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Policy Paper on Increasing Carbon Sequestration in the Gulf-Houston Region Through Targeted Large Scale Planting of Native Trees and Flora Species

Summer 2019

Part of the Gulf-Houston Regional Conservation Plan 3rd Key Goal- Increase of 0.4% in Carbon Sequestration Annually

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<p align="center">**Gulf-Houston RCP- 3rd Key Goal (Increase of 0.04% Carbon Sequestration Annually)**</p>

I.   Introduction

A. Background on Houston Wilderness[1]

Houston Wilderness works to protect and celebrate the coastal prairies, forests, wetlands, and waterways of the 13 counties around Houston, Galveston Bay, and the Gulf of Mexico. Houston Wilderness connects with other nonprofits in this space, work on grants to enact environmentally resilient and sustainable solutions, and educate the public, especially children, about the values of our ecological diversity.

Houston Wilderness and the many partners involved in the 8-county *Gulf-Houston Regional Conservation Plan* (www.GulfHoustonRCP.org) began implementation of three key goals in 2018. These three RCP goals, which overlap and complement current nature-based actions/initiatives taking place regionally, are as follows: (**1**) reaching *24% by 2040* in protected/preserved nature-based infrastructure in the 8-county region, (**2**) reaching *50% by 2040* **in** nature-based stabilization of riparian, developed & undeveloped, agricultural and coastal areas in the region, and (**3**) working toward a **.4% annual increase** in nature-based carbon offsets on stabilized regional lands through enhanced native soils, plants and trees throughout the region. Per our mission and current programming, Houston Wilderness works closely with governmental, business and NGO partners on advocating for and implementing these three key goals, including continued facilitation of the www.GulfHoustonRCP.org website, the RCP Working List of Projects and interactive GIS-based mapping, distribution of informational policy papers, and opportunities for submission of collaborative multl-partner grants related to the 3 key goals.

This policy paper is part of HW's work on the 3rd key goal - to provide research, opportunities and information to help the 8-county region increase its organic carbon sequestration rate to .4% annually in its soils through large-scale tree planting and use of native grasses throughout the region.

B. Background on the 8-county Gulf-Houston Regional Conservation Plan[2]

Facilitated by Houston Wilderness, the *Gulf-Houston Regional Conservation Plan* (Gulf-Houston RCP) is a long-term collaborative of environmental, business, and governmental entities working together to implement a resilience plan for the Gulf-Houston region. In addition to providing a unique online interactive database of all targeted nature-based infrastructure projects taking place in the region, the three key goals of the eight-county Gulf-Houston RCP include: (1) increasing the current 9.9% in protected/preserved land in the eight-county region to 24% of land coverage by 2040, (2) increasing and supporting the region-wide land management efforts to install nature-based stabilization techniques, such as low-impact development, living shorelines, and bioswales, to 50% of land coverage by 2040, and (3) providing research and advocacy

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[1] http://houstonwilderness.org/
[2] http://houstonwilderness.org/gulf-houston-regional-conservation-plan

<p align="center">2</p>

for an increase of 0.4% annually in air quality offsets through carbon absorption in native soils, plants, trees, and oyster reefs throughout the eight county region.
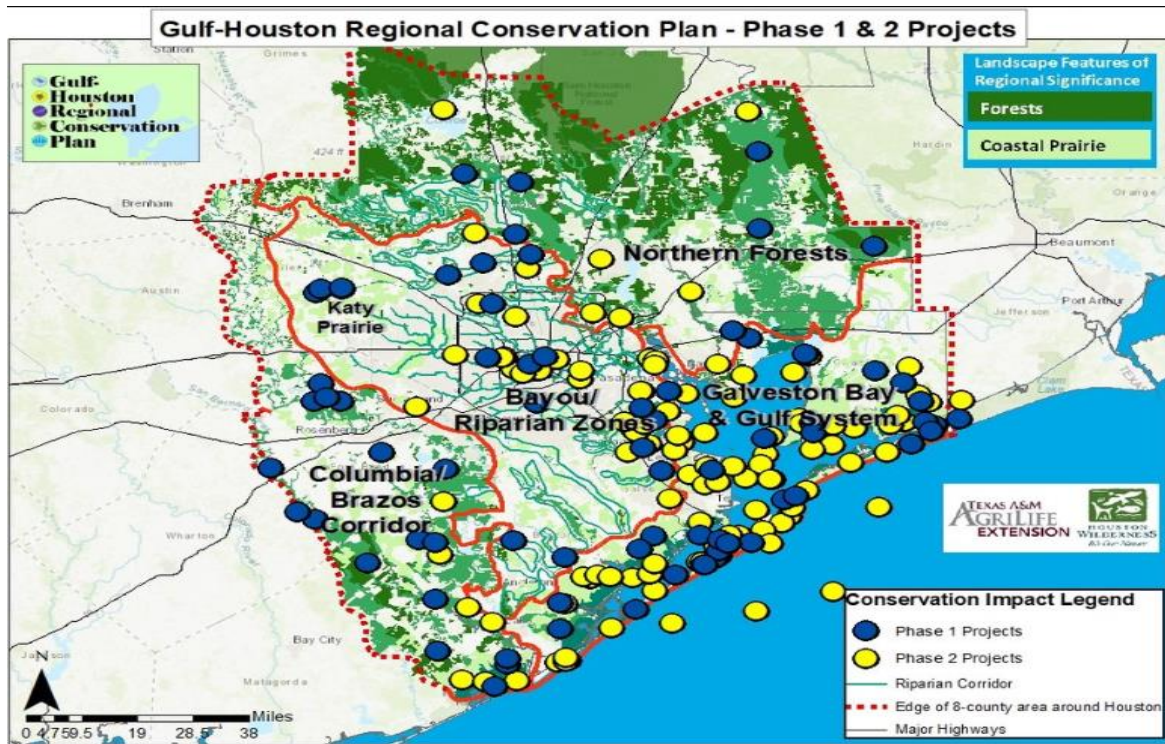

Figure 1 shows the Gulf-Houston Regional Conservation Plan Phase 1 & 2 Projects.[3]
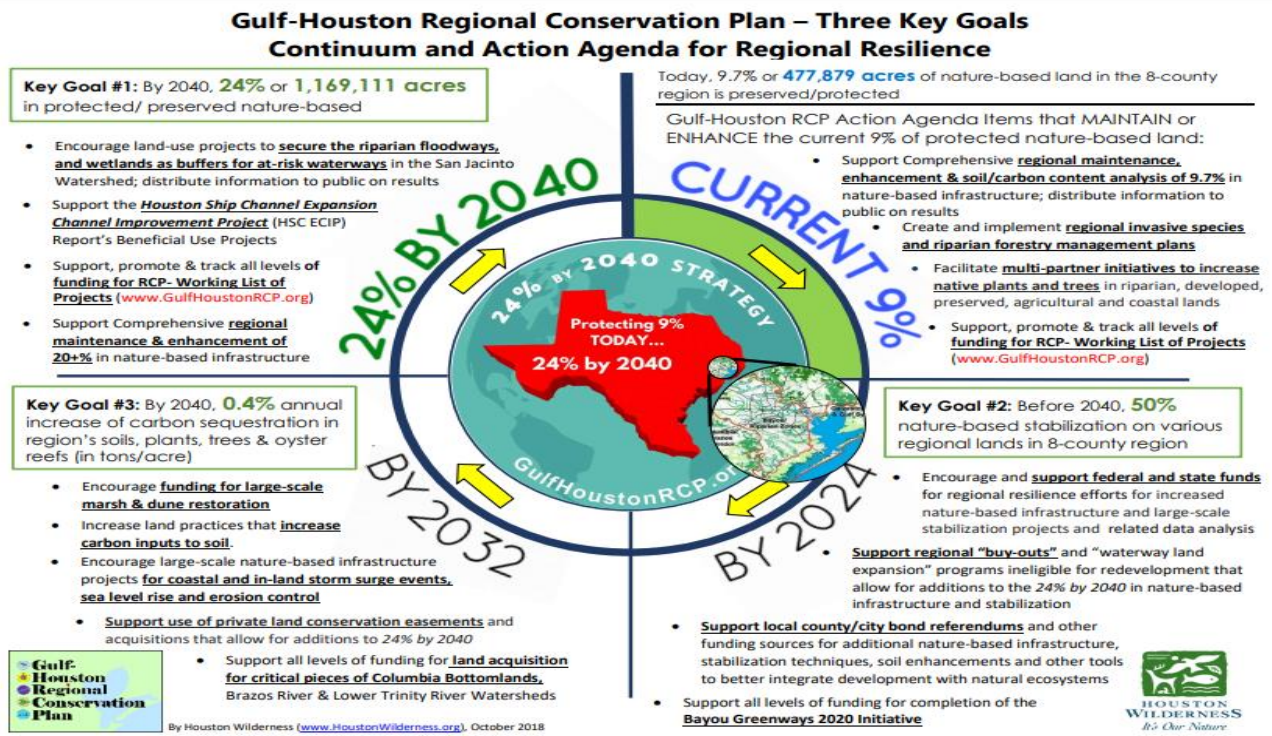

Figure 1 outlines the action agenda to the three key goals of the Gulf-Houston RCP.[4]

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[3] http://www.gulfhoustonrcp.org/#vision_maps
[4] 3

C. Basis of 0.4% Annual Increase

This policy paper concentrates on the 3rd Key Goal which is based on international, national, and regional needs.

