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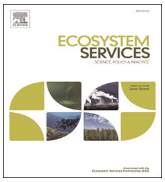

Natural infrastructure investment and implications for the nexus: A global overview

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ABSTRACT

As deeply interlinked challenges to water, energy, and food security appear poised to accelerate in the coming decades, interest has grown in landscape-based approaches to manage water–energy–food (W–E–F) nexus risks and trade-offs. Both engineered and “natural infrastructure” approaches are needed to increase productivity and resilience in W–E–F systems and to meet pressures of a growing global population and changing climate. However, to date little information exists about the use of nature-based solutions globally, the scale of present investment, funders' motives, or observed results.

This paper uses data from a global survey of watershed investments to examine the state of investment in “natural infrastructure”-based solutions for water, which can also address nexus challenges. We find that at least US $1 billion (B) flowed to watershed investment programs tackling nexus risks and trade-offs in 2013. But attention is focused largely on agricultural impacts on water and driven mainly by water service providers and the public sector. Our preliminary findings suggest that potential funders may be unaware of, or constrained in their ability to implement, nature-based strategies to address nexus-related challenges, and that current investment likely does not match the scale of risk or dependency of our W–E–F systems on healthy landscapes.

1. Introduction

Connections between global water, energy and food (W–E–F) systems have attracted significant attention in recent years (Hellegers et al., 2008). Each of the three ‘nodes’ of the nexus has a complex – and often critically important – relationship with the other nodes. Energy production for example relies on water for extracting fossil fuels, growing biofuels, generating hydroelectricity, and cooling power plants. Water is also a basic requirement for food production, including for cropland or pasture irrigation, processing raw materials, or supporting aquaculture and wild capture fisheries. Agriculture is already the largest user of water globally, and population growth and changing food preferences are expected to be a key driver of growth in water demand in coming decades (McKinsey & Co., 2011). Meanwhile, water systems require energy to make water accessible and safe for human use: to extract groundwater, treat drinking and waste water, pump water through distribution systems, and operate flood control structures. In the US, energy costs can be 25–30% of a water utility's total operating costs (USEPA, 2008). Food production is increasingly dependent on energy as well. Energy is needed to operate mechanized farm equipment, produce fertilizer (whether synthetic or mined), to pump and treat water for irrigation, and to process, package, and transport food products.

Interconnections across the W–E–F nexus pose major systemic risks to society, thanks to the presence of trade-offs, cascading effects, and competition for resources between these systems. Addressing systemic risks poses significant challenges for resource managers. To some extent, these challenges are inherent given the complexity of nexus relationships and the reality of resource constraints, but they are also linked to a history of uncoordinated management in each of the three spheres. Nexus relationships are often complex and poorly understood. A solution in one system may cause problems in another, and potential synergies often go untapped (Hellegers et al., 2008; Hussey and Pittock, 2012). For example, expanding natural gas's role in a region's energy portfolio to reduce carbon dioxide emissions can have unintended consequences for water or food: hydraulic fracturing to extract natural gas from shale reserves for instance has introduced a new source of water demand in many areas, leading to conflicts with agricultural or urban water users (Jaffe, 2014).

Pressure on W–E–F systems is expected to grow in the coming decades, exacerbating nexus challenges (Hoff, 2011). Global population growth and economic development is expected to drive increased demand for energy, water, and food production capacity, with demand projected to outstrip supply by 2030 by margins

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ranging from 32% for primary energy supply to as much as 249% for arable land (McKinsey & Co., 2011). Meeting future demand will require significant investment into built, human, and natural capital. But while the financial wherewithal may be within reach,[1] the natural resources needed to support such a transition are in decline in many places. Resource constraints threaten to aggravate nexus conflicts and the impact of trade-offs. Global food production systems, for example, rely on significant inputs of energy, water, fertilizer and land – and absolute scarcity of these inputs as well as competition with other uses will affect how well future production can respond to growing demand. In turn, increased global food demand will require more energy, more arable land (possibly requiring expansion of irrigation), and more water supply, treatment, and storage, unless greater efficiencies can be achieved in energy, land and/or water use (Khan and Hanjra, 2009). Beyond these pressures on built and natural capital bases, nexus challenges have significant implications for development and equity (Bazilian et al., 2011; ICIMOD, 2012), and for security (Parthemore and Rogers, 2010).

