


Natural Infrastructure in the Nexus

Suzanne Ozment, Kara DiFrancesco, Todd Gartner

Nexus Dialogue Synthesis Papers

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Available from: IUCN (International Union for Conservation of Nature)
Global Water Programme
Rue Mauverney 28
1196 Gland
Switzerland
Tel +41 22 999 0000
Fax +41 22 999 0002
www.iucn.org/publications

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The Nexus Dialogue on Water Infrastructure Solutions

Since 2012, the International Union for Conservation of Nature (IUCN) and the International Water Association (IWA) have collaborated on a joint initiative to address competing demands on water resources across the water, energy and food sectors. The objective has been to identify how multi-sectoral solutions are, or could be provided through infrastructure and other means, including new technologies and investments in ecosystem services. The Dialogue grew out of the Bonn Nexus Conference[1] in November 2011. One of the objectives in Bonn focused on launching concrete initiatives to address the water, energy and food security nexus in a coherent and sustainable way. The conference highlighted the renewed interest to invest in water infrastructure in different parts of the world because of valid concerns for water storage, water supply and flood protection, as well as food security, population growth, and the need to adapt to climate change impacts.

The Nexus Dialogue[2] successfully organized a series of regional "Anchor" workshops in Africa, Latin America, Asia (with UNESCAP), and for the Amu Darya River Basin in Central Asia (with the EastWest Institute). Learning from these workshops culminated in the Nexus Symposium held in Beijing in November 2014, in partnership with the Global Water Partnership (China).

The Dialogue has focused on water, energy and food to ensure focussed cross-sectoral discussion. The aim was also to prevent creating new silos around issues such as ecology, carbon, soil, climate, etc. Sectors do not operate in these silos; they operate through public sector profiles that are loosely structured on water, energy and food production as staples of societal needs and economic development. The purpose of the Dialogue was to identify consensus on sustainable and resilient water management for water, energy and food security.

The nexus is not a one-way discussion. Rather, it challenges beliefs within the tribal nature of disciplinary silos. The nexus as a construct challenges the application of knowledge, and it highlights the need for greater integration on core elements such as data collection, sharing, and interpretation. Through dialogue, opportunities can be created to bring together people with a variety of experiences from across sectors, to brainstorm, and exchange knowledge, with the ultimate aim to move to developing and implementing practical actions.

There are many ways to not agree about the nexus. What becomes clear is that there is a competitive advantage for all institutions, public, private, etc., to better understand the cause and effect relationships they are involved in through both implementation of their mandates, and policy actions and reform. Through better identification of risks, sharing the risks, and optimising the trade-offs that need to be made between sectors, advantages for all sectors can emerge.

1 http://www.water-energy-food.org/en/home.html
2 http://www.waternexussolutions.org/1x8/home.html

Who is this paper for?

Increasing urbanisation and economic growth provide significant benefits, but also pose a range of challenges especially for water quantity and quality. Water, energy and food security rely on water infrastructure. Recognition of the closely bound interaction between water, energy and food (or the management of land for food, fodder, and fuel production) – the nexus – has led to new demands for water infrastructure and technology solutions.

The aim of the synthesis papers is to bring together sectoral best practice, and to make connections between the multi-sectoral components of the nexus. The papers identify and analyse the main drivers for joint solutions, and the opposing factors that limit working together across sectors. Key factors for an appropriate enabling environment are identified to allow cross-sectoral opportunities to work better and at the most appropriate scale to help bolster existing development approaches. The nexus is only valid as a point of focus if it leads to better development.

The Papers are targeted to a broad audience, but principally four main groups of stakeholders:

Policy Advisors – individuals who advise decision making committees, senior staff and individual decision makers about issues related to policy delivery and reform, investment choices, and activities to deliver national, regional, and global commitments to resource management, environmental protection, and economic development. This includes those in regulatory agencies.

Practitioners – individuals and agencies who are involved in implementing projects and programmes within or across the water-energy-food sectors. This includes those who are involved in managing and/or designing interventions that tackle competition for water or degradation of ecosystems as a consequence of different sectoral demands for water, for example water for irrigation, hydropower or cooling water, or public water supply. Practitioners include people and agencies in public, private and civil society sectors.

Investors – individuals and agencies that are responsible for conventional water, energy, and food investments, as well as community investors and larger social impact investors. This could include development banks, national government, private finance, philanthropy, urban and city infrastructure investors.

Researchers – individuals who study inter-sectoral linkages through policy research, modelling, system based approaches, infrastructure and engineering, conservation and ecosystems, urban and rural interactions, etc.

The Synthesis Papers are designed to highlight sectoral best practice, and to identify connections between the multi-sectoral components of the nexus. The papers are designed to be stand-alone documents, but also relate to each other as key thematic areas in the nexus that have been identified from stakeholder discussions during the Dialogue between 2012 and 2015.

All the papers have benefited from lead authors and reviewers from different institutions and disciplines to ensure multi-sectoral and disciplinary perspectives.

1. Clean technology for nexus infrastructure solutions - Simon Howarth, Michael Bruce Beck, and Rodrigo Villarroel Walker
2. Water stewardship and corporate engagement in the nexus - Stuart Orr and James Dalton
3. Influencing pathways of investments for the nexus - Kala Fleming and Alan Kalton
4. Natural Infrastructure in the nexus - Suzanne Ozment, Kara DiFrancesco, Todd Gartner
5. Governance of the nexus - Dipak Gyawali
6. Learning from the nexus dialogue - Damian Crilly, Katharine Cross, Mark Smith, James Dalton, Carolina Latorre, Raul Glotzbach, Rebecca Welling, and Dan Wang

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Contents

Executive Summary

This paper discusses how natural infrastructure, the networks of land and water that provide services to people, can help decision makers and infrastructure managers address interconnected challenges facing water, energy and food systems, often referred to as the "nexus". Natural infrastructure can help maintain an adequate supply of clean water, which in turn supports energy and agricultural systems. Presenting the most recent developments, studies, and approaches regarding natural infrastructure, the paper examines reasons and ways to include natural infrastructure in this nexus, challenges that have prevented increased investment in natural infrastructure, and recommendations for moving forward.

Natural infrastructure helps to address some of the urgent challenges faced by today's infrastructure systems:

- Natural infrastructure can provide many of same services as built infrastructure, including the ability to purify water, control water temperature, minimize sedimentation, regulate urban storm water runoff, reduce the impact of floods, hold and slowly release water into and from groundwater aquifers, sequester carbon, and provide food (Figure 1).
- Given that at least $1.32 trillion a year in water infrastructure investments are needed to keep up with business-as-usual (WEF 2013), it has become increasingly important to consider how nature can substitute, safeguard, or complement engineered infrastructure projects in ways that are proven to be effective and cost-competitive.
- As climate change, population growth, and increasing consumption of resources create new threats with implications across the nexus, natural infrastructure provides flexibility that enables adaptive management that is necessary to cope with changing conditions, and is more likely to sustain benefits in the midst of uncertainty and increased variability.

The conservation, restoration and sustainable management of natural infrastructure is a viable and increasingly popular strategy to secure and enhance water, energy and food systems worldwide.

- Recent studies estimate that the global community invests about $12.3 billion per year to protect, manage, and restore natural infrastructure to secure water resources (Forest Trends 2014).
- Decision-support tools, guidance, and willing partners exist to help design and implement natural infrastructure projects.

Yet, decision makers do not regularly evaluate options to invest in natural infrastructure.

- Currently, investments in natural infrastructure are narrow in scope and do not sufficiently account for the potential conflicts between providing adequate food, energy, and water services. Forest Trends (2014) reported that the energy and agriculture sectors collectively contributed less than 1% of all natural infrastructure investments in 2013, which suggests these sectors are missing opportunities to invest in natural infrastructure for its cross-sector benefits.
- Decision makers often lack information to adequately evaluate and compare natural infrastructure options to business as usual, and therefore default to better understood engineered solutions.
- Natural infrastructure introduces complexity and uncertainty into system design that engineers are not wholly equipped to address, because it often requires multi-stakeholder engagement and longer time horizons.
- A mismatch between the priorities and incentives of potential investors and the benefits offered by natural infrastructure has stymied the development of natural infrastructure projects.

- Lack of clarity on how natural infrastructure aligns with many regulatory systems has also dissuaded investment.

