Global Warming and Vegetation Types

Introduction

Could there be a link between what vegetation types people chose for land cover and global warming (GW)? Do decisions made regarding what vegetation types to plant have an effect on GW? What vegetation types would be preferable from a perspective of effecting GW? Though there are other possibly more significant factors contributing to GW, this paper focuses on the link between land cover vegetation and GW and how this applies to sustainable design principles. Part I of this paper illuminates possible answers to the above questions. Part II reviews the author's parents' property and analyzes the vegetation types in regards to GW. Part III of this paper attempts to develop a list of design guidelines for selecting vegetation types from strictly a GW issue perspective.

Part I

GW is a theory about how increases in atmospheric concentrations of greenhouse gases due to human activity are causing global temperatures to rise. Human activities, such as the burning of fossil fuels and deforestation for agricultural purposes, release greenhouse gases into the atmosphere (Oren 2001). In fact, according to one estimate, atmospheric concentrations of carbon dioxide have increased 31% since 1750 (Lal 2004). Humans burn fossil fuels when driving gasoline engine cars and creating electricity at coal-powered plants. When fossil fuels are burned, greenhouse gases such as carbon dioxide and methane are often released into the atmosphere. Table 1 displays changes in atmospheric concentration of greenhouse gases since 1750, generally when the industrial revolution began (IPCC 2001). Chemicals are categorized as greenhouse gases due to their property of retaining solar energy on earth. Greenhouse gases are a reason why the earth has habitable temperatures and are necessary for life on earth to exist. In other words, if the earth's atmosphere did not retain at least some solar energy, it might possibly be too frigid for life to exist on earth. However, the theory goes that anthropogenic concentration increase in atmospheric greenhouse gases is causing the near earth-surface average temperature to rise and even a small increase in the average global temperature could have significant detrimental effects, including changes in glacier retreat/rising sea level, agricultural yields, and species extinctions (Watson 2000).

Table 1: Increases in Greenhouse Gases since 1750

gas	present concentration	percent increase since 1750
carbon dioxide	379 ppm	31%
methane	1,745 ppb	151%
nitrous oxide	314 ppb	17%
chloroflourocarbons	268 ppt	--

Several greenhouse gases are given off by the combustion of carbon-based compounds (fossil fuels). Once released into the atmosphere, a removal mechanism for carbon compounds is plant respiration. Plants uptake of carbon dioxide and through the process of photosynthesis convert carbon dioxide to cellular carbon compounds. Carbon compounds in living matter eventually end up in the soil. This process is part of earth's carbon cycle.

Certain land cover vegetation types retain more carbon than other land cover vegetation. Carbon is retained in both the plant matter and the dead organic matter in the soil. A metric for measuring the amount of carbon retained by vegetation land cover is carbon sequestration. The author performed a literature search for vegetation types and carbon sequestration. The author was hoping to find average carbon sequestrations for vegetation types, including lawns, prairie, forest, flower gardens, and vegetable gardens. However, after searching through several scientific articles, the author noticed that most articles focused on one type of land cover, usually specific to one location in the world, and that carbon sequestration was quite difficult to measure. The author did not find a list of average carbon sequestrations for vegetation types. The author did find estimates of soil organic carbon (SOC) density in various ecosystems. The information is presented in the following Table 2 (Prentice 2001). The SOC density could be used to calculate the amount of carbon stored in an area.

Table 2: Estimates of Soil Organic Carbon (SOC) in Ecosystems

ecosystem	**area (10^9 ha)**	**SOC pool (billion tons C)**	**SOC density (tons C/ha)**
tropical forest	1.76	213-216	121-123
temperate forest	1.04	100-153	96-147
boreal forest	1.37	338-471	247-344
tropical savannas and grasslands	2.25	247-264	110-117
temperate grassland and scrub land	1.25	176-295	141-236
tundra	0.95	115-121	121-127
desert and semi-desert	4.55	159-191	35-42
cropland	1.60	128-165	80-103
wetlands	0.35	225	643

Another fairly interesting table of data that the author located was the SOC density for soil orders. The density of SOC could be applied to areas if the soil order was known. However, this is less applicable to site design because soils in areas of development are probably considered to be in transition and the SOC carbon for this soil would likely be changing. Also, for non-"developed" soils, organic carbon concentrations can very significantly. This information is shown in Table 3 (Eswaran et al., 2000).

