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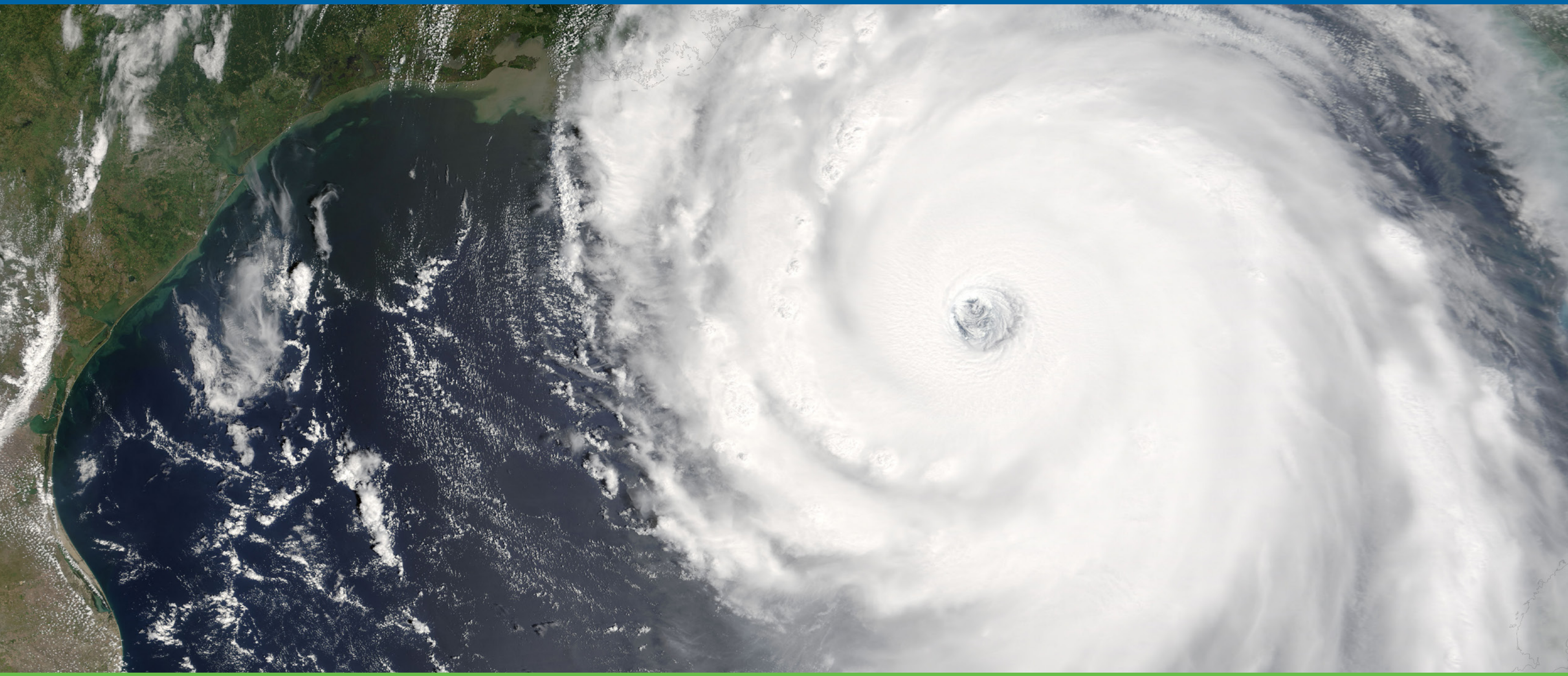

TEXAS COASTAL EXCHANGE

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"Texas Coastal Exchange"

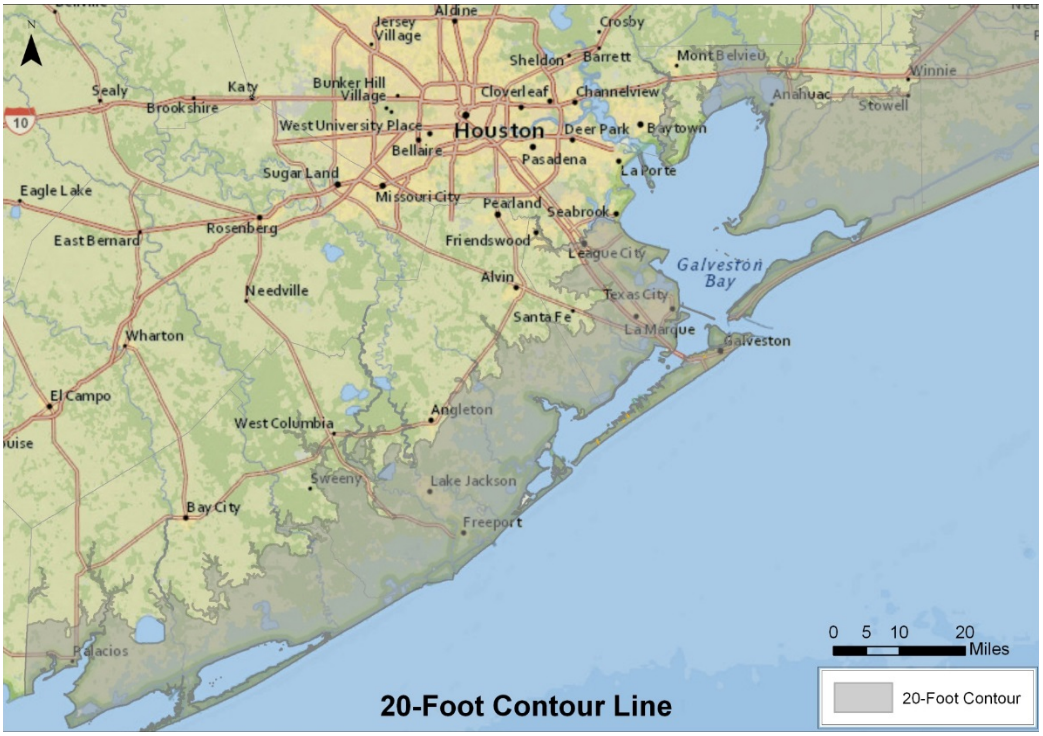
Introduction

The Texas Coastal Exchange (TCX) is a concept developed by the Severe Storm Prediction, Education, and Evacuation from Disasters (SSPEED) Center at Rice University under a grant from the Houston Endowment. The TCX was conceived as a nonstructural hurricane surge damage reduction concept in which landowners who restore natural areas to provide certain ecological protection services receive compensation through a voluntary market exchange. Over time, this concept has emerged as a mechanism to address several of the most important issues of the early twenty-first century, including flood damage mitigation, water quantity and quality enhancement, climate change, and fish and wildlife conservation, as well as a means to provide economic resilience in both the farm and ranch community and the oil and gas industry. In short, restoring natural systems through the creation of a voluntary private sector market may enable major progress in addressing several key present-day issues and spearhead major strides toward a circular macroeconomic system that will be required for the future.

The idea for the TCX emerged from observations of aerial flyovers of the flooded areas east of Galveston Bay after Hurricane Ike as well as the plan prepared for the Bolivar Peninsula post-Ike. These flyovers showed that hurricane surge water came ashore with Ike, pouring off of the low-lying coastal plain and wetlands back into the Gulf of Mexico several days after Ike made landfall. From this aerial view and subsequent computer modeling, it became clear that this low-lying coastal plain stored vast quantities of surge water without incurring the massive damages experienced elsewhere on the coast. Further, the post-Ike report from Bolivar indicated that landowners from low-lying wetlands and prairies on the bay side of the peninsula were interested in generating additional sources of income. These two observations led the SSPEED Center team to search for ways in which to store surge water and generate income for landowners, resulting in the TCX concept.