1. International

a) "4 per 1000" Initiative[5]

The international initiative "4 per 1000", launched by France on 1 December 2015 at the COP 21, consists of federating all voluntary stakeholders of the public and private sectors under the framework of the Lima-Paris Action Plan (LPAP). The aim of the initiative is to demonstrate that agriculture, and in particular agricultural soils, can play a crucial role where food security and climate change are concerned. Supported by solid scientific documentation, this initiative invites all partners to state or implement some practical actions on soil carbon storage and the type of practices to achieve this (e.g. agroecology, agroforestry, conservation agriculture, landscape management, etc.). The ambition of the initiative is to encourage stakeholders to transition towards a productive, highly resilient agriculture, based on the appropriate management of lands and soils, creating jobs and incomes hence ensuring sustainable development. The Executive Secretariat of the "4 per 1000" initiative is hosted by the CGIAR System Organization, an international organization based in Montpellier. An annual growth rate of 0.4% in the soil carbon stocks, or 4‰ per year, in the first 30-40 cm of soil, would significantly reduce the CO_2 concentration in the atmosphere related to human activities. Targeted policy measures include: reducing deforestation and encouraging agro-ecological practices that increase the quantity of organic matter in soils and meet the 4 ‰ target per year. In fact, the more you cover the soil, the more the soil becomes rich in organic matter and thus in carbon by doing some of the following: (1) nourish the soils with manure and compost, (2) restore crops, pastures, and degraded forests and the arid and semi-arid areas of our planet, (3) plant trees and legumes (which also fix nitrogen from the atmosphere in the soil, favouring the foliar growth of plants), (4) collect water at the foot of plants.

b) United Nations "Trillion Tree Campaign"[6]

The UN derived their Trillion Tree Campaign from the Billion Tree Campaign by Wangari Maathai. Three trillion trees currently exist globally. The world has space for up to 600 billion mature trees without competing with agricultural lands. To restore these trees, we need to plant at least a trillion trees, since some will not survive. Additionally, we must protect the 170 billion trees in imminent risk of destruction. They are crucial carbon storages and essential ecosystems to protect biodiversity.

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[5] https://www.4p1000.org/
[6] https://www.trilliontreecampaign.org/

A trillion trees could capture 25% of all human-made CO2 emissions and hereby help to keep global temperature rise below the crucial 2°C limit. The trillion trees do not replace the need to avoid carbon emissions, as agreed in Paris, but are a necessary addition. Anyone can register trees that have been planted or are planning to be planted by signing up and creating an account at the Trillion Tree Campaign website: www.trilliontreecampaign.org
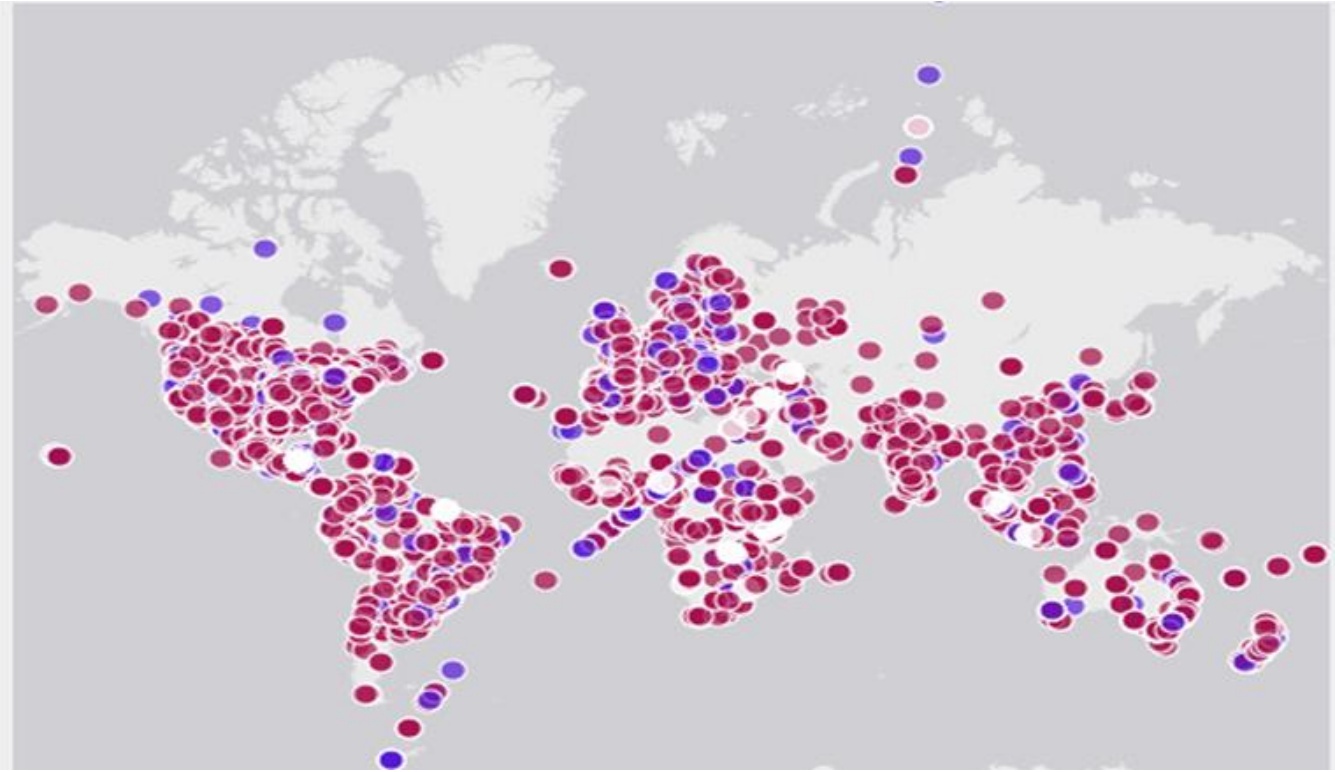
Figure 3 shows 13.6 billion trees that have been planted and registered on the website since 2006.[7]

2. **National**

    a) The Clean Power Plan, announced in August 2015, set the first-ever limits on carbon pollution from U.S. power plants, the largest source of the pollution in the country that's driving climate change. We are already seeing the impacts of climate change in extreme weather, droughts, wildfires, floods, and other disruptions around the world. Limiting carbon pollution from the nation's power plants is the single-biggest step we can take to fight climate chaos.[8]

[7] https://www.trilliontreecampaign.org/explore
[8] https://www.nrdc.org/stories/how-clean-power-plan-works-and-why-it-matters
[9] https://climatenexus.org/climate-change-us/politics-and-policy/fact-checking-clean-power-plan-claims/

3. **Regional**

    a) Gulf-Houston Regional Conservation Plan- 3rd Key Goal[10]

      The Gulf-Houston Regional Conservation Plan (RCP) third key goal is that by 2040, an annual increase of 0.4% in carbon sequestration in the 8 county region's soils, plants, trees, and oyster reefs (in tons/acre) will be targeted. This goal will be reached by encouraging funding for large-scale tree planting across the 8 counties, marsh and dune restoration, increasing land practices that increase carbon inputs to soil, and encouraging large-scale nature-based infrastructure projects for coastal and inland storm surge events, sea level rise, and erosion control. The Gulf-Houston RCP will support use of private land conservation easements and acquisitions that allow for additions to 24% by 2040. Additionally, the Gulf-Houston RCP will support all levels of funding for land acquisition for critical pieces of Columbia Bottomlands, Brazos River, and Lower Trinity River Watersheds. Overall, in line with international and corporate organic carbon offsets for global carbon emissions, the RCP supports a 0.4% annual increase in regional nature-based carbon offsets on stabilized lands through enhanced native soils, plants, and trees. Both the 24% by 2040 NBI Strategy and the 50% Stabilization goal help reach this annual 0.4% goal.

II. Background on Carbon Sequestration

Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide. It is one method of reducing the amount of carbon dioxide in the atmosphere with the goal of reducing global climate change. [11] Carbon may come from organic material supplied by plants, waste products produced by other organisms, or the bodies of other organisms.[12]

A. Texas Carbon Oxidation Rate in Soils[13]

1. Tillage Practices[14]

    a) Blackland soils in central Texas, USA consist primarily of 4.5 million hectares of Vertisols (Udic and Entic Pellusterts) (Puentes et al. 1988[15]). These deep and dark colored soils were the basis for much of Texas early agriculture. By the 1920s more than 70% of the Blackland Vertisols were tilled to produce crops, using the inversion tillage practices common at that time (US Department of Agriculture 1993). In retrospect, a benefit of intensive tillage was to oxidize organic matter in the soil and thus release plant nutrients for the growing crop. Cotton produces small amounts of residue

[10] http://www.gulfhoustonrcp.org/

[11] https://www.usgs.gov/faqs/what-carbon-sequestration?qt-news_science_products=0#qt-news_science_products

[12] Lowenfels, Jeff, and Wayne Lewis. *Teaming with Microbes: The Organic Gardeners Guide to the Soil Food Web.* Page 19. 11th ed., Timber Press, 2018.