Table 3: Soil Carbon and World Soil Orders

soil order	**area (Mha)**	**SOC density (tons/ha)**	**soil inorganic carbon density (tons/ha)**
alfisols	1,262	125	34
andisols	91	220	0
aridisols	1,570	38	290
entisols	2,114	42	124
gelisols	1,126	281	6
histosols	153	1,170	0
inceptisols	1,286	148	26
mollisols	901	134	96
oxisols	981	128	0
rocky land	1,308	17	0
shifting sand	532	4	9
spodosols	335	191	0
ultisols	1,105	124	0
vertisols	316	133	50

Another article examined how organic carbon was distributed by soil depth for different biomes. For the purposes of this paper, the information is simplified to just include the average metric for SOC content, as displayed in the following table (Jobbagy 2000).

Table 4: Global Summary of Soil Organic Carbon content

biome	**land area (10^{12} m^2)**	**SOC content (kg/m^2)**
boreal forest	12	12.5
crops	14	17.7
deserts	18	11.5
schlerophyllous shrubs	8.5	14.6
temperate deciduous forest	7	22.8
temperate evergreen forest	5	20.4
temperate grassland	9	19.1
tropical deciduous forest	7.5	29.1
tropical evergreen forest	17	27.9
tropical grassland/savanna	15	23.0
tundra	8	18.0

There was an article based on the vegetation and soils of Great Britain, which discussed a slightly different metric. While the information above, all discussed carbon in the soil, the Great Britain paper provided information for how much carbon was in the vegetation. This information is displayed in Table 5. This information, although it was collected in Great Britain, is somewhat applicable to lands in the Northern Hemisphere, and, in the least, useful for comparison (Milne 1997)

Table 5: Carbon Density for Land Cover Vegetation

cover type	**vegetation carbon density (tonnes/hectare)**
cereal	1
crops	1
pasture, etc.	1
fallow	0
horticulture	1
unimproved grass	1
shrub	2
heath	2
bogs, etc.	2
maritime	2
broadleaf	55.3
conifer woodland	23.4
mixed woodland	38.6
non-vegetated	0

Another aspect to should be considered is the aspect of scale. That a single yard and the decisions regarding land cover and vegetations could significantly affect something as large as the earth's atmosphere seems rather unlikely. However, what about the sum of all the yards around the world? According to one estimate, across only the Country of the United States of America, there are 163,800 square kilometers of turf grass (Milesi 2005). Human beings obviously can and do significantly alter the landscape. Land use and land cover changes are the result of decisions made by landowners (Alig 2003). If a significant portion of that turf grass area were reforested, the amount of carbon sequestered by that land would increase (Alig 2003). Another reason why one yard may significantly affect GW has more to do on its influence of the behavior of visiting humans. If one property owner alters their landscape to retain more carbon, this may influence other property owners who view the landscape to make a similar decision.

Part II

Part I of this report presented information about land cover, vegetation, and soil organic content and attempted to relate it back to the decisions made by small property owners. Part II will analyze a specific property using some of the information presented in Part I in an attempt to bring some actual values into perspective. The author chose his parent's property for this analysis. Figure 1, which is the residence of Bill and Kathryn Reed, is located at 15854 Lowell Road in Lansing, Michigan.

Figure 1: Property for Analysis

The property is basically a rectangle consisting of two near squares about one acre in size each. The square on the fight (east) consists of a driveway, house, and mostly mowed lawn. The back (left and west) square consists of a small barn and meadow area, which is just starting to undergo the process of reforestation. Table 6 shows how the areas located on the property are divided and provides approximate areas for each category. Please note that the impervious area includes the areas of the house, the driveway, and the barn.

Table 6: Land Cover Areas

land cover	**area**
total area	87,120 ft^2 (2 acres)
impervious area	5,400 ft^2
mowed lawn	38,200 ft^2
meadow	43,560 ft^2

Based on the information provided in Table 6, the information provided in Table 2, and several assumptions and conversations, the author calculated that the property holds 109 tons of organic carbon in the soil. That is equivalent to 12 kg/m^2.

