GREEN INFRASTRUCTURE

for the U.S.

Maps and Apps to connect the most valuable landscapes in the nation

By Arancha Munoz-Criado

What is the Green Infrastructure Initiative?

Green Infrastructure for the U.S. is a large-scale, ambitious initiative for the twenty-first century. Its objective is to transform communities into sustainable centers by identifying an interconnected system of landscapes to preserve natural habitats, protect biodiversity, and promote healthier lifestyles, thus improving the quality of our lives while supporting intelligent and balanced economic growth across our communities.

We now have the technology and tools to deliver it.

- Intact Cores
- Surface Water
- National Scenic and Historic Trails

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Why Now?

Growth is inevitable. Let's grow intelligently, while preserving our most valuable landscapes. The time is now.

More than a century ago, Frederick Law Olmsted looked out over the Yosemite Valley and saw a place worth saving. He proposed the revolutionary idea of a nationwide system of parks and greenways, which inspired the creation of the US National Park Service. As the Park Service approaches its centennial this August, we are reminded that the construction of interconnected federally protected land is perhaps the first investment in green infrastructure in the United States. Olmsted believed that we should identify, preserve, and connect our most valuable landscapes for the benefit of current and future generations. This belief is the foundation of the green infrastructure initiative.

Building a connected system of landscapes requires the evaluation of natural assets at the beginning of the land development process. Almost 50 years ago, Ian McHarg's seminal book, Design with Nature, proposed that planning begin with a consideration of the land's natural and cultural features: its biodiversity, soils, slopes, drainage, and water. McHarg discussed the idea of layering spatial information, landscape features, and natural resources data to create a development plan that works with nature instead of against it.

Green infrastructure is first and foremost a spatial concept that requires data about the landscapes and the technologies necessary to analyze and understand the best plans for growth. While growth may be inevitable, we can choose development that has a smaller footprint, protects key habitats, and makes the landscape more connected and resilient.

Today, more than 39,000 local government entities regulate the use of 70 percent of the US land base, but many of them do so in isolation and without access to tools to assess the condition and potential of the environments in their respective jurisdictions. Integrating green infrastructure and geographic information system (GIS) technology in the planning and development process enables municipalities to preserve and connect the county's most critical landscapes.

Esri's GIS technology offers decision-makers in all levels of government tools to understand air, water, and land systems so that we may avoid mistakes that could compromise the present and future health of our planet. If we can start thinking of natural resources as part of a connected infrastructure that supports our everyday lives, perhaps we can also recognize the need to actively conserve those resources. In an effort to make this vision a reality, Esri launched the green infrastructure initiative to assemble, evaluate, and produce a model that will enable governments to protect and restore biodiversity while guiding economic development decisions.

I dream of creating and preserving a network of interconnected landscapes that spans the entire United States—a rich treasure for the whole nation. Building sustainable, healthy communities that can withstand rapid or disruptive growth is possible. But we need to work together. And we need to start now.
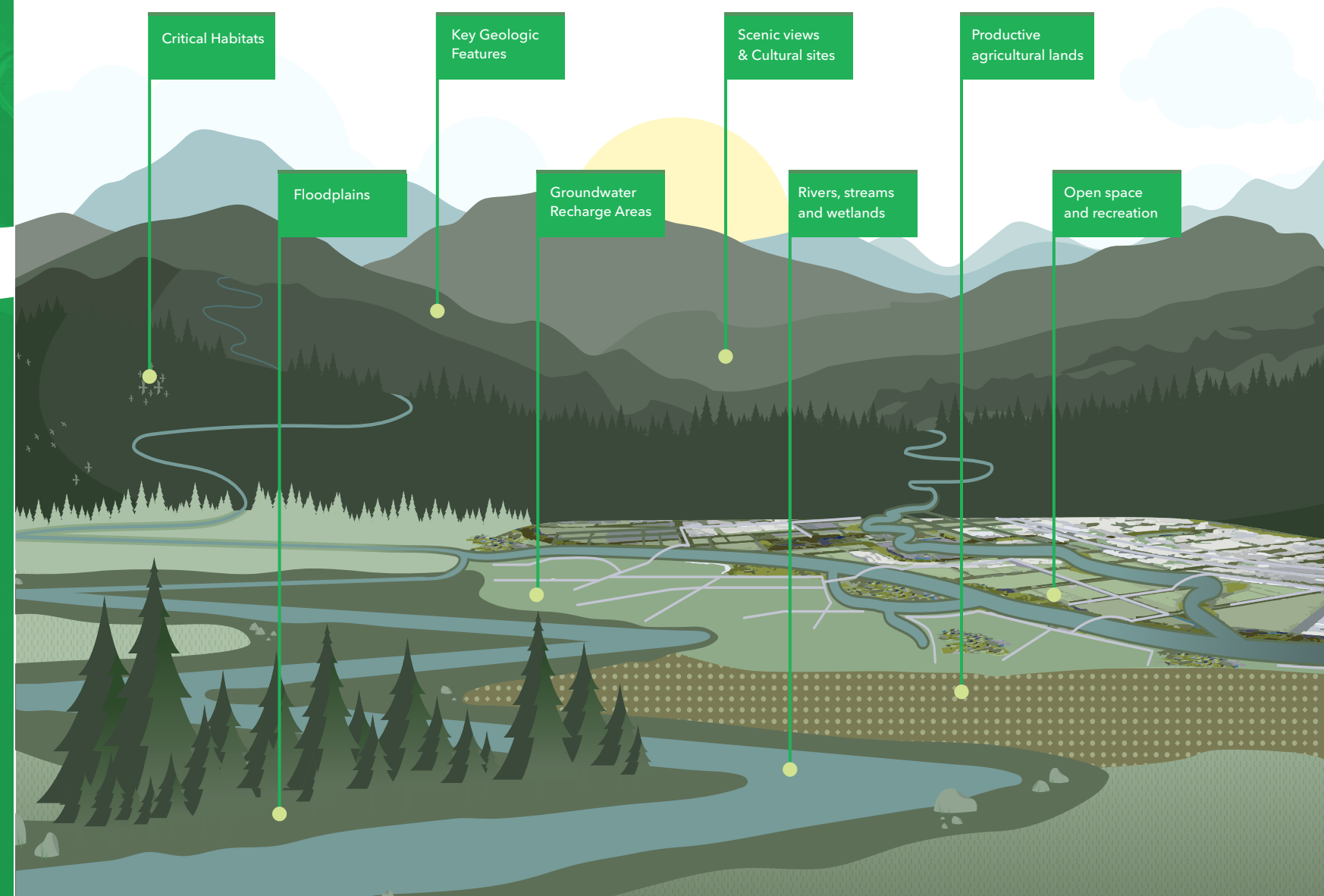
Jack Dangermond is president and founder of Esri, the world leader in GIS software development and its application in business, health, education, conservation, utilities, military and defense, oceanography, hydrology, and many other fields.

What is
Green
Infrastructure?

Green infrastructure is a strategically planned and managed network of open space, watersheds, wildlife habitats, parks, and other natural and seminatural areas that enrich and sustain communities.

Green infrastructure is about **identifying** and **connecting** the most valuable landscapes before growth and development begin.

Critical Habitats

Key Geologic Features

Scenic views & Cultural sites

Productive agricultural lands

Floodplains

Groundwater Recharge Areas

Rivers, streams and wetlands

Open space and recreation

Green
Infrastructure
Has Deep Roots

Green infrastructure is an old idea with new relevance. It began with Olmsted's concept of interconnecting parkways to cities and expanded to McHarg's idea that growth should begin with an assessment of the natural landscape. But it has renewed relevance because entire species and ecosystems have been lost because of human impact, use, and exploitation, and natural systems have become increasingly fragmented. Today, many states have built statewide models of key habitats and started individual projects to revitalize these landscapes.

The degradation, fragmentation, and loss of landscapes are not only caused by unabated sprawl but also from conservation efforts and planning that do not consider the bigger picture.

Green infrastructure gives answers.

- Is the template for planning growth at any scale, ensuring the preservation of the ecological functions of the landscape and avoiding sprawl.
- Allows the coordination of conservation and investment efforts through a holistic view of the landscape.

Connection is the key to sustainable environments.

Fragmented landscapes have a difficult time surviving environmental fluctuations such as climate change. But an interconnected green infrastructure enables species to migrate, reproduce, and adapt to changing conditions. Connectivity also gives people ways to access, enjoy, and appreciate the natural world.