Over the past two years, the project team has been investigating innovative concepts to generate income for landowners of approximately 2 million acres of low-lying coastal prairie, wetlands, and woodlots with a goal of either storing or attenuating hurricane surge flooding. This in turn led the project team to investigate several different types of natural systems, including oyster reefs, coastal wetlands, coastal prairies, and bottomland hardwoods, as well as specialty habitat creation options. The initial area of interest was the approximately 2 million acres of land at or below the 20-foot elevation contour adjacent to the bay and/or Gulf in Chambers, Galveston, Brazoria, and Matagorda counties, as shown in Figure 1. This 20-foot elevation was chosen because it represents the current reasonable worst-case hurricane surge along the coast (i.e., without considering future sea level rise or increasing storm intensity). This geographic area could provide a significant buffer for the rest of the region. However, given the strong negative perception of new regulation, our team concluded that this buffer can only be (rapidly) established through market-based mechanisms. The TCX is such a mechanism.

Figure 1. Low-lying areas of the upper Texas coast



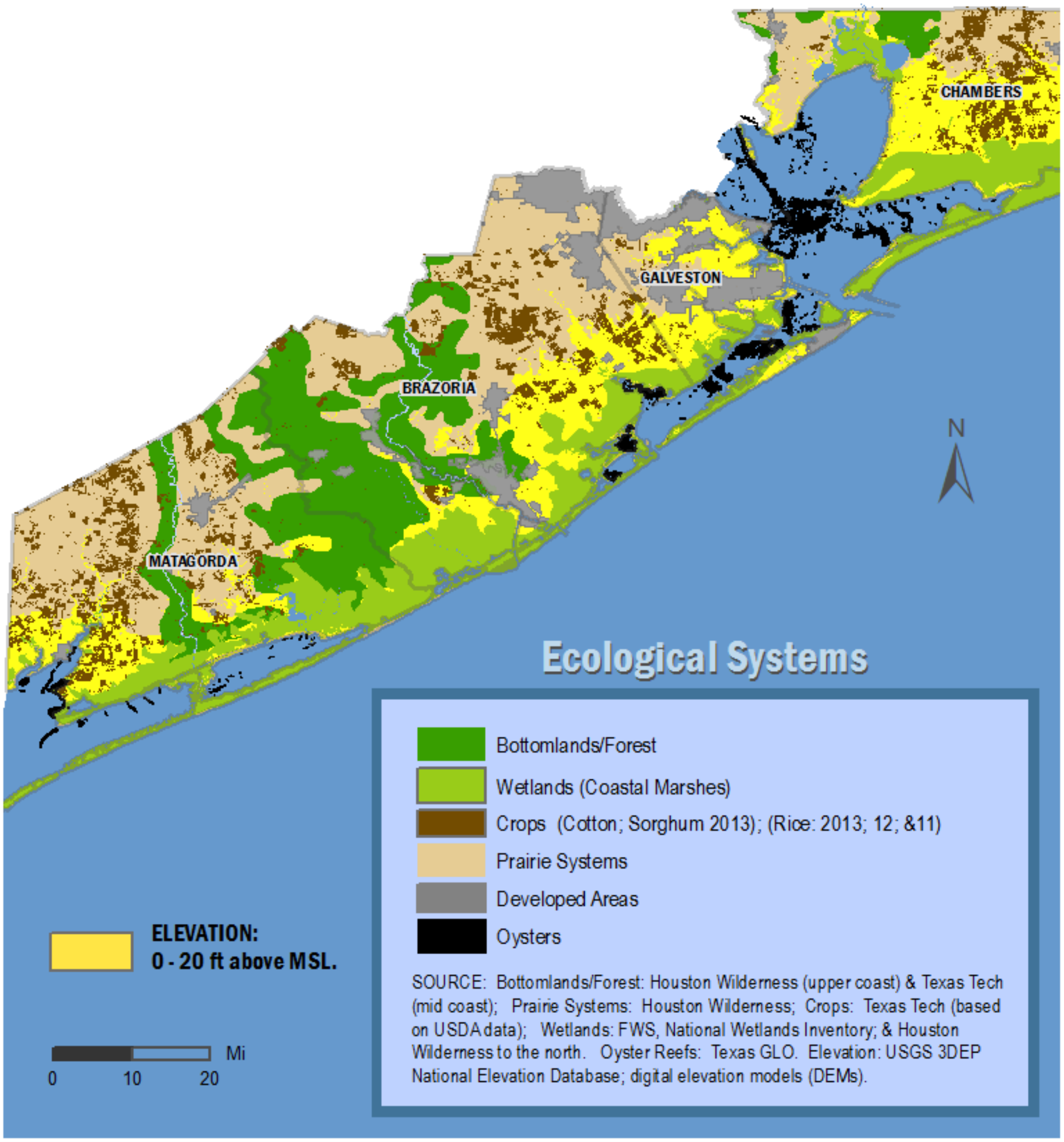
Note: Approximately 2 million acres of the four coastal counties near Houston are below the 20-foot contour elevation, which is considered a minimal reasonable area for hurricane surge inundation.

Source: Severe Storm Prediction, Education, and Evacuation from Disasters (SSPEED) Center, Rice University.

The TCX is based upon the concept that natural ecological systems provide services to communities. However, in the past, these services generally have been taken for granted, and typically no dollar value has been accorded to this work, except for cases of resource harvesting such as timber sale, hunting leases, or cattle raising. It is increasingly becoming apparent that there is a dollar value in these ecological services and that markets can be developed to allow landowners to reap compensation from restoring, protecting, and stewarding the ecosystems that provide these services. In this way, protection, income, and conservation goals merge to produce a fascinating potential for the upper Texas coast, as well as the rest of Texas and the United States.

Ecosystem Services of the Upper Texas Coast

Figure 2. Ecosystems of Galveston, Chambers, Brazoria, and Matagorda Counties



Note: The pasture and cropland are considered prairie for the purposes of restoration. The area included up to the 20-foot contour is shown in yellow.

Source: SSPEED Center, Rice University.

The upper Texas coast is replete with ecosystems as shown in Figure 2. These systems provide environmental protection services and have the potential to generate revenue for landowners. For example, oyster reefs occur within East, Galveston, West, Christmas, Drum, and Matagorda bays, as shown in black in Figure 2. Oyster reefs offer great potential for shoreline protection, performing an excellent wave break function. This function is important on a day-to-day basis as well as with regard to larger storm events in which breaking the waves may reduce the most damaging impact of the storm surge. They also provide excellent fish habitat, as can be attested by virtually every fisherman in the Galveston Bay complex, many of whom usually stop at one or more reefs during fishing trips to the region. Research is needed to determine whether the conversion of carbon dioxide to calcium carbonate (oyster shell) is a reliable and sufficiently scalable activity for permanently removing carbon dioxide from the atmosphere. As a policy matter, oyster reefs should be integrated into the standard coastal protection toolbox because they are less expensive than traditional structures like seawalls, dikes, and levees. They also provide significant environmental benefits compared to the damage caused by most traditional structures. An image of the oyster reef as a breakwater is shown in Figure 3.