[13] Soil carbon pools in central Texas: Prairies, restored grasslands, and croplands by K.N. Potter and J.D. Derner

[14] https://www.iuss.org/19th%20WCSS/Symposium/pdf/0222.pdf

[15] Puentes R, Harris BL, Victora C (1988) Management of Vertisols of temperate regions. In 'Vertisols: Their Distribution, Properties, Classification and Management'. (Eds LP Wilding, R Puentes), pp. 129-145. (Texas A&M University Printing Center, College Station, Texas, USA)

returned to the soil to replenish the organic carbon oxidized by the agricultural practices of the time. As a result of the agricultural practices commonly used at that time and the choice of crops, tilled soils were severely depleted of organic carbon compared to the native prairie in 1949. About 80% of the Blackland Vertisols are in farms and ranches. Of that amount, about half are planted to croplands and the rest predominately are improved pasture.

2. Better Management of Tillage Practices[16]

a) An opportunity to compare soil properties with a known starting condition was discovered recently by the USDA-ARS Grassland Soil and Water Research Laboratory for a study area near Riesel, Texas. In 1949, a series of soil samples were taken from five fields at the GSWRL-Riesel site (Baird, 1950). The samples were oven dried and placed in labeled cartons and stored in a dry location for over 55 years. The management history of these fields was recorded for most of the intervening years. The goal of the original study was to determine the effect of cropping on soil water storage. In 2004, these fields were sampled again. The objective of the current study was to compare soil properties between the management regimes and between the two sampling periods. The soils studied in this project are located near Riesel and Temple in central Texas, USA. Soils in all fields are Vertisols (Udic Pellusterts)(Soil Survey Division Staff 1993). Soil organic carbon concentration was significantly greater in the surface 15 cm for the 2004 sampling period than in the 1949 sampling period: 2.77 percent in 1949 and 3.31 percent in 2004. However, mean differences in concentration between the two sampling periods were not significantly different for depths greater than 15 cm. Prior to 1949, the native prairie site had been grazed for an extended period of time.
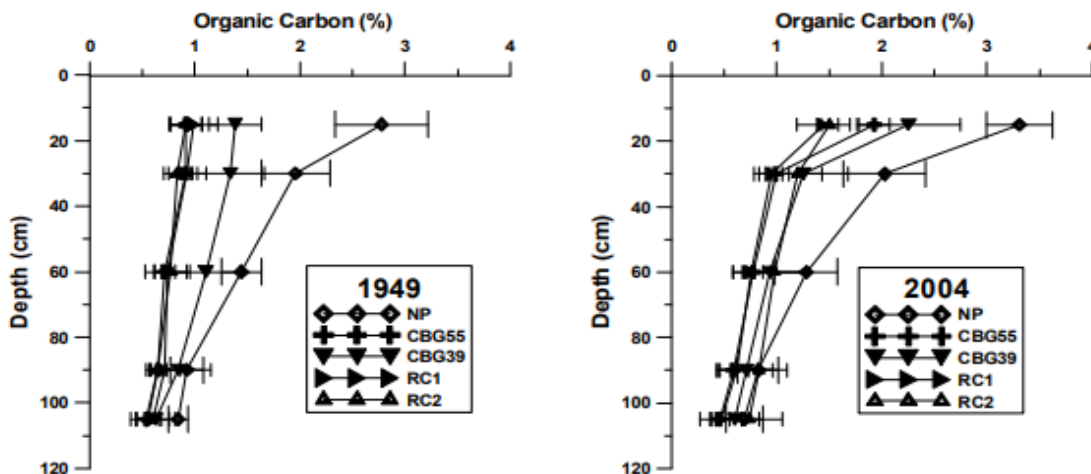
Figure 4. Comparisons of soil organic carbon profiles from 1949 ad 2004 samples for selected management practice. NP is Native Prairie, CBG is Coastal Bermuda Grass, and RC is Row Crop. Error bars present ± one standard deviation.

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[16] https://www.iuss.org/19th%20WCSS/Symposium/pdf/0222.pdf

Differences in soil organic carbon between the 1949 samples and the 2004 samples are a result of management and weather effects. This has resulted in a large increase in the amount of residue being returned to the soil, which in turn replenished some of the organic matter being oxidized. It should be noted that the change in soil carbon concentration found in this study is without the use of no tillage management practices. Restoring the soils to perennial grass vegetation replenished the carbon concentration in the surface.

3. **No Tillage Practices**[17]

   a) Soils in central Texas were degraded during the first 70 years from 1880 to 1949 of cultivation. This is illustrated by the loss of soil organic carbon. In the last 60 years changes in crops, fertilization and management practices have resulted in a slow rebuilding of the soil organic carbon in the soil profile. Use of no-tillage and conversion to perennial grass accelerates the accumulation of soil carbon.

B. Regional Soils, Trees, and Plants

Recent research has shown that modern conventional practices have increased soil organic carbon sequestration at a rate of 0.15 Mg C/ha/yr. Intensive management practices such as no-tillage increase this rate an additional 0.3 Mg C/ha/yr. Conversion from row cropping to perennial grass production increases sequestration to 0.45 Mg C/ha/yr.[18]

The current carbon stock in the Gulf-Houston 8-county region is around 30 tonnes/ha.[19] The carbon content in the 8 county region ranges from 28.3-33.1 tonnes/ha.[20] Both of these ae taken from a 15 cm depth of the soil.

Figure 5 shows soil organic content in the 8-county region.[21]
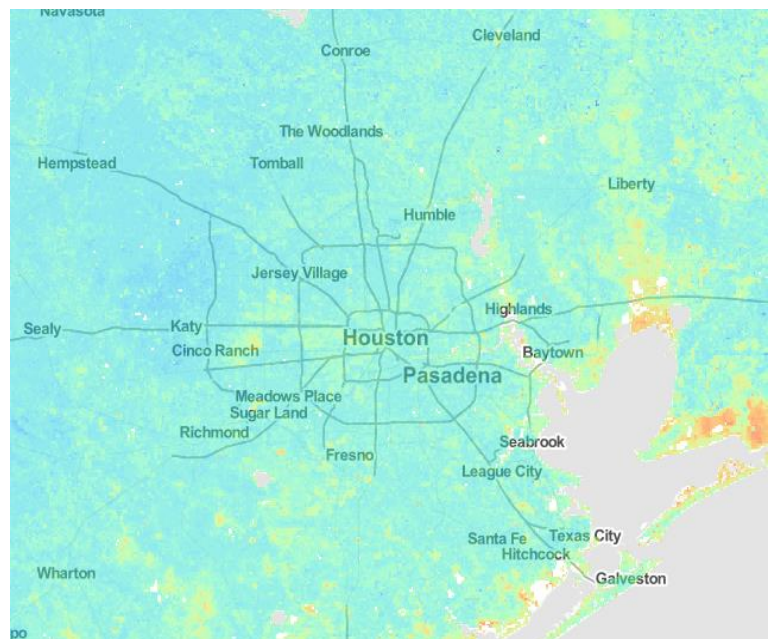
[17] https://www.iuss.org/19th%20WCSS/Symposium/pdf/0222.pdf
[18] 18
[19] https://soilgrids.org/#!/?layer=ORCDRC_M_sl3_250m&vector=1
[20] 20
[21] 20

a) The third key goal of the Gulf-Houston RCP supports a 0.4% annual increase in nature-based carbon offsets on private and public lands through substantially enhanced native soils, plants, and trees throughout the region. Most of the region's current soil carbon content contains only 28-33 tons/acre. But, these soils have the capacity to absorb 64-77 tons/acre. By planting native trees and grasses with high levels of carbon absorption abilities, the region can achieve this an annual 0.4% increase in organic carbon sequestration. For example, if 2,000 Loblolly Pine trees are planted in 2019, in ten years, each of the Pine trees will absorb as much as 479 pounds of carbon each year for a total of 958,000 lbs – a 0.17% increase in carbon sequestration in the soil around those trees. Multiple initiatives are beginning around the region, including the City of Houston and Harris County, to plant millions of trees over the next decade.