To increase investment in natural infrastructure, and consequently reap the multiple cross-sector benefits of this strategy, champions from industry, communities, governments, utilities, academia, financial institutions, international development organizations, and conservation groups need to:

- Identify opportunities where investing in natural infrastructure makes economic sense.
- Communicate successes and challenges as a contribution to a robust body of literature on the business case of investing in natural infrastructure.
- Institutionalize the assessment of natural infrastructure in food, water and energy system design.
- Establish the enabling conditions necessary to inspire confidence in natural infrastructure as a feasible strategy.

These actions could transform the way infrastructure systems are designed, built, and maintained. New partnerships that proactively identify opportunities to invest in natural infrastructure, leverage new sources of financing, and reform policy and standards will broaden investment in natural infrastructure. In the coming decade, industry and governments should institutionalize investment in natural infrastructure as a core strategy to address food, water and energy security and move towards mixed portfolios of complementary natural and engineered infrastructure.

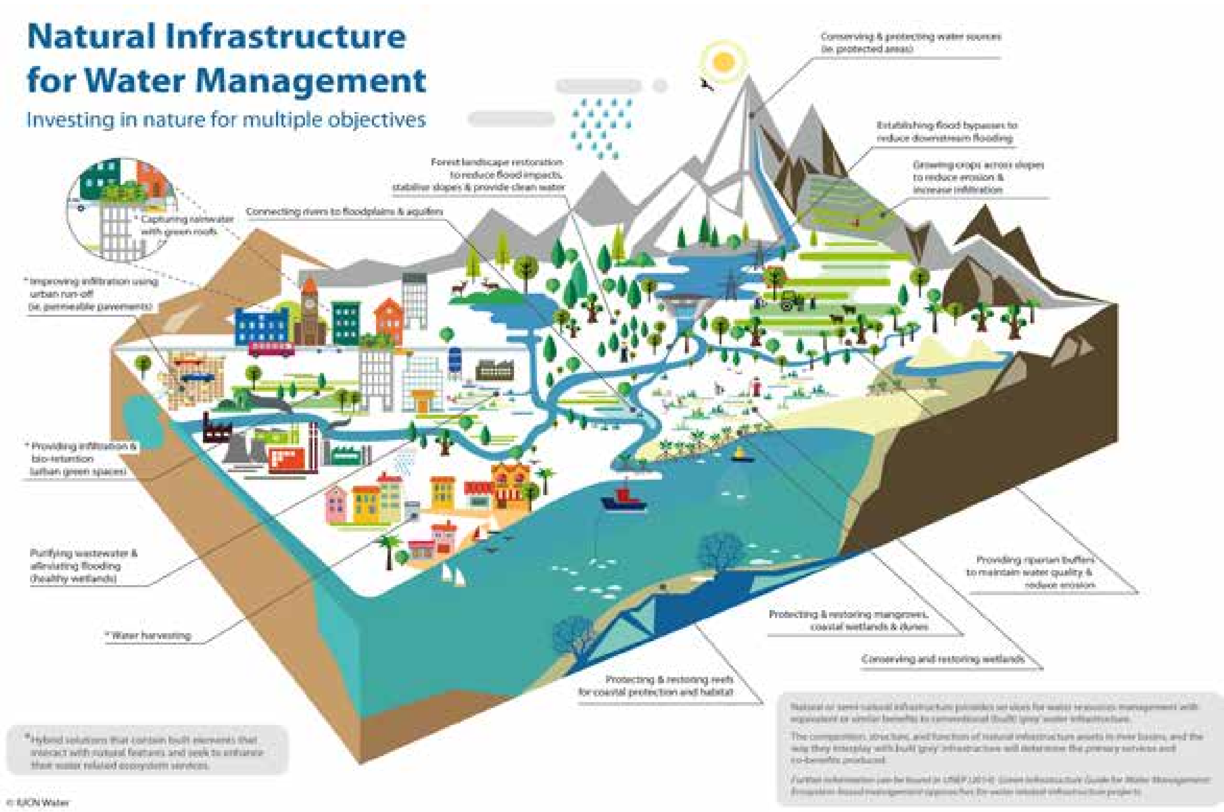

Figure 1. Examples of Natural Infrastructure for water management (IUCN 2015)

Natural Infrastructure in the Nexus

Suzanne Ozment[a], Kara DiFrancesco[b], Todd Gartner[c]

Background

Infrastructure challenges facing water, energy and food security

Countries around the world face challenges of developing new infrastructure while also operating, maintaining, rehabilitating, and ensuring environmental compliance of the aging infrastructure that supports water, energy and food systems. New approaches are needed to meet the present-day financing and sustainability challenge for water, energy, and food related infrastructure which will require the development of novel, cost-effective strategies that optimize its benefits and minimize negative impacts.

Traditionally, governments and the private sector have relied on engineered approaches, or "gray infrastructure," to secure food, water, and energy systems. These solutions have included treating polluted water to make it drinkable, dredging sediments from hydropower and irrigation reservoirs to increase capacity, and lining rivers with levees and flood control dams to increase arable land to grow crops. Although these engineered solutions have significantly improved the quality of life for many, in this era of fiscal austerity, it is becoming more difficult and less appealing to build and maintain the large engineering projects of past generations. At current investment levels, the global community will invest $10 trillion in water infrastructure investment between 2013 and 2030 according to an estimate by McKinsey & Co (Dobbs et al. 2013). Similarly, a 2007 OECD study estimated that $1.3 trillion must be invested annually in urban water infrastructure maintenance, repair, and replacement by OECD countries as well as Brazil, Russia, India, and China, not accounting for service expansion to meet the needs of growing populations (WEF 2013).

On top of this massive investment challenge, the "deep uncertainty" (Lempert, Bankes, and Popper 2003) associated with how land use change, climate change, and population growth will impact food, water and energy security poses an unprecedented challenge to planning future infrastructure systems. Long-lived infrastructure investments (typically 50-200 years) will be exposed to shifting climatic conditions, which, according to most models, will vary greatly from current conditions (Stocker, Dahe, and Plattner 2013). Yet, the magnitude and even the direction of change remain unknown for precipitation, temperature, storm intensity and frequency, and other crucial variables of infrastructure planning. For example, annual precipitation in the Northwestern U.S. is projected to increase up to 18% or decrease by as much as 10% by the end of the century; projections regarding climate impacts on extreme events, such as floods and droughts, exhibit even greater uncertainty

a Associate, Natural Infrastructure for Water, World Resources Institute, Washington, DC
b Principal Consultant, Wicked Water Solutions, LLC, Bend, OR
c Senior Associate and Manager, Natural Infrastructure for Water, World Resources Institute, Portland, OR

(Melillo, Richmond and Yohe 2014). Addressing these uncertainties in infrastructure planning necessitates new decision making processes and management strategies that are also able to take into account changing environmental and social conditions (Stakhiv, 2011).

Natural infrastructure as part of the solution

In light of these daunting challenges, integrating natural infrastructure[1] with engineered solutions provides a promising approach that can help to reduce costs, protect and restore ecosystem services, enhance resilience to climate change, and provide a suite of additional social and economic benefits, detailed throughout this chapter (Table 1, Figure 1). Natural infrastructure is defined as a "strategically planned and managed network of natural lands, such as forests and wetlands, working landscapes, and other open spaces that conserves or enhances ecosystem values and functions and provides associated benefits to human populations" (Benedict and McMahon 2006). In this definition, emphasis must be placed on the phrase "strategically planned and managed"; for example, a protected forest or a working agricultural landscape managed to provide services akin to infrastructure would be considered natural infrastructure, yet similar forest or agricultural landscapes not managed for these services would not necessarily be considered natural infrastructure.

Natural infrastructure can be implemented as a substitute or complement to traditional gray infrastructure, and in both cases, it has reduced costs while enhancing environmental benefits. Six U.S. cities, for instance, have saved between $50 million and $6 billion by investing in sustainable watershed management, instead of new water treatment facilities (Gartner et al. 2013). Recent work by The Nature Conservancy indicates that water utilities could save up to $890 million each year in water treatment costs if they invested in all possible watershed conservation actions (McDonald and Shemie, 2014). Figure 2 compares the costs of gray infrastructure investments (such as new water filtration facilities) with alternative green infrastructure investments (such as forest protection, wetland restoration, or low-impact development programs) across four U.S. cities. The graph shows that in each city, green infrastructure investments had lower up-front costs than gray infrastructure investments, as a means to achieve comparable water security goals. Box 1 further illustrates this point by summarizing how efforts to protect natural infrastructure in Maine (United States) provide cost savings opportunities to the local water utility.