Figure 3. An oyster reef as a breakwater adjacent to coastal wetlands

Source: United States Fish and Wildlife Service.

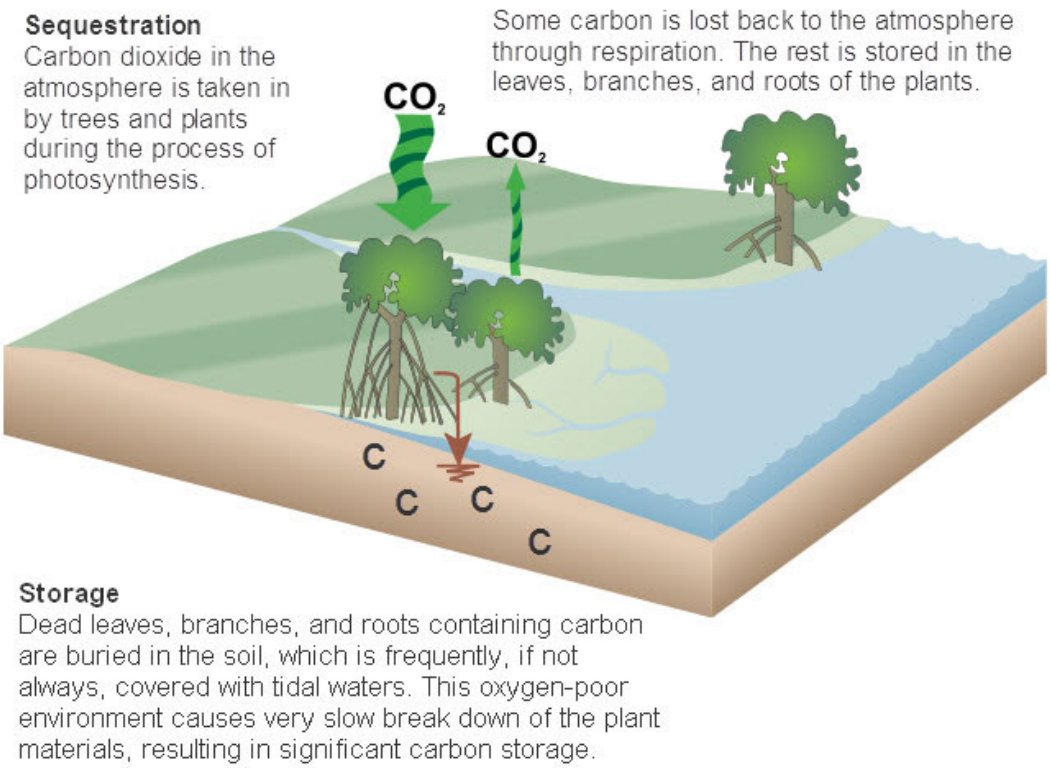
Native prairie is another example of a robust ecosystem service provider on the upper Texas coast. Native prairies clean the air by removing carbon dioxide, filter pollutants from water runoff, slow water runoff in rain events, and store water in times of drought. Much of the TCX area that used to be native coastal prairie is now home to non-native pasture grasses and agricultural land uses, neither of which offer the ecosystem benefits of native coastal prairie and which both result in net environmental damage. These lands are amenable to being restored to native conditions, and the policy implications of engaging the resulting ecological services are broad and deep. Very importantly, the vast majority of these lands are privately owned, and landowners who would restore the prairie could and should be compensated for the services provided.

For example, restored prairie could help significantly with reducing climate change. Published reports from other regions indicate that the 15-foot-deep root system of native prairie sequesters 2 to 3 tons of carbon dioxide per acre annually into the soil. Anecdotal evidence suggests that upper Texas coastal prairie would produce similar results, though further scientific study is needed and underway. Perhaps more importantly, certain types of grazing such as adaptive multi-paddock (AMP) grazing are shown to increase the amount of carbon dioxide sequestered per acre. Both peer-reviewed and more recent studies in press have demonstrated that an alternative method of livestock grazing (including AMP grazing) can rapidly restore soil health by adsorbing and storing very high amounts of atmospheric CO_2. Grassland soils can store 3 tons C/ha/year (4.5 tons CO_2/acre/year) or more, compared to less than a ton per acre on some continuously grazed pastures. In AMP grazing, paddocks are heavily stocked for a short period of time, stomped and "fertilized" by the animals, then left to recover. In the recovery process, photosynthesis pulls nearly four times more carbon dioxide out of the air as the grass grows and soil carbon is increased, making the soil healthier. Putting it into context, this means that the carbon footprint of Harris County—which at 18.6 million tons of carbon dioxide is the highest of all U.S. counties—could be stored yearly by restoring about 6 million to 9 million acres of prairie, an attainable goal given the land areas surrounding Harris County alone. It would take only 100,000 ranchers to sequester about 1 gigaton of CO_2/year. In doing so, they would restore 250 million acres of pasture ecosystems, improve flood and drought resistance, and significantly improve ranch economics.

Native prairie could also significantly help with the many water challenges the Houston region faces—flooding, drought, and drinkability. In the native prairie, the root system and the associated microbiome and soil insects create a lattice of pores and pathways that can store significant amounts of water in near-surface soil reservoirs as well as in surface depressions. This lattice system creates a "reservoir" in the soil that reduces runoff and peak flows from larger storm events. This system also augments seeps and springs over time through flow within the soil system, which serves as a kind of water "savings account" for times of drought. Our understanding of soil hydraulics is relatively young, but anecdotal evidence suggests restored prairie on the upper Texas coast would produce similar results (further scientific study is needed and underway). Given that both severe drought and flooding in the region over the last decade have shown that structural solutions are not succeeding, policymakers should actively engage the significant water resilience contribution prairie may yield. Lastly, restored native prairie also has the ability to produce both flora and native fauna, including bees, monarch butterflies, bobwhite quail, and numerous songbirds. While metrics from the upper Texas coast are lacking, anecdotal evidence of these floral and faunal values of restored prairies is very strong.

A third coastal ecosystem is the coastal saltwater and brackish wetlands that form the first landward ecosystem moving in from the bays and the Gulf. These wetlands are salt tolerant and also have an impressive root system that injects carbon into the soil at higher rates than native prairie, with reported amounts indicating a strong potential to store 3 to 4 tons of carbon dioxide per acre of wetland. These saltwater marshes also play an important role in the life cycle of many marine species. Studies of marsh productivity indicate that an acre of coastal marsh serves as habitat for about 7,900 white shrimp, 8,800 brown shrimp, and 7,600 blue crabs at various times of the year. Waterfowl hunters for centuries have known about the waterfowl usage of these marshes, which are also home to numerous fish-eating and other wading birds. Figure 4 illustrates the concept of carbon sequestration in a mangrove wetland, which may be suitable for portions of Galveston Bay.

