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Soil is central to a healthy and sustainable future for Texas

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Soils figure prominently in our daily lives and in many ways we seldom consider. What role do our soils play in our efforts to improve the health and lives of all Texans? And, can we assign an economic value to this role?

Billions of people worldwide share the hope for a better future for themselves and their children. And, the same is true of Texans. The water we drink, the food we eat, and the landscapes we admire are all underpinned by the soil that performs functions, and provides 'services', we often take for granted.

What is an ecosystem? An ecosystem is defined as a community of biological organisms and the environment they live within. It includes the idea that organisms interact among themselves and with their environment in a complex manner. These interactions define the overall function of the ecosystem, but they are also vulnerable to disturbance. The term ecosystem is not just applied to remote natural areas, but also to urban and suburban landscapes. Some commonly noticed ecosystems include forest ecosystems, grassland ecosystems, agroecosystems, and aquatic ecosystems.

Soil is critical to the functioning of an ecosystem

Soil is the foundation of most habitats for organisms whether they live belowground or aboveground. In addition, soil is the foundation for food production and water availability. Another function of soil that might be surprising is their capacity to recycle waste materials and break down pollutants. Because of these diverse functions, soils are a major factor for maintaining the health and sustainability of ecosystems and their performance.

What are ecosystem services provided by soils? Humans are participating members of ecosystems. As such, we receive many benefits from other members and functioning parts of ecosystems. We call these benefits ecosystem services. Generally the services can be grouped into four categories:

(1) Provisioning: such as providing food, water, timber, gas, oil, and fiber.

(2) Regulating: such as regulating water flow and filtration of water, decomposition of wastes, pollination of flowers, and flood control.

(3) Cultural: such as how ecosystems affect the development of societies and cultures, provide aesthetic value and inspire creativity of art, music, and architecture.

(4) Supporting: such as natural processes that support the nutrient and water cycling.

Our health and well-being, as well as our economic interests can be improved by understanding and appreciating the role that soil plays in contributing to the ecosystem services throughout Texas. However, we must recognize that many of our actions can alter or

disrupt the health of soils and subsequently the health of ecosystem functions.

Can we assign an economic value to the role of soil in these services? The answer is yes. The economic valuation of some ecosystem services are more easily defined than others. However, assigning economic value to broader ecosystem services provided by soils should create awareness and recognition of the impacts of our actions can have on ecosystems. Thinking more carefully about the things we often take for granted in natural and urban environments in Texas can only help raise awareness and direct our actions towards our responsibility to ensure the sustainability of our ecosystem services and to minimize our disturbances. This publication invites you to explore the role that soils play in the provision of ecosystem services, as well as the value Texans derive from these services in terms of our health and economic betterment.

Seven Key Soil Functions

Soils can be thought of as providing 7 key functions in the environment. All of these key functions are at play in the State of Texas every day. Recognition that soil is not a limitless resource and that its appreciation and protection can improve the impact of these functions. Each function plays a role in the provision of ecosystem services that provides benefits to all Texans.

1. Food production (agriculture and forestry)

The soil functions as a medium to support the plants that we use to produce food, fiber, and bio-energy materials. It serves as a physical support and protective environment for plant roots. It provides a reservoir of available water and nutrients for plant growth. Plant growth is a direct result of photosynthetic activity (absorbing sunlight) to produce plant material and energy. Plant material decays in the soil due to the activity of microorganisms, which use it for their energy and growth.