There is a strong evidence (e.g. E.O.Wilson, R.Forman, J.Lawton) that connected networks are critical to sustain the capacity of our natural environment to provide ecosystem services such as clean water, climate regulation, and crop pollination, as well as providing habitats for wildlife.
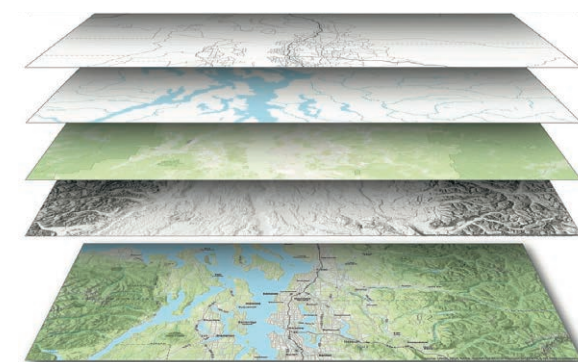
Components
of Green Infrastructure

Green infrastructure is an interconnected network of land that combines several key components:

- Sites that support relevant ecological, cultural, agricultural, and scenic values
- Hazard areas that pose environmental risks or costs to the community if developed
- A network of ecological corridors and functional connections that link all these areas

Green infrastructure identifies, connects, and preserves the landscapes of greatest ecological, cultural, and scenic value to create an interconnected network of open spaces, watersheds, wildlife habitats, parks, and other natural and seminatural areas. These landscapes provide communities with the vital services that enrich and sustain the quality of life.

Individual elements of green infrastructure vary in form, size, and function across sites and at varying scales; however, the combination and connection of these elements are what create a continuous green landscape across the nation. Whether or not these elements are recognized in our planning is up to us; but the fact is, these landscapes deliver critical, life-enhancing services.
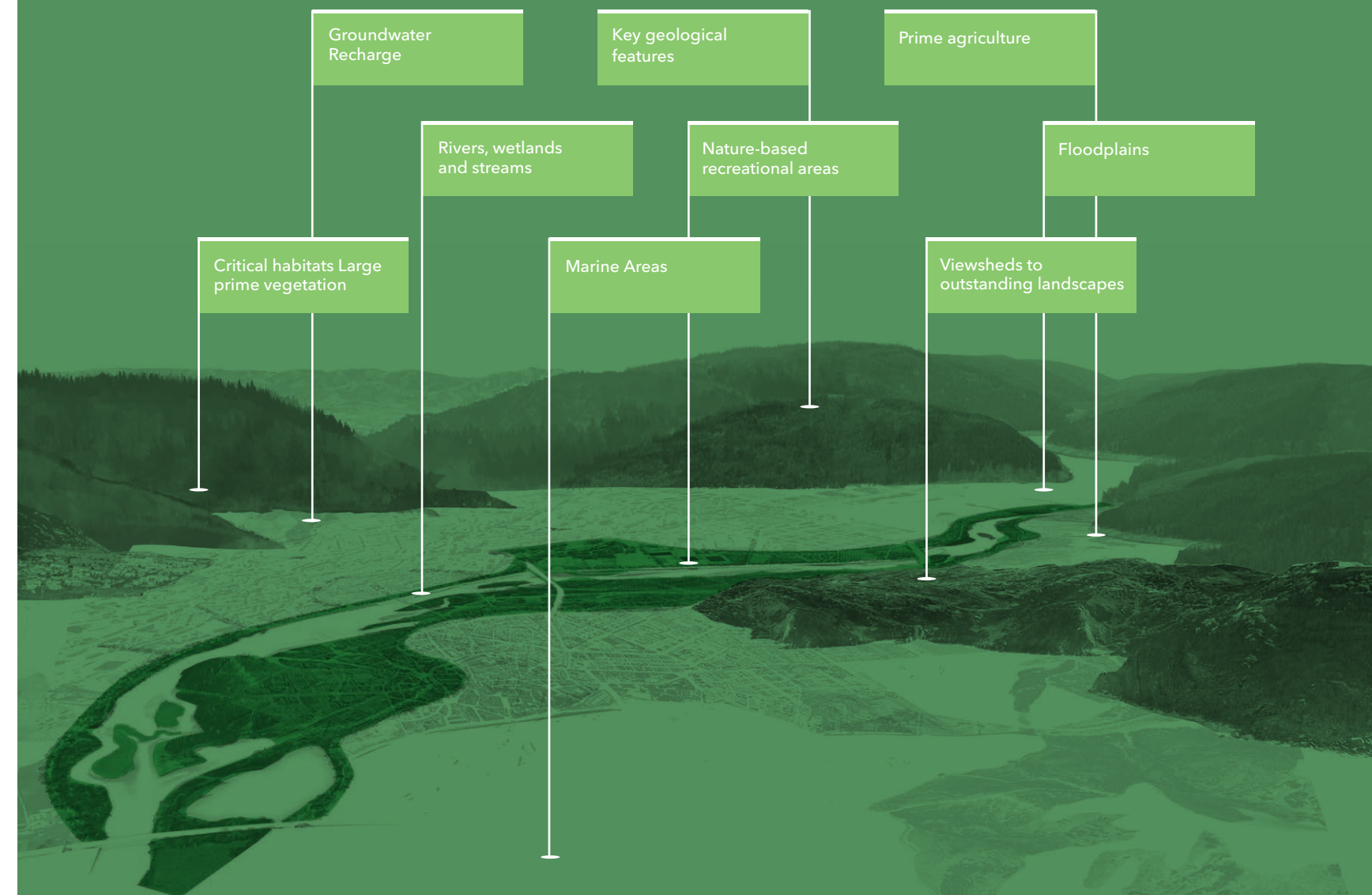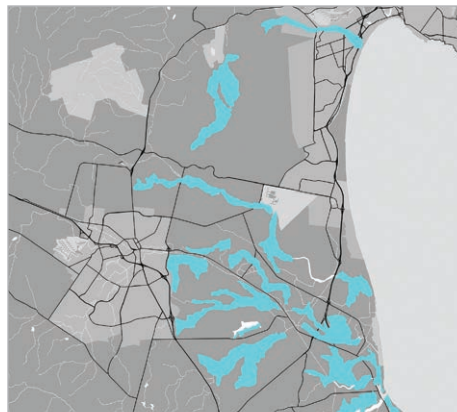
When appropriately planned, designed, and managed, green infrastructure delivers a wide range of benefits— from providing sustainable transport links to mitigating the effects of climate change.

The principles of green infrastructure apply to any landscape from forests to deserts, from suburban to agricultural areas. The green infrastructure approach to planning works as well in pristine, natural areas as it does in communities with intense human activity.

Ecological Resources

Cultural, Historic & Scenic Resources
Parks & Recreation

Hazard Areas
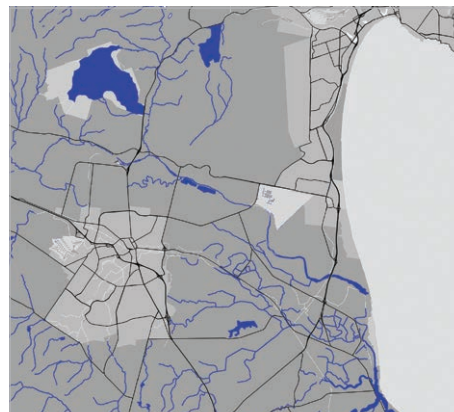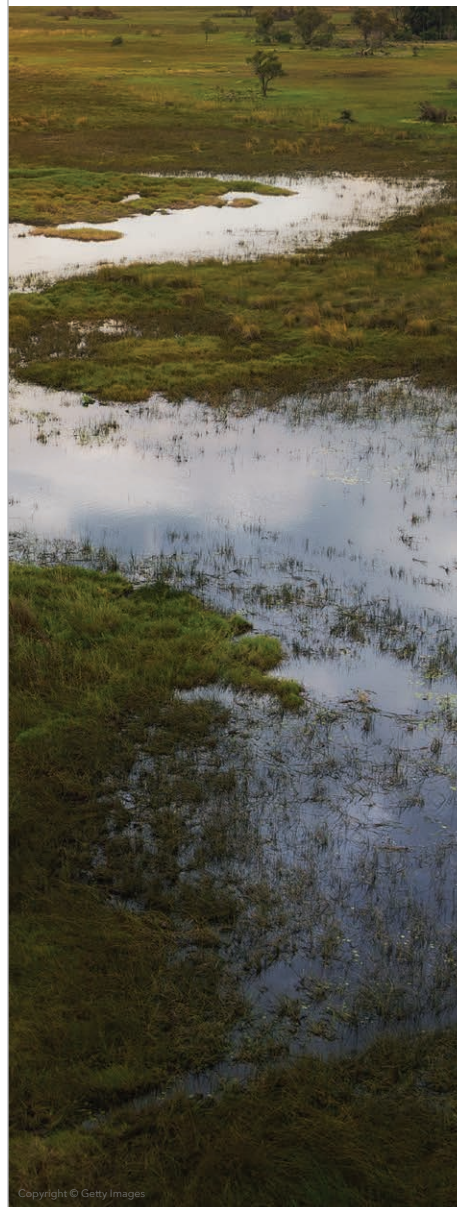
Connections

Green Infrastructure Map

Green infrastructure helps identify the most important landscapes in your community that should be preserved to

- Foster environmental benefits including clean air, freshwater, vibrant wildlife, and food sources.
- Conserve places that provide high quality of life and preserve cultural values.
- Connect people with nature.
- Avoid hazard areas by using natural landscapes as buffers against storms, floods, or drought.
- Allow space for natural environments to adapt to climate change.

