Sustainability Fee Project Report 2014-2015: Assessment of Water Quality and Soil Carbon Storage to Ensure Environmental Quality at GSU Campus

By

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The research project has two parts, first part involves analysis of campus surface water quality and the second part involves measurement of campus soil carbon storage. The storm water runoff from off-campus and on-campus sources has the potential to pollute the campus water bodies and the findings of our study shall recommend remedial strategies, which may help authorities to take necessary actions. The campus soil carbon distribution has been inventoried and the factors (land use, management) supporting soil C stocking have been identified and recommended to help authorities promote climate change mitigation and adaptation strategies on campus.

Part 1: Assessment of Water Quality at Georgia Southern University Campus

Study Details

To maintain the environmental quality of Georgia Southern campus, it is very important to ensure the maintenance of its surface water quality. GSU campus has approximately 125 acres of wetlands and 20 acres of lakes, ponds and creeks, which has the potential to sustain a wide range of flora and fauna supporting the urban green lifestyle on campus and hence, it is important to have an idea about the pollution levels in campus waters. To accomplish this objective, water was collected from fifty sites on campus (vide infra, Figure 1) using standard water collection techniques (Figure 2) and analyzed using Perkin Elmer Inductively Coupled Mass Spectrometry (ICP-MS) and Dionex ICS1100 Ion Chromatography (IC), monthly from August to November 2014 and from January to May 2015. The sample preparation involves a critical step of filtration using variety of filters to rid of micro-particles from the water samples (Figure 3). Further sample preparation for ICP-MS, involves acid digestion of the sample by using 2.5 M ultrapure nitric acid solution in water. IC measures the concentration of anions and ICP-MS detects and quantify the cations in the surface water samples. In this report, contaminant refers to any element or substance measured to be present in the water. Twenty-six contaminants were consistently measured over the collection period, and their potential sources will be the major topic of discussion for this report along with the possible remediation techniques. The contaminants measured were calcium, bromide, chloride, nitrate, nitrite, potassium, magnesium, sodium, silicon, sulfate, phosphate, aluminum, arsenic, boron, beryllium, cobalt, chromium, copper, fluoride, iron, manganese, molybdenum, nickel, lead, antimony, and zinc. The accepted values of the contaminants according to the Environmental Protection Agency (EPA) are listed in Table 1.

List of water collection sites on Georgia Southern University's campus:

1. Beautiful Eagle Creek flowing from S. Main St.
2. Beautiful Eagle Creek at first bend
3. Beautiful Eagle Creek at second bend
4. Beautiful Eagle Creek under bridge
5. Beautiful Eagle Creek flowing under Fair Rd.
6. Pond between baseball field and parking lot 12 – North
7. Pond between baseball field and parking lot 12 – South
8. Drainage ditch by sidewalk by practice baseball fields
9. Behind the Department of Psychology's psychology clinic
10. Pond by the College of Art and Theatre – West
11. Pond by the College of Art and Theatre – East
12. Lake Wells – North West
13. Lake Wells – South West
14. Lake Ruby – North West
15. Lake Ruby – West
16. Lake Ruby – East
17. Small drainage ditch by Dorman Drive near Math and Physics Bldg.
18. Small stream behind Parking and Transportation – North
19. Small stream behind Parking and Transportation – South
20. Behind Lakeside Café
21. By sidewalk between Forest Dr. Bldg. and Lakeside Café – East
22. By sidewalk between Forest Dr. Bldg. and Lakeside Café –West
23. Drainage ditch on opposite side of sidewalk from site 24
24. Drainage ditch near northern corner of the Engineering Bldg.
25. Between Lanier Dr. and Knight Dr. (Near University Villas)
26. University Villas Pond – NE corner
27. University Villas Pond – SE corner
28. University Villas Pond – SW corner
29. Intersection of Forest Dr. and Plant Dr. – SE corner
30. Intersection of Forest Dr. and Plant Dr. – SW corner
31. Forest Dr. opposite of site 32 – North side of street
32. Forest Dr. between parking lot 33 and Olympic Blvd. – South side of street
33. Eastern intersection of Forest Dr. and Nursing Bldg. spur – East
34. Opposite of intersection of Old Register Rd. and Forest Dr.
35. Intersection of Forest Dr. and Old Register Rd. – West
36. Drainage ditch on Akins Blvd. north of site 37
37. Drainage ditch on Akins Blvd. north of Recreational Activity Center (RAC) pond
38. Northern pond by RAC – North
39. Northern pond by RAC – South
40. Education Bldg. and Chemistry/Nursing Bldg. Pond – West
41. Education Bldg. and Chemistry/Nursing Bldg. Pond – East
42. Southern pond by RAC – North
43. Southern pond by RAC – West
44. Southern pond by RAC – South

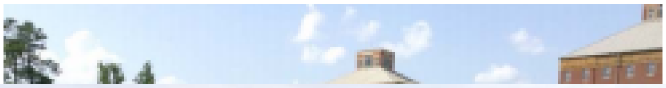
45. Drainage ditch by southern entrance to RAC
46. Intersection of Akins Blvd. and Malecki Dr.
47. Malecki Dr. on inside corner of shallow bend
48. Malecki Dr. on outside corner of sharp bend
49. Drainage ditch in wooded area on southern end of tailgating area
50. Drainage ditch in wooded area directly west of site 49

Figure 1: Few exemplary locations of water collection sites on campus

Site 5 – Beautiful Eagle Creek

Flowing into Fair Rd.

