AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

RESEARCH PROGRAM ON Water, Land and Ecosystems

LED BY: IWMI International Water Management Institute

ISSN 2521-1536

TOWARDS SUSTAINABLE INTENSIFICATION: INSIGHTS AND SOLUTIONS BRIEF NO. 3

RE-CONCEPTUALIZING DAM DESIGN AND MANAGEMENT FOR ENHANCED WATER AND FOOD SECURITY

August 2017

IN PARTNERSHIP WITH:

Acknowledgments

The team acknowledges the contributions and efforts of Meredith Giordano (Principal Researcher, IWMI), Douglas Merrey (independent consultant), and Alexandra Evans (independent consultant) in preparing the content for this series; and Caroline Holo (intern), Miles Bell (intern) and Aishwarya Venkat (intern) for their assistance with literature and data collection. We would also like to acknowledge the support of WLE scientists and partners in the preparation and review of the briefs.

Donors

This research was carried out as part of the CGIAR Research Program on Water, Land and Ecosystems (WLE) and supported by CGIAR Fund Donors (http://www.cgiar.org/who-weare/cgiar-fund/fund-donors-2).

Citation

CGIAR Research Program on Water, Land and Ecosystems (WLE). 2017. *Re-conceptualizing dam design and management for enhanced water and food security.* Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE). 12p. (WLE Towards Sustainable Intensification: Insights and Solutions Brief 3). doi: 10.5337/2017.212

/ sustainability / intensification / dam construction / water security / food security / ecosystem services / infrastructure / reservoirs / river basins / local communities / economic aspects / environmental economics / cost benefit analysis / net primary productivity / habitats / nutrients / sediment /

ISSN 2521-1528 (Print)
ISSN 2521-1536 (Online)

Copyright © 2017 CGIAR Research Program on Water, Land and Ecosystems, International Water Management Institute (IWMI).

Unless otherwise noted, you are free to copy, duplicate or reproduce, and distribute, display, or transmit any part of this paper or portions thereof without permission, and to make translations, adaptations or other derivative works under the following conditions:

ATTRIBUTION. The work must be attributed but not in any way that suggests endorsement by WLE, IWMI or the author(s).

NON-COMMERCIAL. This work may not be used for commercial purposes.

SHARE ALIKE. If this work is altered, transformed, or built upon, the resulting work must be distributed only under the same or similar Creative Commons license to this one.

Front cover image: Ian Taylor

Editor: Marianne Gadeberg
Designer: Michael Dougherty

SERIES INTRODUCTION

Raising global food production is essential to eradicate hunger and achieve food and nutrition security. But agriculture has become the world's single largest driver of environmental degradation, and it is pushing Earth beyond its natural boundaries. **Sustainably feeding future generations requires a fundamental shift in global agriculture.**

Since its inception in 2012, the CGIAR Research Program on Water, Land and Ecosystem (WLE) has developed scientific evidence and solutions for **sustainably intensifying agriculture**. For WLE, sustainable intensification means more than minimizing agriculture's environmental footprint; it means making sure that agriculture adds value to the environment, while it supplies global populations with sufficient food, nutrition and income.

More than 500 million smallholders worldwide stand to benefit from sustainable intensification of agriculture. Historic commitment to the UN Sustainable Development Goals (SDGs) and the Paris Climate Agreement further highlights the need for investing in sustainable and resilient agriculture.

But achieving sustainable, healthy food systems requires identifying **incentives** for sustainable farming. Likewise, it hinges on social and institutional innovations to **mitigate trade-offs and achieve synergies**, and **enable equitable access** to knowledge and resources. Not least, integrated solutions that work across sectors, disciplines and scales will be essential to realizing such a fundamental shift. Such innovations are what WLE has worked to develop. The Program's findings are summarized in this series of briefs, titled ***Towards sustainable intensification: Insights and solutions***.

Key Reading

Rockström, J.; Williams, J.; Daily, G.; Noble, A.; Matthews, N.; Gordon, L.; Wetterstrand, H.; DeClerck, F.; Shah, M.; Steduto, P.; de Fraiture, C.; Hatibu, N.; Unver, O.; Bird, J.; Sibanda, L.; Smith, J. 2017. Sustainable intensification of agriculture for human prosperity and global sustainability. *Ambio* 46(1): 4-17.

DEFINITIONS

Average net primary production – is the production of plant, algae and phytoplankton, which form the base of the food chain.

Drawdown zone – is the area at the edge of a body of water that is frequently exposed to the air due to changes in water level. Changes in water level can be caused by evaporation or by water usage in the case of reservoirs.

Ecosystem services – are classified as provisioning, regulating, habitat and cultural services, where

- Provisioning services refer mainly to goods that can be directly consumed, and include food, water, raw materials, such as fiber and biofuel, and genetic, medicinal and ornamental resources.
- Regulating services comprise regulation of climate, air quality, nutrient cycles and water flows; moderation of extreme weather events; treatment of waste – including water purification; prevention of erosion; maintenance of soil fertility; pollination; and biological controls, such as pests and diseases.
- Habitat services are those that maintain the life cycles of species or maintain genetic diversity, through quality and quantity of suitable habitat, e.g., natural vegetation that enables the natural selection of species to maintain a diverse gene pool or which serve as a source of pollinator and pest control agents. These types of habitats benefit people primarily by maintaining stocks and flows of biodiversity, which underpin and ensure the resilience of many of the provisioning, regulating and cultural services provided by ecosystems.
- Cultural services refer to the aesthetic, recreational and tourism, inspirational, spiritual, cognitive development and mental health services provided by ecosystems. (WLE 2014)

Nutrient fluxes – sediments serve as a major carrier and storage agent for nutrients such as phosphorus, nitrogen and potassium (Baran et al. 2015). Fluxes of organisms, detritus, nutrients and other materials into reservoirs strongly affect primary productivity: denitrification, burial in sediments and nutrient turnover mean that reservoirs act as nutrient sinks, blocking the flow of nutrients downstream (McCartney et al. 2016).