Groundwater Recharge

Key geological features

Prime agriculture

Rivers, wetlands and streams

Nature-based recreational areas

Floodplains

Critical habitats Large prime vegetation
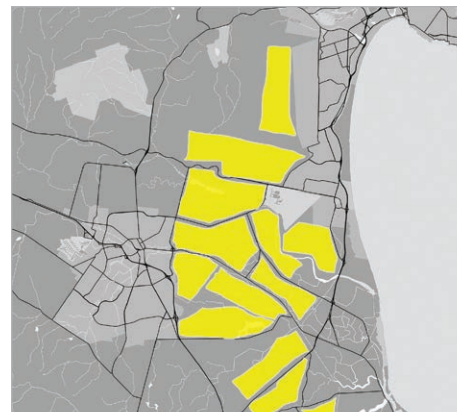
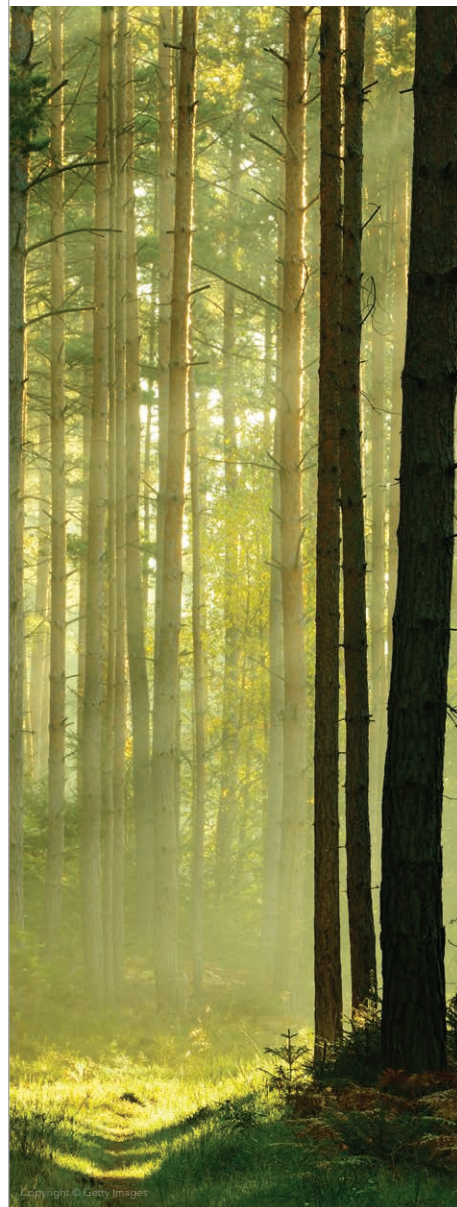Marine Areas

Viewsheds to outstanding landscapes
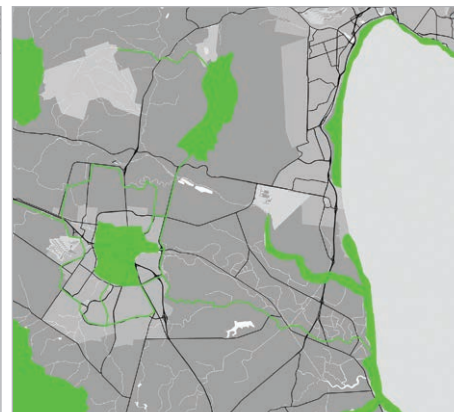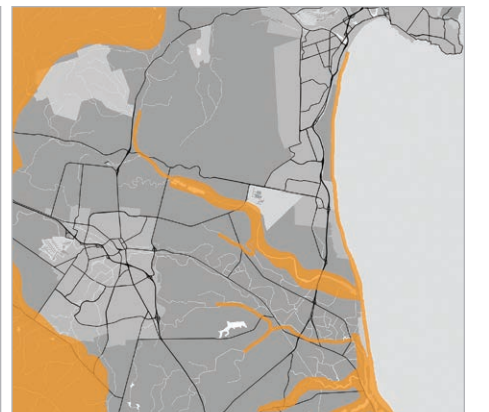
Wetlands

Rivers, Streams, Lakes

Critical Habitats.
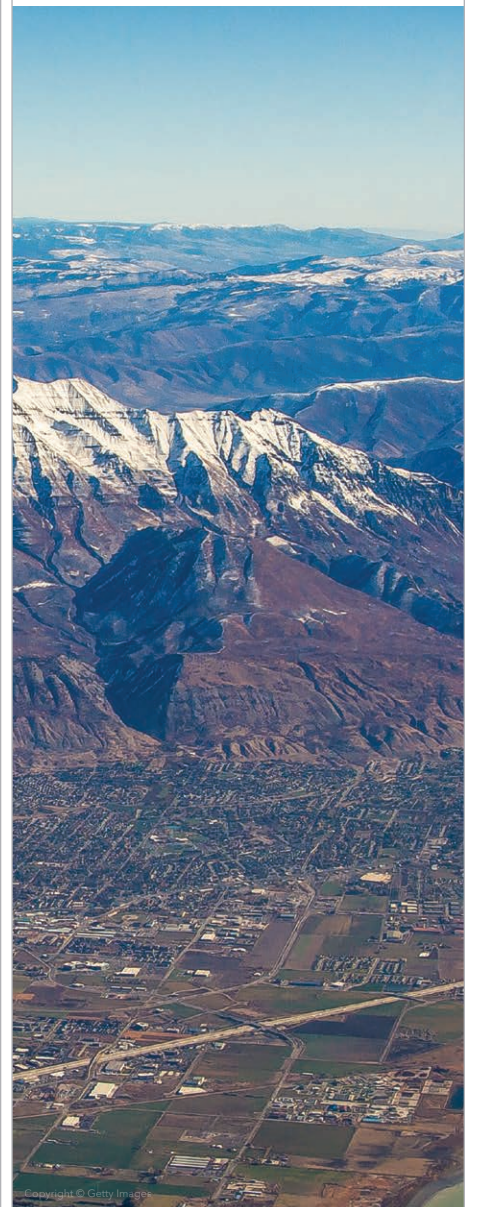Forests and Prairies

Prime Agriculture

Culture, Recreation,
Scenic Views

Hazard Areas, Floodplains
and Steep Slopes

Green Infrastructure
across scales

Valuable landscapes don't stop at municipal boundaries. To prevent fragmentation, it's important to understand where critical landscapes are located and how they function across municipalities. Green infrastructure offers a holistic approach to planning. It identifies key natural services across all scales—at regional, local, and urban scales.

At the regional scale, green infrastructure emphasizes organization and connectivity. At the local and urban scales, it demonstrates how the interaction of different spaces impacts the design of cities as well as how they are lived in and sensed.

Green infrastructure addresses the landscape from a regional perspective because species, habitats, scenic views, and development seldom regard administrative borders. What happens upstream will have an impact downstream. It's important for communities to consider green infrastructure at a regional scale to understand how the broader landscape may affect local flooding, habitats, scenic views, and the ability of communities to balance growth and development.
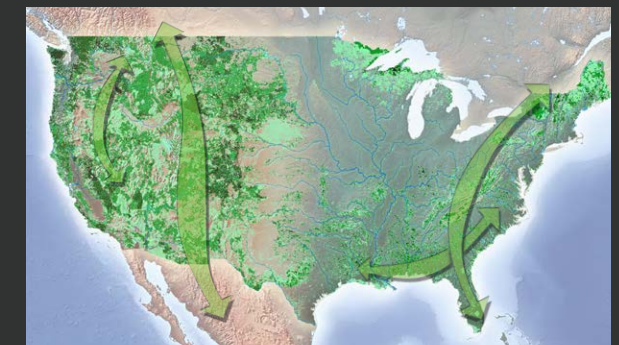
National Scale

At a Regional Scale

Green infrastructure creates a connected network of green spaces that conserve natural ecosystem values and functions, providing vital services like clean water, soil for agriculture, and breathable air.

At a local Scale

Green infrastructure creates greenbelts around towns, inhibits urban sprawl, and preserves urban identity. It connects communities with nature and retains the important scenic and cultural landscapes that make a community unique. It also provides recreational and health benefits.