Sites 40 & 41 – The pond by the Education Bldg. and Chemistry/ Nursing Bldg.



Sites 42, 43, & 44 – The southern pond by the Recreational Activity Center (RAC)

Figure 2: Collecting water samples at GSU campus

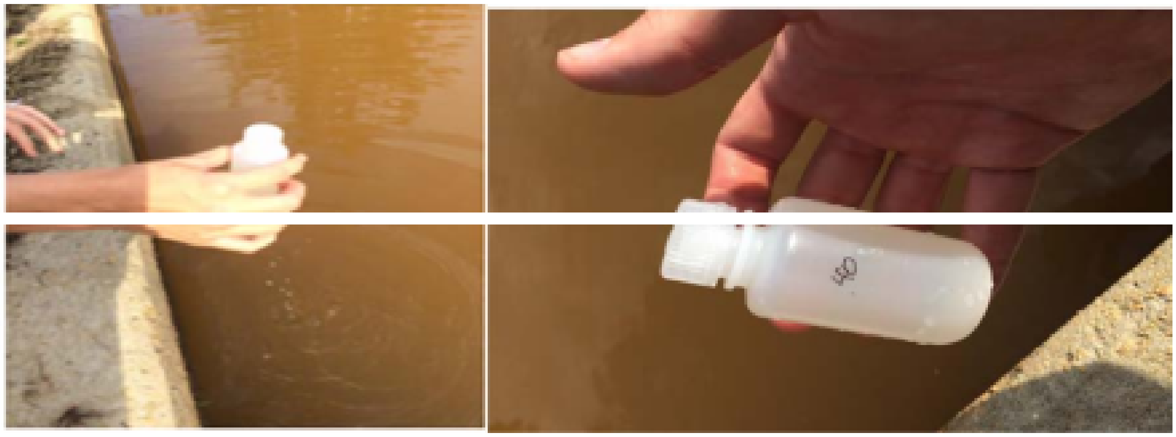


Figure 3: Filtering water samples through 1.0 µm, 0.45 µm, and 0.20µm filters to rid the sample of any macro particles.

Table 1: Concentration of elements in GSU campus water as compared to EPA approved standard guidelines

Pollutants/ Elements	Highest Concentration in GSU Campus Water (ppm)	EPA approved Concentration in Drinking Water (ppm)	EPA approved Concentration in Instream Water in Georgia (ppm)
Aluminum	0.3795	0.2	N/A
Antimony	0.1965	0.006	0.640
Arsenic	0.1087	0.010	0.340
Beryllium	0.0217	0.004	N/A
Boron	0.22	7.0 (DWEL)	N/A
Calcium	27.2676	N/A	N/A
Chromium (total)	0.1462	0.1	0.336
Cobalt	0.1196	N/A	N/A
Copper	0.2223	1.3	0.007
Iron	0.5958	0.3	N/A
Lead	0.2279	0.015	0.030
Magnesium	4.3238	N/A	N/A
Manganese	1.1605	0.05	N/A
Molybdenum	0.2626	0.2 (DWEL)	N/A
Nickel	0.1775	0.7 (DWEL)	0.260
Potassium	8.047247	N/A	N/A
Silicon	9.5046	N/A	N/A
Sodium	26.0286	N/A	N/A
Zinc	5.2841	5.0	0.065
Fluoride	3.3729	4.0	N/A
Chloride	130.3495	4.0	N/A
Nitrate	35.9719	10	N/A
Phosphate	1.85	N/A	N/A
Sulfate	35.0888	250	N/A
Sodium	32.56	N/A	N/A
Nitrite	11.1786	1.0	N/A
Bromide	11.3508	N/A	N/A

Possible Sources of Pollution

All water bodies on campus receive some amount of storm water runoff from roadways. These bodies either have water from parking lots purposefully routed to them through combinations of concrete culverts, concrete pipes, and ditches; or they collect storm water runoff from roadways as a result of natural and artificial local topography. Roadway runoff has been shown to possess aluminum, calcium, copper, iron, lead, magnesium, manganese, nickel, potassium, sodium, and zinc (Apul et al. 2010).

