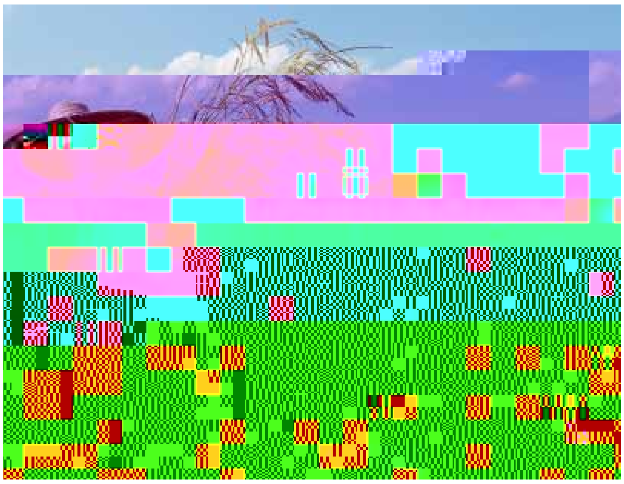
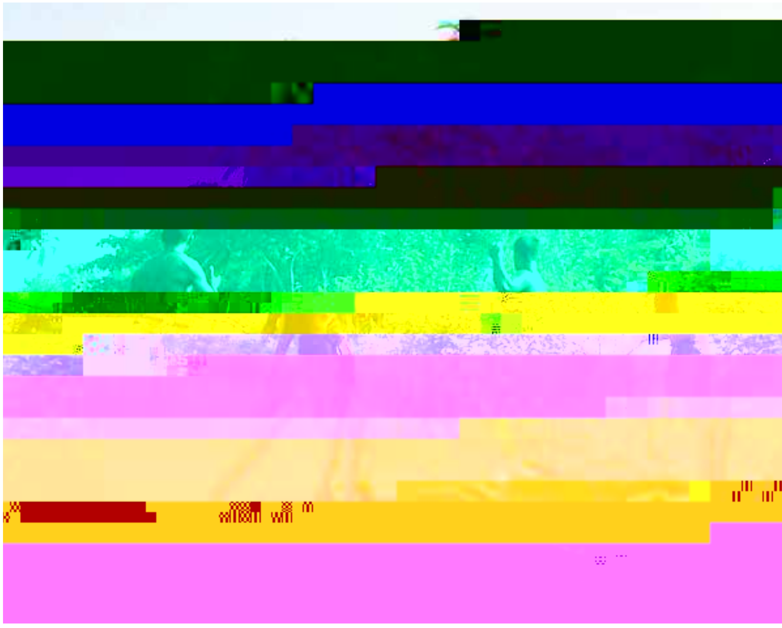
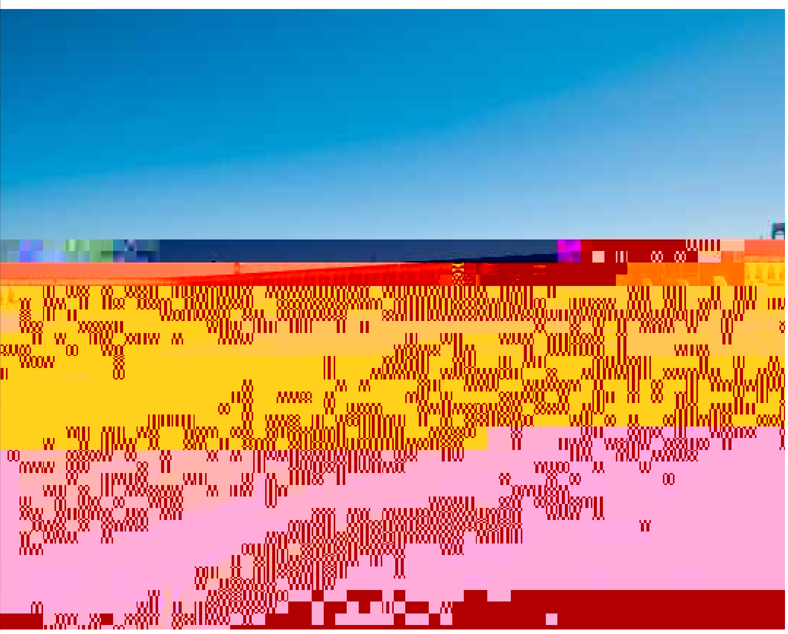
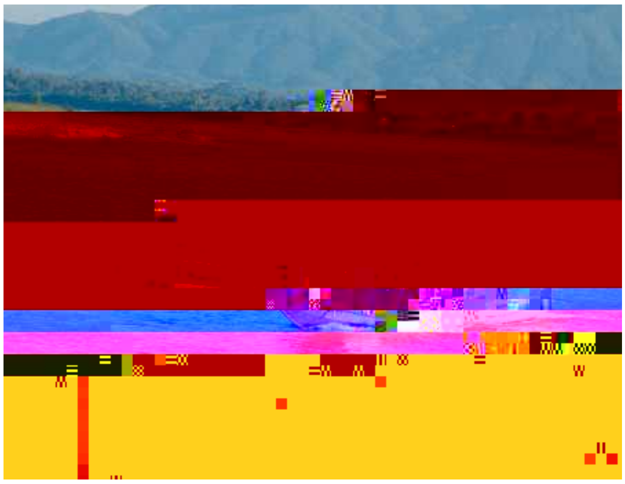
Putting Nature in the Nexus:

Investing in Natural Infrastructure to Advance Water-Energy-Food Security









without their benefits. Aquatic ecosystems – including rivers, lakes, streams, marshes, aquifers, estuaries and coastal deltas – provide abundant food and fiber, water purification, fish and wildlife habitat, tourism and recreational opportunities, shipping routes and employment. Ecosystem services underpin fisheries providing the primary source of protein for hundreds of millions of people, and likewise sustain water supply to irrigated agriculture. Ecosystems store and release water that powers hydroelectric generation. They hold back soil for farmers and slow siltation of reservoirs. They move sediments downstream, continually re-building the rich productivity of the world's deltas. Ecosystems slow floods and store water for release during drought, saving lives, livelihoods and health and reducing hunger. Aquatic species provide genetic and biochemical resources invaluable for health and pharmaceuticals. The linkages and inter-dependencies that characterize the water-food-energy nexus are mediated, in whole or in part, by ecosystems. However, to continue to provide these services within the nexus, nature itself depends on functioning ecological processes and species assemblages and on the flow and cycling of water. [2]

Yet, as the Millennium Ecosystem Assessment also made clear "the use of…freshwater…is now well beyond levels that can be sustained even at current demands, much less future ones."[3] Pressures on freshwater resources are intensifying because of population growth, industrialization, migration to cities and rising affluence. The squeeze on water supplies is increasingly acute. Water use worldwide grew 9-fold over the 20th century[4], or twice the rate of population growth, with per capita supply of water reduced by one-third in just the 20 years from 1970 to 1990.[5] Future growth in water demand will only tighten the squeeze. Under 'business as usual' economic growth, global demand for water is projected to grow by more than 50% by 2030, to a level 40% above current reliable water supply.[6] Such pressures on water resources are undermining the water-food-energy nexus. Their impacts on ecosystems compound and deepen disruption of the nexus.

Policy failure drives unsustainability. The failure to place economic value on water, the relative political weakness of ministries of environment and water compared to ministries that finance infrastructure development, and a misperception that water allocated to the environment is water unavailable for humans all contribute to degradation of aquatic ecosystems and their vital services. Policy failure too often leaves ecosystems out of investments made in infrastructure for water, food and energy security, despite the value of the benefits ecosystem services provide to each.

The conclusion at the Millennium was that future human well-being is tied to solutions for meeting water needs for development, but that development without sustaining ecosystems – as the support system for humanity – is not a solution. Reframing the problem now as the 'water-food-energy nexus' does not change the fundamental folly of ignoring the integral role of nature's services in development.

3. Understanding Nature as Nexus Infrastructure

Critical services from nature equate to functions of infrastructure (Table 1). Upland forests, aquifers, lakes and wetlands provide water storage, wetlands filter water, rivers provide conveyance and transportation, floodplains and wetlands lower flood peaks in downstream cities, while mangroves, coral reefs and barrier islands protect coasts against storms and inundation. With the term infrastructure defined as 'the stock of facilities, services and installations needed for the functioning of a society', nature is part of infrastructure portfolio of every country and every economy. Nature is then 'green infrastructure' or 'natural infrastructure' based on its capacity to complement, augment or replace the services provided by traditional engineered infrastructure.

Natural infrastructure does not replace the need for built infrastructure. It may sometimes be a better option, such as when the costs and benefits of ecosystem services exceed those of engineered options. In all cases, however, built infrastructure has a natural counterpart in watersheds. For example, dams benefit from forests that stabilize soils and hold back erosion upstream. Lakes and wetlands provide water storage and therefore reduce the reservoir volume needed and thus the cost of built water storage. The multiple ecosystem services provided by natural infrastructure multiply the benefits received. In this sense, well-functioning natural infrastructure is necessary for built infrastructure to perform its functions better, to ensure projected benefits and to increase returns on investment.