At a Urban Scale

Green infrastructure at the urban scale connects public spaces like squares, parks, and streets with the surrounding landscapes and ecological resources. It also includes the tree canopy that keeps a city cooler in summer, adds natural beauty, helps clean the air, and reduces storm water runoff.
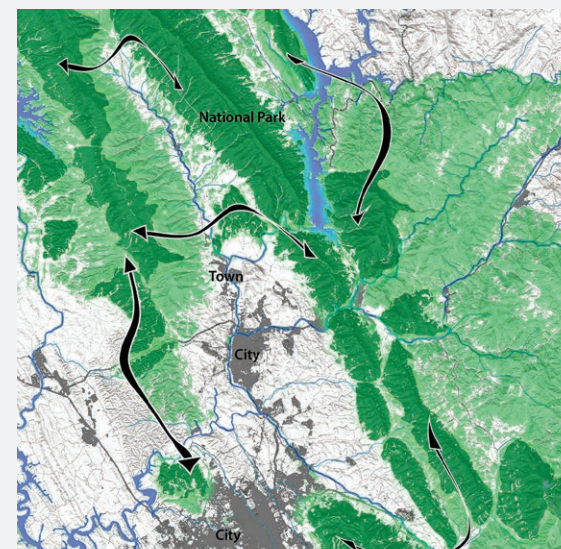
AT A REGIONAL SCALE
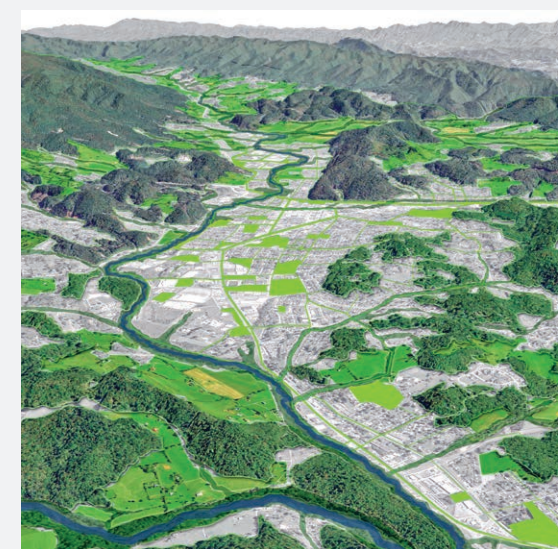
AT A LOCAL SCALE

AT AN URBAN SCALE

How Does It
Work?

Green infrastructure is about prioritization.

Changes to the landscape happen fast; so setting priorities is critical. A green infrastructure strategy reworks the traditional order of planning by having decision makers identify and map landscapes of highest value first, before growth. With a green infrastructure map, communities work together to evaluate and prioritize which areas to protect. Equipped with this information, communities can create a development plan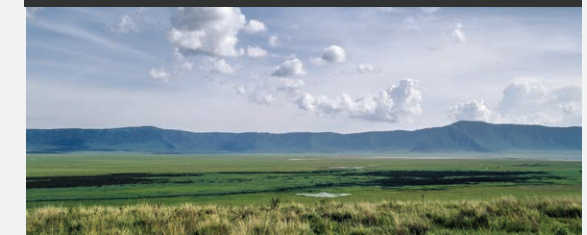 that takes into account how to preserve and connect valuable landscapes—inside and outside boundaries—while growing in a sustainable way.

New developments and citizens benefit from landscapes that preserve a community's identity, support environmental values and biodiversity, and avoid hazard areas.

Connections are key

Isolated landscapes have a difficult time thriving and being resilient enough to survive change (such as climate change). Joining landscapes into an interconnected green infrastructure enables species to migrate, exchange genetic material, and adapt. Connections also give people ways to access, enjoy, and appreciate the natural world.

Most often, corridors follow waterways and valleys. Others may follow concentrations of biological diversity or migration patterns, or they may create green links among communities.

Green infrastructure frameworks use two components:

1. **Cores** – These are areas of high conservation value and ecological quality that form the heart of the ecological network. They may contain rare or important habitats or have the conditions to support them.

2. **Corridors** –These are connectors that improve the functional and ecological connectivity between core areas, enabling species to move between them. Corridors may also act as links between communities and nature.
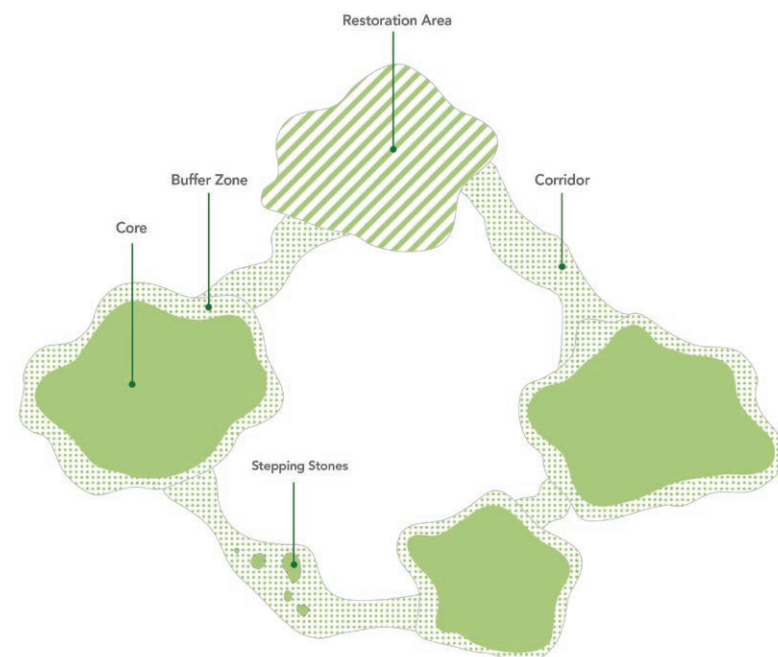
Currently land is developed first, relegating green space to whatever zones are left after urban growth. The green infrastructure process reverses the order, first identifying the landscapes of greatest value and then planning growth.

1 Identify ecological values

Identify the areas of greatest ecological value—wetlands, rivers, lakes, prime forests, critical recharge areas, intact cores with high potential for biodiversity, marine areas, and estuaries.
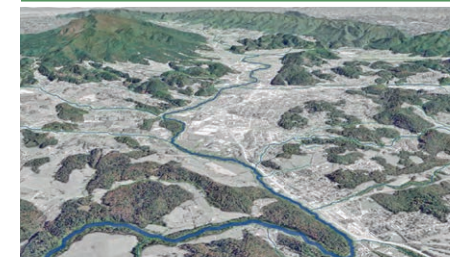
2 Add cultural and scenic values

Add areas with the greatest cultural and scenic values and ones that are most highly rated and loved by the population. Include any hazard areas, prime agriculture, cultural sites, and historic trails, scenic views areas, and floodplains.

3 Design Connections

Design connections between these areas to preserve the ecological functions and make surrounding landscapes accessible. Connection is also ensured on an urban scale by creating an urban green infrastructure that links urban public spaces with the landscapes of highest value in the surrounding area.

Restoration Area

Buffer Zone

Corridor

Core

Stepping Stones

Everyone
Benefits

Benefits are achieved when green space conservation and management are integrated with land development and built infrastructure planning. Green infrastructure provides ecological, economic, and social benefits that support sustainable development:

Ecological Benefits
- Maintains/Restores habitat
- Improves watershed health/water quality
- Improves air quality
- Enhances biodiversity
- Mitigates storm water/flooding
- Regulates climate
- Sequesters carbon
- Improves more sustainable modes of transport

Economic Benefits
- Attracts businesses and workers
- Generates revenue
- Provides access to local businesses
- Increases property values
- Lowers energy costs
- Lowers health care costs
- Promotes renewable energy
- Increases local food production

Social Benefits
- Enhances the quality of the place
- Enables recreation
- Improves public health
- Promotes equity and access
- Fosters community
- Connects people with nature
- Educates people about nature's role

