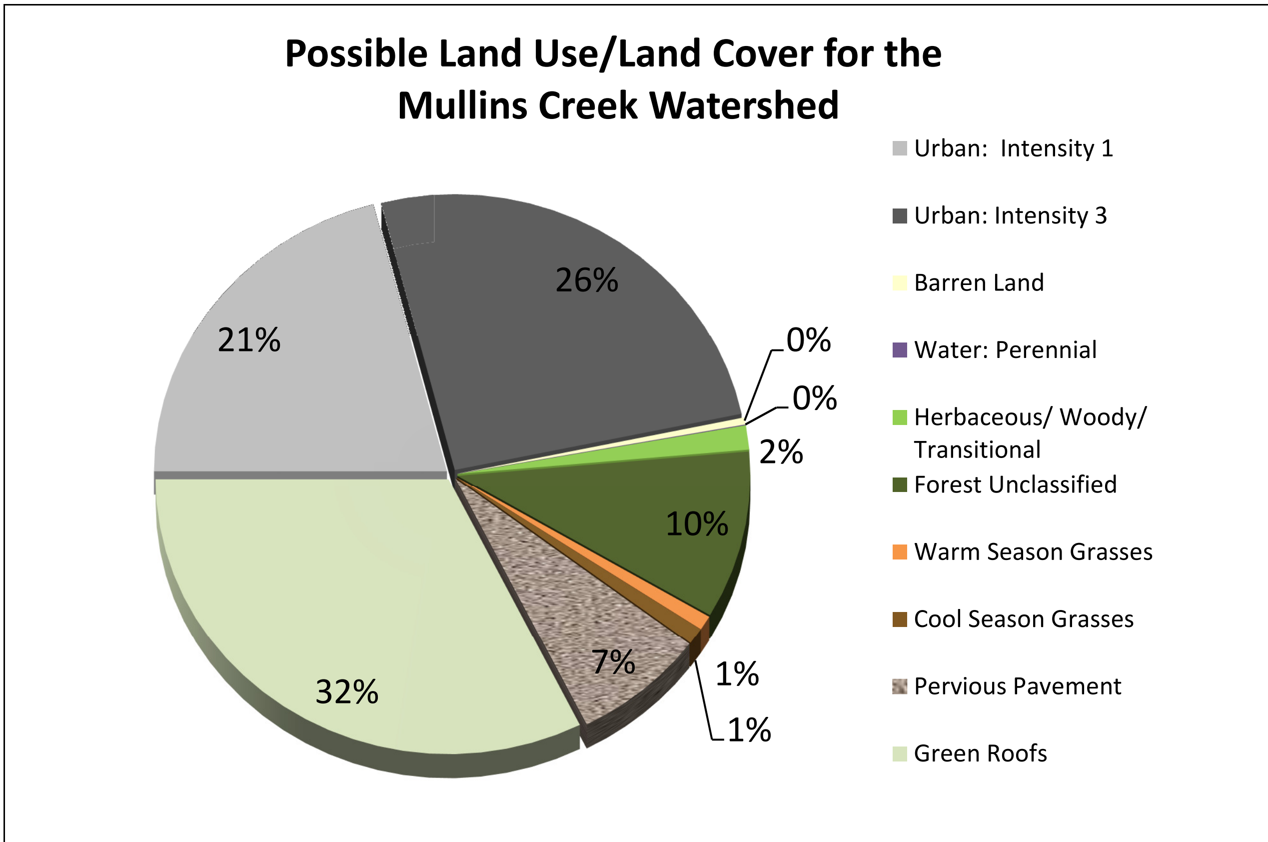

Figure 8. Possible Land Use/Land Cover for Mullins Creek Watershed

3. Results and Recommendations

The map of possible land use and land cover for the Mullins Creek Watershed depicts possible areas that could be altered without significant infrastructure modification. With the land use and land cover changes suggested, the percent gain in ecosystem services with the recommended design is 7% (See Table 6). Land uses such as forest and herbaceous/woody/ transitional decreased slightly in service value due to the placement of pervious pavements and green roofs. However, with the placements specified, the gain of service values increased because of the simultaneous decrease in urban land use. Urban: Intensity 1 decreased by 2% in land area, and Urban: Intensity 3 decreased by 17%.

Table 6. Comparison of Present and Possible Land Use/Land Cover and Ecosystem Services

Land Use/ Land Cover	Urban: Intensity 1	Urban: Intensity 3	Barren Land	Water: Perennial	Herbaceous/ Woody/ Transitional	Forest Unclassified	Warm Season Grasses	Cool Season Grasses	Pervious Pavement	Green Roofs	TOTAL
Constanza Biome	Urban	Urban	Desert	Lakes/Rivers	Grass/ Rangeland	Forest	Grass/ Rangeland	Grass/ Rangeland	Grass/ Rangeland (50%)	Grass/ Rangeland (75%)	
Present Area (ha)	105	150	2	0	7	49	4	5	0	0	322
Possible Area (ha)	103	127	2	0	7	49	4	5	15	11	323
Percent difference	-2	-17	0	0	0	0	0	0	200	200	
Total Present Value ($ yr^{-1})	0	0	0	1508	1697	47209	1059	1202	0	0	52674
Total Possible Value ($ yr^{-1})	0	0	0	1508	1695	47049	1022	1161	1830	2013	56279
Percent difference	0	0	0	0	0	0	-4	-3	200	200	7

A cost comparison of implementation versus ecosystem service gain was also conducted (Table 7). This comparison was done in order to demonstrate whether the implementation of new land use methods would provide any financial savings as well.