Table 1. Examples of green and grey infrastructure providing same beneÞ ts

ÒGreenÓ infrastructure	Gray infrastructure	BeneÞ t
Forests and wetlands	Water filtration facility	Clean drinking water
Forests (on slopes upstream of hydroelectric facility)	Periodic sediment dredging	Reliable power and flood control
	Sea walls	Shoreline protection from storms
Mangroves		
Coral reefs	Breakwaters and groins	Reduced beach erosion
Natural floodplains	Dikes and canals	Flood prevention
Wetlands	Tertiary water treatment facility	Clean effluent from municipal or industrial processes

Unhelpfully, policy frameworks for economic development and poverty reduction tend to marginalize ecosystems as simply a conservation issue. This overlooks their value and productivity in the economy and has led historically to decisions on investment in infrastructure for water, food and energy security based on options assessments that have been incomplete. The costs and benefits of the infrastructure functions of nature, including for lowering risk, have typically been excluded. The result has been biodiversity loss, but also the loss of capital assets and hence sub-optimal investments in infrastructure.[7]

The alternative is to treat nature as infrastructure in managing the water-food-energy nexus and in plans for financing infrastructure investment. Natural infrastructure can then be integrated within financing and investment for grey infrastructure. This would result in mixed portfolios of engineered and natural infrastructure in river basins in which each complements the other, with results in terms of cost-effectiveness, risk and sustainable development that are closer to optimal.

The cost-effectiveness of integrating natural and built infrastructure was recognized in planning upgrades to the drinking water supply system of New York City. In the now classical example of investing in nature as infrastructure, conserving the forests and wetlands of the Catskill, Delaware, and Croton watersheds (USA) to maintain water quality cost approximately $1.5 billion, compared to the projected cost to the city for building a new water filtration plant of $6-8 billion and annual operating costs of $300 million.[8,9] Likewise, in the Sarapiqui watershed in Costa Rica, a hydropower company pays $48/hectare annually to upstream landowners for forest management and restoration based on the avoided costs of reservoir dredging and the operational benefits of more reliable streamflow.[10,11] Furthermore, green infrastructure yields ancillary benefits—carbon sequestration, hunting, recreation opportunities, scenic beauty, and wildlife habitat, among others—that the substitute engineered infrastructure typically does not provide.

The costs of ignoring natural infrastructure values can be high, especially for poor people and the most vulnerable. The Diama dam was constructed in the Senegal delta in 1985 to stop dry season influx of saline water into the lower delta and to store water for irrigation. By 1994, starved of annual floods, the delta was hyper-salinised and choked with invasive weeds. Only 44,000 hectares of the planned 375,000 hectares of irrigation was farmed. Daily income per fisher was reduced to less than $3 per day, there were fewer than 20 women able to gather grasses for weaving and livestock grazing was virtually absent. Infrastructure engineered for agricultural intensification had degraded the natural infrastructure of the delta and the livelihoods that went with it. People were poorer, less water secure and less food secure as a result. Seasonal flooding of the delta was then restored and by 1998, daily income per fisher was over $20, more than 600 women were reaping weaving materials from the delta, and cattle were again grazing in the delta (at the rate of more than 150,000 cattle days per year).[12]

Fixing past failure to incorporate nature into infrastructure investments is also costly. In the Komadugu Yobe Basin in Nigeria, upstream of Lake Chad, engineers built dams in the 1960s and 1970s to store water for agriculture and drinking water supply. Much of the promised investment in irrigation infrastructure never materialized, but altered streamflow patterns downstream devastated ecosystems. Waterways and wetlands were choked by invasive weeds, and reduced annual flooding deprived farmers of water their crops depended on. Fisheries, agricultural and pastoral livelihoods were destroyed, leading to conflict in communities and causing loss of production and income that left poor people at higher risk of food insecurity. In 2006, based on multi-stakeholder consensus, the Federal Government of Nigeria and the governments of the six federal riparian states agreed that without restoration of the river basin, food and water security of the 23 million people living there would continue to degrade. Providing an initial endowment of $13 million, they set up a trust fund that aims to meet the estimated $125 million cost of restoring river flows and wetlands and implementing sustainable basin management.

4. Valuing Natural Infrastructure

Water infrastructure development is on the rise globally, for water storage, water conveyance, flood defense, irrigation and hydropower, particularly in developing countries and as a response to climate change. For example, more than 2,000 large dams are planned or under construction in South America, more than 50 large dams are underway in China's Yangtze River basin alone and the hydropower industry is evaluating opportunities for expanding energy production from existing facilities throughout the United States. By 2030, irrigated area worldwide is expected to expand by 45 million hectares to meet food demand by the world's growing population, an increase of almost 25%.[13] Now is therefore the time to put in place policies that will place ecosystems – and the infrastructure benefits they provide – inside the water-food-energy nexus. If policy frameworks leave ecosystems outside the nexus, past failures and costly mistakes that have led to the destruction of biodiversity and marginalization of vulnerable people will continue to be repeated.