What is the source of these contaminants in roadway runoff? Not surprisingly, motor vehicles have been found to be a major contributor of various metals present in the air (Masri et al. 2015). These metals eventually settle to the ground, especially around roadways and surrounding soils where there is heavy traffic (Cordos et al. 2010). A brief overview of the various parts and substances of motor vehicles and their associated emissions follows.

Antifreeze has been noted by the EPA as a source of roadway runoff pollution (EPA 1995). Different antifreezes on the North American market contain varying amounts of multiple additives including silicate, borate, phosphate, and molybdate (EET Corp. 2011).

Used oil in cars is high in zinc, copper and lead, with typical amounts of 90 ppm Zn, 0.77 ppm Cu, and 0.27 ppm Pb (Davis et al. 2001). High amounts of zinc are in virgin oil for engine protection, while copper and lead seem to accumulate in the oil during use (Davis et al. 2001).

Brake linings are a source of zinc, copper, lead (Davis et al. 2001, Hjortenkrans et al. 2007) and antimony (Hjortenkrans et al. 2007). A study in Stockholm, Sweden calculated the metal emissions from brake linings to be 2400 kg/year of copper, 24 kg/year of lead, 360 kg/year of antimony, and 710 kg/year of zinc (Hjortenkrans et al. 2007).

Tires add several metals to the atmosphere. Typically 30% of a tire’s tread rubber is worn off during normal use (Wik and Dave 2009). Tire wear debris contains manganese, iron, cobalt, nickel, copper, and lead (Thorpe and Harrison 2008). The most common contaminate emitted by tires is zinc, with an estimated 10,000 to 11,000 metric tons having been released due to tire wear in the United States during 1999 (Councell et al. 2004).

Wheel weights are weights usually made of lead that are attached to vehicle wheels as balances (Aucott and Caldarelli 2012). These weights tend to fall off of wheels onto roadways and contribute lead to the environment (Frazer and van der Touw 2014) by being scraped by traffic (Root 2000). This process is sometimes referred to as “lead loading” (Frazer and van der Touw 2014, Root 2000).

Buildings have also been found to be a contributor to pollution of stormwater runoff. Roofing, such as galvanized metals, asphalt shingles, fiberglass, and wood can be a source of nitrogen, copper, lead, zinc, and iron (Clark et al. 2008). These roofing materials can also be a source of aluminum and manganese (Lye 2009).

Another potential source of contaminants are the chemicals used for landscaping and horticulture on campus. Fertilizers used on campus are of the ratings 10-10-10 and 16-4-8 and contribute to elevated nitrate, sulfate, chloride, fluoride levels (Hudak and Sanmanee 2003) as well as elevated phosphate (Qiu et al. 2014), nitrite, and potassium (Melo et al. 2012) levels in campus waters. The herbicides and pesticides used on campus are Atrazine 4L, GlyStar Plus (glyphosate), and MSM Turf (metsulfuron-methyl).

Atrazine is used as an herbicide and pesticide throughout the United States (Gilliom and Hamilton 2005). It is mainly used to control broadleaf and grassy weeds in agricultural crops (Fang et al. 2015). Atrazine is a toxic chemical that remains in soil and aquatic systems after its use due to slow degradation rates (Choi et al. 2013). In one study in Lake Oconee in Georgia, areas with the highest concentration of atrazine were those bordering residential areas and a golf course (Sherchan and Bachoon 2011). Those levels reached 1.20 ppb and 1.80 ppb, respectively, which is lower than the 3 ppb concentration considered by the EPA to be harmful. A step in atrazine degradation is dechlorination, which is most likely what is leading to high levels of chloride in some areas of water on campus (Kim et al. 2007).

Glyphosate is a broad-spectrum herbicide and is best known as the active ingredient in Roundup (Borggaard and Gimsing 2008). It is used extensively in both agricultural and urban areas (Coupe et al. 2012). It is prevalent in urban areas because it is highly efficient and is considered harmless (Hanke et al. 2010), though toxicity problems have been indicated (Borggaard and Gimsing 2008). Glyphosate has high sorption ability, so is thought to have low mobility in soils and not reach water sources through leaching or runoff (Daouk et al. 2013). In one study of glyphosate runoff in agricultural fields, the agricultural loss rate was 0.1% (Siimes et al. 2006). In another study which focused on runoff from agricultural fields and urban areas combined, the loss rate was 2.2% (Hanke et al. 2010). A proposed reasoning for the increase of runoff of glyphosate in urban areas is an increase of copper in the soils of urban areas, which contributes to the release of glyphosate from the soil (Daouk et al. 2013). Glyphosate is completely degraded to water, carbon dioxide, and phosphate, which could be a source of phosphate on campus (Forlani et al. 1999).