Unlike gray infrastructure, which is generally designed to meet a limited set of purposes, natural infrastructure tends to perform well across a wide range of conditions and offers a wide variety of functions, opening up the potential to provide multiple benefits across food, water and energy systems, as well as other benefits to society and the ecosystem. For example, a floodplain may attenuate larger flood volumes than can be held within a levee lined river channel, and the floodplain can also be used to grow food, sustain bird and fish species, and provide recreational benefits to people.

Natural infrastructure falls under what is commonly referred to as a "soft path" (Gleick 2003) management option, because it provides robust, low-regret, and multifunctional adaptation strategies (Sussams et al, 2015). These are strategies that make sense despite the great uncertainty and range of risks associated with future scenarios because they can operate well and cost-efficiently across a variety of conditions. For example, during dry periods, many natural forests and floodplains continue to slowly release cool, shallow groundwater into streams. These same areas also reduce soil erosion, and store water, thereby reducing downstream flooding during heavy storms. Natural infrastructure is also easier to adjust and adaptively manage as future climate conditions become clearer because it tends to be more flexible and reversible than gray infrastructure. Once large gray infrastructure is built, it is often socially and economically difficult to reverse, remove or adapt. The value of natural infrastructure, on the other hand, can appreciate over time as ecosystems become more mature and potentially more resilient. Where gray infrastructure exists, natural infrastructure can enhance, protect, or increase its useful life by, for example, retaining sediment and reducing the need to dredge reservoirs.

1 Sometimes called "green infrastructure."

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Box 1. Natural Infrastructure for Water Security: Clean Water in Maine, U.S.

The Portland Water District (PWD) supplies drinking water to more than 200,000 people in the Portland, Maine area. The watershed providing water to Portland, Maine is currently so clean that the U.S. Environmental Protection Agency has waived requirements for PWD to install filtration systems. This represents a major avoidance in energy use, since pumping, filtering, and delivering water through a built filtration system can represent as much as 60% of a municipality's energy use.

Since most of the watershed is owned by many private landowners, PWD cannot accurately predict or control future changes to the watershed. There is a risk that deforestation for residential development or agriculture in the watershed could degrade water quality and threaten PWD's filtration waiver. To address this risk, in 2009, PWD partnered with several conservation organizations to determine if investing in natural infrastructure was feasible for their watershed. Using a cost-effectiveness analysis framework, PWD and partners compared the cost of a new filtration system with the cost of a 20-year natural infrastructure investment program.

They found that investing in natural infrastructure would sufficiently protect water quality, at a small fraction of the cost of installing a new filtration system. Under the most optimistic scenario examined, the natural infrastructure program would generate a savings of $110 million. Under the least optimistic scenario, natural infrastructure is still economically superior when considering the carbon and habitat benefits of watershed management.

As of 2013, the PWD has increased their contributions towards land protection to 25 percent of the program's transactions. Land trusts will likely fund a large portion of the program. The Clear Water Carbon Fund, which markets the carbon sequestration benefits of reforestation to fund tree planting within priority areas, will also finance some of the program's transactions. The partners are also examining options to leverage cost-share programs from the Farm Bill, such as the Conservation Stewardship Program and Environmental Quality Incentive Program, as well as state-level bonds, to increase financial incentives to landowners to participate in the program.

Source: Gartner et al. 2013.

Water management issue (Primary service to be provided)		Green Infrastructure solution	Location: Watershed	Location: Floodplain	Location: Urban	Location: Coastal	Corresponding Grey Infrastructure solution (at the primary service level)
Water supply regulation (incl. drought mitigation)		Re/afforestation and forest conservation	■				Dams and groundwater pumping Water distribution systems
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Water harvesting*	■	■	■		
		Green spaces (bioretention and infiltration)			■		
		Permeable pavements*			■		
Water quality regulation	Water purification	Re/afforestation and forest conservation	■				Water treatment plant
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Green spaces (bioretention and infiltration)			■		
		Permeable pavements*			■		
	Erosion control	Re/afforestation and forest conservation	■				Reinforcement of slopes
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
	Biological control	Re/afforestation and forest conservation	■				Water treatment plant
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
	Water temperature control	Re/afforestation and forest conservation	■				Dams
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Green spaces (shading of water ways)			■		
Moderation of extreme events (floods)	Riverine flood control	Re/afforestation and forest conservation	■				Dams and levees
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Establishing flood bypasses		■			
	Urban stormwater runoff	Green roofs			■		Urban stormwater infrastructure
		Green spaces (bioretention and infiltration)			■		
		Water harvesting*	■	■	■		
		Permeable pavements*			■		
	Coastal flood (storm) control	Protecting/restoring mangroves, coastal marshes and dunes				■	Sea walls
		Protecting/restoring reefs (coral/oyster)				■	

Table 1. Natural Infrastructure solutions for water resources management

Source: UNEP 2014.

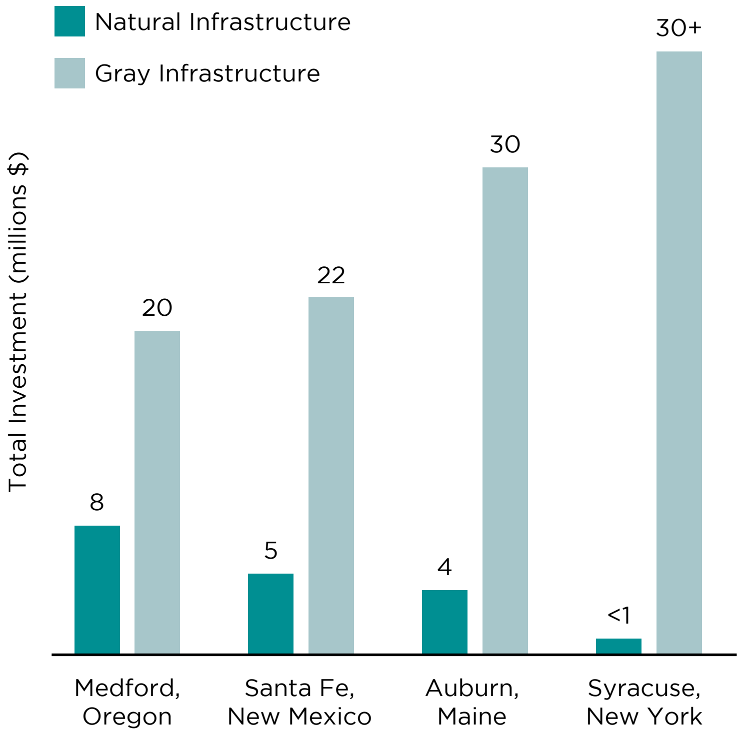

Figure 2. Comparison of green versus gray infrastructure costs for cities to meet WQ requirements in the United States.

Source: Gartner et al. 2013.

Overview of Efforts to Date

Natural infrastructure is both an old concept, and an important re-emerging approach to address challenges at the nexus of food, water and energy security. In the 1890's, the need to protect valuable watershed benefits led to the creation of the United States National Forest System and "water preserves" outside of growing cities like Boston and Philadelphia (Gartner et al. 2014). More recently, cities such as Rio de Janeiro, Beijing, Tokyo, and Melbourne have protected forestland to secure drinking water supplies (Dudley and Stolton 2003).

These isolated success stories have gained international attention recently, as an effective strategy to overcome water, energy and food challenges. As a result, investment in natural infrastructure is rapidly rising worldwide. According to Forest Trends, in 2013, there were 403 active natural infrastructure for water investment programs (and 51 in development) worldwide totaling US$12.3 billion, aimed at better managing watersheds in order to provide water storage, pollution filtration, or flood mitigation (Forest Trends 2014, Figure 3). These programs have protected more than 365 million hectares of natural infrastructure, which is an area the size of India.

The speed at which the natural infrastructure approach is being adopted seems to be increasing: between 2011 and 2013, the number of watershed investment programs reporting outcomes tripled (Forest Trends 2014). This dramatic increase results from both an actual increase in investment, as well as from more reporting on investments.

Box 2: Example of corporate investments in natural infrastructure: Unilever Tea Kenya

In 2000, Unilever Tea Kenya (UTK) faced critical water shortages at its tea plantations, due to high rates of regional deforestation. As forests were cleared and degraded for fuel wood and grazing, aquifer and stream recharge declined in the region, threatening tea productivity. UTK decided to engage the people that were degrading forests to improve watershed stewardship through reforestation efforts. UTK started growing native tree seedlings and donating them to the surrounding farmers and communities for planting. Between 2001 and 2009, 850,000 trees were planted to help protect regional water supplies.