Climate change increases uncertainty around sustainable growth across the W–E–F nexus. In addition to increased frequency and severity of flood and drought, climate change will likely decrease freshwater availability annually or seasonally in many places, associated with increased variability in precipitation and streamflow and reduced snow and ice storage (Jiménez Cisneros et al., 2014). Negative impacts on water quality are also anticipated, thanks to higher water temperatures, increased pollutant concentrations, increased stormwater runoff, and sea level rise (Jiménez Cisneros et al., 2014). For food production, changes in precipitation, temperature, and radiation may increase the water demand of certain crops, exacerbating these availability and quality challenges. Irrigated agriculture may be the most economic sector in terms of increased scarcity relative to demand, since irrigation accounts for 70% of global withdrawals and 90% of global consumptive use (Wada et al., 2013; Shiklomanov and Rodda, 2003). Climate-related impacts on hydropower generation are more difficult to predict, given uncertainty around precipitation and streamflow changes (Jiménez Cisneros et al., 2014). Finally, thermal energy generation is vulnerable to reduced plant efficiency and useable capacity during some periods in regions where freshwater availability is reduced (Golombek et al., 2012; Flörke et al., 2012; van Vliet et al., 2012).

1.1. Nature in the nexus

In light of these challenges, the need to invest in natural capital has emerged as a key component of a nexus framework that addresses global W–E–F needs in an integrated fashion (Bizikova et al., 2013; Bogardi et al., 2012; ICIMOD, 2012). Water is at the core of nexus challenges (World Economic Forum Water Initiative, 2011) and healthy ecosystems are central to maintaining a healthy global water system (Rockstrom et al., 2014; Alcamo et al., 2008). Natural infrastructure – such as forests, wetlands, or rivers – is critical for maintaining adequate water quality and quantity. It also underpins the broad range of ecosystem services contributing to human well-being, including maintaining food security – as a source of food (such as wild foods and fish), genetic material for improving existing or new crops, pollination, and pest/disease control.

Importantly for the nexus, nature-based solutions for water can address trade-offs, via landscape-based approaches that enhance water, energy, and/or food security simultaneously. Healthy forests, wetlands, and floodplains for example filter sediments, toxins, and nutrients, improving water quality while reducing the need for energy-intensive water treatment. Sustainable agricultural practices – such as organic agriculture, eco-agriculture, or multi-functional agricultural landscapes – can conserve water, improve water quality, improve quality and safety of food, reduce erosion and soil loss, reduce the need for energy-intensive inorganic fertilizers, and mitigate climate change through reducing greenhouse gas emissions.

Natural infrastructure can also improve the functioning of built infrastructure, and help society to fully capture or exceed the expected returns on infrastructure investments. Degraded landscapes often place additional stress on W–E–F systems. Declining infiltration or soil water storage capacity may necessitate investment in additional water conveyance or storage infrastructure. Increased erosion or results of land degradation can cause a reservoir to silt up more rapidly than expected, or require additional treatment technology. Reservoir siltation also poses challenges for hydroelectric systems, reducing the expected lifespan of the reservoir or increasing operational costs associated with energy generation.

However, despite the potential for nature-based solutions, to date information about these approaches – the scale of current practice, guidance on identifying and implementing projects, and data on effectiveness – is either lacking entirely or largely anecdotal (Bizikova et al., 2013).

In this paper, we examine results from a global survey of investment in watershed services (IWS) programs (Bennett and Carroll, 2014) to identify programs addressing interlinked nexus challenges. All programs expressly take as their goal water security, but many also appear to pursue co-benefits including ones related to energy and food security. Our goal is to build a preliminary understanding of the use of nature-based approaches to manage nexus trade-offs and risks, the scale of financial investment in such strategies, and outcomes observed to date. We also seek to identify patterns or gaps in investment activity, and implications for developing sustainable global W–E–F production systems in the coming decades.

2. Material and methods

Our data comes from an inventory of IWS programs developed in 2014, based on a global web-based survey, interviews with program developers, and desk research. Programs were identified through outreach to Forest Trends' Ecosystem Marketplace's (FT-EM) existing database of program contacts, promotion of the survey through Forest Trends' website and social media, and desk research.

Altogether 498 programs were investigated and 483 program profiles developed, of which 405 were determined to be actively transacting payments for watershed services suppliers and 56 to be in developing stages. 207 programs responded to the survey and data was collected on another 198 programs through desk research and/or interviews.

The survey's scope extended to any mechanism involving a financial transfer between a buyer and a supplier of watershed services. Programs tracked included those close to the classic definition of payments for ecosystem services (PES) (Engel et al., 2008; Wunder, 2005) as well as other market-based mechanisms channeling investment into natural infrastructure for water, such as water quality trading and the purchase and retirement of water rights to augment instream flows (Bennett and Carroll, 2014).

Only operational programs were considered in the analysis. Program characteristics related to buyer profit status, sector, and

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[1] McKinsey & Co (2011) estimates that meeting demand for primary energy, water, land, and steel will require a capital investment of US $3 trillion a year by 2030, while current investment totals around $2 trillion a year.

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