Then, the author decided to calculate how much carbon could be stored on the property if 50% of the meadow area was allowed to be reforested and 50% of the mowed lawn area. Based on the author's personal knowledge of the property, these adjustments are quite possible. Table 7 displays the Adjusted Land Cover Areas.

Table 7: Adjusted Land Cover Areas

land cover	**area**
total area	87,120 ft^2 (2 acres)
impervious area	5,400 ft^2
mowed lawn	19,100 ft^2
meadow	40,865 ft^2
forest	21,765 ft^2

Based on the information provided in Table 7, the information provided in Table 2, and several assumptions and conversations, the author calculated that the adjusted property would hold 148 tons of organic carbon in the soil. That is equivalent to 17 kg/m^2 and a 36% increase over the property as is.

This should be considered a quick and dirty analysis. Reasons that the analysis may not be accurate include: the average SOC density data may not be applicable to this property; certain portions of the meadow area are significantly different due to being seasonally wet; and a SOC density for the lawn area was not provided, so the author made an assumption that it would be similar to the SOC density for in croplands. Please note that this is just a calculation for SOC. It does not take into consideration organic carbon held in the biota (mostly vegetation) and also inorganic carbon in the soil. This analysis also does not mention the temporal component. There is potentially a delay in time after the land cover changes till when the soils underneath the new land cover would reach its ultimate carbon sequestration amount.

Yet, please note that the analyses results do provide some perspective on how much carbon can be stored in the soil after land cover changes and also show that a property as small as two acres can store an amazing mass of carbon. On a larger scale, one article indicates that there is a potential SOC sequestration of 1 to 2 Petagrams of carbon per year for the world (Lal 2003).

Part III

So, Part III of this report will examine criteria for sustainable site design based solely from the perspective of carbon sequestration and global warming. Please note that some of the following criteria may in fact not be sustainable for other reasons. The author points out these criteria and elaborates as to why they might be appropriate for designing sustainable sites.

One article (Lal 2004) brought up several land management techniques associated with farming. These included the following:

- Practice no tillage farming. Tilling breaks up the soil colloids, which increases macropore space introducing oxygen gas at an increased rate. This increases aerobic microbiological respiration which converts organic carbon into carbon dioxide gas and reduces the amount of SOC.
- Grow cover crops. Growing cover crops replenishes soil organic matter and also reduces erosion.
- Judiciously spread organic manures and compost. Organic manures and compost not only include additional organic carbon material but also speed the growth of soil structure or colloids, which help hold organic carbon in the soil. This practice may not be considered sustainable if so much material is applied that significant amounts are carried away in rainwater run-off and pollute surface water
- Judiciously irrigate. Keeping the soil wet slows the transfer of oxygen gas into the soil and slows aerobic microbiological respiration of organic carbon matter. This practice may not be considered sustainable as water resources should also be conserved.
- Restore degraded soils. Degraded soils could be improved and would potentially store much SOC relative to its original condition.

- Convert agricultural spaces to forests. More carbon can be sequestered by a forest landscapes than a agricultural landscape in both the soil and the vegetation. This practice may not be considered sustainable, especially if food needs to be produced from the land in question.

Some more sustainable site design criteria based solely on GW and land cover vegetation can be inferred by the above information regarding the SOC densities in different ecosystems. These include:

- Conserve/restore/construct fens and bogs. Although these land areas were only approximately touched upon (wetlands in Table 2), it is known that these land areas are capable of storing massive amounts of SOC. In fact, soil taken from fens and bogs is often nearly 100% organic matter.
- Maximize areas of forest and prairies. These land covers appear to store more SOC than crops, deserts, and non-vegetated areas.
- Limit areas of mowed lawn and crops to a minimum. Mowed lawns and crops appeared to not store a relatively high amount of SOC.

Conclusions

Implications of the literature search indicated that there was a wide variety of data out there. A paper summarizing SOC values from the perspective of sustainable site designers was not located by the author and would be a helpful addition to academic knowledge. The analysis indicated that a large mass of soil organic carbon could be sequestered by altering the land cover vegetation type of a two acre property. The main conclusion that the author would like readers to grasp from all this information is that the decisions of property owners regarding land cover and vegetation can reduce GW by not only the insignificant contribution of storing more organic carbon in the biota and soils of their property but also by that property will be an example of sustainability for other property owners. Thank you for reading!

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