- There are approximately 550 billion tons of plant animal, and microbial biomass on Earth
- Plants, including crops and forests, make up 450 billion tons, or 82% of the total biomass on Earth

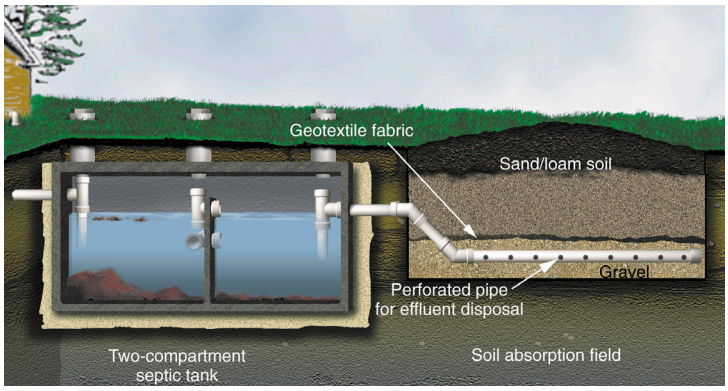
2. Transforming nutrients, filtering and storing water

The soil is a vast reserve for water storage across the world. The texture of a soil (i.e., the content of sand, silt, and clay particles), as well as the density with which it is compacted, affects the rate at which water moves through the soil. Sandy soils generally allow water to move more rapidly, while soils containing greater amounts of clay can store more water for plants. Microorganisms living in the spaces between soil particles use water and nutrients in the soil just as plants do. These bacteria, fungi, and very small insects also feed on decaying plant material to release nutrients in the soil. The movement of water and the transformation of nutrients and organic residues serve as a vast filtering and detoxification system for precipitation (e.g., rain and snow) around the world.

- Although less than 1% of the world's supply is stored at any given time in rivers, lakes, and soil, the passage of water through these systems provides an invaluable service in improving its quality for drinking and irrigation.
- Soil can treat sewage to reduce human exposure to

Crops like sorghum (left, Texas A&M AgriLife photo by J. Mowrer), pastures full of wildflowers (center, Texas A&M AgriLife photo by J. Mowrer), and long-leaf pine forests (right, Texas A&M AgriLife photo courtesy of the Department of Ecosystems Science and Management) are all examples of how soils function to produce biomass in Texas.

disease-causing organisms. In fact, this is exactly what a household septic system does!



Home septic systems rely on soils to absorb and transform household wastes. Drainfields are constructed in soils where microbes consume consume nutrients and wastewater. (EL-5227: OWTS: Septic Tank / Soil Absorption Field.)

3. Reservoir for genetic biodiversity and for species habitat

Soil provides a habitat for the greatest diversity of microorganism species than any other environment on the planet, and can be considered its own micro-ecosystem. In fact, there are more individual microorganisms in a spoonful of soil than there are people on this earth. Soil microorganisms occupy many important niches within their environment, providing many different services such as plant residue decomposition, providing nutrients for plants, and degradation of pollutants. Many commonly used antibiotics for human medical treatments are in fact produced by soil microorganism, while many more are yet to be undiscovered, but represent an exciting frontier for the future of human and animal health. Larger organisms, including many insects, mammals, and reptiles make their home in the soil as well.

- Every gram of soil (~ 0.035 oz) contains approximately 1 billion bacterial cells.
- Children's immune systems are made more robust by early exposure to soil organisms.
- The management of land has a very big influence on soil biodiversity.

4. Physical environment for humanity and its culture

In areas where the soil or climate hinders adequate food production or water availability, resources such as food and water must be transported in from far away. Soils provide a foundational support for all buildings we live and work in. Soils support the parks and natural areas we recreate in as well. It is a landscaping and engineering medium to be dealt with when planning and building transportation systems such as highways and railroads. Soils are also used as a medium for the concealment and disposal of vast amounts of refuse.

In Texas, we deal with special soils that shrink when dry and swell when wet. The cracking and heaving caused by this behavior demands special consideration when building structures on these soils.