1. **Current NRCS Soil Data for 8 County Region**[22]
   a) The Soil Organic Carbon (SOC[23]) stock in the 8-county Gulf-Houston region ranges from 64-77 Mg/ha.[24]
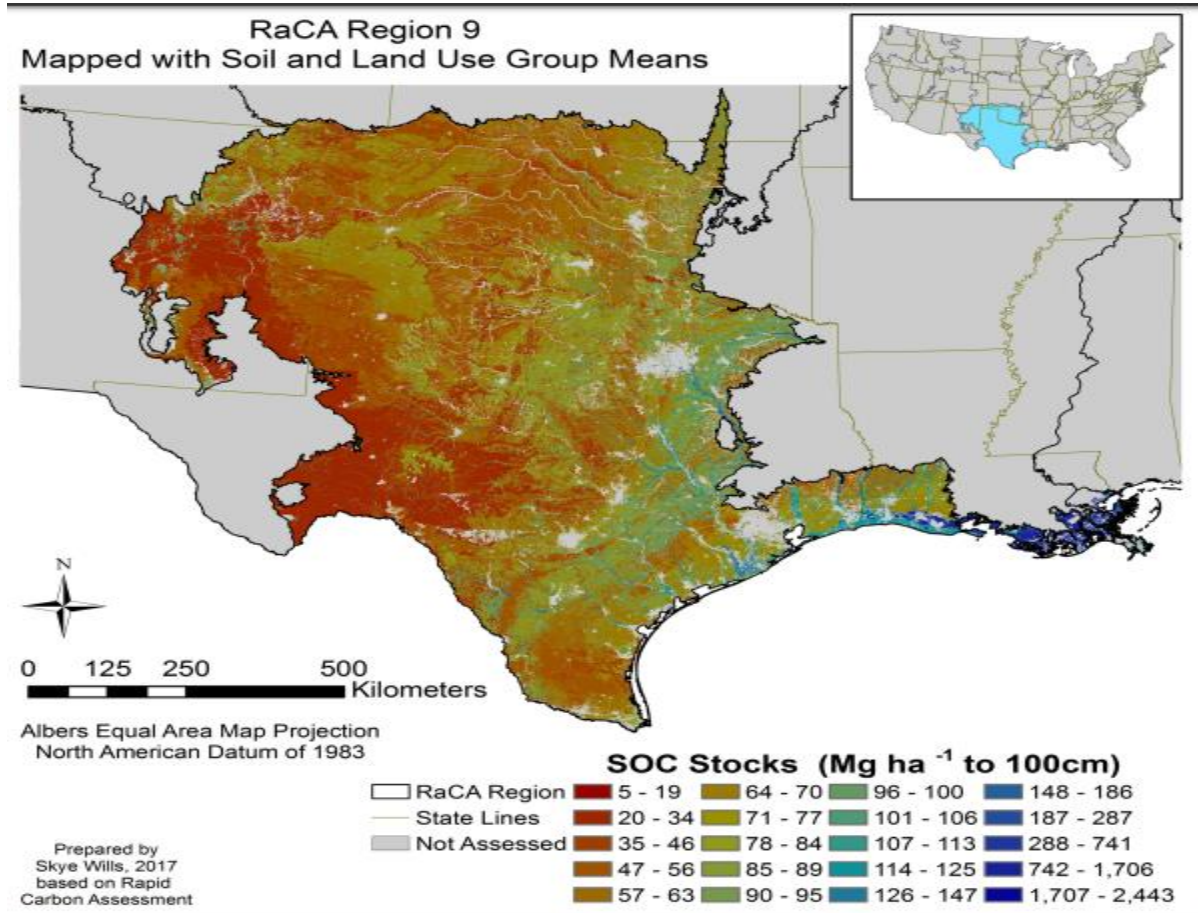
Figure 6 shows Soil Organic Carbon Stocks for the 8-county Gulf-Houston Region.[25]

[22] https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054164
[23] https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052842.pdf
[24] https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053179.pdf
[25] 24

b) Soils of the Gulf-Houston Region[26]

Alfisols contain topsoil and up to 20-40 inches of sandy loam (sand mixed with clay) before reaching a clay pan. These soils typically form under grassland vegetation. Surface runoff is slow to very slow, permeability is very slow, and the available water holding capacity is high due to high clay content at depth.
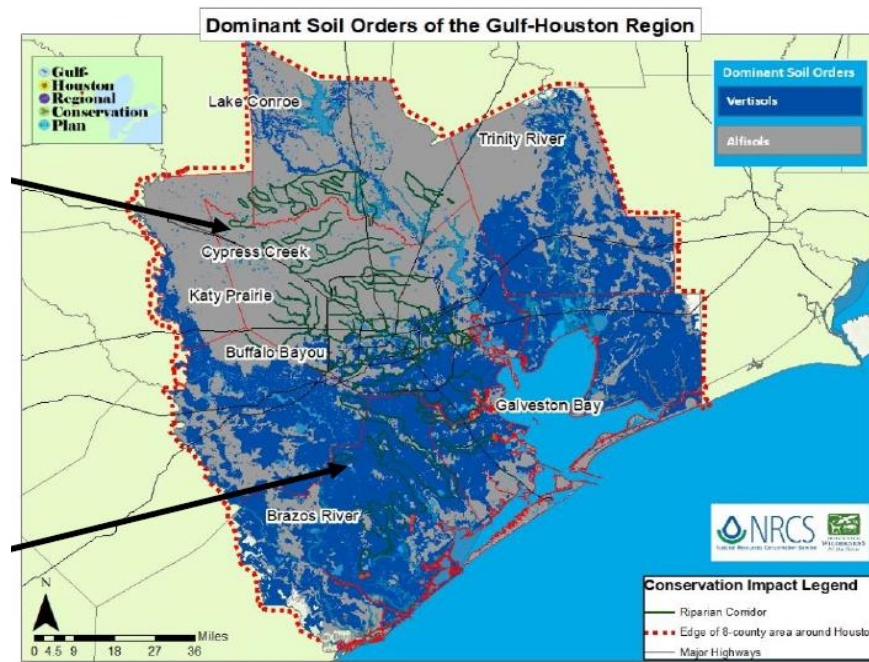
Figure 7 shows dominant soil order in the 8-County Gulf-Houston

Vertisols are clay-rich soils (40-75% clay content) that shrink when dry, swell when wet, and consist of topsoil sitting top of a deep clay pan. When dry, vertisols form large cracks that may be more than three feet deep and several inches wide. These cracks greatly influence the infiltration and runoff behavior particularly during rain events, and are responsible for many building foundation and road repairs. Vertisols typically form under grassland vegetation and are self-mulching, highly fertile soils due to their high clay content. The vertisol's self-mulching allows for unique surface features called gilgai, which consists of subtle topographic changes of microhighs surrounding circular microlows (mounds & depressions). The subsurface clays become saturated quickly during rain events, causing runoff to pool on the surface. Depressions associated with gilgais allow the excess runoff to be detained until evaporation or drainage to a waterway. Historically these depressions were used as temporary watering holes and habitat for wildlife and as a natural farming irrigation system.

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https://static1.squarespace.com/static/52387981e4b0a2c53f25a411/t/5ca2463a0852298776527868/1554138687051/RCP+REGIONAL+SOIL+TWO-PAGER+for+Gulf+Coast+Prairie+Region+-+Info+Sheet+%28OCT+2018%29.pdf

2. Gulf-Houston Native Tree Species[27] - Calculations of Carbon Increase by Year

Tree species	CO_2 sequestrated (lbs./tree/year) DBH ≈ 10 years
Live Oak	268
River Birch	215
Green Ash	200
Slippery Elm	197
Laurel Oak	194
Winged Elm	179
Eastern Cottonwood	176
Water Oak	173
Black Willow	169
Boxelder	159
Elm	151
Sweetgum	150
Baldcypress	146
Willow Oak	142
Red Maple	139
Plum	139
Southern red Oak	121
White Ash	118
American Elm	114
Swamp chestnut Oak	114
American Sycamore	111
Loblolly Pine	106
Black Cherry	101
Oak	94
Shortleaf Pine	91
Shumard Oak	90
Longleaf Pine	85
Tulip Tree	81
Willow	79
Black Walnut	76
American Basswood	76
Hickory	75
Sugar Maple	71
Washington Hawthorn	68
Redbay	64
Savannah Holly	63
Holly	59
Sugarberry/Hackberry	58
Southern Magnolia	55
Post Oak	55
Bitternut Hickory	54
White Oak	54
Flowering Dogwood	46
Black Tupelo	46
Red Mulberry	44
Mockernu Hickory	44
Pecan	44
Common Persimmon	38
American Holly	33
American Hornbeam	31
Southern Crabapple	27
Eastern Redbud	19
Eastern red Cedar	17
Carolina cherry Laurel	2

Figure 8 shows carbon sequestration (in lbs.) estimate over 1 year for certain native tree species.[28]

When native tree species are planted in an area, the trees begin absorbing organic carbon from the air into the trees and the surrounding soil right away, with increases in carbon sequestration every year. So, for example, (1) If 2,000 Live Oak trees are planted in 2019, by 2020 each of the Live Oak trees will be absorbing 268 pounds of carbon each, for a total of 536 000 pounds/year (268 tons/yr); and (2) If 2,000 Loblolly Pine trees are planted in 2019, by 2020 each of the Pine trees will be absorbing 106 pounds of carbon each year (106 tons/yr). If mulch and/or organic compost is added to the base of the trees, the carbon absorption is up to 4 times higher in the soils annually.