The key to working with ecosystems in the water-food-energy nexus is the application of analytical tools for, first, quantifying the services provided by ecosystems and, second, estimating their economic value. Economic valuations for the infrastructure benefits of ecosystem services are based on, especially, market prices for products (e.g., wetland fisheries), the cost of replacing ecosystems through engineering (e.g., water filtration) or the costs of damage avoided (e.g.. flood attenuation).[14]

With valuations for green infrastructure in hand, decision makers can weigh up the costs and benefits of alternate choices for infrastructure development and operation, with a more complete picture of cost effectiveness for water, food and energy security and impacts on sustainable development more broadly. For example, cost-benefit analysis for a dam proposed for the Tana River, Kenya was carried out to assess the projected financial profitability and economic returns of various options for dam design. The dam is the last installation in a cascade of dams, but which would bring the natural biannual flooding of the Tana floodplain and delta to an end. The scheme was profitable based on hydropower generation, but none of the economic analyses considered the environmental impacts of the dam or the resulting social impacts. The changes in river flow would devastate downstream grasslands, lakes, riverine forests and mangroves that are natural infrastructure for livestock, agricultural and fisheries livelihoods and for rural and urban water supplies. When the effects of changes in river flow of the existing dams on downstream natural infrastructure were valued, they had a net cost of $26 million, which the new dam would increase to $45 million. However, an alternate dam design that accounted for natural infrastructure by including measures to simulate downstream flooding – an example of dam 're-operation' – could reverse many of the negative social and environmental impacts downstream while remaining a viable financial investment option for hydropower. In this case, incorporating natural infrastructure into decision making would improve overall outcomes for water, food and energy security.[15]

Integrating values for natural infrastructure into cost-benefit analysis for infrastructure opens the possibility of optimizing infrastructure development for a river basin. It would then be possible to identify mixed portfolios of engineered and natural infrastructure that would best meet multiple development objectives

Sustainable dam management to help meet water, energy and food demand – based on designing and regulating new and existing infrastructure projects to incorporate overall system health and solutions that meet society's long-term social, environmental and economic needs. On Maine's Penobscot River (USA), abundant fisheries were the cultural foundation for the Penobscot Indian Nation and the economic driver of the local economy. A series of hydropower dams built over the past century contributed to the decline of the river's overall health, blocking access for salmon and other species. The power company, the Penobscot Indian Nation, environmental groups and numerous state and federal agencies and riverside communities joined forces to restore more than 1,000 miles of river habitat without diminishing hydropower generation in the basin. This effort involves removing two dams in the lower river, installing a state-of-the-art fish bypass to a third dam further upstream and increasing energy production at dams elsewhere in the basin where impacts on fish are low.

CertiÞ able standards for watershed stewardship – to encourage widespread adoption of and investment in sustainable water management practices by companies and utilities globally. Existing private sector standards and market safeguards do not adequately consider water resources, which can lead to negative impacts for poor local communities. The Alliance for Water Stewardship (AWS) is working to create the first-ever global independent freshwater certification organization that rewards and recognizes water users and service providers based on criteria for protection of freshwater ecosystems and their services. The aim of certification to provide a unifying framework for utilities, businesses and communities to act and invest together to ensure that their watershed is managed responsibly, to the benefit of local people, biodiversity and business. Where the water stewardship standard is in place, large water users will be obliged to ensure that water needs of poor communities and ecosystems are met, that catchment management is improving for the good of everybody and that information is shared openly.

6. Conclusions and Policy Recommendations

- Clear quantification of the returns on investment from river basin management for water, food and energy security. Governments and financing institutions should apply economic tools to create a business case in which the dividends from investing in river basin management for water, food and energy security include accounting for livelihood and economic development benefits from ecosystem services.

- Making investment in natural infrastructure an integral component of financing for river basin development, in investment packages that combine engineered and natural infrastructure. Governments, the private sector, and water users should use a sound business case to mobilize innovative financing of water resources management. Financial institutions and governmental agencies should make financing available to local initiatives for watershed management through decentralized funds and credit schemes that integrate clean and adequate water for all, ecosystem services, livelihoods and economic development. Water utilities and private sector water users should participate in development and implementation of the global water stewardship scheme.

- Financing for natural infrastructure in holistic packages combining priority management actions with empowerment of stakeholders to undertake implementation. Governments, financing institutions and civil society should help with the effective application of natural infrastructure options through ecosystem management and restoration together with capacity building and support for reforms of natural resource governance.

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