5. Source of raw materials for industries and buildings

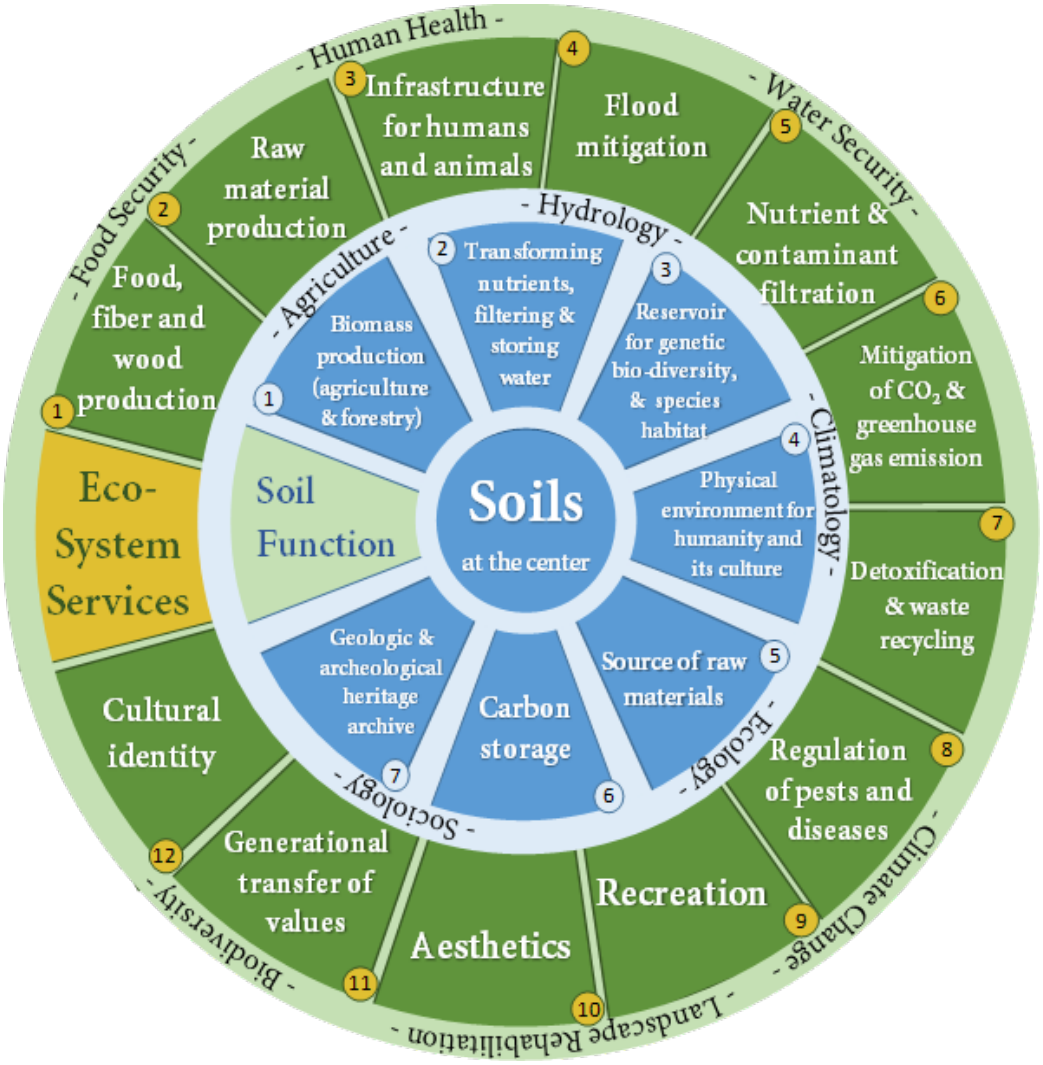
Soils provide many raw material deposits. Sands may be collected for building. Clays may be used for ceramics. Some clay minerals are also used in variety of industrial products. One example is bentonite clay used as drilling fluid by oil industry. Texas also mines a large amount of raw materials for limestone and cement.

6. Carbon storage

Carbon is the basis for all life on Earth. It exists in many forms, including the carbon dioxide (CO2) that makes up a small portion of our atmosphere (~ 0.041%). In soils, carbon may be part of the inorganic soil mineral complex. It may also be part of living organisms or of decaying organic tissue. This form of carbon is called soil organic carbon (SOC). There is more carbon in and under the Earth's soil than is contained in all the plants that grow above its surface. There remains a high potential for increased carbon storage in soils that can have a positive effect on both biomass production and the regulation of atmospheric CO2 balances. Texas has 12 separate ecoregions and 1300 soil types, combining to create a multitude of different capacities for storing carbon in soils across the state.