Metsulfuron-methyl is a sulfonylurea herbicide used to control grasses and broadleaf weeds usually in cereal crops (Gonzalez Matute et al. 2012). It works by interfering with plant cell growth (Singh and Singh 2012). Sulfonylurea herbicides are cheap (Gonzalez Matute et al. 2012) and work well in small applications of 2 to 75 grams per hectare (He et al. 2007), making them economical. While atrazine and glyphosate have stable time frames for half-lives, metsulfuron

methyl has no stable degradation rate (Wang et al. 2011), making its longevity in the environment, including surface waters, hard to assess. Trace amount of bromide may come from organobromane

compounds usually present in fertilizers (Neal et al. 2007) and from deicing agents as in road salts (Corsi et al. 2010).

A potential main source for calcium, sodium, chloride, magnesium, potassium, and sulfate is concrete. In one study, water from urban streams that had been transported by concrete infrastructure was compared to water from rural streams that had not been transported by concrete infrastructure. It showed an average increase of over 500% in concentrations of calcium, an average increase of nearly 100 % in concentrations of sodium and chloride, and an average increase of over 100% in concentrations of potassium, with high average increases also found in magnesium and sulfate (Wright et al. 2011). Concrete pipe is used extensively throughout campus as culverts and storm drains. The high levels of these contaminants are likely associated with concrete use.

Calcium levels varied widely across campus, with 3.1008 ppm and 27.2676 ppm being the ultimate low and high across the testing period. The EPA does not regulate the amount of calcium in water, and thus does not recommend any maximum amount. Calcium occurs naturally but also is used in cement, concrete, bone meal (as fertilizer), and in different forms as flocculants in waste water. Any of these sources could have contributed to the levels of calcium across campus. Concentrations seem highest along roadways and in drainage locations for parking lots.

Potassium is another element that is not regulated by the EPA. It can be used in fertilizers, synthetic rubber, and as a treatment for wastewater. Its levels vary much less across campus than calcium, but it follows the same pattern as calcium, with highest concentrations along roadways and in drainage locations for parking lots.

Sodium, also not regulated by the EPA, varies greatly across campus with a recorded low of 0.9616 ppm and high of 26.0286 ppm. Its levels rise in drainage locations for parking lots, with its highest levels being in the RAC ponds. This makes sense in terms of earlier stated nonpoint pollution sources since sodium levels are heightened near roadways and concrete infrastructure, both of which surround the RAC ponds.

Aluminum is a familiar metal. Our cans, engines, car bodies, and even synthetic rubber is made from it. The highest level of aluminum recorded in campus water was 0.3795 ppm. It was from a location on Beautiful Eagle Creek that is filled with grasses meant to catch contaminants from upstream. These grasses are doing their job. The EPA recommends a maximum of 0.2 ppm of aluminum for safe drinking water, and most locations fell well below this mark.

Arsenic is also a familiar element, and the EPA recommends no arsenic in drinking water, but enforces a maximum of 0.010 ppm. Our campus goes well above that limit, with our highest level of measured arsenic being 0.1087 ppm with little variance in amounts among the different locations. Many of arsenic's uses have been replaced with methods safer to humans, but a few still remain. Nitarsone is the last remaining of many forms of arsenic used in poultry production. It is to be removed from the market at the end of 2015. Arsenic is alloyed with lead in car batteries and with copper and zinc in a strong brass alloy. It is also an ingredient in heartworm medication for dogs. Chromated copper arsenate (CCA) is a combination of chromium, copper, and arsenic used as a wood preservative. It was banned from use in the United States in 2003, but structures already in place were allowed to remain. A recent study from the University of Florida found that when wet, CCA treated wood can leach arsenic much higher than the EPA enforceable limit, which can contaminate water and soil sources (Khan et al. 2006).

Beryllium levels are stable around campus, with a low of 0.215 ppm and a high of 0.0217 ppm. The EPA enforces a maximum of 0.004 ppm for drinking water. We go well above that limit. A popular application for beryllium is beryllium copper. It is used in a variety of musical instruments, wires, welding supplies, and car parts.

Cobalt is also used in beryllium copper. It may occur naturally in water, but usually occurs in the environment in association with other metals that it tends to be alloyed with, such as copper, manganese, nickel, and arsenic. There is no EPA recommendation for cobalt levels, but average drinking water contains 0.002 ppm. On campus, we have levels up to 0.1196 ppm, and levels stay within a very small range across campus.

Iron is a metal applied in many fields, including automobiles, pharmaceuticals, water, and as pesticides and fertilizers. Iron levels reach a maximum of 0.5958 ppm on campus, though the EPA safe drinking water recommendation is 0.3 ppm. The highest levels of iron are seen in water bodies that are small and mostly stagnant, not necessarily by major parking lots, but with close access to roads.

Manganese levels are high on campus. The EPA recommends levels of 0.05 ppm, but only because of the staining properties of manganese. According to the EPA, health risks do not become a concern until levels reach 0.5 ppm. The highest level on campus is 0.3147, which is triple the amount of most sites on campus. Manganese is found naturally with iron, but is used industrially as an additive to iron, steel, and aluminum. Its most practical use as it relates to campus water levels is probably its use as an additive in unleaded gasoline. In fact, manganese levels at main drainage locations for parking lots on campus are at least double the normal levels on campus.