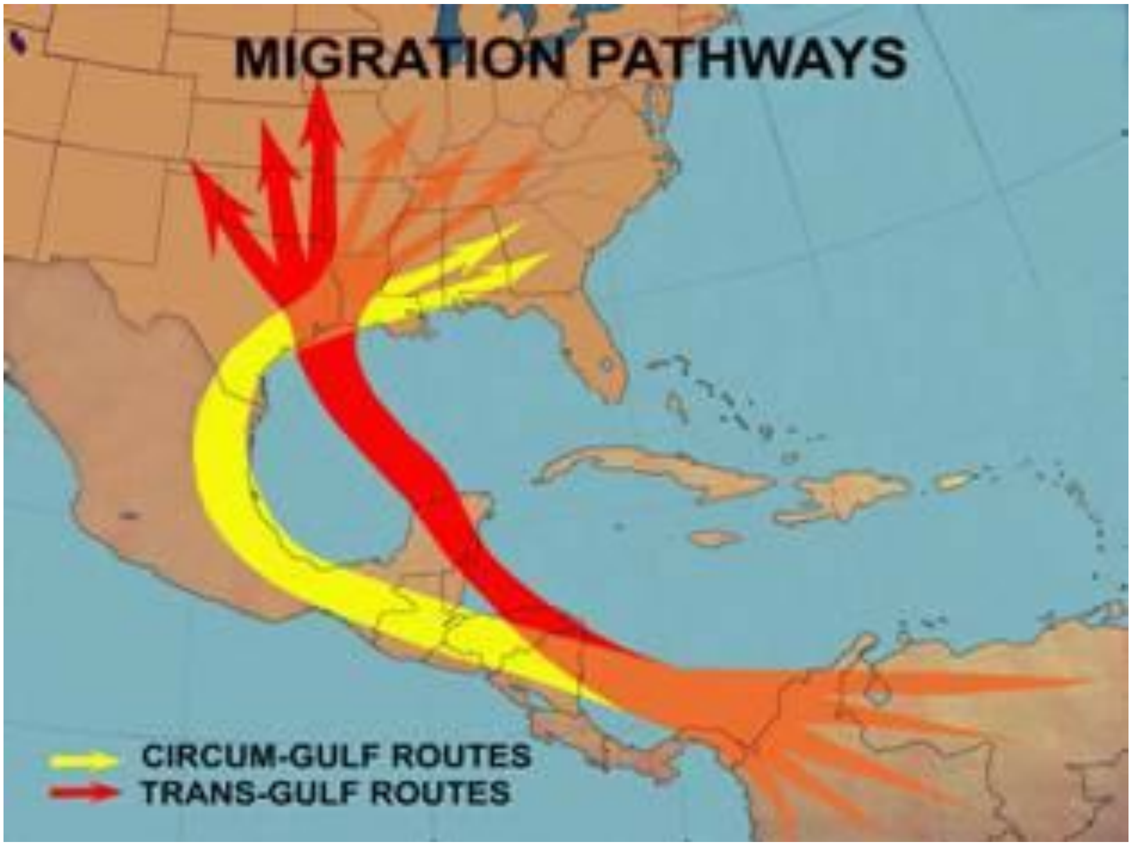
Figure 4. Diagram showing the carbon sequestration process using an example of a mangrove wetland



Source: National Oceanic and Atmospheric Administration.

The fourth coastal ecosystem is the bottomland hardwood forest along the major river corridors, most notably the Brazos, San Bernard, and Colorado river systems, as shown in green in Figure 2. These forests sequester carbon in the wood and soil, with estimates ranging up to 4 tons of carbon dioxide per acre per year, and hold significant volumes of floodwaters during and after riverine flooding events. The birdlife of the so-called Columbia Bottomlands of Brazoria and Matagorda counties is of national significance as it draws more than 24 million songbirds migrating in the spring and, to a lesser extent, the fall. These bottomlands are a beautiful, double-canopy forest with an extremely diverse plant system. Figure 5 illustrates the convergence of bird migration pathways across the Columbia Bottomlands.

Figure 5. Major bird migration pathways across the Gulf from the Yucatan Peninsula and around the Gulf circumference, with convergence in the upper Texas coast



Source: http://lyndagoff.com/songbird-migration-across-the-gulf-of-mexico/.

Finally, there is the potential to develop highly specialized habitats that may attract certain types of species. Along the Texas coast, there is a need, particularly in areas lacking bottomland forests, for small woodlots adjacent to the Gulf of Mexico or a bay. These localized habitats have tremendous value as "rest stops" for migrating songbirds. Similarly, there is a need for additional "territories" in the Matagorda Bay system for the expanding Aransas-Wood Buffalo wild flock and the last remaining wild flock of endangered whooping cranes. In both cases, landowners may be compensated for creating and/or stewarding and supporting such habitats, as they should be considered as potentially improving migratory success and species recovery. Figure 6 depicts a Baltimore Oriole, an example of a migratory songbird that may travel through the Texas coast.

Figure 6. Baltimore Oriole

Note: Neotropical migrant species such as the Baltimore Oriole migrate through the Texas coast and need woodland habitat for rest, food, and water.

Source: http://www.refugefriends.org/photos/var/resizes/Gallery.

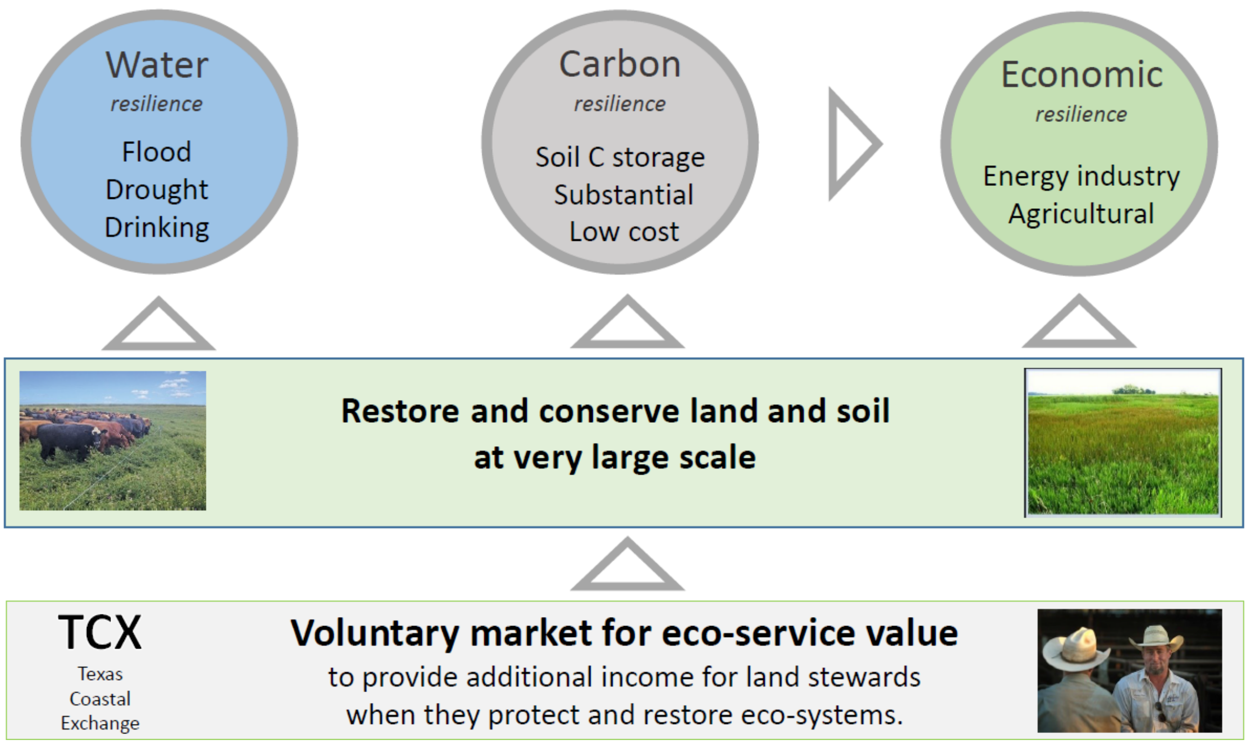
Developing the Market—Sellers and Buyers

There is no doubt that the rich ecological systems of the coastal low-lying areas, if protected and/or restored, have a tremendous potential to provide ecological services. The more difficult task is to identify and develop the markets by which potential service users will begin to pay for these services. The good news is that such a market is developing and may be ready for implementation in the not-too-distant future.