7. Geologic and archeological heritage archive

When we gaze across the surface of the landscape, we may forget that the soil has a history that is often linked with the history of human activity. Soils often conceal and protect paleontological and archeological treasures of considerable value towards better understanding the history of our planet and ourselves. Soil may also be considered a reservoir for much more recently placed information for use in forensic investigations of crime scenes.



Soils are a major component in ecosystems. Each of the 7 key functions of soils integrate into one or more of 12 ecosystem services. The functions and services outlined in the concentric cirles above appear to have many overlapping characteristics. Still all soil function can be tied to the services without stretching the imagination. Thus, soils remain at the center.

The Value of Ecosystem Services

An ecosystem service is defined as a benefit to society received as a result of a well-functioning ecosystem process. The idea that soils have a real economic value is fairly new and underscores that fact that soils provide a variety of important ecosystem services of which we are often unaware. The idea is that soils provide services essentially for free, and if we were suddenly forced to perform these services without them, it would come at a real and significant cost. While it is difficult to put an exact price on all of these benefits, estimates place the value of some ecosystem services in excess of $17 trillion per year. As an example, the biological fixation of nitrogen by soil microorganisms that contributes plant available nitrogen in soils can be easily estimated at $50 billion per year alone in equivalent fertilizer costs. These services arise as a result of one or more of the '7 Key Soil Functions'.

- Soils provide 12 recognized ecosystem services
- Globally, ecosystem services may be valued at > $17 trillion per year in benefits to society

1. Food, fiber, and wood production ($25 billion)

The value of agricultural and forestry production can be easily estimated and intuitively linked back to soil. Global values range from $0.80 per lb of animals sold or $9,000 per acre per year for food biomass grown on organic production farms. Texas has approximately 130 million acres of agricultural production alone. The market value of all agricultural and timber products is over $25 billion dollars annually.

Did you know? Texas is the national leader in production of cattle, cotton, hay, sheep, goats, and mohair.

Texas agriculture and forestry production statistics:

- Cattle: $11.2 billion
- Cotton: $3.8 billion
- Forestry: $520 million

The hair of Angora goats is used to make a silky fabric called mohair (credit Ron Pope, Texas A&M)

2. Raw material production ($6.1 billion)

Topsoil, clay, and peat are examples of unprocessed raw materials that come from soil. Minerals, which include limestone, cement, salt, gypsum, sand and gravel, gemstones, and clay total approximately $3.9 billion in revenues for the state.

3. Infrastructure for humans and animals ($2.2 to $7.5 billion)

The physical environment that humans, plants, and animals live in is supported and provided by soil. It also provides a space for the reproduction of countless types of flora and fauna. Texas has 6 of the top 20 most populous cities in the United States (Houston, San Antonio, Dallas, Austin, Fort Worth, and El Paso), all of which are built on soil. Estimated value ranges from $13 to $44.5 per acre.

4. Flood Mitigation ($2 to $78 billion)

A well-functioning ecosystem can better withstand extreme weather events such as floods. Economic losses due to Hurricane Harvey in 2017 have been estimated to be between $90 and $190 billion. Urban environments allow very little infiltration and percolation of water into the soil due to sealing of the surface by buildings, parking lots, and roadways. Transforming non-permeable surfaces to permeable ones in Texas cities through approaches involving low impact development (LID) and green infrastructure planning can definitely reduce the severity and duration of flooding events to come. Estimated value ranges from $12 to $476 per acre.