Lead is commonly used in construction and automobiles. Over half of the lead produced in the United States is used in automobiles, mostly in the car battery as electrodes. There is a constant level of lead across campus water bodies, with no significant increase around any particular area of campus or type of water body. The EPA enforces a maximum of 0.015 ppm lead in drinking water. Campus levels are consistently around 0.2120 ppm.

Antimony is a metal mostly used in flame retardants and lead-acid batteries (such as car batteries). The EPA maximum allowable amount for drinking water is 0.006 ppm. The highest concentration on campus was 0.1965 ppm at the source of Beautiful Eagle creek. The lowest concentration on campus was 0.1662 ppm.

Zinc is used in a variety of industries, from brass to vitamins to tires. The highest recorded level of zinc in this study was 5.2841 ppm, which was an outlier. The EPA safe drinking water recommendation is 5 ppm of zinc. The major areas for zinc contamination were the main drainage areas of major parking lots. Zinc can be released into the environment by wear of tires. In the United States in 1999, approximately 10,000 to 11,000 metric tons of zinc were released by tire wear (Councell et al. 2004). That is a significant portion, and most likely the cause of zinc contamination on campus.

Analyses and Remediation

The average concentration of elements and particulates over the period of a year (2014- 2015) is shown in the Figures 4 and 5. The areas of the highest levels of contamination are consistently the RAC ponds (the destination of RAC parking lot run off), the drainage ditch near Old Register Road (the destination of run off from a parking lot uphill on Forest Drive), and Lake Ruby (the destination of run off from the parking lot by the CAT). While all collection sites on campus are collectors of roadway runoff, these three areas also collect water from three major parking lots on campus. These parking lots host hundreds of motor vehicles daily, which means vast amounts of oil and antifreeze is being leaked and a higher concentration of vehicle emissions from gas exhaust and tire/break wear exists. Other areas also have a buffer of grasses between the roadways and the water collection sites, whereas the water in the areas of highest contaminant concentrations have no grass buffers, as the water is instead navigated by concrete pipes or flows over asphalt.

Water sources that are tested downstream from these areas, when available, always have significantly lower levels of contaminants because they have been filtered by well-managed grasses on campus. To prevent the run off from entering their initial target bodies of water, we could replicate the grass strategy by planting grasses at the edges of water where we know the run off is entering, instead of keeping it well mowed. This will allow for the contaminants to be captured in the grass and for these most contaminated bodies of water to become cleaner. If campus prefers to keep the grounds trimmed, they may choose to install permeable pavement systems in the parking lots generating the highest contamination levels. These systems are made of porous asphalt, pervious concrete, etc. and work by allowing storm-water runoff to drain through them. The water is then filtered by subsurface layers. This has been proven multiple times to be an effective method of removing oils and heavy metals from runoff and re-entry into the environment (Scholz 2013; Welker et al. 2013; Zhao and Zhao 2014).

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1 3 5 7 9 11 13 15 17 19 21
23 25 27 29 31 33 35 37 39
41 43 45 47 49 **Water
Collection Sites**

NO2 Cl

F

PO4 SO4 NO3 Br

Figure 4. The average concentration of anion particulates present in campus water over the period of 2014-2015

Concentration (ppm)

2

Sb
1.8

Pb
1.6

Ni
1.4

Mo
1.2

Mn
1

Fe
0.8

Cu
0.6

Cr

0.4

B

1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49

Co

0.2

As

Water Collection Sites

Be

0

Figure 5A

0

50

Mg
20

K

Ca

40
10

Zn

Si
0
30
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
37 39 41 43 45 47 49 **Water Collection Sites**

Na

Figure 5B

Figure 5. The average concentration of elements present in campus water over the period of 2014- 2015.

Part 2: Development of Soil Carbon Inventory of Georgia Southern University Campus: Understanding the Climate Change Mitigation Potential

The southeastern coastal plain (SCP) region of the United States, located between the Gulf of Mexico and the Atlantic Ocean represents a very unique subtropical eco-region with diverse flora, fauna and agro-climatic conditions (USGS 2014). The economy of SCP is heavily dependent on timber, tourism, fisheries, pulp and paper production and agriculture, which in turn relies on its forest plantations, natural resources, soil quality and 29,000 miles of coastline (EPA 2013). These resources are commonly threatened by the effects of climate change, and SCP is no exception. Climate change is an environmental challenge that can be detrimental to the ecology and economy of SCP (IPCC 2014). The 100-year liner trend (1906-2005) is an increase of [0.56