Return on green infrastructure investment is high. Well-maintained and managed green infrastructure improves the image of regions and neighborhoods, boosting economic growth. It attracts and retains high-value businesses and entrepreneurs and is proven to increase property values.
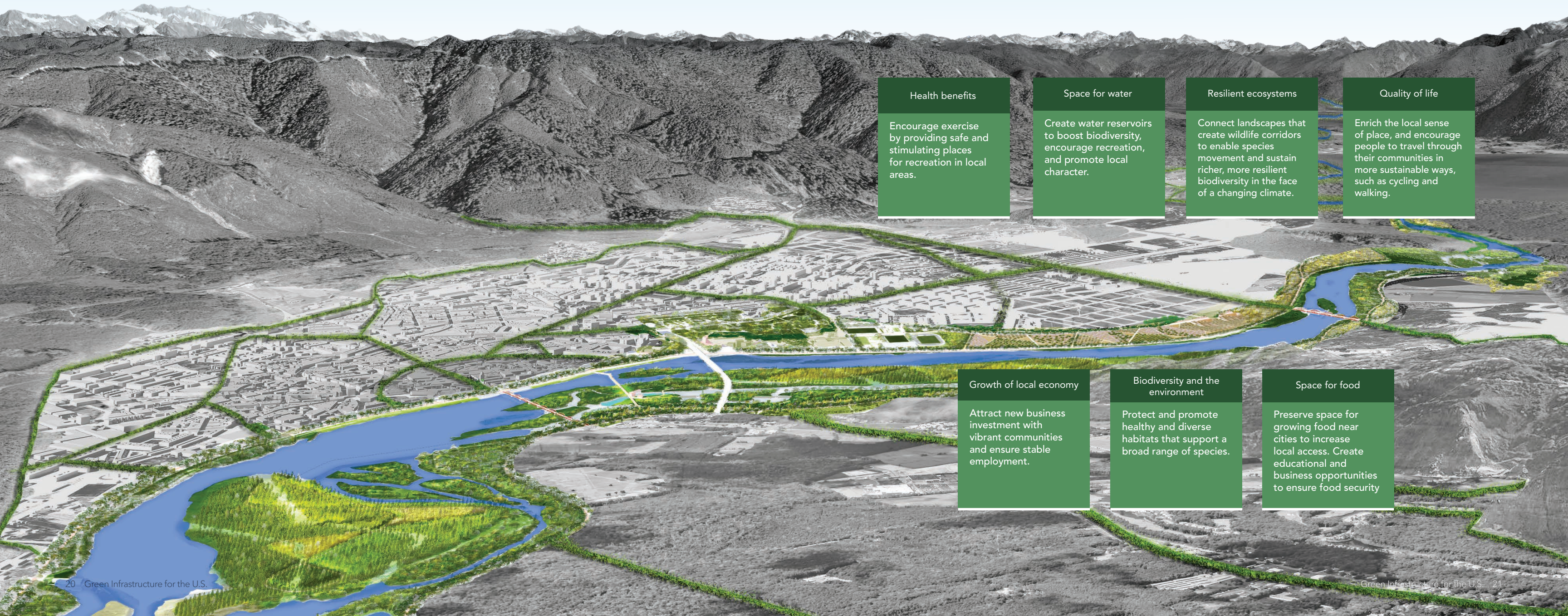
Health benefits

Encourage exercise by providing safe and stimulating places for recreation in local areas.

Space for water

Create water reservoirs to boost biodiversity, encourage recreation, and promote local character.

Resilient ecosystems

Connect landscapes that create wildlife corridors to enable species movement and sustain richer, more resilient biodiversity in the face of a changing climate.

Quality of life

Enrich the local sense of place, and encourage people to travel through their communities in more sustainable ways, such as cycling and walking.

Growth of local economy

Attract new business investment with vibrant communities and ensure stable employment.

Biodiversity and the environment

Protect and promote healthy and diverse habitats that support a broad range of species.

Space for food

Preserve space for growing food near cities to increase local access. Create educational and business opportunities to ensure food security

Everyone
Has a Role

Green infrastructure brings together government agencies, local citizens, planners, developers, and conservationists who use their skills, experiences, funding streams, and opportunities to effect change. This also includes those who make decisions on how, when, and where to develop and conserve land as well as the people who actively participate in the planning process.

Green Infrastructure
and

If you are a

You

Agriculture, forestry, nature conservation, water, marine and fisheries, urban planning, climate policy, transport, energy, disaster prevention, land-use policies, and financing instruments.

If you are a

Planner or Local Government

Identify the most valuable landscapes to determine which should be protected or handled with care so as to avoid or reduce developmental impacts. Landscapes may provide important ecological functions that need to be conserved such as land where water recharge occurs, scenic vistas, habitat for rare species, and recreational areas. Use maps to show how investments are prioritized. Include these maps in policy documents, such as comprehensive plans, zoning reviews, or economic development plans.

Developer

Identify the most efficient solutions at the lowest costs in terms of impact on land, water, and energy consumption. Discover the best places to build to optimize property values, such as proximity to scenic viewsheds, cultural sites, and open space.

University

Use the data and maps in ecology, landscape architecture, or planning courses. Embed the concept of green infrastructure in all related fields.

Environmental, Land Trust and Others Groups

Make more informed decisions when setting conservation goals. Determine which landscapes are well connected, where connections could be restored, and which areas are in need of conservation action, easements, or other land management. Improve synergies between all groups concerned.

Communities

Learn where the most valuable landscapes in your community are found and advocate for their conservation, or manage your own lands in ways that conserve them and keep them connected. Connect with nature.

Federal Government

Determine how key resources on federal lands connect to and are supported by the broader landscape, and vice versa. Identify opportunities for collaboration with adjacent landowners and managers.

School

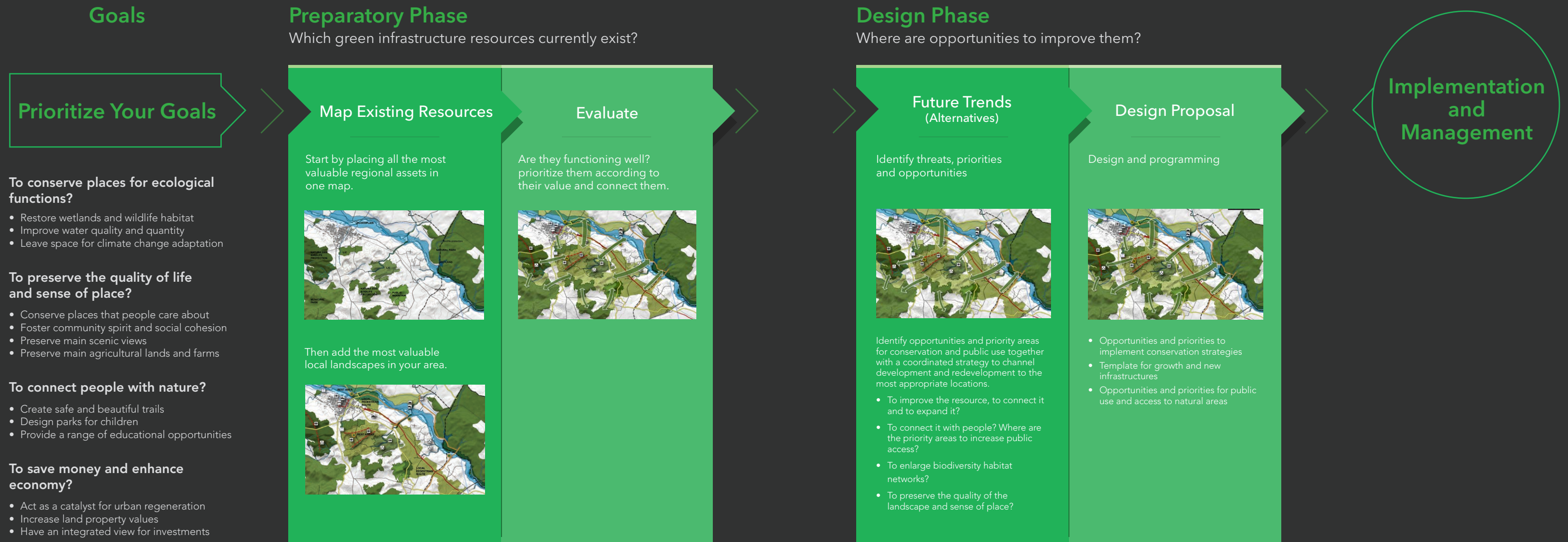Teach children the importance of nature. Find and propose site-specific Green Infrastructure projects.

> Green infrastructure is about transparency— know where the most valuable landscapes in your community are and learn more about them.

Green Infrastructure in the
Planning Process

Green infrastructure is a framework for conservation and development. It considers the complex interactions among natural habitats, surface water, flood management, biodiversity, food production, and recreation, together with housing, transportation, and energy.

In the planning process, first identify, evaluate, and prioritize areas that are critical to preserve before growth occurs. Seeing all those areas in one map helps find opportunities and set priorities.

Green infrastructure planning evaluates the types of natural and cultural resources available today and prioritizes those assets that are most important for your community.

Goals

Prioritize Your Goals

To conserve places for ecological functions?

- Restore wetlands and wildlife habitat
- Improve water quality and quantity
- Leave space for climate change adaptation

To preserve the quality of life and sense of place?