Source: Unilever 2009.

New initiatives to scale up natural infrastructure investments are emerging. The Nature Conservancy (TNC) has established 32 multi-stakeholder watershed protection programs, called Water Funds, aimed at ensuring high quality drinking water downstream (TNC 2014a). This model of collective action has forged unlikely, but effective, partnerships among business, governments, and farmers to manage water across landscapes. Several funders, including TNC, the FEMSA Foundation, the Inter-American Development Bank, and the Global Environment Facility have supported growth of these partnerships by establishing the Latin American Water Funds Partnership (IDB 2011).

The corporate sector is taking actions to demonstrate how natural infrastructure bolsters corporate performance: the beverage company Anheuser Busch Inbev announced a strategy in 2013 to engage in watershed protection measures at all of their facilities located in seven countries over five years (AB Inbev 2013). Coca-Cola, SAB Miller, and other beverage companies have taken similar measures to protect source water (Forest Trends 2014, Box 2). Finally, conservation and development organizations have developed decision support tools and guidance that aid in the assessment and implementation of natural infrastructure projects, making natural infrastructure considerations easier to incorporate into decision making (Box 3).

Despite this progress, very few sectors of government and industry are investing in natural infrastructure at all, and only a fraction of natural infrastructure opportunities are being realized. Although the global market size of watershed investments is substantial ($12.3 billion), it does not compare with the estimated $1.3 trillion annual water infrastructure investment challenge. About 93 percent of documented natural infrastructure investments in 2013 were made in China alone, primarily related to reforestation upstream of reservoirs (Forest Trends 2014). Programs in all other countries combined committed less than $1 billion (Forest Trends 2014). While innovative financing mechanisms are emerging, $10.8 billion of these investments took the form of public subsidies, such as grant and cost-share programs. While public finance is a critical mechanism to protect and manage natural infrastructure, it is insufficient and shrinking in the midst of intensifying environmental challenges.

Furthermore, utilities, companies, and communities that could directly benefit the most from natural infrastructure typically do not invest in this approach, the reasons for which are discussed in the following section. Most of the world, including the water, energy and food sectors, underinvests in natural infrastructure relative to the scale of the opportunity, cost-effectiveness, and current and future risk exposure.

Summary of Watershed Investment Programs (2013)	
Total Active/Pilot Programs	403
Total Programs in Development	51
Value of Transactions	US$12.3 billion
Hectares Protected	365M hectares

Figure 3. Number of watershed investment programs by world region

Source: Forest Trends 2014.

Box 3. Examples of Natural Infrastructure Tools and Guidance

A variety of tools and guidance documents are available to help public agencies, planners, engineers, and other decision makers make smart investments in natural infrastructure. These tools often include functions to optimize a range of benefits, allowing users to address water security, energy security, agricultural sustainability, and climate resilience together.

For national and international agencies or organizations, high-level screening tools can aid in focusing and prioritizing regions for further examination. Examples of screening tools include:

- **Urban Water Blueprint Map** (TNC 2014b) estimates the level of conservation needed to achieve a reduction in sediment and nutrients for more than 500 cities worldwide.
- **Global Forests for Water Map** (WRI forthcoming) combines global data on water stress with near real-time high-resolution forest change data, enabling users to view where ecosystem change may be having adverse impacts on water resources. It helps users identify risks to existing water resource and hydropower facilities and prioritize upstream conservation and restoration opportunities.
- **Aqueduct Global Flood Analyzer** (WRI 2015) provides users an open-access online platform to quantify and monetize river flood risks worldwide. The Analyzer estimates current and future potentially affected GDP, affected population, and urban damage from river floods for every state, country, and major river basin in the world.

Site-level spatial analysis tools enable planners, engineers, and site managers to estimate the environmental outcomes of a natural infrastructure project, and compare with other options.

- **InVEST (**NCP n.d.) models the quantity and economic value of ecosystem services delivered by natural infrastructure projects under different scenarios.
- **Soil and Water Assessment Tool** (Texas A&M University n.d.) predicts the environmental impact of land use change at a watershed scale.
- **Site-level economic valuation and financial analysis frameworks** enable natural infrastructure champions and decision makers to evaluate the costs and benefits of natural infrastructure relative to business as usual.
- **Green-Gray Assessment** (Gray, Gartner, and Mulligan 2014) provides a step by step process to economically value the benefits of natural infrastructure and cost out projects in ways that are easily comparable with conventional capital budgeting.

Guidance documents prepare practitioners to identify, evaluate, plan, and execute natural infrastructure strategies.

- **Natural Infrastructure** (Gartner et al. 2013) is the most comprehensive guide to natural infrastructure strategies for the United States covering key enabling conditions such as the underlying science, partnership development, financing mechanisms and making the business case.
- **Green Infrastructure: Guide to Water Management** (UNEP 2014) provides an overview of frameworks, best practices, and case studies from around the world.

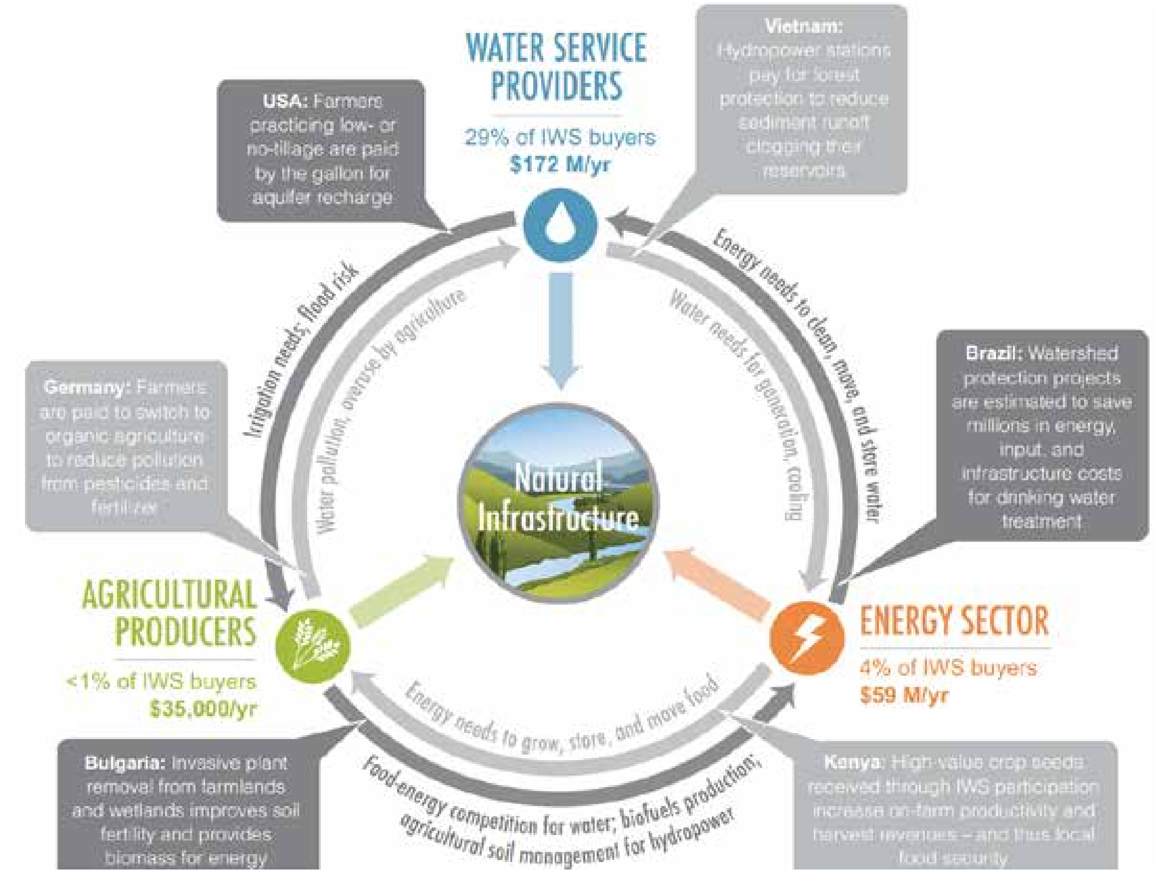

Figure 4: Nexus investments in natural infrastructure for energy, food and water

Source: Forest Trends 2014.