to 0.92] °C in global surface temperature (IPCC 2007). The linear warming trend over the 50 years from 1956 to 2005 (0.13 [0.10 to 0.16] °C per decade) is nearly twice that for the 100 years from 1906 to 2005 (IPCC 2007). Climate models also suggest that the Southeastern coastline will likely experience stronger hurricanes and sea level rise, which could present problems for coastal communities and ecosystems (EPA 2013). Global average sea level rose at an average rate of 1.8 [1.3 to 2.3] mm per year over 1961 to 2003 and at an average rate of about 3.1 [2.4 to 3.8] mm per year from 1993 to 2003 (IPCC 2007). Sequestration of atmospheric carbon into soil has been recognized as a major strategy to mitigate climate change (IPCC 2007). The potential of a region to store carbon in soil depends primarily on its land-use pattern. Including central and northern parts of Florida and southeastern Georgia, SCP covers approximately 143,843 km^2, (USGS 2014), which has a great potential for stocking carbon in soil. Pine and mixed hardwood forests covered much of the ecoregion traditionally (USGS 2014). The native longleaf pine (*Pinus palustris*) was the dominant tree species; however, its current extent has been reduced by as much as 98 percent (Wear and Greis, 2002). Forests have been cleared for lumber and converted to pine plantations that favor the faster growing slash (*Pinus elliotii*) and loblolly pine (*Pinus taeda*) (USGS 2014). Longleaf pine and other forests have also been converted to cropland, pasture, mining, and urban uses (USGS, 2014). The loss of traditionally forested areas has a negative impact for overall soil carbon sequestration by plants within the ecoregion.

In this study we have measured the soil carbon storage of capacity of Georgia Southern University campus in Statesboro, GA, located well within the SCP region. The initiative of making a campus soil carbon inventory or measuring the climate change mitigation resilience potential is not very common US for universities. Georgia Southern University (GSU) aims to be a great advocate of green-initiatives and sustainable practices. In the case of climate change, GSU must ensure that proper initiatives are taken for climate change mitigation management. With a large campus, GSU has great potential to store carbon in its soil and become a carbon sink. Under anthropogenic influence, carbon stocking in soil depends primarily on the land-use pattern, followed by landscape management practices such as fertilizer/compost application, mulching, soil tiling, pruning/harvesting, and removal/deposition of biomass (Saha, 2009).

Study Location

The study took place on Georgia Southern University campus located in Statesboro, GA, 32.4194° N, 81.7767° W, which lies well within the SCP region. GSU campus was divided in five land-use categories; 1) unmanaged forest (UF), 2) managed forest (MF), 3) lawn and garden (LG), 4) roadside tree plantings (RT), and 5) athletic fields (AF). The unmanaged forest category had a high plant species diversity followed by the managed forest land-use category. However, unlike UF, MF category is affected by management techniques such as, prescribed burning, removal of leaf litter, and walking trail management. The lawn and garden category had low plant species diversity, containing plants renowned for their aesthetic value. The roadside tree planting land-use category also has low plant species diversity containing tree, bush, and grass species. Finally, the athletic field land-use category has the lowest plant species diversity, containing only grass species. Table 1 below highlights the major plant species included in each land-use.

Table 1. Major plant varieties at GSU campus by land-use

Unmanaged and Managed Forest

Common name	Scientific name
Azalea	*(Rhododendron spp.)*
Black tupelo	*(Nyssa sylvatica)*
Dogwood	*(Cornus florida)*

Live oak *(Quercus virginiana)*

Longleaf pine *(Pinus palustris)*

Hydrangea *(Hydrangea quercifolia)*

Privet *(Liguestrum japonicum)*

Red bud *(Cercis canadensis)*

Red maple *(Acer rubrum)*

Slash pine *(Pinus elliotii)*

Southern magnolia *(Magnolia grandiflora)*

Water oak *(Quercus nigra)*

Wax myrtle *(Myrica cerifera)*

Lawn and Garden

Canna lily (*Canna spp.)*

Cypress (*Cupressus spp.)*

Roses (*Rosa spp.)*

Live oak (*Quercus virginiana*)

River birch (*Betula nigra*)

Bermudagrass (*Cynodon dactylon*)

Centipede grass *(Eremochloa ophiuroides)*

Roadside Tree Plantings
Crape myrtle (*Lagerstroemia indica*)

Live oak (*Quercus virginiana*)

Loblolly pine (*Pinus taeda*)

Bermudagrass (*Cynodon dactylon*)

Centipede grass (*Eremochloa ophiuroides*)

Atheletic Fields

Bermuda grass (Tifway 419) (*Cynodon dactylon*)

Soil Sampling and Analyses

Each land-use category was sectioned off and then divided in a grid fashion using satellite maps. 50 sampling points were chosen per land-use and soil samples were collected from two depth classes, 0 – 20 cm and 20 – 50 cm using steel augers and mallets, and plastic bags to avoid carbon contamination. Total number of sampling points were 250 from five land-use categories and total number of samples were 500 (two depth class per sampling point).