- Conserve places that people care about
- Foster community spirit and social cohesion
- Preserve main scenic views
- Preserve main agricultural lands and farms

To connect people with nature?

- Create safe and beautiful trails
- Design parks for children
- Provide a range of educational opportunities

To save money and enhance economy?

- Act as a catalyst for urban regeneration
- Increase land property values
- Have an integrated view for investments

Preparatory Phase
Which green infrastructure resources currently exist?

Map Existing Resources

Start by placing all the most valuable regional assets in one map.

Then add the most valuable local landscapes in your area.

Evaluate

Are they functioning well? prioritize them according to their value and connect them.

Design Phase
Where are opportunities to improve them?

Future Trends
(Alternatives)

Identify threats, priorities and opportunities

Identify opportunities and priority areas for conservation and public use together with a coordinated strategy to channel development and redevelopment to the most appropriate locations.

- To improve the resource, to connect it and to expand it?
- To connect it with people? Where are the priority areas to increase public access?
- To enlarge biodiversity habitat networks?
- To preserve the quality of the landscape and sense of place?

Design Proposal

Design and programming

- Opportunities and priorities to implement conservation strategies
- Template for growth and new infrastructures
- Opportunities and priorities for public use and access to natural areas

Implementation and Management

The
Green Infrastructure
Website

Esri has compiled a unique resource for green infrastructure planning. For the first time, a national green infrastructure framework is available to help connect landscapes, support native species and ecological processes, protect cultural resources, and promote cooperation among landowners.

A green infrastructure national framework is essential to ensure coherence and efficiencies across administrative boundaries. The Esri website supports green infrastructure planning and provides information about the most important landscapes in your community. It offers a basemap of intact habitats, or cores, from which to start defining green infrastructure at other scales. Local data can be added to refine the model and to set local priorities and goals. A Green Infrastructure atlas provides existing national data coverage and authoritative information for use in your own projects. National and local agencies, organizations, experts, and local citizens can all access information that can be added to locally significant sites and data.
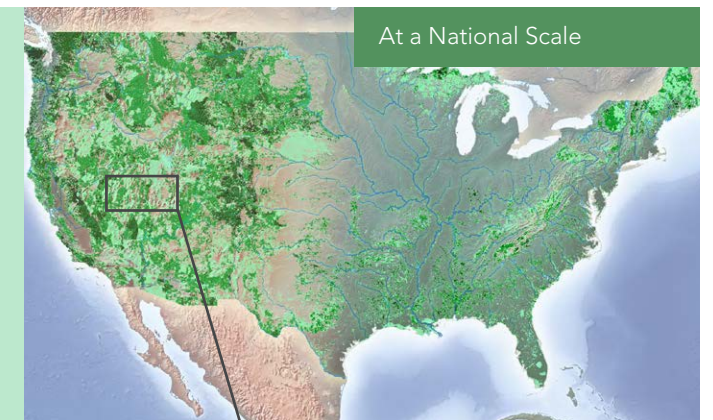
ArcGIS and the green infrastructure atlas facilitate the understanding of ecological processes and human relations. They provide tools to ask questions and find answers visually.

Green Infrastructure Atlas

An Interactive Green Infrastructure Map

Apps

Guidance

Enabling people to use
Green Infrastructure

**1** ### Start with the national intact habitat cores map.

To facilitate the definition and delineation of green infrastructure at the local scale, Esri created a national map of intact habitat cores and GIS applications. The map shows intact areas in the USA that are greater than 100 acres. You can view, evaluate, and change the size or other attributes based on your land management goals.

At a National Scale

2 ### Use the Green Infrastructure atlas.

You can add areas of ecological, cultural, visual, and agricultural values, as well as hazard areas like flooding, from the layers of the Esri Green Infrastructure atlas.
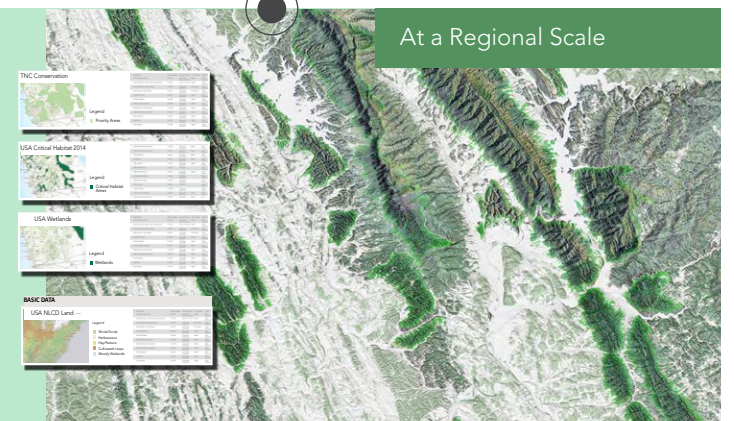
At a Regional Scale

3 ### Add local data and design your Green Infrastructure Plan.

Local governments and agencies can refine and update the maps by adding local data such as significant wetlands, nature reserves, and known sensitive areas. You can also apply Esri's apps to help with the design of the local green infrastructure.

At a Municipal Scale

It All Starts With a National Basemap of Intact Habitat Areas

The map identifies natural intact areas, or cores, larger than 100 acres in size and at least 200 meters wide, which are largely undisturbed. Data was added to include a diverse assortment of hydrology, species, landform, elevation, soils, and ecosystem-related information. The process identified more than 570,000 core areas across the contiguous United States.

The Green Infrastructure site (esri.com/greeninfrastructure) provides a basemap of intact habitat areas, or cores, from nationally available 30-meter datasets to create a common national framework from which to start defining green infrastructure at other scales.

Plans for local and regional green infrastructure can use this basemap as a starting point from which to add relevant data to consider local opportunities, needs, and goals. All landscapes that are critical to preserve healthy communities for the future can be recorded on the green infrastructure map. This enables participants to find opportunities for collaboration on the priorities for conservation.

What makes an intact, high quality habitat?

Cores serve as a predictor for the integrity of the habitat and the likelihood that they support a diverse assemblage of species. Cores are ranked for their ability to support native species.

The following key factors are included:

Size:
More areas to roam, more opportunities for different habitat types.

Types and extent of water:
More water-dependent species; attracts wildlife.

Intactness/lack of fragmentation:
Less disturbance and less edge effect from roads, pipelines, or power lines. When there is more edge, there is less interior habitat to support native species, and more invasive or non-native species can enter and overtake the natural habitat.

Shape:
A core that is long and skinny may have less protection from invasive plants and animals than one that is thicker and deeper. Core thickness is one way to evaluate the resistance to disturbance.

Soil diversity:
The greater the diversity of soil types, the more types of plants, insects, and animals may be supported.

Known Species Diversity:
The types and diversity of species monitored or predicted to be present provide another measure of the core's likelihood to be a good-quality habitat.
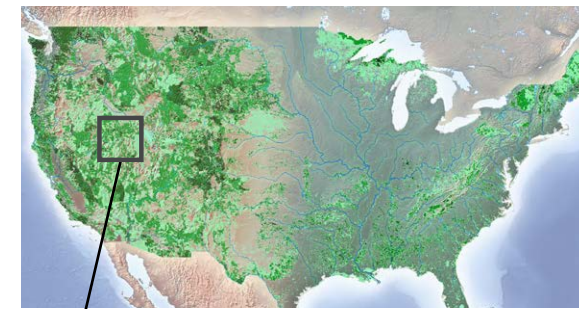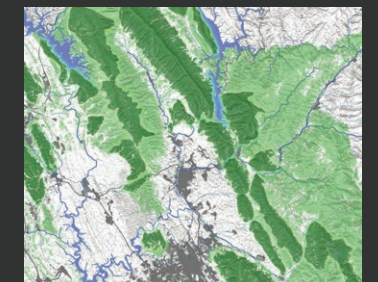

Identify regional green infrastructure first. Landscapes and ecological functions cross administrative boundaries. They require a regional view.