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[27] HW Regional Native Tree Species ranking charts - 10 yr (2019)
[28] 28

Tree species	Total CO$_2$ Stored (lbs.) DBH ≈ 10 years			
Live Oak	1023	Black Walnut		386
Black Cherry	971	Shortleaf Pine		374
River Birch	925	Hickory		355
Boxelder	898	Black Tupelo		354
Laurel Oak	875	Flowering Dogwood		338
Water Oak	869	Holly		337
Red Maple	859	Winged Elm		327
Willow Oak	739	Elm		326
Sweetgum	719	Southern Magnolia		322
Slippery Elm	669	Redbay		322
American Elm	667	Willow		281
Tulip Tree	659	American Basswood		261
American Sycamore	652	Carolina cherry Laurel		232
Green Ash	624	Red Mulberry		219
Eastern Cottonwood	591	Savannah Holly		192
Black Willow	590	Sugar Maple		191
Loblolly Pine	479	Common Persimmon		164
Washington Hawthorn	448	Mockernu Hickory		140
White Ash	447	Post Oak		139
Southern Crabapple	445	Bitternut Hickory		138
Plum	445	White Oak		136
Baldcypress	443	Pecan		135
Longleaf Pine	425	American Hornbeam		133
Southern red Oak	416	American Holly		127
Shumard Oak	413	Sugarberry/Hackberry		111
Swamp chestnut Oak	412	Eastern Redbud		72
Oak	407	Eastern red Cedar		45

Figure 9 shows carbon sequestration (in lbs.) estimate over 10 years for certain native tree species.[29]

Trees provide a number of co-benefits including improving air quality, cooling buildings and having positive impacts on public health. An analysis of the urban forest in Houston, Texas, reveals that this area has an estimated 33.3 million live trees with tree canopy that covers 18.4 percent of the city. Roughly 19.2 million of the city's trees are located on private lands. The most common tree species are yaupon, Chinese tallowtree, Chinese privet, Japanese privet, and sugarberry.[30]

Austin's urban forest removed an estimated 1253 tons of air pollution with an associated value of $2.8 million, based on the number of cases per year of avoided health effects. Its gross carbon sequestration is about 92,000 tons per year with an associated value of $11.6 million per year (not accounting for carbon loss due to tree mortality and decomposition). By shading buildings, tress in Austin reduce energy costs by $18.9 million annually and provide an additional $4.9 million per year by reducing the carbon emissions from fossil-fuel based power sources. [31]

[29] HW Regional Native Tree Species ranking charts - 10 yr (2019)
[30] Houston's Urban Forest, 2015, U.S. Dept of Agriculture (2015)
[31] David J. Nowak et al., *Austin's Urban Forest,* (Newtown Square, Pennsylvania: U.S. Forest Service, 2016). https://www.fs.fed.us/nrs/pubs/rb/rb_nrs100.pdf.

3. Native Grass Species[32]- Calculations of Carbon Sequestration by Year[33]

Just like native tree species, there are also native grass species in Texas. There was a study conducted in San Antonio, Texas where native grass species were studied.

a) Soil and vegetation were evaluated along IH-35 within Bexar County for carbon content. The objectives of this study were to evaluate the vegetative composition and carbon sequestration potential of vegetation along IH-35. Three 20 m transects were placed at each site and percent vegetative cover was estimated and above ground plant biomass and soil was collected from three 0.25 m2 subplots along each transect. Plant and soil samples were analyzed for carbon content using the loss-on-ignition method. Two non-native grasses, Bermuda grass and King Ranch Bluestem, were the dominant cover. Bermuda grass was more efficient in absorbing $CO2$ compared to King Ranch Bluestem. The top 10 cm of soil in all samples contained more organic carbon than the lower 10 cm. Collection of field data has been completed and the soil and plant carbon content is being analyzed with the final results presented at the conference.
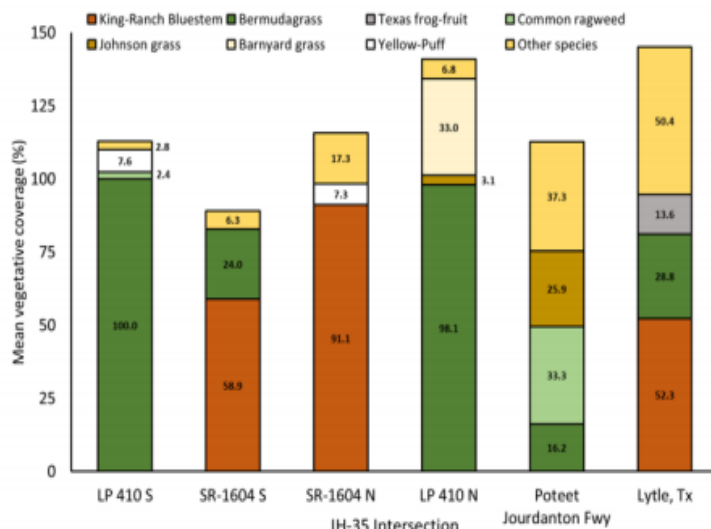
The data collected during May to August 2018 has only been partially analyzed. Preliminary results indicate that grassy strips along IH-35 in Bexar County are dominated by King Ranch Bluestem (Bothriochloa ischaemum var. songarica) and Bermuda grass (Cynadon dactylon), two non-native grasses (Figure 10).

Figure 10. Percent vegetation cover by species at the six sites sampled.[34]

A total of 55 species were observed among the six sites indicating low species richness. Diversity indices have not been evaluated, but are likely to be low as 5 of the 6 sites were dominated by 1 or 2 non-native species. Native plant coverage was low at all sites. Two native species, common ragweed and Texas Frog-Fruit, comprised 33.3 and 13.6% coverage, respectively at single sites but most native species coverage was less than 10%. Out of the nine dominant plant species among the study sites, six are native and three are non-native. The three non-native species include Bermuda

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[32] file:///C:/Users/Houst/Downloads/Carbon_Sequestration_of_Soil_and_Plants_along_IH-3.pdf
[33]CARBON STORAGE AFTER LONG-TERM GRASS ESTABLISHMENT ON DEGRADED SOILS by Potter, K. N.; Torbert, H. A.; Johnson, H. B.; Tischler, C. R.
[34] 32

grass, Johnson grass (Sorghum halepense), and King Ranch Bluestem, all of which are invasive in Texas and form monocultures.
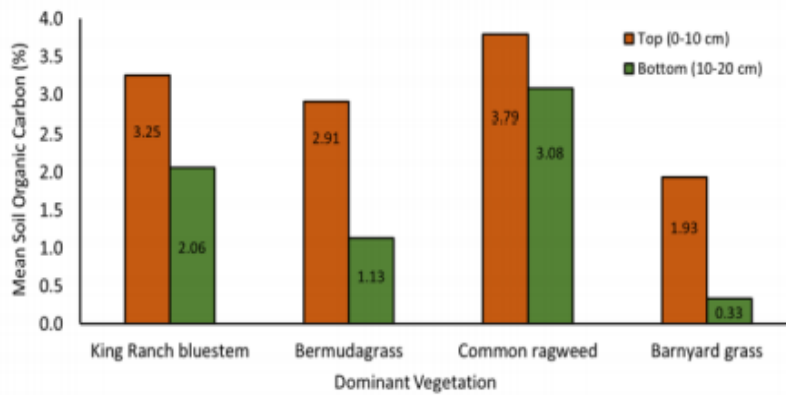
Only 50% of the soil and 0% of the plant samples have been analyzed for carbon content. Soil carbon content was greater in the top 10 cm compared to soil carbon at 10-20 cm below the surface based on limited samples (Figure 11).

Figure 11. Mean percent soil organic carbon by dominant vegetative cover (by mass) within each plot.[35]

Carbon was highest in association with common ragweed (Ambrosia artemisiifolia), a native species, and lowest in association barnyard grass (Echinocloa crus-galli), a non-native species. Bermuda grass and King Ranch Bluestem were intermediate in carbon content. Analysis of the carbon content in other species will provide more insight into the ability of native species to sequester carbon and translocate it into roots compared to non-native species. Soils located in arid regions have low concentrations of carbon due to infrequent precipitation and decreased microbial activity. In New Mexico, soil carbon was strongly correlated with precipitation.

The results of this study may represent minimal estimates of carbon due to minimal precipitation during the summer sampling period. Increased plant species richness and diversity along roadways may result in greater annual carbon sequestration. Warm season grasses generally have a higher root to shoot ratio comprised of greater fine root densities than cool season grasses and the continual senescence of fine roots incorporates greater carbon into soil profile. Conversely, cool season grasses and forbs are important along roadways for carbon sequestration, trapping sediment and preventing erosion during the cooler months in South-Central Texas. d. Carbon soil content in an undisturbed Central Texas prairie containing a mix of native and nonnative species was greater than improved grasslands and agricultural sites. In disturbed and compacted roadside soils, carbon may be a limiting factor in native plants becoming established. Based on limited analysis, soil carbon content was higher under coverage of a native species (common ragweed) compared to three non-native species. Upon completion of final data analysis, the vegetative coverage will be used to create a GIS model of the different vegetation types along IH-35 to estimate carbon sequestered along IH-35. The estimated

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[35] [32](#)

carbon content (t/ha) of each site will be calculated for all plant species, total plant and leaf litter, soil, and total (plant, leaf litter, and soil) to evaluate the carbon sequestration potential of roadside vegetation and soils.