Soil samples were then dried in an Isotemp Oven at 72°C for 48 - 72 hours. After the samples were sufficiently dried they were prepared for further analysis. The samples were prepared by individually packing 30 g of 2 mm sieved soil into scintillation vials with ceramic beads required for grinding. The samples were then placed in a Ball Mill Grinder for 3 minutes to produce a fine powder required for soil carbon analysis. The carbon content of soil was analyzed in a Flash 2000 Combustion NC Soil Analyzer to obtain a carbon concentration value. Bulk density values were achieved by digging 1 m x1 m x1 m pits in each land-use category. Sample cores (196 cm^3) were inserted horizontally into the wall of each pit at the center of each depth class. One bulk density core was taken at 0-20 cm and another at 20-50 cm for each land-use. Total soil carbon was calculated as using the formula:

Total Soil Carbon = C concentration (%) x BD x Depth
Where, C concentration (%) = percent concentration of C in soil samples, BD = Bulk density (g/cm^3), Depth = Depth of soil sampling point (cm)

Data was analyzed using JMP Pro Statistical Software, where statistical significance was assessed through a one-way analysis of means/ANOVA, where a $p<0.5$ indicated a significant difference. Comparison of means was conducted by way of Tukey-Kramer HSD.

Results and Discussion

To assess the climate change mitigation potential of Georgia Southern University campus we considered the soil carbon storage data as an indicator. Due to the lack of time sequenced data expanding over long time intervals, the current C stock values for each land-use area will be most representative of the effects of land-use. When examining C stock potential the C concentration in each soil sample is combined with bulk density for the land-use area as a whole to provide a total soil carbon value.

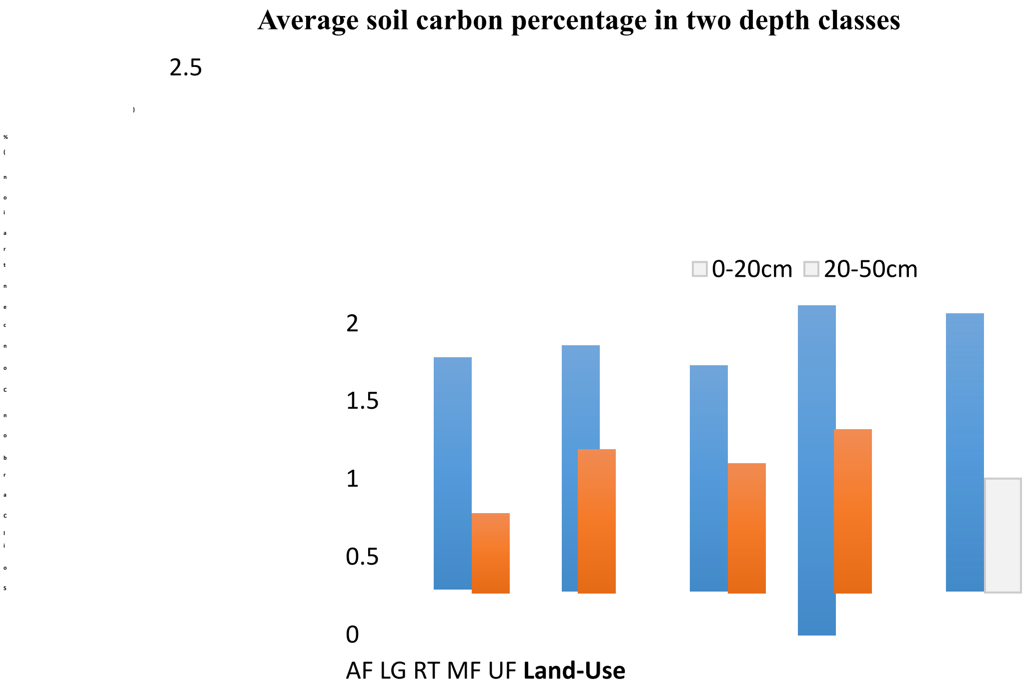

Figure 1. Average soil carbon percentage in two depth classes.

Figure 1 shows the soil C concentration among all land–uses at depths of 0-20 cm and 20-50 cm. The MF has the highest concentration of soil C in the upper 0-20 cm depth class at 2.148 %. The UF forest falls at 1.810 % (not significantly different) in the upper depth class. The MF category leads in the lower 20-50 cm depth class, with a value of 1.061 %. In both the upper and lower depth classes, the forested land-use areas show the highest concentrations of soil C, with the exception of the lower depth class in the UF category. In the upper 0-20 cm depth class, the RT and MF land-use area are significantly different. In the lower 20-50 cm depth class, the AF and MF land-use areas are significantly different.

In Figure 2 the total soil carbon in two depth classes has been presented. UF and MF are significantly different than the RT and AF land-use areas among the 0-20 cm depth class. In the lower 20-50 depth class the MF category is significantly different than the AF, RT, and UF land use areas. The forested areas remain the highest in soil C volume, with the exception of the lower 20-50 cm depth class in the UF land-use.