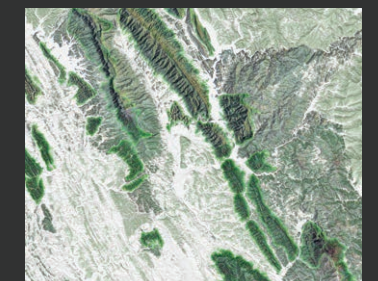USA intact natural areas greater than 100 acres
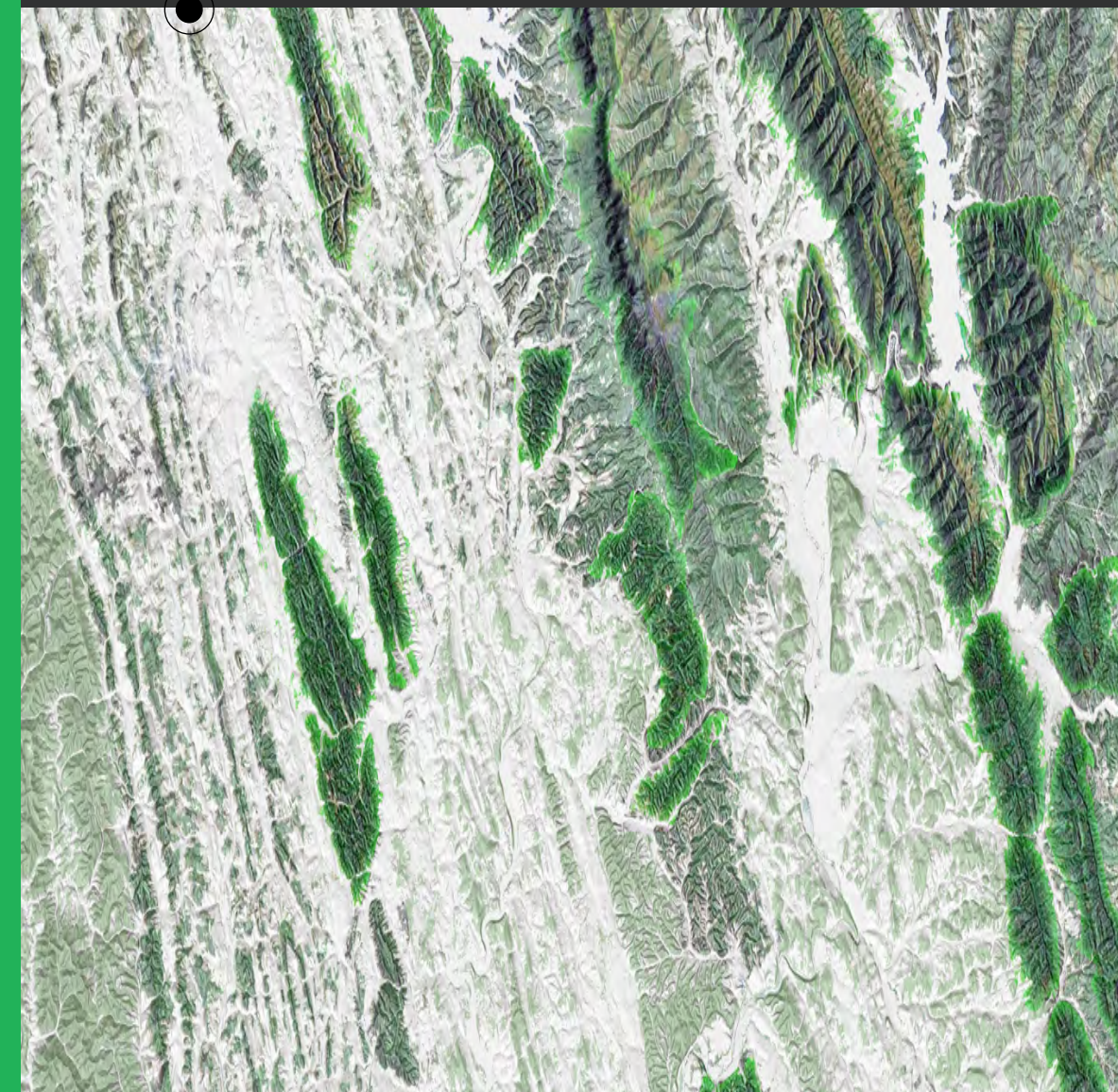
Add local data

Ecological resources

Cultural and visual resources

Hazard areas

Tools and apps for everyone

Visit esri.com/greeninfrastructure to model and map green infrastructure in your area. The website contains the latest ArcGIS apps, maps, and other resources for use with your data to identify critical landscapes, assess risks, explore connections, and create landscape strategies for your area. Browse the growing list of maps and apps available in the Green Infrastructure atlas. Type in your ZIP code to see green infrastructure around you.

Once you have created a map in any of these apps you may take it to the following Apps to deliver your plan.

ArcGIS Online

The ArcGIS Online Map Viewer can be used to view and explore all the green infrastructure layers organized on the green infrastructure website and stored in the Green Infrastructure atlas. It can be used to add new data, publish new maps, and perform simple spatial analysis. A green infrastructure data download app will permit the extraction of both Esri's derived habitat core areas and source data used to create the cores for local desktop analysis.

GeoPlanner

For planners, Geoplanner allows you to measure proposed changes to our natural assets directly. It allows you to assess the quantity, quality, and location of our natural capital. It helps you determine how the state of our natural capital assets affects the benefits they can provide to people.

ArcGIS Pro

This tool allows groups to perform their own analysis, perhaps incorporating more detailed information, such as individual buildings, as fragmenting features or a higher-resolution digital elevation model (DEM) or refining and updating the model on your desktop by adding data, such as locally rare species, or subtracting areas that have been developed. The green infrastructure center's green infrastructure model includes the configuration files and toolbox that Esri used to create the national intact habitat cores dataset and is available on Esri's green infrastructure website.

View Existing Intact Habitat Cores
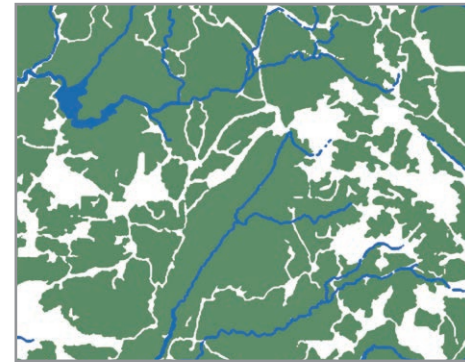
Filter Habitats Cores

**Score Habitat Cores**

Apps to make the connection

The planning and design of a corridor is a function of the conservation and/or recreation goals. At the national and regional scales, main connections should be identified, although the ultimate design and adjustment need to be done at the local scale and with local data.

Corridors may be designed for a single species or for several species, as well as to maintain ecological processes like water movement. They may also be designed to link communities to their surrounding landscapes. They are also a function of land availability, landowner interest, and land management.

For larger regional areas containing thousands of cores, a new tool introduced with ArcGIS 10.4—Cost Connectivity—produces a vector solution using cost surfaces which are raster-based data. The benefit of this is a fast processing at large scales of analysis.

The expense of traveling from any given core to neighboring cores can be assigned to a core as an attribute, and the network of the least expensive connections uniting the more valuable cores across a landscape can be computed.

Prioritize and connect to define green infrastructure
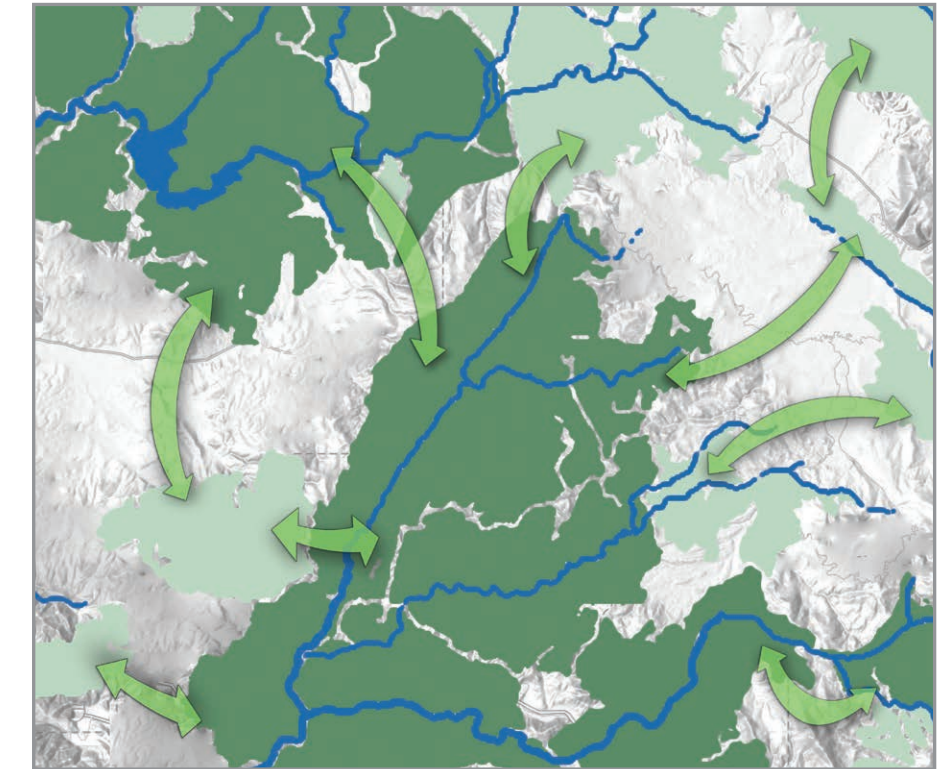
Envisioning **Priorities** and **Opportunities**