Both buyers and sellers are necessary in order to create and/or encourage the development of a market. As envisioned, this market is voluntary on the part of both buyers and sellers, setting up a willing-buyer and willing-seller marketplace. The job of the Texas Coastal Exchange is to encourage and assist in the realization of a market supporting ecosystem protection and/or restoration and economic activity compatible with occasional surge inundation.

Figure 7 outlines the basic concept of the TCX. The creation of the voluntary market provides income that induces landowners to manage their properties in ways that increase regional water, climate, and economic resilience. This exchange concept is based upon monetary compensation being provided for beneficial land management actions, as described above. If this cash flow can be established, amazing results can be achieved.

Figure 7. Graphic depiction of the resilience potential of the Texas Coastal Exchange



Source: Image by Henk Mooiweer, Innovenate, for SSPEED Center.

As part of our work on the TCX, the SSPEED Center has undertaken extensive research on both the existence and willingness of buyers and sellers to enter this voluntary market. Generally speaking, there is great interest among potential sellers, as will be discussed below. There is also great interest, albeit more cautious, among potential buyers. However, there is no doubt of the excellent potential for creating this voluntary market.

The SSPEED Center team has conducted many interviews and discussions with coastal landowners and the feedback is quite similar from all areas of the Texas coast. The current agricultural economic model is not working well for many coastal landowners. Many rice farmers are being forced out of the industry because of water availability issues. Many ranchers are barely breaking even with current cattle management practices. Virtually all parties interviewed indicated interest in potential ecological markets if they could generate positive cash flow. Most landowners were not interested in transactions that required either fee simple trading of lands or permanent conservation easements. However, there would be great receptivity if longer-term commodity contracts could be utilized in these transactions. So, if there is a market and if the development costs are less than the cash flow, and if commodity contracts can be utilized, then sellers certainly exist. In fact, most landowners currently have a great need for an alternative agricultural economic model. On the other hand, determining the existence and willingness of buyers is difficult. There are numerous examples of payment for ecosystem services under various environmental laws—including wetland mitigation banks, endangered species habitat offsets, the use of natural systems to remove nitrogen and phosphorus from rivers and bays for pollution control, and the planting of trees to reduce thermal pollution through shading. However, these are involuntary, regulatory programs, generally mandated by federal environmental laws, such as Section 404 and Section 303(d) of the Clean Water Act, and the Endangered Species Act. The challenge is to develop buyers for ecosystem transactions without the "stick" of regulation.

There is a strong emerging market for legitimate solutions that can be implemented fast, affordably, and at a meaningful scale. Nature-based solutions have the capability to meet those criteria. The real issue is the timing of the development of this market as well landowners' ability to "stack" various transactions such that the same restored ecosystem may generate income from several buyers for several separate ecosystem services provided. So, where are these markets and when are they going to emerge?

Currently, the Earth is experiencing a series of events attributable to climate change, particularly weather events that are abnormal in terms of storm frequency and intensity, as well as drought duration and intensity. Hurricanes are becoming more intense and dangerous, flooding rainfalls are more frequent, and dependable water supply is decreasing as evaporation rates increase and droughts become more severe. The sea level is rising, as are atmospheric and oceanic temperatures around the globe. And while we have not seen the full brunt of predicted impacts, the changing climate is becoming more and more obvious, with greater numbers of U.S. citizens accepting that climate change is real and that humans have caused it, conclusions reached by the scientific community years ago.

The corporate community is slowly coming to the consensus that they can and should do something to address carbon dioxide emissions, driven by a number of factors, including consumer demand and lender requirements. Most international corporations are developing carbon neutral business plans, a trend strengthened by the Paris Conference of Parties (COP 21) held November 30–December 12, 2015. Plans are being developed around the world to limit global carbon dioxide emissions to stabilize global temperatures in response to a 2-degree Celsius rise, which represents about 54 billion tons of carbon dioxide emissions worldwide per year. To stabilize at this level, developed countries such as the United States will need to reduce emissions. After conservation and energy source substitution, the only viable solution is terrestrial sequestration of carbon, or storing it in soil, as described above. An alternative of geologic sequestration (i.e., mechanical pumping of carbon into subsurface storage systems) so far has been struggling to reach meaningful scale and is too expensive, costing in excess of $60 per ton of CO_2 sequestered. By contrast, the cost per ton for terrestrial sequestration—such as that provided by restored marshes, prairies, and forests—is significantly lower, with current prices of about $11 per ton in regulated markets and internal price estimates at major oil companies in the $40 to $60 per ton range. For alternative grazing solutions, there is no cost to the landowner to store CO_2. These alternative grazing methods significantly increase soil health, which leads to increased ranch profitability. Any payment for storing soil carbon is additional income for a rancher.

In effect, every corporation in the United States will be assessing how to minimize and then zero-out their carbon footprint over the next decade or so. And there is only a certain amount of land suitable for sequestering carbon, potentially storing 7 to 14 billion tons of carbon dioxide per year unless processes such as AMP grazing can significantly increase carbon sequestration rates. Ultimately, if carbon neutrality is required in the consumer supply chain, the maximum terrestrial sequestration capacity could be significantly exceeded by demand.

Consider the following scenario. If an oil company decided to market “carbon neutral” gasoline due to consumer demand, that company would need to calculate the total amount of carbon dioxide emitted during the gasoline production at a 150,000 barrel per day refinery and determine the CO_2 emissions associated with the combustion of that gasoline, then arrange for (i.e., pay for) sufficient ecological sequestration services to store that carbon dioxide in the ground. The company would also need to assess upstream carbon dioxide emissions from the production and transportation of the oil to the refinery. Without going into detail, calculations can be made for the carbon dioxide emissions required to produce and transport the oil to the refinery, to refine the oil into gasoline, and then to burn the gasoline in a car. On average, a mid-sized car in the United States burns about 382 gallons of gasoline per year. Once the total carbon dioxide emissions per gallon of gasoline is calculated, the raw cost to store the produced carbon dioxide in the ground is about 8 cents per gallon of gas consumed (making numerous assumptions). That means that for about $30 a year, the carbon footprint for an average American driver could be sequestered.

Two interesting business models can emerge from these calculations. First, a company selling gasoline could offer a carbon neutral product by adding 8 cents to 10 cents per gallon (depending on the mark-up on the carbon dioxide sequestration). Or, automobile manufacturers could add $300 to a car’s sale price and incorporate the sequestration of the vehicle’s carbon footprint over 10 years of use into the purchase price. Whether the costs are enforced at the pump or at the auto dealership, an arrangement could be made with a landowner to sequester carbon dioxide emissions. Similar models can be further developed and brought to scale for airlines, as soil carbon storage offers a cost effective and scalable solution to fly CO_2-neutral.