Table 7. Comparison of service value and implementation cost

	Green Roofs	Pervious Pavement
Cost ($/ft^2)	14	2
Life Expectancy (yr)	20	20
Area (ha)	11	15
Area (ft^2)	1,184,030	1,614,587
Ecosystem Service Value ($)	583,375	87,998
Cost of New Practice ($)	16,576,422	3,229,173
Net Profit ($)	-15,993,047	-3,141,175

The cost of implementing green roofs and pervious pavements is much greater than the service value gained from them over their expected life spans. However, the valuation of ecosystem services is not exact, but rather used for evaluation of the effect of land use change. Researchers have argued that placing a value on ecosystem services is "impossible or "unwise" due to the fact that the full impact of ecosystems is unknown (Costanza et al., 1997). Therefore, though the monetary value placed on ecosystem services for this study is much less than the known value of implementing the proposed design, the redesigning of developments should be considered in order to gain back services necessary for human survival.

Due to the evidence found through service value calculation in both the present and possible watershed for Mullins Creek, it is recommended that land use be altered in the locations specified using green roofs and pervious pavements in order to obtain an increase in total ecosystem service value.

There are other possible designs that could improve ecosystem service value of the watershed. In addition to green roofs and pervious pavement, other land use changes could be implemented. Drastic changes, such as major conversion of urban areas to herbaceous and forest areas, would provide a greater increase in service value. Other possible ecosystem alterations could involve stream restoration methods. Addition of riparian zones, which are vegetative strips along the stream bank, would increase vegetative cover, which provides many services. Pools and riffles could be incorporated into the stream as well. Riffles, which are stream areas of shallow depth and higher velocity, oxygenate the water and also naturally create pools above them. Pools provide habitat for fish and other wildlife. Stream bank stabilizers such as brush mattresses and fiber logs prevent erosion and therefore reduce sediment loads in the stream. The cost of stream restoration of an urban stream can range from approximately $100 to $300 per foot (NCEEP, 2004). With the surface stream in the Mullins Creek Watershed at about 7450 feet long and about 3000 feet of that stream on campus, the cost of stream restoration would be significantly large. Restoration on the campus stream alone would total approximately $600,000.

The stream is mostly the water: perennial LULC with herbaceous areas immediately surrounding it. Estimating that a stream LULC would comprise of 50% water: perennial and 50% herbaceous, a service value for a restored stream on campus was calculated (Table 8). With a stream restoration implemented, up to $25,102 of ecosystem services could be restored. As in the other studied LULC changes, the cost of implementation is greater than service value. The service value should again be considered a comparison tool and not an explicit monetary value. The addition of these methods would provide some land use change and increase the service value in the existing stream area.

Table 8. Ecosystem Service Value of Stream Restoration on Campus

Land Use/ Land Cover		Water: Perennial	Herbaceous/ Woody/ Transitional	
Constanza Biome		Lakes/Rivers	Grass/Rangeland	
Area (m^2)		28714	28714	
Area (hectare)		2.87	2.87	TOTALS
Ecosystem Services and Values (Constanza Method) ($ ha^{-1} yr^{-1})	Gas Regulation		7	7
	Climate Regulation		0	0
	Disturbance Regulation			0
	Water Regulation	5445	3	5448
	Water Supply	2117		2117
	Erosion Control		29	29
	Soil Formation		1	1
	Nutrient Cycling			0
	Waste Treatment	665	87	752
	Pollination		25	25
	Biological Control		23	23
	Habitat			0
	Food Production	41	67	108
	Raw Material			0
	Genetics Resources		0	0
	Recreation	230	2	232
	Cultural			0
Total Value per ha ($ $ha^{-1}yr^{-1}$)		8498	244	8742
Total Value ($ yr^{-1})		24401	701	25102

4. FINAL REMARKS

From the assessments performed on the Mullins Creek Watershed, it was found that the ecosystem service values available in the current watershed are much less than those in the watershed prior to urban development. The large percentage of urban land use and land cover in the watershed is the major reason for the loss of services since 1871, the year the university was founded. By altering some areas of the urban land use in the watershed by integrating green roofs and pervious pavements, some of the services that have been lost could be regained. Though the watershed can never be fully returned to the land use and land cover of pre-development, which was mainly forest and herbaceous land, the land use distribution of the watershed can be monitored in order to remain accountable for the level of services available in the present-day. The use of ecosystem service valuation is not to evaluate the monetary profit that would be gained, but to understand the service profit given by natural land uses. Though the Constanza Method is performed by placing a monetary value on ecosystem services, it is not meant to place an explicit value on these services. Rather, the system is used so that humans may be able to understand their relative value. By understanding ecosystem service values and what they represent, the community can better plan for future developments so that the level of service values is maintained or improved.

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