The intact habitats cores model generates a map depicting the highest quality, most intact habitats. It can be applied or modified using ArcGIS to create local and regional green infrastructure plans for conservation or restoration priorities.
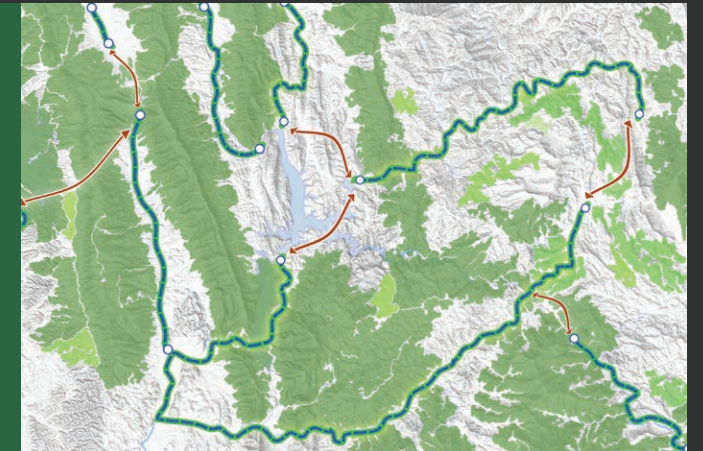
■ Intact natural cores

Where can existing protected areas be enlarged? Which areas should be protected or restored to avoid hazards or to protect water quality?

You can visualize a holistic approach for new opportunities for protected areas.

Take the basemap. Add existing Protected Areas. And begin to explore, learn, and propose new ideas.

□ Existing protected areas   ■ Intact natural cores

Where is there a strong interest in conservation at the national or the community level?

Create an overlay map to show which priority areas are already protected and how, for example:

• US Fish and Wildlife Service reserves or national parks
• Sanctuaries managed by land trusts such as The Nature Conservancy (TNC), National Audubon Society, or local land conservancies
• National or state scenic rivers
• Other known and locally relevant priorities.

— — Existing protected area   ■ Rivers   ■ Intact natural cores

Where are the lands along river corridors that should be preserved?

You can identify river corridors and design future regional parks to connect them with cities. River corridors have exceptional significance in a landscape providing a hydrologic sponge, trapping sediments during floods, and serving as habitats for floodplain species. Intersect the map of intact habitats cores with other layers such as vegetation, type of soil, slope, land use, etc. The resultant map helps you better connect your landscapes.
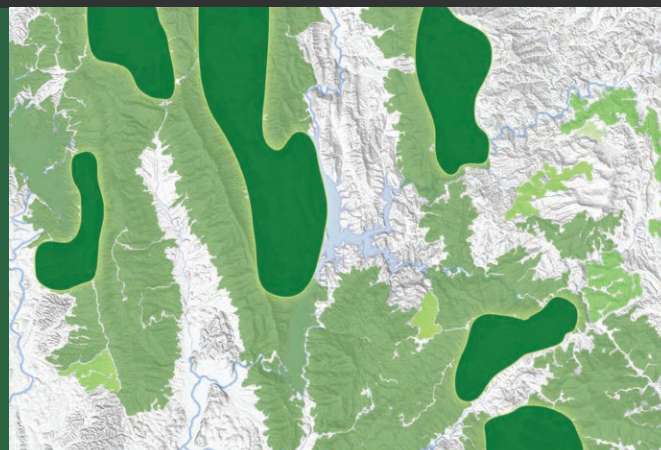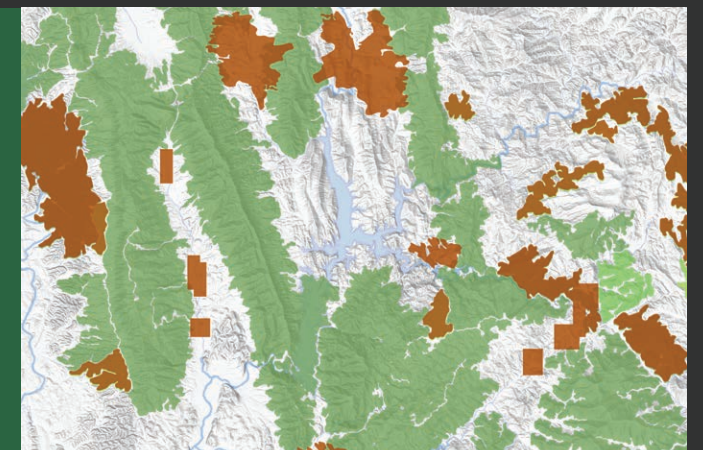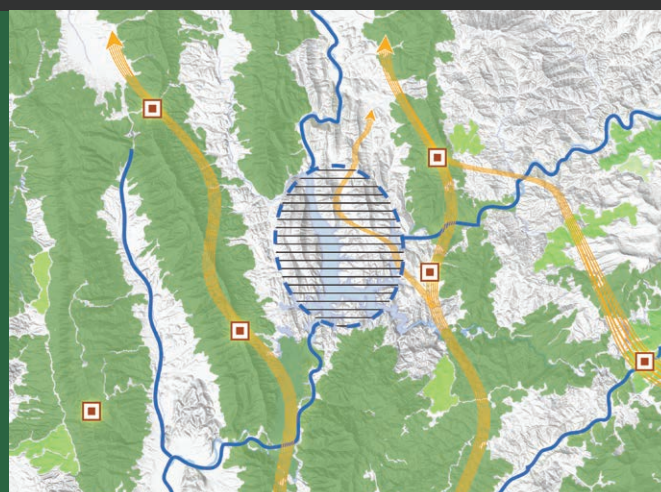
➜ Connections   ■ Intact natural cores

Where are the opportunities for land acquisition? Which areas should be connected?

Find opportunities for land acquisition. Where are areas of high value resources that are not under federal, state, or local protection? Where should budgets for habitat restoration be allocated to be more efficient? Overlay the parcel map on the Green Infrastructure map and find which parcels of land connect different intact habitat cores.

■ Large parcels   ■ Intact natural cores

How can we connect our community with the surrounding landscapes?

Connecting urban areas with the surrounding landscapes has many benefits:

• Increases property values
• Promotes social cohesiveness
• Improves the quality of life
• Allows access to nature
• Promotes climate adaptation

■ Surrounding green infrastructure   ■ Urban open spaces   ➜ Connections
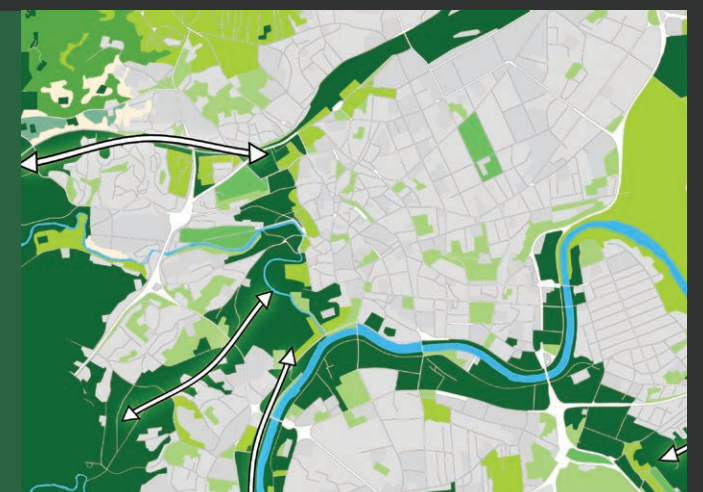
U.S. Green Infrastructure
2030

Trails connect historic and cultural features

Rivers, wetlands and streams are preserved

All towns and cities have direct access to nature

Connected large intact forests and prairies provide habitat for wildlife

Economic activities benefit from outstanding surroundings

High quality agriculture soils support farms and national security

We preserve the views to the most beautiful landscapes

Communities and towns are surrounded by their own landscapes

Green Infrastructure for the U.S. is a large-scale, ambitious initiative for the twenty-first century. Its objective is to transform communities into sustainable centers by identifying an interconnected system of landscapes to preserve natural habitats, protect biodiversity, and promote healthier lifestyles, thus improving the quality of our lives while supporting intelligent and balanced economic growth across our communities.

Esri has compiled a unique resource for green infrastructure planning. For the first time, a national green infrastructure framework is available to help connect landscapes, support native species and ecological processes, protect cultural resources, and promote cooperation among landowners.

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