Discussion

Natural infrastructure in the nexus

As noted by Krchnak, Smith, and Deutz (2011), "Nature is the unseen dimension of the nexus." Figure 4 (reproduced from Forest Trends 2014) illustrates, through examples, the interconnections among natural infrastructure, water supply, agriculture and energy production, along with relative investments of these sectors in natural infrastructure. Forest Trends (2014) reported that the energy and agriculture sectors collectively contributed less than 1% of all natural infrastructure investments in 2013. While Forest Trends' market estimates may not capture all direct investments in natural infrastructure, the trends suggest that natural infrastructure is not being fully utilized in terms of the wide suite of benefits it can provide to address nexus issues.

Natural infrastructure plays four important nexus roles in helping to secure water, energy, and food for humans and ecosystems:

- Natural infrastructure **links together the nexus elements** and plays overlapping roles in the management of water, energy, and food systems. As such, it can provide **cross-sector benefits**, potentially multiplying economic returns on investments.
- Natural infrastructure for water helps attenuate floods and droughts, providing a buffer against inter-annual variability as well as the added variability associated with climate change, thereby **improving the resilience of water, energy, and food systems.**
- Natural infrastructure can help **maintain the function and extend the lifespan of the gray infrastructure** that supports water, energy, and food systems.

- Natural infrastructure can **mitigate negative externalities** resulting from the operation of gray infrastructure to meet water, energy, and food demands.

The following sections describe the various roles that natural infrastructure plays in the nexus in more detail.

Natural infrastructure and water services

Communities around the world face a growing water crisis. In developed countries, much of the built water supply infrastructure is nearing the end of its useful life (Mirza and Haider 2003; American Society of Civil Engineers 2013; Sægrov et al. 1999), while 748 million people, primarily in developing countries, lacked access to improved drinking water sources in 2012 (WHO 2014). Increasing demand, land use change, and more extreme weather events compound these water challenges.

Harnessing the water-related services provided by sustainably managed forests, wetlands, and floodplains has a major role to play in combating the water crisis, particularly in the face of future climate stresses. For example, watersheds with more forest cover have been shown to have higher groundwater recharge, lower stormwater runoff, and lower levels of nutrients and sediment in streams when compared to areas dominated by urban and agricultural uses (Brett et al. 2005; Crosbie and Chow-Fraser 1999; Matteo, Randhir, and Bloniarz 2006). (see Box 4) Whereas flood infrastructure such as levees and dams often degrade aquatic habitat by altering the natural flow regime and cutting off floodplains from rivers. Preserving floodplains and/or reconnecting them to rivers can instead provide flood management benefits, while also conserving ecosystem values and functions (Opperman et al. 2009; Opperman et al. 2010; Poff et al. 1997). Investing in natural ecosystems can also be a cost-effective strategy for regulatory compliance in comparison to costly water treatment plants or other built infrastructure (Box 1).

Natural infrastructure, water, and food production

Producing food to meet the demand of the growing global population requires vast amounts of land and water, often resulting in the degradation of both terrestrial and aquatic ecosystems. In many areas of the world, swaths of large-scale monocultures have replaced formerly healthy, natural land habitat, while fish farms compete for space with natural coastal and freshwater habitats. Intensive production in these lands and waters through unnatural, chemical inputs further stresses these ecosystems.

Fortunately, when intentionally designed, food production systems can serve as natural infrastructure that provides services well beyond the production of food and other agricultural products (Box 5). For example, agricultural land, such as the rice fields on Yolo Bypass outside Sacramento, California, can be used as natural flood storage areas, while providing essential habitat and nutrients for

Box 4. Natural Infrastructure Strategies to Combat Drought in Brazil

The 20 million inhabitants of Sao Paulo, Brazil have endured increasing water shortages in recent years. Deforestation in the watersheds that supply water to Sao Paulo have exacerbated droughts by causing sedimentation, water pollution, and reductions in regional water storage capacity. Recognizing the importance of restoring the health of these watersheds to secure water for Sao Paulo, the Brazilian Water Agency, The Nature Conservancy, the Sao Paulo State Environmental Agency, and the Extrema Municipality have implemented the Water Producers Program (WPP). The WPP pays landowners $95 per hectare to protect or restore forests, with funds provided by water user surcharges and the Extrema municipal budget.

TNC projects that protecting 14,300 hectares of forestland in the watersheds feeding Sao Paulo could reduce sedimentation by 50 percent, amounting to $2.5 million annually in avoided costs. Between 2006 and 2012, the project had protected more than 1,500 hectares.

Sources: TNC 2012; Gartner et al. forthcoming.

Box 5. On-farm watershed management in Kenya

Lake Naivasha in the Great Rift Valley of Kenya supplies water to local communities, horticulture and floriculture producers, geothermal power production, and small holder farmers, supporting the livelihoods of more than 500,000 people (FAO 2013). As population and industrial activities have grown in the region, water abstraction and pollution have increased as well. To reduce further impairments to the lake and ensure its sustainable use going forward, in 2008 WWF-Kenya, Care-Kenya, and the Lake Naivasha Water Resources User Association initiated a basin-wide Payment for Ecosystem Services scheme, compensating water users for improved stewardship (Chiramba, Mogoi, and Martinez 2011). Under the scheme, farmers in areas designated to be watershed degradation "hot spots" receive $17 per year to implement best management practices which include planting native vegetation, terracing to reduce soil erosion, and tree planting in riparian areas. Members of the Lake Naivasha Water Resources User Association (mainly horticulture exporters) pay into the PES scheme to increase water availability to sustain their activities. In addition to improving water security, the $17 payment has enabled farmers to implement practices that enhance their long-term productivity: harvest revenues have reached 30 times the value of the original payment over the past several years (Forest Trends 2014).

Sources: Chiramba, Mogoi, and Martinez 2011; FAO 2013.

wildlife (Sommer et al. 2001) (Box 6); urban agriculture can help manage stormwater (Seiter 2014), and rooftop gardens regulate building temperatures without the use of fossil fuels (Liu 2002). Mangroves supporting sustainably managed aquaculture and fisheries can also play a key role in mitigating coastal flood damage and help coastal communities adapt to rising sea levels (Rönnbäck 1999; Rao et al. 2013).

In addition, natural infrastructure can enhance agricultural systems and help mitigate the negative impacts of intensive food production. As the largest global consumer of water, the agricultural sector can deplete waterways or even cause rivers to run dry, as well as cause lands to subside due to groundwater depletion. However, conjunctively managing the natural storage provided by aquifers along with constructed reservoirs can help ensure that sufficient water remains in streams to support aquatic ecosystems throughout the year. For example, during times of abundance, water can be stored in underground aquifers and recovered for agriculture during low flow years, rather than depleting surface water sources and riverine ecosystems (Bredehoeft and Young 1983; Richter and Thomas 2007).

Agricultural systems that incorporate trees or shrubs (agroforestry) can be more biologically diverse, more profitable, and be more sustainable than forestry or agricultural monocultures, due to their ability to control runoff, maintain soil organic matter and fertility, provide additional sustenance and/or marketable product, and potentially increase nutrient recycling through nitrogen-fixation or decomposition of tree litter (Jose 2009). In addition, natural riparian buffers along streams can absorb toxic pesticides and fertilizers as well as trap soil running off agricultural fields before they enter waterways (Matteo, Randhir, and Bloniarz 2006; Lee, Isenhart, and Schultz 2003).

Natural infrastructure, water and energy

Water is used in almost every aspect of energy production, making it the second largest withdrawer of water after agriculture globally. In the energy sector, water is used for cooling during thermoelectric power generation (coal, nuclear, natural gas), which warms the water. While much of the water used to cool power plants is returned to rivers or other water bodies, some water is lost to the atmosphere and energy production process. The extraction and processing of fossil fuels also requires large quantities of water, and energy production of all kinds can degrade water quality and change the timing of river flows, both of which can have

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Box 6. Flood Control in California

California's water management system is comprised of a web of canals, reservoirs, levees, bypasses, and dams that move water around the state to: supply agricultural, residential and industrial users with water; manage floods; produce hydropower; facilitate navigation; and provide recreation. Not only does the built system often fail to meet demands - it has also contributed to the severe degradation of critical fish and wildlife habitat. Among the state's 129 native fish species, 7 have become extinct, 31 are listed as threatened or endangered under the federal and state Endangered Species Acts (ESAs), and another 69 are in decline (Hanak et al. 2011). Ninety-five percent of the state's wetlands disappeared with the growth of agriculture and grazing in the 19th century, thus eliminating crucial natural infrastructure that attenuated floods and provided habitat to a wide range of fish, birds, and other species (Isenberg 2010; Mount 1995; Hanak et al. 2011).