The real question is: when will it be done? A look at corporate websites gives some insight into the potential demand for carbon sequestration services. In November 2015, Shell Oil initiated the Quest project in Alberta, which involved technological capture and storage, albeit at high costs per ton of carbon dioxide. ConocoPhillips stated in a 2015 corporate report that the company has integrated carbon costs into all future project investments decisions, a process most major oil and gas corporations are also implementing. Certain BP stations in Atlanta are offering carbon-neutral fuel in association with the Zero Clean Driving program. Exxon is openly proposing a carbon tax. And while none of these actions defines a land rush for terrestrial sequestration, these actions do indicate that the carbon-climate nexus is at the front of corporate consciousness at the board of directors level, where most of these companies now have corporate committees on climate issues. This is no longer a philanthropic issue for these corporations but rather part of the corporate strategic decision-making process regarding the long-term viability of the industry vis-à-vis climate impacts.

Other major corporations are requiring carbon neutrality planning and implementation, including offsetting remaining emissions. Prior to COP 21, specific pledges were made by Coca-Cola, Dell, Enel, General Mills, Ikea, Kellogg, NRG Energy, Procter & Gamble, Sony, and Walmart, among others. Monsanto pledged to become carbon neutral by 2021, a huge commitment. Several major European construction companies including GlaxoSmithKline, Interface, Lloyds Banking Group, Philips, and Tesco have accepted the Prince of Wales' challenge to create nearly Zero Energy Buildings (nZEB) for new facilities by 2020 and strive toward nZEB retrofit by 2030. Unilever seeks to become carbon positive by about 2030. And Airports Council International issued a pledge to seek carbon neutrality by 2030. These and many others are working with the United Nations to implement its Climate Neutral Now offsetting scheme. Most of these announcements came during the COP 21.

There are other methods of corporate participation. In some cases, various types of certification programs, such as LEED, SITES, ENVISION, or the Living Building Challenge, may require or award project points for carbon offsets. In other cases, competition may require offsets. But the bottom line is that carbon offsets will be pursued by major corporations over the next decade.

The potential carbon market and interest in carbon neutrality goes much further than major corporations. More than 677 U.S. colleges and universities have signed a carbon neutral pledge as proposed by the nonprofit Second Nature, including Rice University and the Houston Community College System. These institutions are committed to evaluating their carbon footprint and options for attaining carbon neutrality. Among the key issues are understanding options to conserve energy, electricity alternatives, and offsetting. The full "supply chain" of the generation of carbon dioxide emissions needs to be understood as well. Most of these commitments mature in the 2030s to 2050s, although a recent trend has been to accelerate these compliance dates: Oberlin College has committed to meeting its goals by 2025, while a few such as Colby College have already attained carbon neutral status.

There is also a potential market in service companies such as law firms, accounting firms, and other vendors who wish to establish carbon neutrality as a professional credential, thereby catering to corporations seeking to reduce their supply chain footprint. The Blackburn & Carter Law Firm in Houston committed to carbon neutrality several years ago, and offset the 50 tons of CO_2 footprint that its 10 employees generated by purchasing marshland voluntary offset credits. It is anticipated that other service firms will seek carbon neutral certification in the future in order to increase their marketing appeal, which should create a potential local market for carbon dioxide emission credits.

And fourth, the gift market is likely to emerge. Each of us has an individual carbon footprint that we generate daily. The U.S. carbon dioxide footprint per capita is about 17.5 tons per person per year. Several online foot-printing websites allow individuals to calculate their personal footprint. As society becomes more and more conscious about carbon dioxide emissions, a reasonable gift may be to offset one's carbon footprint. Given the many otherwise worthless gifts we all receive over the years, a carbon footprint offset, or a habitat purchase for a fisherman or birdwatcher, may be the perfect gift of the future.

The potential ecological services market is not limited to habitat protection or carbon sequestration. Texas is experiencing major water problems. The state suffers both from too much and too little water at different times. Rain events are increasingly more intense, with both the frequency of and total inches of rainfall experienced rising in various storm events. Due to both urban and rural land development patterns, most of this water runs off, turning rivers and bayous into flowing torrents that flood more land areas. On the other hand, periods without rainfall are increasing both in extent and severity. And then of course, the state experiences hurricanes that bring surges of Gulf waters inland, which can devastate human settlements in minutes. In short, the water system is becoming more volatile and certainly at variance with historic recorded patterns.

The restoration and enhancement of prairies, freshwater wetlands, and bottomland forests can have an impact on both flooding and water supply. Ike demonstrated that low-lying natural ecosystems such as coastal wetlands and prairie pastures can survive and even thrive after short-term inundation by hurricane surge, performing a valuable function of storing water. Natural prairies have extensive root systems that allow rainfall to percolate deep into the soil system, providing greater storage than heavily grazed, nonnative, "improved" pastures. Anecdotal evidence indicates that restored prairies tend to "green up" faster after rains than do "improved" pastures. In addition, the cattle "tanks" on these restored ranchlands take a bit longer to fill but retain water for a substantial time after adjacent tanks on improved pastures have become dry, indicating soil water storage and lateral movement. Research suggests that restored prairies could absorb more rainfall, potentially shaving off the peak flow (flood) levels of large storm events at the watershed level and, over time, restoring seeps, springs, and the base flow of streams and rivers during times of drought. Much more research is needed to confirm these anecdotal reports and develop appropriate metrics and models to reflect this important benefit of restored native prairie systems, and certain advanced computer models have begun to incorporate soil storage into their computational methods.

Restored ecological systems do more than sequester carbon and optimize water storage and retention. These native systems are home to countless native species of fish, wildlife, and insects, which will experience a resurgence with these restored ecosystems. Pollinating insects will be fully mobilized. Game species such as bobwhite quail, doves, duck, and geese will return. The U.S. conservation model, which has been based upon the purchase of either fee simple or easement property rights, could be transformed by the largest change in conservation thinking in decades.

In addition to water, carbon, and ecological resiliency, ecosystem service transactions have the potential to also offer economic resiliency at a national, if not international, scale. Oil and gas exploration, development, and usage is a major carbon emitter globally, and it is a major employer in Texas and throughout the world. It is hard to imagine a future where the current economic model for oil and gas companies remains unchanged. In order to do business in the future, oil and gas companies will have to address the volume and impact of carbon emissions, and internal oil and gas business models will incorporate future carbon dioxide costs (from $40 to $60 per ton CO_2) in projecting the financial viability of future projects, although nature- based soil carbon storage has the opportunity to be viable at lower costs, which might boost rapid scaling. Companies with the foresight to anticipate and address this issue will have no difficulty transitioning in the future. Those that fail to act effectively and in a timely manner will fail. Without internal changes, be it through conservation, alternative fuels, and/or mitigation efforts, certain oil and gas companies will go the way of the horse and buggy when the car came along.

After conservation, the easiest and most affordable method for the oil and gas industry to address this carbon dioxide pollution issue is to make arrangements (i.e., pay farmers and ranchers via a robust and legitimate market mechanism) for the removal of their carbon dioxide emissions from the atmosphere. While much industry effort has been focused on pumping carbon dioxide into deep geologic formations, this alternative is currently estimated to cost a minimum of $60 per ton of carbon dioxide sequestered. In addition, there are enormous challenges to finding acceptable geological storage capacity at scale. However, a restored ecosystem will naturally “pump” tons of carbon dioxide into the soil each year at basically no or even negative cost and deliver many additional benefits. Plants will absorb atmospheric CO_2 and via photosynthesis turn CO_2 into sugars that are transported into the root system and microorganisms living in soil, not only sequestering carbon but creating healthier soil in the process. So, in order to address this challenge to its economic future, the oil and gas industry will be driven—not by regulation but by the market system—to sequester to survive. Coal is already on its way out because consumers are choosing not to buy coal. The same future faces the oil industry, albeit a bit later.