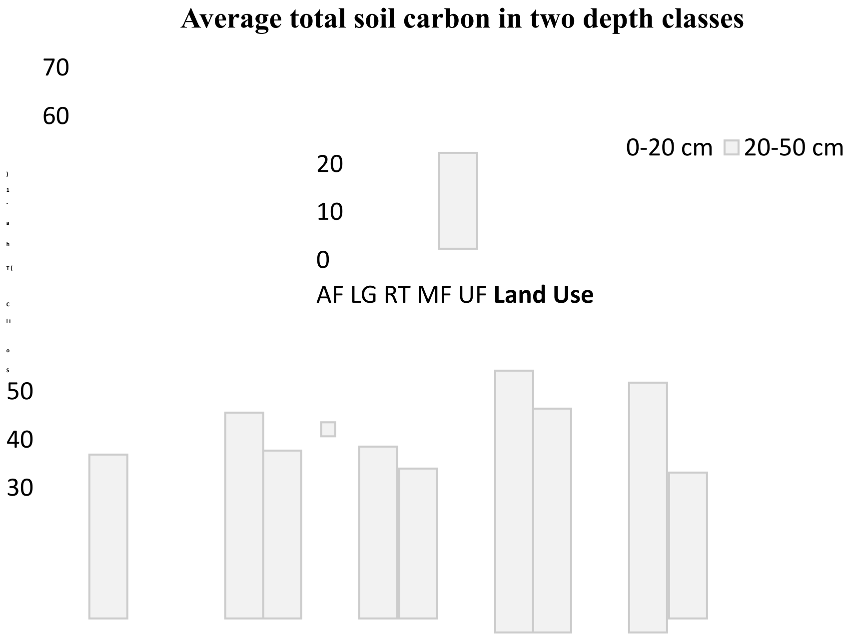
Average total soil carbon in two depth classes

Figure 2. Average total soil carbon in two depth classes

The percentage and total amount of carbon is higher in upper soil class (0 -20 cm) than the lower depth class (20 – 50 cm). This is because of the higher volume and network of roots in the upper class that led to greater accumulation of carbon. Forests (Unmanaged and managed) had higher concentration and amount of carbon compared to other three land-use systems. This can be attributed to presence of greater number of trees in the forest systems. More trees result higher volume of roots and leaf litter, which contribute to soil organic carbon formation. Total carbon (0 – 50 cm) under all five land-use systems has been shown in fig. 3. The forested areas remain the highest in soil carbon volume. In this graph, the MF land-use area is statistically different than the RT and AF categories. The UF is statistically different from the AF land-use.

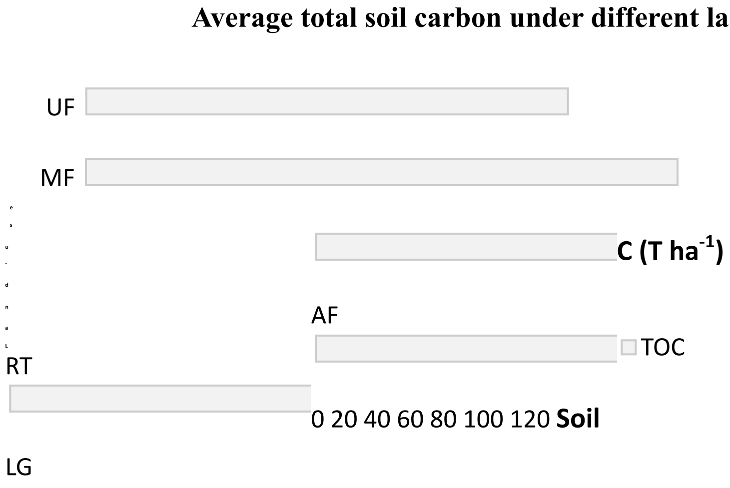
Average total soil carbon under different land-use

Figure 3. Average total soil carbon under different land-use

Again the higher carbon amount in forested areas is attributed to presence of more trees compared to lawn & garden, roadside and athletic fields. The lowest amount of carbon was found in the athletic fields and it is primarily because there are no trees and only turfgrass is present, which has lesser root volume and leaf litter than trees.

Important Note: *Although 500 soil samples were collected, due to technical (software) malfunction of the TN/TC Analyzer, a portion of samples could not be analyzed properly. The results provided are based on the samples that were properly analyzed and do not include that* *small portion of the improperly analyzed (unanalyzed) samples. The instrument is being fixed by the external technician. Once fixed, that small portion of soil samples will be reanalyzed and the dataset and results will be updated. The total amounts of soil carbon under different category might change to some extent from what is presented here, however, we believe that the trends in categorical differences for soil carbon amount will remain the same.*

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