In contrast to the concrete and steel infrastructure, Yolo Bypass has been heralded as a natural infrastructure success story in California's water management history (Sommer et al. 2001; Opperman et al. 2009). The Bypass is California's largest contiguous floodplain, providing flood control, bird and fish habitat, productive agricultural land, and recreational opportunities for wildlife enthusiasts. This natural infrastructure was established nearly 100 years ago to mimic natural aquatic systems in the valley in ways that would protect nearby communities from severe floods. It sustains the highest salmon population in California by providing refuge for young fish and a nutrient rich food source. It is also home to nearly 200 species of birds and an essential stopover for migratory birds along the Pacific Flyway. When it is not flooded, it is a varied mosaic of wetlands, wildlife habitat, and seasonal agriculture, including productive rice patties (Sommer et al. 2001).

Box 7. Hydropower in Costa Rica

More than 80 percent of Costa Rica's electricity is generated by hydropower. In the 1990's, Costa Rica's hydropower sector faced an acute crisis as landowners upstream of these reservoirs cleared their land for livestock and agriculture. With the forest gone, soil erosion increased and caused sedimentation in the reservoirs, lowering reservoir capacity and threatening to deteriorate the hydropower turbines. To address this and similar issues stimulated by rapid land use changes, Costa Rica established a National Fund for Forest Financing to facilitate investments in natural infrastructure. Hydropower companies pay into the fund, which in turn pays landowners upstream of the company's dams to conserve or reestablish tree cover, thereby reducing river siltation and the need for reservoir dredging (Hanson, Talberth, and Yonavjak 2011).

To illustrate, the hydropower company Enel pays about $10 per hectare per year to the National Fund for Forest Financing, and the government of Costa Rica contributes an additional $30 per hectare, largely financed from fuel and water tax revenues (Hanson, Talberth, and Yonavjak, 2011). The fund makes cash payments to those owners of private lands upstream of Enel's facilities who agree to reforest their land, engage in sustainable forestry, and/or conserve existing forests. Landowners who have recently cleared their land or are planning to replace natural forests with plantations are not eligible for compensation. The financial compensation of $48 per hectare per year is thought to be comparable to the potential earnings from raising cattle, and thus this program has had high participation rates and has been very successful. Between 1997 and 2012, the National Fund for Forest Financing distributed approximately US$340 million achieving environmental improvements on more than 1 million hectares, involving more than 10,000 landowners (Porras, Barton, Chaco-Cascanet, and Miranda 2013). The program has multiple benefits: it rewards farmers for sustainable agricultural practices, improves watershed health, and promotes energy security by reducing wear and tear on hydropower facilities.

detrimental effects on aquatic ecosystems. Natural infrastructure can effectively mitigate some of the adverse environmental impacts of energy production.

Releasing unnaturally warm water into aquatic ecosystems is harmful and potentially deadly to many aquatic species, (Coulter et al. 2014; Teixeira, Neves, and Araújo 2009; Houston 1980) so power plants are often required by law to limit the heat they add to watersheds through the release of wastewater. One way to do this is to build very large, expensive refrigeration units or cooling towers (gray infrastructure) to cool the wastewater before releasing it into the environment. Alternatively, power plants and other utilities can mitigate their warm-water emissions using thermal credits - units of temperature rise prevented by the resulting shade from restoring trees and shrubs on riverbanks, which then become a form of natural infrastructure. For example, the city of Medford, Oregon was able to meet its legal thermal requirements for wastewater using cooling shade from natural infrastructure at a cost roughly half that of mechanical means (Rutberg 2013).

While dams play an essential role in the production of hydroelectric power, natural infrastructure can help improve the efficiency and longevity of this gray infrastructure. As a river flows into a reservoir and slows, sediments carried by the river sink to the bottom of the reservoir. Over time, sediments accumulate, resulting in a gradual loss of the dam's ability to store water, thus reducing its generating capacity. Sediments that enter hydropower turbines can cause abrasion and damage of other components, reducing the efficiency of power generation and potentially requiring costly repairs. Deforestation and other land use change can accelerate the sedimentation process and also alter rainfall patterns, affecting power generation. Reforesting watersheds above dams helps prevent erosion, naturally slowing the reservoir sedimentation process, as well as increasing power generation efficiency and the longevity of hydropower facilities (Box 7).

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Scaling up natural infrastructure

In response to growing nexus challenges, some cities, businesses, and communities have started to acknowledge the clear and compelling evidence for integrating natural infrastructure into built systems. Yet, natural infrastructure is far from reaching a scale commensurate with the challenges facing society. There are many reasons for the continued default to gray infrastructure solutions, including:

1. **Institutional inertia and pervasive knowledge gaps regarding natural infrastructure's benefits and linkages to the nexus.** Gray infrastructure solutions have dominated water management systems and engineering curricula for decades, which has led to informal biases and skepticism of natural infrastructure approaches. These informal biases are perpetuated in that capital budgeting and asset valuation methods fail to account for natural infrastructure as an asset. As a result, because infrastructure decision makers and constituents do not have a clear understanding of the benefits of natural infrastructure, they often do not attempt to incorporate natural infrastructure into traditional infrastructure designs. Since the nexus sectors operate in silos, they overlook opportunities to collaborate on new solutions and co-invest in natural infrastructure.
2. **Inability to quantitatively evaluate and compare project costs.** Even though tools and methods exist to help evaluate the business case for investing in natural infrastructure (Box 3), infrastructure decision makers often lack the technical capacity to design natural infrastructure projects that optimize costs and benefits. Site-specific assessment of environmental factors that must be considered in evaluating natural infrastructure projects is beyond the typical uniform water system development process, and few engineers are trained in such assessments. One complicating factor is the inherent uncertainty associated with natural systems, and how, for example, natural infrastructure might respond to a changing climate (Dalton et al. 2013). Without reliable quantitative analysis, those charged with evaluating infrastructure options are limited to (weaker) qualitative arguments for natural infrastructure investments.

Challenges 1 and 2 describe ways in which decision makers are not yet able to identify or evaluate good opportunities to invest in natural infrastructure. Additional issues arise where economic or policy systems do not clearly accommodate or prioritize characteristics that are unique to natural infrastructure. Natural infrastructure introduces new forms of complexity in at least two ways:

3. **High transaction costs.** Securing water, energy, and food through a natural infrastructure approach requires coordinated landscape interventions that involve multiple stakeholders. The cost of engaging and negotiating with multiple stakeholders, working across regulatory jurisdictions, and collaborating with dispersed landowners to implement natural infrastructure projects can be time

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consuming and costly. Built solutions often can be completed "within the fence line" of a utility or plant's direct operations, and therefore require less stakeholder engagement than natural infrastructure projects.

4. **Long time horizons.** Natural infrastructure solutions are still emerging and may require a longer period of time to establish than business as usual gray infrastructure options. For projects that restore degraded ecosystems to revive natural infrastructure, the ecological processes to establish the full array of natural infrastructure benefits occur over years and thus may not meet the short-term certainty that may be possible for engineered infrastructure to meet compliance requirements under shorter timelines.

These distinct characteristics of natural infrastructure give rise to challenges in setting conditions that enable the conservation and sustainable management of natural infrastructure:

5. **Insufficient financing.** Questions of who should pay for natural infrastructure, as well as how to fund monitoring or maintenance costs, create challenges for scaling up natural infrastructure. First, those who benefit from existing natural infrastructure often receive those benefits for free, and therefore may not be inclined to pay for maintenance of the natural system, despite the fact that the natural infrastructure benefits could be degraded or lost without sufficient protection and management. Also, natural infrastructure projects often require long-term monitoring and maintenance costs that beneficiaries may not have the ability to finance themselves. While government or long-term investors could provide enabling investments in ways that align with their missions, they typically do not do so. Similarly, financial institutions typically interface with ecosystem management solely through their environmental and social safeguards, rather than by signaling to clients or their own fund managers that natural infrastructure is an investment-worthy project component.

6. **Lack of clarity on how natural infrastructure complies with environmental regulations.** Uncertainty and lack of clarity surrounding how proactive natural infrastructure strategies align with environmental regulations is a widespread deterrent for natural infrastructure. Regulators may shy from natural infrastructure given its inherent uncertainties, the time between project implementation and emergence of results, as well as the natural temporal variability in performance. Regulations across different agencies, jurisdictions, or levels of government might also conflict when natural infrastructure is in question—for example, protecting a municipal water supply through natural infrastructure might require clearance from federal regulatory agencies responsible for water, environment, wildlife, forest, or agriculture, alongside municipal and state agencies tasked with land use zoning. Disagreement or lack of coordination among these agencies can derail natural infrastructure investment.