5. Nutrient and contaminant filtration ($37 to $435 billion)

Soil fertility is maintained through the recovery and recycling of nutrients. Microorganisms are the key players in this process. In natural ecosystems, nutrients are recycled by soil microorganisms from dead organisms into forms that new organisms can absorb. In addition, nutrients may be derived from land application of fertilizers or deposition of livestock manures produced. When performing their function as massive natural filtration systems, soils perform an ecosystem service in absorbing, retaining, and transforming toxic contaminants that could otherwise pose health risks to humans, animals, and plants on land and in aquatic environments such as lakes, rivers, and oceans. This service has been valued at between $220 and $2591 per acre per year.

6. Mitigation of carbon dioxide (CO2) and greenhouse gas emissions ($1.4 to $18 billion)

By using agricultural practices that increase soil carbon storage, the current trend of increasing atmospheric CO2 concentrations can be reversed. These include the reduction of intensive tillage operations in row crops to slow carbon loss and inclusion of cover crops to increase carbon inputs where rainfall is sufficient. Texas farmers currently use these practices less than those in many

other states. Other greenhouse gasses, particularly nitrous oxide (N⁻2O), that are emitted from soil can be reduced when farmers, gardeners, and homeowners follow recommendations for nitrogen fertilizer use. This service estimated to be worth between $8 and $108 per acre per year.

7. Detoxification and waste recycling ($5.2 to $22.4 billion)

Soil microorganisms are very active and under-appreciated little 'critters'. They degrade and decompose many inorganic chemicals as well as organic matter. Many of the compounds they degrade are harmful to humans, animals, and plants. This service is affected by many complex biological processes and is sensitive to soil conditions such as temperature, water, and pH. Estimated economic value for this service ranges between $31 and $134 per acre per year

8. Regulation of pests and disease ($4 to $18 billion)

Soil provides a habitat for many species that perform beneficial roles for plants and animals. The climate in Texas is warmer than that in many states and the belowground ecology is active for much of the year, performing services we hardly even notice . . . as long as it continues to function properly. The value of this service has been estimated to be between $24 and $108 per acre per year.

- Rhizobium bacteria colonize roots to help leguminous plants obtain nitrogen from the atmosphere.
- Arbuscular mycorrhizae fungi in the soil work with crop plant roots to increase water and nutrient uptake from soil.
- Many species of Bacillus bacteria provide plant protection by controlling disease causing agents.

9. Recreation ($52.6 billion)

Soil is present everywhere in Texas where outdoor recreation is practiced in federal, state, and local parks, playing fields, lakes, rivers, and the Gulf of Mexico. Almost $53 billion in consumer spending is directed towards outdoor recreation in Texas, and approximately 411 thousand jobs are provided through this industry that are directly or indirectly impacted by soil.

- Outdoor recreation creates $8.9 billion in wages and salaries in Texas.
- The state collects $1.9 billion in tax revenues from this industry.

10. Aesthetics

Gardens and other arrangements in the landscape that are pleasing to the senses, whether planned or natural create a sense of well-being, bring people together and inspire us in very substantial ways. It is very difficult to put a price on this service. Notable examples of this service to consider are found in the 'healing garden' at the Children's Hospital in Dallas, TX, and the Dell Children's Medical Center in Austin, TX. They were created as a way to help the healing process by letting patients and their families 'take a break' from treatment and just relax and appreciate the beauty of art and nature. The positive effect has been hard to argue with.

11. Generational transfer of values

The way that we interact with the landscape, be it through farming and gardening or through hunting and camping, comes from an appreciation often passed down from one generation to another. In Texas, it is common for multigenerational families to discuss and pass down knowledge related to soil behavior and management, as well as knowledge important to the stewardship of the land. The value of this service is also difficult to quantify.