B. Composting[36]

Composting is a natural process that breaks down organic materials, like food scraps and yard trimmings, into an earthy, nutrient-rich, soil-like material. This soil-like material can later be used as fertilizer. It is no wonder composting is called nature's recycling. Composting is important because it not only helps our environment, but also allows us to downsize our trash cart, which can mean big savings in service fees.

1. Wood Mulch[37]

    a) Mulch is one of the best landscape substances for growing healthy plants and conserving water. The best mulch for your yard is one created from native sources and could include straw, newspaper, sawdust, bark, pine needles, leaves, grass clippings, and compost. They can benefit your lawn and garden by aiding in root development, preventing erosion, suppressing weeds, moderating soil temperature, and adding nutrients as they break down slowly. Mulching also helps conserve water by reducing water lost through evaporation.

Researchers from the University of British Columbia have conducted a study in apple orchards and vineyards, concluding that using mulch in agriculture can cut nitrous oxide emissions up to 28 percent. "In addition to saving water, improving soil, combatting pests and stopping weeds, wood mulch actually reduces the release of a greenhouse gas 300 times more potent than carbon dioxide," says Craig Nichol, senior instructor of Earth and Environmental Sciences at UBC's Okanagan campus. "Provided you are not driving great distances to obtain the mulch, it would appear that mulch could be a powerful tool in helping to reduce greenhouse gas emissions, particularly if used in these agricultural systems." Nitrous oxide emitted from soil accounts for at least half of agriculture emissions that contribute to global warming.

The two-year long study used small emissions-recording chambers to take the measurements and, in addition to reduced levels of nitrous oxide emissions, they found that areas covered in wood mulch also showed a 74% drop in soil nitrates. Nitrous oxide emissions come from nitrates and can also leach into groundwater. While the research has broader implications when applied to commercial agriculture than home gardening, mulch still has so many benefits for gardens.

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[36] http://www.austintexas.gov/blog/what%E2%80%99s-deal-composting
[37] https://www.treehugger.com/lawn-garden/use-wood-mulch-save-planet.html

2. Food Composting[38]

a) Compost is best defined as a mixture of various organic substances (materials), in which the natural decaying of organic matter occurs through the biological process wherein microorganisms convert organic material into a nutrient rich resource.

Today, composting is a technique utilized to accelerate the natural decaying process. The main value of compost as well as a much-needed part of a productive soil complex, is to replenish soil organic matter content. As a soil amendment, compost has a positive, yet low-level effect on soil nutrient levels because nitrogen released by commercial fertilizers is typically immediately available but exhausted in the year, while compost generated nitrogen is slowly released over years. Commercial fertilizers are ideally made up of salts that kill off beneficial microbes and other living organisms in the soil food web. Compost is an organic method of replenishing the nutrients in the soil as well as providing beneficial bacteria and fungi that all play a role in having a healthy fertile soil. When dealing with the processes of recycling organic matter both greens and brows are important. The greens are the food waste and plant matter which are the nitrogen source. The carbon source are the browns, such as shredded wood, dry grass clippings and leaves.

The combination of the correct carbon to nitrogen ratio may vary depending on the materials being used. The standard ratio is 30:2, 30 being the carbon browns and 2 being the nitrogen greens. Aside from the C:N ratios, oxygen is also needed for oxidizing the carbon which triggers the decomposition of organic matter. H_2O is essential in the correct amounts needed to maintain activity in the compost pile. However, if there is too much H_2O anaerobic conditions are created, which means the beneficial microbes that are the main ingredient in the process of decomposition have been killed.

By providing the right amount of carbon, nitrogen, oxygen and H_2O the perfect environment for the microorganisms to thrive in is created, which puts them on the top of the ingredient list for the process of decomposition. Without microorganisms a sterile environment is created that makes it impossible to create a final product of compost. Common microorganisms that are in compost piles consist of bacteria, actinomycetes, fungi, molds, yeast, protozoa, and rotifers. The goal is to get the compost pile to reach temperatures that range between 135-160 degrees Fahrenheit to fully decompose organic matter. If temperatures are too low, decomposition will not occur; if temperatures exceed 160 degrees a sterile environment is created along with hazardous conditions that could start fires.

With proper monitoring of piles and constant evaluation of temperatures along with moisture and oxygen levels, compost at a more consistent level is produced. The ideal finished compost resembles a dark brown or black crumbly texture that is moist to the touch but has no odors besides the smell of

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[38] https://ag.txstate.edu/orgs/bobcatblend/compost.html

rich earth. Not all compost is fully decomposed and most people prefer different levels of decomposition because they are aware that the minute twigs, straw, hay and such will decay in their yard garden with time and continue to exchange nutrients needed for vital plant growth. Keep in mind, to use compost that is not fully decomposed should not be used to start seeds of any sort whether it is flowering plant or edibles because the delicate roots may come in contact with decomposing material that can cause harm to your plants by introducing disease and taking nutrients away

II.   **Increase Carbon Sequestration- Steps Needed to Increase Soil Sequestration by 0.4% Annually**

   A.   **Large-scale Tree Planting Initiatives with Targeted Tree Species for High Carbon Sequestration**

      1.   **TXDOT-Houston District's** *Freeway Forestation Green Ribbon Program* & **City of Houston's** *Million Trees+ Houston Initiative*

         a)   Two large-scale tree planting projects, among others, have been successful in the Greater Houston Region and provide evidence of the viability reaching .4% in soil-based carbon sequestration annually.

           With the support of the Houston-based Quality of Life Coalition, TxDOT's Houston District created a large-scale tree planting initiative centered around its Green Ribbon Program. In Greater Houston, the initiative became known as "**Greater Houston's Freeway Forestation Program**" and within 10 years, 1 million trees had been planted along almost all of Houston's major freeway corridors. Starting in 2003, the program has been transformative for the Greater Houston area, where major freeways are prevalent. Consideration of the benefits of ecosystem services provided by trees was discussed and supported during the program's implementation but exact consideration of carbon sequestration impacts of the various tree species planted over the years has not been calculated. The 1 million+ trees planted along the freeway rights-of-way were tracked and calculation of carbon sequestration could be performed, if TxDOT provides the data to Houston Wilderness.

           Million Trees + Houston is another public/private initiative designed to vastly increase one of the Houston area' greatest natural resources, its trees. Houston, the nation's fourth largest city, kicked off this ambitious plan in 2006 after studying the Million Trees efforts our country's three larger cities, New York City, Los Angeles, and Chicago. Key partners in this effort are the City of Houston, TxDOT and Harris County for the public sector, and *Trees for Houston* and the *Quality of Life Coalition* for the private sector. Also, many corporations were asked to participate by providing a special "Gift of Trees" with their respective employee holiday giving programs, as part of the *Million Trees + Houston* initiative.

2. **Bayou Greenway Initiative**[39]

   a) In less than a decade, Houston Parks Board launched an ambitious initiative that will transform Houston into a healthier and happier city. With the support of community members, donors and public partners, Houston Parks Board and its project partners are creating 150 miles of trails and bridges that will connect Houston's major bayous. That's one continuous ribbon of green, here by 2020. 1.5 million Houstonians will live within 1.5 miles of the Bayou Greenways.

   b) It started with 77 miles of trail that were originally built along the bayous by entities such as the City of Houston, Harris County, the Texas Department of Transportation and TIRZs. By 2012, Houstonians showed overwhelming support for Bayou Greenways 2020, which would set aside $100 million in funding towards new trails and parks for the city. Since then, Houston Parks Board has leveraged the commitment, support and expertise of its private, civic and philanthropic partners to raise another $120 million and connect Houstonians to our improved, safe and beautiful bayous —all throughout Brays, Buffalo, Greens, Halls, Hunting, Sims, White Oak, and the West Fork of the San Jacinto River. Since the beginning, the work of Bayou Greenways 2020 is an invitation to get closer: to get closer to our friends, to joy, to our city, to curiosity, to our goals, to our health; to get closer to the things that matter; to step outside and into parks, onto trails, and along bayous to create community and make memories, together. Houston Parks Board and its project partners are transforming our bayous into Greenways, connecting people to trails, parks and neighborhoods.

3. **Houston Parks and Recreation Department (HPARD)**[40]

   a) The Greenspace Management Division oversees the daily maintenance of Houston's parkland, esplanades, greenspaces, and urban forest. The division also maintains greenspace for certain city facilities, including Houston Public Libraries and Health Department Multi-Service Centers. To provide greater accountability and service, the division's job duties are divided into seven sections: Grounds Maintenance; Urban Forestry; Sportsfield Management; Horticulture; Greenspace Adoption; Court Restitution and Community Service; and Lake Houston Wilderness Park.