At the same time, the farm and ranch agricultural community is facing economic hardships. However, if these land stewards were to become “carbon farmers,” it would open up a considerable financial opportunity. Using the corporate internal projected cost of $40 to $60 per ton of CO_2 and assuming that restored prairie could sequester about 3 tons of CO_2 per acre/year, this would generate a cash flow of between $120 and $180 per acre per year. Revenue of this magnitude (along with other “stacked” transactions) could lead to tremendous economic improvement in this sector of the agricultural community and to a major modification of future agricultural production models.

A collaboration between private landowners and the oil and gas industry to restore ecosystems and set up a market to sequester carbon dioxide, manage rainwater, and reduce flood flows would be a huge win-win for those industries and a win for Texas and the United States. First, sequestration of large amounts of carbon dioxide could proceed rapidly. Second, the oil and gas industry (at least companies that choose to participate) would be taking steps to insure its resiliency into the future, a key element for Houston's economic future. Third, the farm and ranch economy in rural Texas, which has been suffering, will get a huge financial jolt and gain long-term stability. Fourth, the water supply will be enhanced and the impact of flooding will be reduced, and fifth, native fish and wildlife will benefit substantially. Collectively, these changes will create a more resilient social structure and economy while restoring native ecological systems.

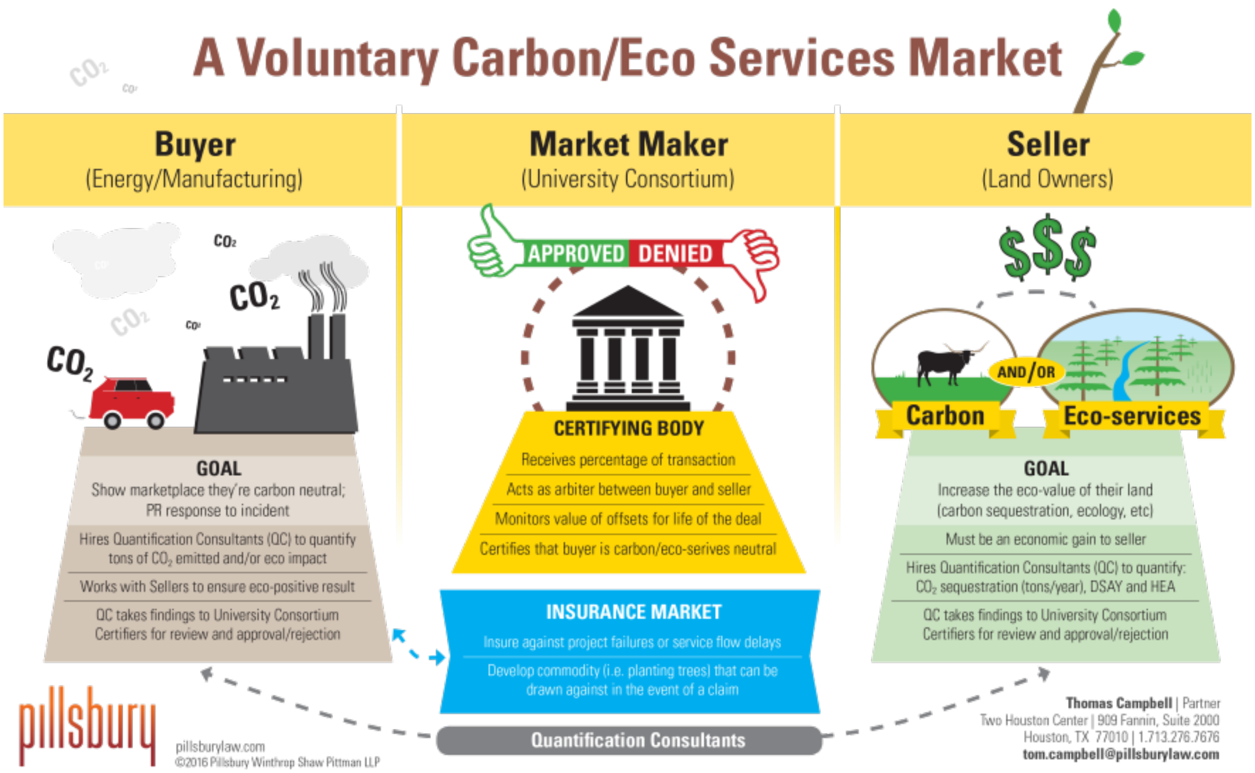
In short, ecosystem service transactions can play a major role in changing our future. There are many challenges to setting up these markets and ensuring that the product purchased is actually delivered, including key issues about metrics, validation, verification, and permanence. These involve countless legal matters, but also many opportunities. The bottom line is that nature is ready to do what is has been doing for billions of years. We need to be ready for development and deployment in the not-too-distant future, and we currently are not prepared to accommodate, aid, or even understand the implications of this new market and the challenges to implementing it in a relatively short time frame. Society needs a major research and development focus that will rapidly catalyze this opportunity to create this market exchange, aid and abet the transitions, and anticipate problems. And we should get in front, rather than continuing to lag behind, in solving the huge societal issue of climate change.

Developing the Market—Legal Framework

As a general statement, the transactions proposed by the Texas Coastal Exchange are contracts for services between a landowner and a buyer. Carbon transactions should be based upon the ability to keep carbon in the ground for several decades. Many coastal landowners have been reluctant to enter conservation easements, so the contract must allow sufficient time to accurately measure the absorption of atmospheric carbon dioxide in soil and demonstrate that it is indeed being sequestered for the desired length of time. Similarly, transactions involving long-term water supply and drainage improvements must be based upon certainty that these ecosystem service improvements will be maintained over a long period of time, as is the case with habitat improvements. In short, all of these transactions will require a set of legal instruments to guarantee that the benefits are maintained over decades. Since the enhancement of soil carbon and soil water significantly benefit farm and ranch economics, there is an important economic incentive for land managers to continue to improve their lands.

Figure 8, prepared for the SSPEED Center by Tom Campbell of the Pillsbury Law Firm of Houston, illustrates the legal framework for the transactions. A buyer, a seller, and a market facilitator are needed. The certification entity must either approve or disapprove the transaction and provide transactional transparency to ensure that the claimed benefits have in fact occurred. Additional research will determine the appropriate entity to undertake this facilitation.