Conclusions and Recommendations

Efforts to date have raised the profile of natural infrastructure in addressing interconnected challenges among food, water and energy security. As a result, natural infrastructure investments have been growing. Nonetheless, natural infrastructure is still most commonly used as a reactive safeguard at a small scale, often with unknown quantifiable impacts. What will it take to move from small, isolated natural infrastructure initiatives, towards a coherent global movement where natural infrastructure is considered a core strategy to manage water, energy, and food security risks?

Possibly the most critical scaling mechanism for natural infrastructure is further demonstration of the business case for investment. Once decision makers are aware that natural infrastructure is not only good for the environment, but can also be good for their budgets, this market will naturally grow. A more robust collection of financial assessments and demonstration projects around the world would go far in providing the evidence to overcome informal biases against natural infrastructure, and help to legitimize this approach. It would also provide much needed information regarding circumstances when natural infrastructure works best (and when it is not a suitable strategy), as well as best practices for operationalizing the approach.

Another important scaling mechanism for natural infrastructure is the formation of multi-stakeholder partnerships dedicated to addressing the food, water, and energy nexus. Multiple stakeholders across a landscape must coordinate to build momentum for natural infrastructure projects and then design, implement, and maintain those projects (Gartner et al. In review). According to Forest Trends (2014), collective action partnerships (where multiple stakeholders work together towards the same goal) made up a third of newly established natural infrastructure partnerships between 2011 and 2013. Table 2 outlines key factors for the success of these projects and partnerships, and the role of key actors in achieving these goals is outlined subsequently.

The decision makers ultimately responsible for designing and implementing infrastructure systems, as well as the financiers, regulators, academics, and international organizations that set enabling conditions and provide support for natural infrastructure, all play important roles in overcoming these challenges. These groups can take immediate steps to support increased investment in natural infrastructure, in ways that provide solutions to food, water and energy nexus issues:

Industry, municipalities, and others implementing infrastructure projects

Those who design, implement, or approve water, energy or food security projects are ultimately responsible for decisions of whether or not to incorporate natural infrastructure into planning. Utilities, municipalities, and companies with high dependence on water, among others, should:

THEME	SUCCESS FACTOR
Building Momentum	• Presence of drivers or windows of opportunity for natural infrastructure investments • Presence of champions and effective advocates • Investment is supported by asound business and economic case • Effective partnerships are established for source water protection • Effective public outreach and communication
Designing	• Landscape assessments are conducted to identify priority areas for investment • Sustainable financing mechanisms are available
Implementing	• Partners have defined reponsibilities and the capacity for implementation • Capacity to work across different types of landownership
Maintaining	• Outcomes are monitored and reported based on an agreed upon definition of success • Capacity to leverage sufficient funding to achieve landscape scale impacts • Capacity to look ahead and plan for the future

Table 2. Diagnostic framework of success factors at different stages of natural infrastructure

Source: Gartner et al. In review.

- *Commit to routinely assess the feasibility of natural infrastructure* in new projects. Screen all water, energy, and food system projects for opportunities to strategically integrate natural infrastructure. Conduct financial analysis to determine the feasibility of incorporating natural infrastructure into project plans.
- *Publicly release the results of assessments and identify barriers* to implementing natural infrastructure. Detailed documentation of natural infrastructure projects can provide a foundation for replication efforts, and it is also essential to the development of robust and effective policy frameworks to encourage natural infrastructure where it makes sense. As groups adopt these tools and provide feedback, the tools can be refined and improved for future use.
- *Forge partnerships* across sectors and with other beneficiaries to secure and restore natural infrastructure at a meaningful ecological scale, when it makes business sense to do so.

As a critical mass of decision makers adopt the suite of methods and tools to evaluate promising natural infrastructure projects, their experiences will help overcome the information and capacity challenges previously mentioned. They will also contribute towards the growing evidence base which demonstrates that integrating nature into infrastructure decisions can be financially, environmentally, and socially superior to business as usual. Testing the screening and spatial analysis tools will uncover new insights about the geographic areas and conditions where natural infrastructure is most viable, and where it is not. Likewise, as more financial analyses of natural infrastructure options become available, the business case for natural infrastructure will be clarified, inspiring others to follow suit.

Some organizations are taking steps to incorporate natural infrastructure options into routine planning processes and establish new natural infrastructure projects. For example, Dow Chemical and Shell Oil have established small teams tasked with reviewing corporate infrastructure projects in the pipeline, to consider whether natural infrastructure is a fit for them (Maxwell, McKinsey, and Traldi 2014). Similarly, the World Business Council for Sustainable Development included "Investing in Natural Infrastructure" as one among 20 potentially transformative business solutions comprising its Action 2020 corporate sustainability agenda (WBCSD 2014).

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Financial institutions

Development banks, insurance companies, venture capital funds, commercial lenders, and grant-making institutions can help overcome the financing, cost, and capacity challenges that have prevented the utilization of natural infrastructure to date. These financial institutions can bolster the resilience and sustainability of their investment portfolios by supporting natural infrastructure projects. Any financial institution with water, energy, or food industry investment portfolios may not be aware of natural infrastructure solutions but are in fact supporting projects in which these approaches could be integrated. Without evaluating those investments for natural infrastructure options, however, these opportunities go unrealized. Lenders can incorporate natural infrastructure evaluations into lending standards and portfolio management. For example, The International Finance Corporation, signatories to the Equator Principles, and members of the Natural Capital Declaration are incorporating natural capital assessment protocols into their lending standards (Maxwell, McKinsey, and Traldi 2014). Financial institutions can also provide technical assistance and offer preferred lending or other incentives for their clients to invest in natural infrastructure, helping overcome the previously highlighted challenges of high transaction costs and lack of financing. The Inter-American Development Bank (IDB) offers technical assistance to clients that are willing to incorporate natural capital management into a broader project proposal (IDB n.d.).

The emergence of new sustainable venture funds with longer time horizons may prove useful in overcoming temporal (long time horizons) challenges associated with financing natural infrastructure projects. The Livelihoods Fund, a new venture fund worth $46 million, finances projects in reforestation, sustainable farming, and conservation to protect ecosystem services (Livelihoods Fund n.d.). An upfront investment from the Livelihoods Fund allows project development and risk reduction before corporate off-takers purchase improved water quality, carbon offsets, sustainable agricultural goods, etc. Replication and expansion of programs such as the Livelihoods Fund are needed to streamline natural infrastructure projects. This and similar funds could dovetail with natural infrastructure projects to supplement start up and administrative funding in the long-term.

National and regional governing bodies

Governing bodies are both well positioned to establish an environment that permits, encourages, or requires consideration of natural infrastructure projects. They also receive the social benefits of positive natural infrastructure externalities, such as improved health from cleaner waters, new job sectors and livelihoods, and maintenance of a rural way of life. Strong regulatory signals and associated policy frameworks are essential to motivating utilities and companies to proactively seek sustainable pathways. Whereas isolated voluntary investments in natural infrastructure will occur when an economic opportunity is known, proactive environmental standards for water protection, land use, carbon reductions, etc. are likely to more effectively catalyze large-scale natural infrastructure investments.

Regulatory flexibility is an essential enabler for natural infrastructure investments, yet many current regulations do not encourage, or may even deter natural infrastructure investments. Regulations should be revised to allow for natural infrastructure strategies to be a feasible compliance mechanism, and governments should promote inter-agency coordination to ensure natural infrastructure solutions do not incur red tape. Governments could promote evaluation of natural infrastructure options during project licensing, for example.

Public agencies and policy makers can also align public incentive programs with local or privately-led natural infrastructure efforts to maximize environmental benefits of these programs. Alternatively, governments can establish publically-led natural infrastructure programs. Costa Rica (Box 7), China, Vietnam, and Brazil, and other nations have established large scale programs that use either public funds, private funds, or a combination to

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finance the protection or restoration of natural infrastructure (Forest Trends 2014). Countries developing national natural capital accounts may also encourage investments in natural infrastructure, in so far as these accounts pinpoint water, energy or agriculture projects where natural infrastructure could add value.