4. **Port of Houston TREES Program**[41]

   a) Houston Wilderness is facilitating this Program in close partnership with Trees for Houston, the Port Houston Authority and other partners. A PoH TREES policy paper has been created that includes rates of CO_2 and GHG absorption, flood mitigation, and BVOC emission by each respective native tree species and ranked by their respective absorption rates. Trees for Houston is selecting native tree species with high rates of CO_2 and GHG absorption; high rates of water absorption; low rates of BVOC emissions to help enhance the riparian areas mentioned previously, as well as to bring the best socio-economic benefit to the port, its residents, its businesses, organizations and infrastructure. Now that a tree inventory of all of Phase 1 properties along the ship channel has taken place, partners will work with volunteers to begin tree planting in the Spring of 2019, and conduct property assessment of species present, and will plant selected tree species and conduct removal of found invasive species.

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[39] https://houstonparksboard.org/about/bayou-greenways-2020
[40] https://www.houstontx.gov/parks/greenspace.html
[41] MASTER Plan of Work_ Port of Houston Tree & Riparian Enhancement of Ecosystem Services (TREES) Programs

Phases 2, which includes interested private commercial property owners along the ship channel, and Phase 3, which includes public lands and some residential areas, will follow the same scope and activities in later year.

Map 1. The Port of Houston TREES Program Sections 1-5
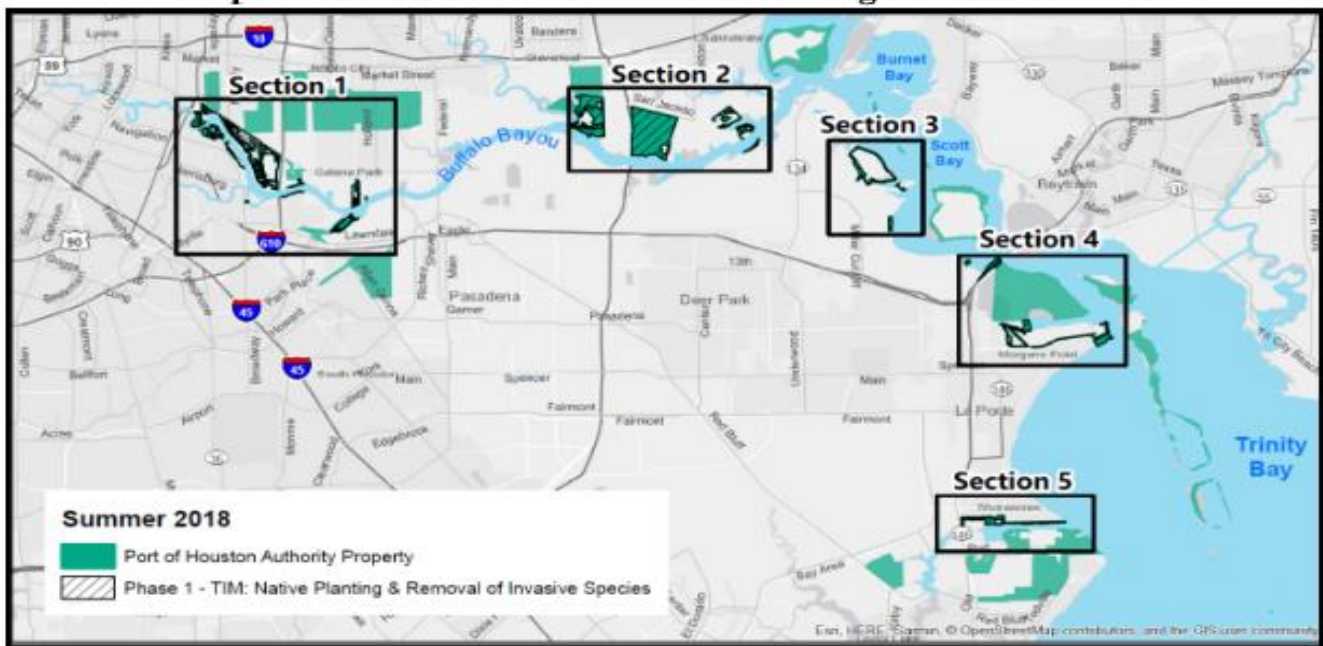
Figure 12 shows how Phase 1 is divided into 5 sections as seen in Map 1.[42]

The PoH TREES Program will ultimately increase the health of the Port & Ship Channel ecosystem through increased air and water quality and erosion control from the native trees. Port Houston TREES will identify the number and species of trees that already exist and target places along the channel that additional trees/grasses can be planted. The ability to conduct a comprehensive inventory of a large-scale ecosystem such as The Houston Port allows researchers, businesses and nonprofit groups the capability to analyze ecosystems more effectively and gain valuable insight into the impacts and ecosystem services. The removal and large-scale tree planting phases of the project will provide a more self-sustaining ecosystem that provides a multitude of ecosystem services (increased air & water quality, increased nutrient cycling & oxygen production and improved aesthetic) for the industrial area.

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[42] MASTER Plan of Work_ Port of Houston Tree & Riparian Enhancement of Ecosystem Services (TREES) Programs

5. **Harris County Flood Control District (HCFCD) Projects**[43]

   a) The Harris County Flood Control District's mission is to devise the Stormwater Management Plans, implement the plans and maintain the infrastructure, all with appropriate regard for community and natural values. Trees play an integral role in fulfilling the elements of the HCFCD'S mission. The Flood Control District looks for ways to preserve significant trees on its right of way whenever possible, or to identify trees that can be moved in advance of construction projects. HCFCD typically plants 12,000 to 15,000 trees annually to replace those lost during construction, to enhance capital improvement projects, and as part of a routine maintenance program. The HCFCD works with individuals and organizations to plant trees and wildflowers in appropriate places on its property and easements.

   The HCFCD plants trees to create a mature forest canopy that over time shades out and prevents the growth of undesirable underbrush that can hinder storm water conveyance and increase maintenance costs. Areas with little or no groundcover require less mowing and maintenance, conserving HCFCD resources. Tree planting in non-conveyance areas such as storm water detention basins, along natural channels, and upper slopes of channels allows HCFCD to reduce the amount of acreage mowed by hundreds of acres annually.

   HCFCD carefully screens potential tree planting sites, with preference given to those: suitable for the establishment of a woodland ecosystem along channels without obstructing access or storm water conveyance, favorable for tree survival, where future channel improvements, construction, or de-silt operations are not currently scheduled, and not crucial for storm water conveyance (such as the upper slopes of channels and storm water detention basins).

6. **CoH TREES Program**[44]

   a) The City of Houston Tree and Riparian Enhancement of Ecosystem Services Program (CoH TREES) is part of the Mayor's Climate Action Plan and Resilience Plan. A Climate Action Plan provides evidenced-based measures to reduce greenhouse gas emissions and preventative measures to address the negative outcomes of climate change. The plan will demonstrate how the City will adapt and improve its resilience to climate hazards that impact the city today as well as risks that may increase in the coming years.

   To comply with the Paris Agreement, the plan will follow science-based criteria that will cap the temperature increase associated with climate change to 1.5 degrees Celsius. Scientists believe that preventing global temperatures from rising more than 1.5 degrees Celsius will avert the worst consequences of climate change. This plan will create ambitious targets to reduce greenhouse gas

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[43] https://www.hcfcd.org/our-programs/tree-planting-program/
[44] http://greenhoustontx.gov/climateactionplan/index.html

emissions and establish a pathway to meet the Paris Agreement goal of becoming carbon neutral by 2050.

7. **Houston Area Urban Forests Project/Houston-Galveston Area Council**[45]

    a) It is the goal of H-GAC's regional urban forestry program to improve the health and diversity of the region's urban forests and increase public awareness about the environmental benefits of trees in the urban setting. The program seeks to integrate urban forestry data into other planning efforts, like H-GAC's Regional Hazard Mitigation Plan, and to develop and implement urban forestry planning projects that identify and prioritize urban forestry conservation and restoration efforts across the region. The program relies heavily upon cooperation from local municipalities and governments and includes opportunities for public education and community-based volunteer opportunities.

    As part of the regional urban forestry program, H-GAC is working with the U.S. Endowment for Forestry and Communities, Inc. and American Forests to evaluate regional urban forestry goals and highlight priority reforestation sites in the greater Houston area. This project is a collaboration with local partners involved in managing the area's urban forests.

    The Houston Area Urban Forests project is a collaboration between national efforts and partners in the Houston area to define a regional approach to evaluating, managing, and restoring our urban forests and tree canopy. The focus of the project will be identifying shared values and priorities, resource needs, and long term methods for coordination among the various entities how manage or support urban forestry in the core of the Houston metropolitan area.

-Plant trees within the COH limits to sequester CO_2.

-Create a clear, actionable tree canopy plan to increase tree canopy coverage X percent by 20XX.