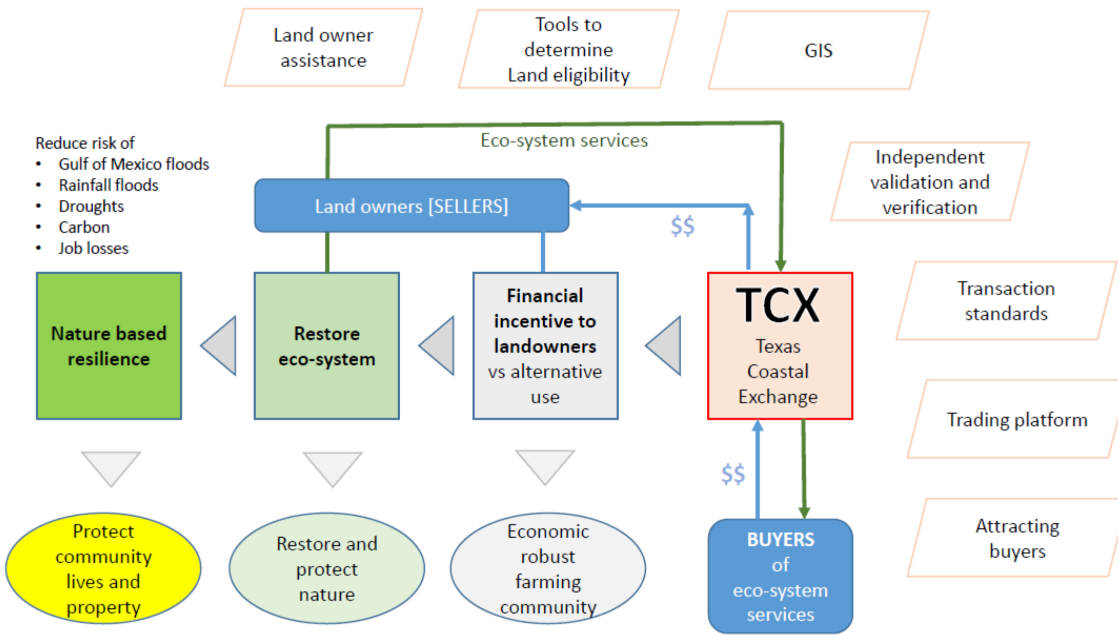
Figure 8. Conceptual diagram of the ecosystem service transaction and the various associated legal issues



Source: Tom Campbell, Pillsbury Law Firm.

Figure 9 depicts a slightly different transactional perspective of the TCX. Here, the exchange facilitates the voluntary transactions between the buyers and sellers of ecological services. The exchange itself provides the infrastructure to support the transactions, including working with landowners to help determine the suitability of their land for various ecosystem services and assisting them in restoring these ecosystems, and also working with buyers to determine their requirements. Among other things, the infrastructure will include transaction standards, a geographic information system, and independent validation and verification services designed to meet buyer requirements. The TCX also may become an independent trading platform, or it may elect to simply work with buyers and sellers, with the actual transaction conducted without the TCX's involvement. These and many other details have yet to be developed, although a website has been created to provide information about ecological services, as further discussed later in this report.

Figure 9. Diagram of the TCX's relationship to buyers and sellers of ecosystem services



Source: Henk Mooiweer, Innovenate, for SSPEED Center.

A diverse range of ecological services transactions can be arranged across various ecosystems, buyers, and sellers. Generally, four basic ecological systems appear to have ecosystem transaction value on the Texas coast: (1) oyster reefs, (2) wetlands, (3) prairies, and (4) forests. There are also four potential buyers, including (1) corporate, (2) philanthropic, (3) governmental, and (4) individuals (gifts), as previously discussed.

TCX plans to rapidly move into the implementation phase. By 2019, the goal is to have 30 landowners with 30 demonstration projects. These samples will include prairie and wetland restoration along with systems such as oyster reefs and forests, if suitable opportunities can be identified. The major focus is to demonstrate that this concept will work and can be rapidly implemented at a scale large enough to make a difference. The goal of the second phase is to have 300 landowners by 2022 and at least 3,000 by 2026, a conservative estimate if these concepts are as successful as we project.

Conclusion

What began as an effort to find a mechanism to provide income to coastal landowners within a 2 million-acre swath along the coast in Chambers, Galveston, Brazoria, and Matagorda counties has grown into a much larger project as the SSPEED Center team got deeper into this research. The pursuit and implementation of these ecosystem service transaction concepts has the potential to transform the Houston-Galveston area, the state of Texas, the United States, and, potentially, the world. In the Houston area, flood abatement would be a major benefit, both along the coast and in areas such as the Katy Prairie west of Houston, which has great potential for retaining storm water and protecting the Addicks Reservoir and the Buffalo Bayou and Cypress Creek watersheds. The carbon footprint of Harris County, which at 18.6 million tons of carbon dioxide is the highest of all U.S. counties, could be offset by restoring about 6 million to 9 million acres of prairie, a task that is doable in the land areas surrounding Harris County. The city of Houston could begin to protect its long-term drinking water sources in the San Jacinto and Trinity rivers by securing natural filtration rights from landowners restoring and/or protecting native prairies and forests.

At the state level, the water supply benefits of ecosystem services have already been recognized in an agreement regarding the future of the Guadalupe River watershed. Under the agreement reached between The Aransas Project and the Guadalupe-Blanco River Authority, a major research effort will focus on the potential impact of restoring the prairies of this watershed in an effort to shave peak flood flows and store water in the soil for slow release through rejuvenated seeps and springs. If this research supports the findings of the SSPEED Center so far, a plan for the transformation of this watershed may be developed in the not-too-distant future. And if the GBRA undertakes these efforts in the Guadalupe River watershed, it is likely that similar practices will be pursued in other watersheds.

At the national level, the potential for terrestrial sequestration of carbon is substantial. At some point, it will make sense economically to raise cattle on native grass rather than feeding them corn that is raised with significant carbon dioxide emissions. Under this scenario, many of the prairies in the Great Plains region will be restored, supplanting corn production for cattle. In this manner, the fertilizer usage for corn would be significantly reduced, lowering the amount of nitrogen and phosphorus storm water discharged into the Mississippi River system and diminishing the dead zone in the Gulf of Mexico. This transformation will also generate significant fish and wildlife habitat, offering a new conservation model for the United States that will have regional variations.

From a global standpoint, it is reasonable to foresee the terrestrial sequestration of between 7 million and 14 billion tons of carbon dioxide, which would make a sizeable impact on the amount of carbon dioxide in the global atmosphere. It is not unrealistic to foresee this as the standard business model of the future. From that perspective, this terrestrial sequestration process offers the oil and gas industry a major opportunity to reduce its carbon footprint and remain relevant into the latter part of the twenty-first century.

Similarly, the standard economic model for agriculture—which emphasizes combustion and fossil fuel-derived fertilizers, pesticides, and herbicides—may be replaced by one that relies on native ecosystems and processes to generate the sold “crop.” To be sure, many forms of industrialized agriculture will remain, but there will be a significant change in the agricultural economic model, particularly for ranchers and feed corn and grain producers.

From one perspective, the implementation of this ecosystems approach could be seen as a major step forward in the development of a macroeconomic system that is consistent with natural cycles and systems. For decades, there has been concern about growth beyond the ability of Earth’s natural system to absorb the impact of resource consumption and waste emission from the human economic system. By conforming our macroeconomic concepts with the world’s ecological cycles—matching the carbon, water, nitrogen, and phosphorus cycles as well as the fishery and avian cycles—we move closer to a long-term global system that can be sustained centuries into the future.

In short, the potential of ecosystem service transactions is significant. Much research remains to be done to fully develop these concepts for implementation, and several contingencies have to occur. However, there is no denying that economic, water, and carbon resilience, as well as new concepts of fish and wildlife conservation, are before us. All we now have to do is make it happen.

Notes

1. As used in this article, ton = metric tonne = 1,000 kg, and gigaton = 1 billion ton.
2. In this paper, the following downstream emissions were used: 81 kg CO_2/bbl for refinery emissions and around 518 kg CO_2 for the full combustion of the products from that amount of crude oil. Therefore, about 600 kg CO_2/bbl need to be stored to run a completely CO_2 neutral oil company.