International development and environment organizations

International development and environmental organizations can increase awareness and provide tools to help inform infrastructure decisions and encourage decision makers to adopt natural infrastructure options analysis in a number of ways. Environmental groups can help develop and refine data sharing services (e.g. common web platforms) and decision support tools (e.g. mapping tools in Box 1) that support the initiation of proactive rather than reactive natural infrastructure projects. They can help shift natural infrastructure discussions from theory to application by, compiling existing case studies and conducting and disseminating research regarding natural infrastructure success factors, for example see *UNEP-DHI Green Infrastructure Guide* (UNEP 2014). These groups can help connect currently insulated actors from different sectors and organizations by providing forums for peer-to-peer learning and helping to establish a coalition and agenda for scaling up natural infrastructure. Widespread participation from national governments, organizations, communities and individuals in the Global Partnership on Forest and Landscape Restoration has set an ambitious goal of restoring 150 million hectares of forestland by 2030. As a result of their involvement in this partnership, several countries are working to ensure that national policies promote and ease the process of landscape restoration. Something similar for a broader suite of natural infrastructure approaches could motivate countries to reform policies and set conditions that enable investments in natural infrastructure.

Academia and educational institutions

Academia and other educational institutions have a role to play in providing a science-based foundation for demonstrating the benefits and costs of natural infrastructure and its appropriate usage. For example, academia can support analysis and build the evidence base regarding the capacity of an ecosystem to provide flood storage, groundwater recharge, or other ecosystem services under different climatic or hydrological conditions. Doing so will require academia to increase efforts to recast their research and teaching across disciplines, including: civil engineering, environmental sciences, land use planning, landscape architecture, economics and policy, etc. Further, educators can advance the effort to scale-up natural infrastructure by instilling the value of natural infrastructure in their students, alongside lessons on gray infrastructure.

Bringing natural infrastructure to scale will require shifting to an integrated and cross-sector approach to infrastructure decision making. This approach will admittedly be challenging to operationalize, given the institutional inertia, uncertainty, and learning curve that must be overcome. Mainstreaming natural infrastructure into decision making in the nexus requires an expansion of demonstration projects and associated documentation of results that better establish the business case for natural infrastructure. Overcoming the financial and regulatory hurdles to initiate such projects will require financial institutions to broaden their lending portfolios and governing agencies to provide a regulatory framework that accommodates, incentivizes, or requires consideration of natural infrastructure projects. The success of these projects depends upon the forging of cross-sector partnerships and rise of champions in the movement to scale up natural infrastructure; international development and environmental organizations are well suited to cultivate such partnerships and champions. These efforts will result in proactively incorporating natural infrastructure options into early design, regulatory, and lending plans, uncovering more opportunities to take advantage of natural infrastructure as a smart, cost-effective, and sustainable solution.

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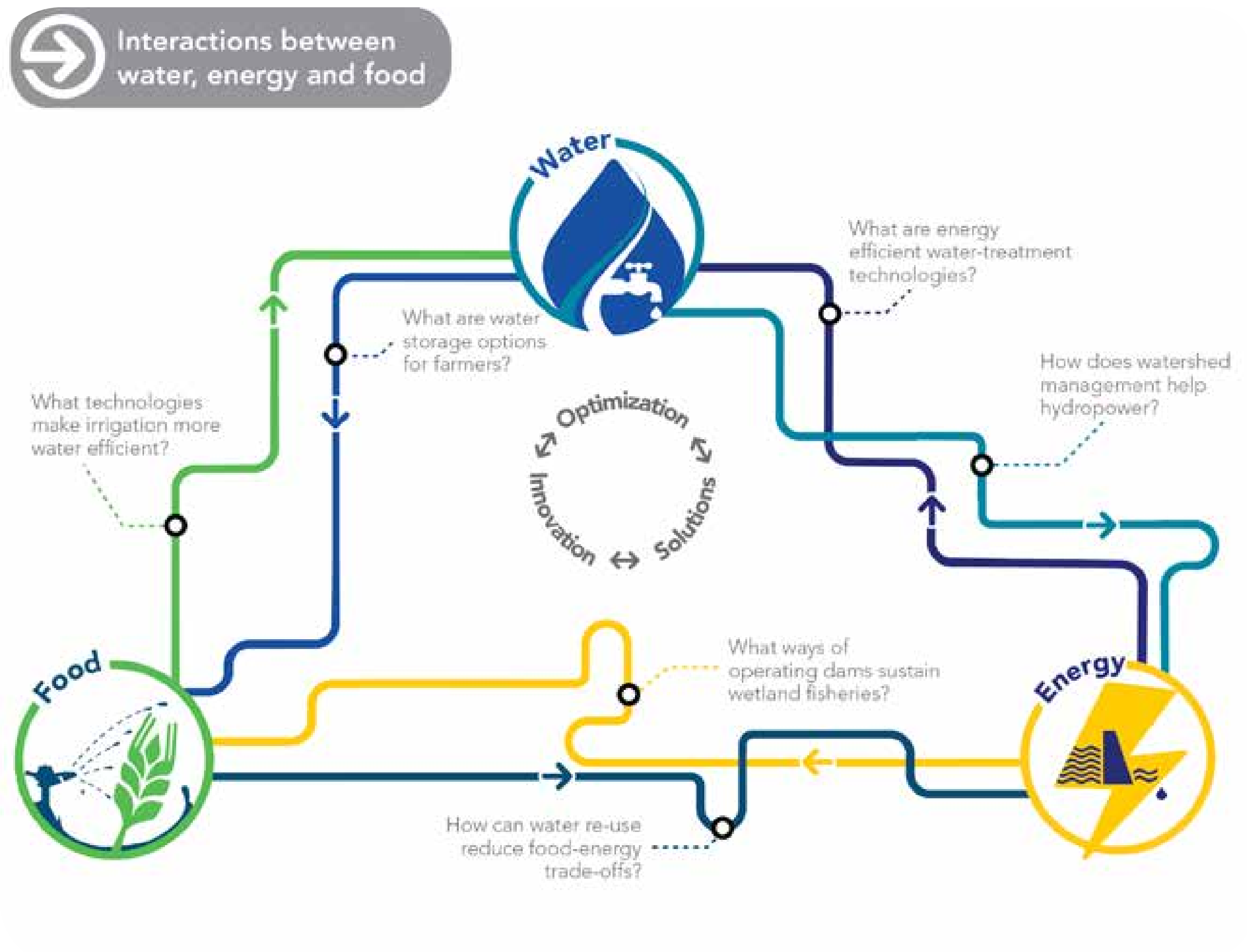
What is the Nexus?

Water uses energy, energy uses water, agriculture needs both and modern society needs all three; and they all rely on infrastructure to manage water. In this way, land, water and energy systems are inter-connected and have become increasingly more complex and dependent on one another. As a result, disturbance and change in one system can destabilise the others. For example, recent extremes of droughts and flood have forced an evaluation of how water infrastructure impacts other sectors – highlighting the need for a 'nexus based' multi-disciplinary, cross-sectoral approach to look for 'win-win' solutions while balancing environmental, social and economic issues. As world populations continue to grow, they will need to be serviced with water, energy and food against a backdrop of climate change.

The nexus – a series of connections, or the focal point of connections. The Nexus Dialogue is designed to speak across sectors to allow for a two way exchange or flow of information and perspectives. Through this process joint learning can be encouraged, perspectives understood, and joint solutions identified.



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About IUCN

IUCN, International Union for Conservation of Nature, helps the world find pragmatic solutions to our most pressing environment and development challenges.

IUCN's work focuses on valuing and conserving nature, ensuring effective and equitable governance of its use, and deploying nature-based solutions to global challenges in climate, food and development. IUCN supports scientific research, manages field projects all over the world, and brings governments, NGOs, the UN and companies together to develop policy, laws and best practice.

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About IWA

The International Water Association is the organisation that brings together science and practice of water management in order to reach a world in which water is wisely managed to satisfy the needs of human activities and ecosystems in an equitable and sustainable way.

The IWA is a global knowledge hub and international network for water professionals and anyone concerned about the future of water. We bring together know-how and expertise to instigate ground-breaking solutions.

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For more information on the Nexus Dialogue, please visit www.waternexussolution.org

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Contact us: info@waternexussolutions.org

CONTACT DETAILS

Dr Mark Smith
Director IUCN Global
Water Programme
Rue Mauverney 28
1196 Gland
Switzerland
www.iucn.org/water

Dr Ger Bergkamp
Executive Director IWA
Koningin Julianaplein 2
2595 AA Den Haag
The Netherlands
www.iwahq.org

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