-Create a city-wide survey of space available for tree planting to understand full potential and best options.

-Work with community partners to increase rate of tree planting.

-Create a city policy to maintain CO_2 stored in current greenspace- no net loss.

-Strengthen Houston tree protection ordinances.

-Encourage green space/trees in new development by updating land-use ordinance.

-Development of an ecosystem credit market-perhaps combining carbon and storm water credits. Develop offset opportunities for residential and commercial properties.
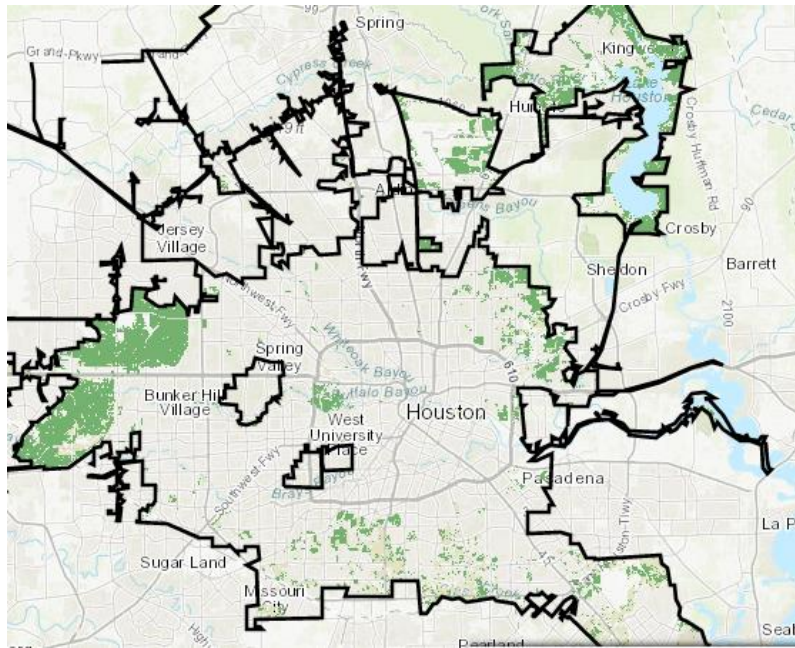
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[45] http://www.h-gac.com/urban-forestry/default.aspx ; https://houstonforests.weebly.com/about.html

B. Regional Ecology- forests/large scale trees[46]

1. Trees in the selected area, as shown in the picture below, store 733.2 thousand tons of carbon, which is 36% of the 2,044.1 thousand tons of carbon stored by trees across the entire city.

Carbon storage includes the amount of carbon bound up in the aboveground and belowground portions of trees.[47]

Class	Tons	Percent	Tons Per Person
Forest/Scrub	733.1K	100	25.62
Grass/Herbaceous/Crop	0.0K	0	0
All	733.2K	100	17.82

Figure 13 shows carbon storage by land cover class.[48]

2. The two species with the highest amounts of carbon storage were loblolly pine and green ash. Collectively, these two species account for 29% of total carbon storage in the selected area.

Species	Tons	Percent	Tons Per Person
Loblolly Pine	115.2K	16	2.8
Green Ash	93.7K	13	2.28
Other (29 more)	524.2K	71	22.74
All	733.2K	100	17.82

Figure 14 shows carbon storage by species.[49]

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[46] Regional Urban Forester: Monica Singhania and Matt Weaver https://texasoakwilt.org/getting-help/texas-am-forest-service-contacts/

[47] http://tfsfrd.tamu.edu/mycitystrees/app#/

[48] http://tfsfrd.tamu.edu/mycitystrees/app#/

[49] http://tfsfrd.tamu.edu/mycitystrees/app#/

	Species	Scientific Name	Private	Public	Total
1	Yaupon	Ilex vomitoria	2,456,851	2,948,221	5,405,073
2	Chinese tallowtree	Triadica sebifera	323,304	4,392,304	4,715,608
3	Chinese privet	Ligustrum sinense	2,293,061	0	2,293,061
4	Sweetgum	Liquidambar styraciflua	938,426	92,041	1,030,467
5	Green Ash	Fraxinus pennsylvanica	0	971,867	971,867
6	Sugarberry	Celtis laevigata	223,528	649,155	872,683
7	Japanese Privet	Ligustrum japonicum	846,385	0	846,385
8	Loblolly Pine	Pinus taeda	236,677	472,216	708,893
9	Hawthorn Spp.	Crataegus spp.	0	668,309	668,309
10	Boxelder	Acer negundo	485,365	0	485,365
11	Cedar Elm	Ulmus crassifolia	0	367,026	367,026
12	Farkleberry	Vaccinium arboreum	327,580	0	327,580
13	Winged Elm	Ulmus alata	39,446	268,980	308,426
14	Water Oak	Quercus nigra	39,446	223,528	262,974
15	Black Willow	Salix nigra	39,446	197,231	236,677
16	Willow Oak	Quercus phellos	0	197,231	197,231
17	Hercules' club	Zanthoxylum clava-herculis	0	190,087	190,087
18	Common Persimmon	Diospyros virginiana	163,790	0	163,790
19	Eastern Redcedar	Juniperus virginiana	163,790	0	163,790
20	American Elm	Ulmus americana	78,892	13,149	92,041
21	Water Hickory	Carya aquatica	0	52,595	52,595
22	American Hhornbeam, Musclewood	Carpinus caroliniana	0	39,446	39,446
23	Cherrybark Oak	Quercus pagoda	39,446	0	39,446
24	Post Oak	Quercus stellata	26,297	13,149	39,446
25	Chinaberry	Melia azedarach	0	26,297	26,297
26	Hackberry	Celtis occidentalis	13,149	0	13,149
27	Overcup Oak	Quercus lyrata	0	13,149	13,149
28	Pecan	Carya illinoinensis	13,149	0	13,149
29	Shumard Oak	Quercus shumardii	13,149	0	13,149
30	White Ash	Fraxinus americana	13,149	0	13,149
31	Osage-orange	Maclura pomifera	0	0	0
	Total		**8,774,326**	**11,795,980**	**20,570,306**

C. Current Data/Research on Carbon Sequestration in Texas

1. US Forests Service[51]- The baseline forest carbon reports provide information from the Forest Inventory and Analysis (FIA) data on carbon stocks and trends for seven different forest ecosystem carbon pools – above-ground live tree, below-ground live tree, standing dead,

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[50] http://tfsfrd.tamu.edu/mycitystrees/app#/
[51] https://www.fs.fed.us/managing-land/sc/carbon

understory, down dead wood, forest floor, and soil organic carbon – for the baseline period 1990 to 2013 (and 2005 to 2013, truncation of the longer baseline).

2. Southern Region Carbon Assessment[52]- Total forest ecosystem carbon (in all seven pools) stored in the Southern Region increased between 1990 and 2013, beginning with approximately 704 Tg (704,000,000 tons/acre) in 1990 and reaching approximately 912 Tg (912,000,000 tons/acre) in 2013 (Figure below).
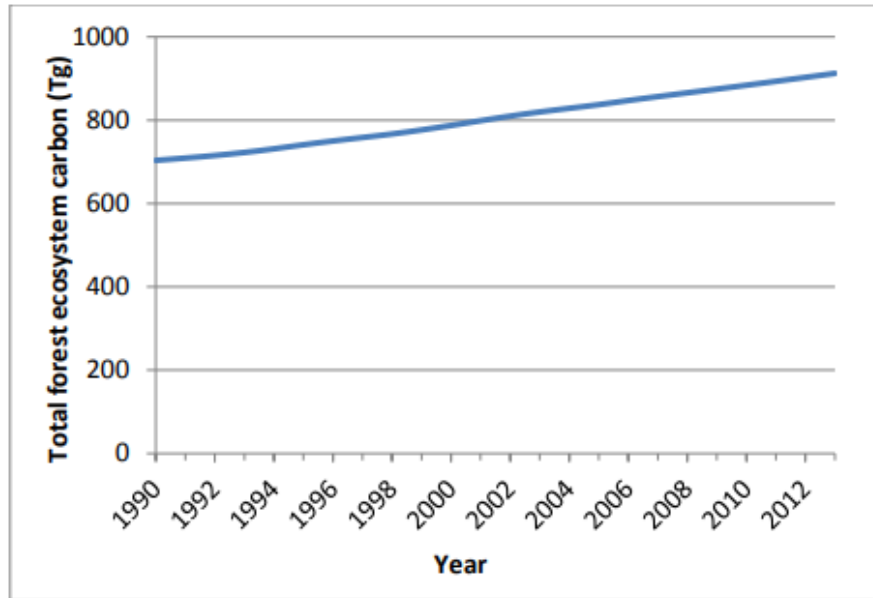

Figure 16. Total forest ecosystem carbon (Tg) for the Southern Region from 1990 to 2013.[53]

[52] https://www.fs.fed.us/climatechange/documents/SouthernRegionCarbonAssessment.pdf
[53] https://www.fs.fed.us/climatechange/documents/SouthernRegionCarbonAssessment.pdf