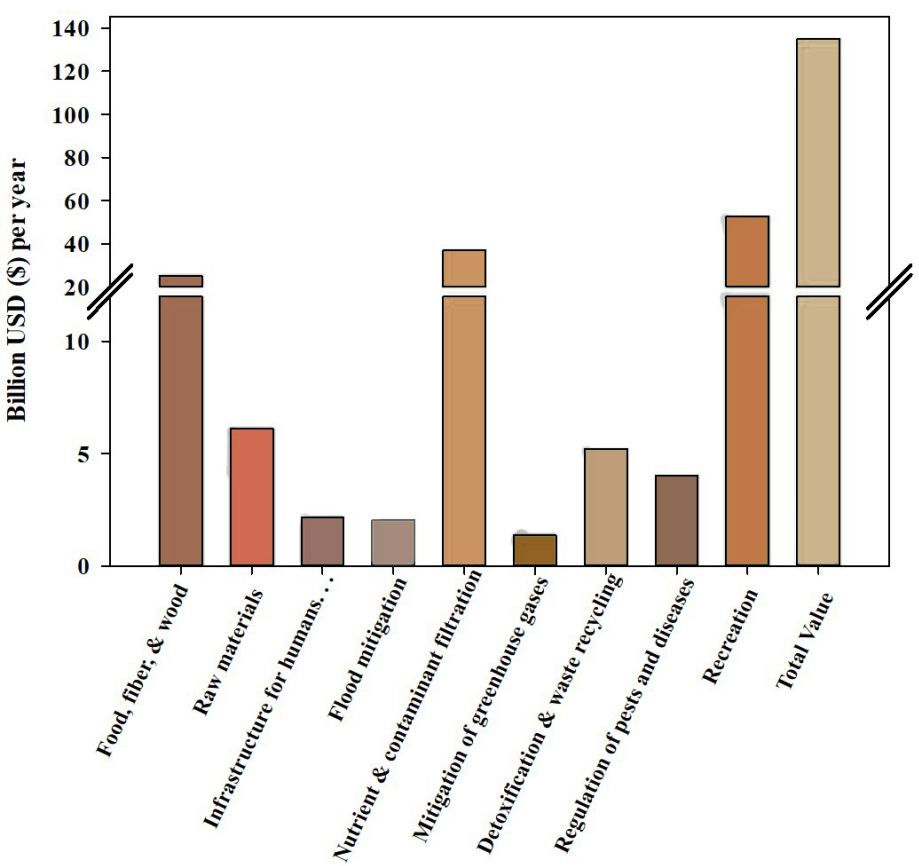
12. Cultural identity

Soil has been used in clay tablets for writing and pottery, in art, and as a building material in architecture. Soil has been eaten for its supposed health benefits (not recommended!). And soil has even played a role in historic battles! The Alamo Mission in San Antonio was at least in part constructed from adobe clay bricks, clay tiles, and primarily with stones taken from near the surface of the landscape. The soil can and does preserve invaluable evidence of our past accomplishments to be uncovered and interpreted by archeologists. Who knows what we'll find?

This chart indicates the relative values of ecosystem services where economic data is available. The total value of ecosystem services provide in Texas may be over $130 billion. Central to all of this provided value is the soil upon which we rely, without even realizing it.

Some of the values estimated in this publication are taken directly from publicly available records. Food, fiber, and wood production for Texas is made available by the USDA national agricultural statistics service (NASS). Raw material values for Texas are compiled by the National Mining Association (NMA). Recreation's contribution to the economy is provided by the Outdoor Industry Association.

Other ecosystem service estimated values are taken from a comprehensive review on the subject by Jónsson and Davídsdóttir (2016). In order to remain conservative, the lowest estimated values from this publication were used on this chart.



Summary

- Soil provides 7 key functions in the environment
- These functions provide an integral support for ecosystems services from which we may unknowingly benefit.
- There are more bacteria in a handful of soil than there are stars in the galaxy
- Ecosystem services are estimated to provide over $130 billion dollars' worth of value in the state of Texas every year. Many values may notbe specified here or may be difficult to assess a value in dollars.

Who is this publication for?

This publication is envisioned as an educational resource for middle and high school classrooms, civic groups, volunteer organizations, and any individual or group who wishes to be better informed about soil functions and the environment around us.

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