Recession agriculture – flood recession agriculture uses the residual moisture of seasonally flooded lands when the floods recede. This may be practiced on the banks of rivers or seasonal lakes.

SUMMARY

Dams provide numerous economic benefits and can mitigate the adverse impacts of water variability and extreme climate events. However, such large-scale water infrastructure has also caused significant social and environmental costs, prompting calls for alternative, nature-based solutions. WLE suggests that collections of built and natural infrastructure, combined with participatory management approaches, can support water and food security, while enhancing livelihoods and environmental outcomes.

Recommendations

- Treat water resources systems as interlinked collections of human-built and natural structures: Planning and managing river basins as suites of complementary natural and built infrastructure can improve benefits, such as reservoir fisheries, recession agriculture, floodplain grazing, flood protection and hydroelectricity production.
- Manage built water structures, such as reservoirs, as aquatic habitat, interconnected with the surrounding landscape: Managing reservoirs as ecosystems can improve habitat diversity, increase fisheries productivity and improve livelihoods, while mitigating adverse human health impacts.
- Invest in natural infrastructure: Natural structures, such as wetlands and floodplains, perform important water resources management functions and can improve the performance of built infrastructure by regulating river flow and reducing erosion and sediment deposition in downstream reservoirs.

INTRODUCTION

The ability to store and regulate water is crucial for achieving economic growth, alleviating poverty, supporting food security aims and adapting to climate change. Built structures, such as dams, can negate otherwise naturally occurring consecutive peaks and lows in water availability and provide a reliable supply of water for irrigation, industrial and domestic purposes as well as hydroelectricity at times when it would not naturally be available. It is widely acknowledged that built infrastructure has a vital role to play in climate change adaptation (McCartney and Smakhtin 2010).

Dams are also a major modifier of landscapes and ecosystems. Their construction can require the resettlement of large numbers of people and can dramatically alter ecosystem services on which local communities, especially poor and marginalized members, depend. Key ecosystem services that tend to be adversely affected as a result of dam construction include fisheries, floodplain agriculture and sediment transport (WCD 2000). Trade-offs between the benefits that large water infrastructure provides and degrades have spurred a discussion on the need for more built infrastructure versus greater reliance on natural infrastructure, such as wetlands and floodplains, to manage water resources and minimize local and downstream impacts.

Research by WLE scientists and partners points to a new approach to infrastructure design and management—one that considers water resources systems as interconnected collections of built and natural structures. When combined with active local community involvement in decision making and benefit-sharing schemes, this approach has potential to reap important social, economic and environmental benefits.

Benefits and costs of built infrastructure

In 2016, hydroelectricity accounted for nearly 17% of the world's total electricity generation and for 70% of renewable energy (REN21 2016). Moreover, large dams support 30-40% of irrigated areas worldwide, or 12-16% of world food production (FAO 2007). Large-scale infrastructure also plays a significant role in reducing flood and drought risks. For the agricultural sector—which absorbs 84% of the adverse economic impacts from droughts and 25% of all damage from climate-related disasters—the potential benefits from mitigating water variability are substantial, as much as USD 94 billion for a single year (FAO 2015; Sadoff et al. 2015).

However, the construction of large dams also comes with significant costs. Globally, between 40 and 80 million people have been displaced as a consequence of reservoir inundation. Historically, resettlement programs have been inadequate and most of these people are worse off than they were prior to being resettled. In addition, the livelihoods of an estimated 472 million people living downstream of dams have been adversely affected by changes in flow regimes (McCartney and Smakhtin 2010). All too often the benefits that dams bring, such as regular supplies of electricity and water, do not translate into improved incomes or direct benefits for local people.

Ecosystem degradation and loss of ecosystem services are often underestimated in traditional cost-benefit analyses, but can have dire consequences for both the environment and the communities that depend on them. In the Mekong River basin, dam construction has increased substantially (Box 1). While the economic benefits are significant (e.g., the estimated hydropower potential in the Mekong Basin is 53,000 megawatts), changes in the water, sediment and nutrient fluxes could significantly affect aquatic ecosystems and fish production. According to the International Centre for Environmental Management (ICEM 2010), the development of 11 hydropower dams on the Mekong mainstream could result in an annual loss of up to 880,000 tons of fish by 2030 compared to the 2000 baseline—a loss worth several hundred million US dollars (Nam et al. 2015; Mille et al. 2016). Dam construction and climate change are also expected to result in reductions of sediment deposition (53-59%), nutrient inputs (47-84%) and average net primary production of Mekong floodplains (30-38%) (Baran et al. 2015). These impacts will disproportionately affect communities living alongside the river (Katus et al. 2016).

BOX 1. MAPPING THE DAMS OF SOUTHEAST ASIA

WLE Greater Mekong maintains the most comprehensive dataset on existing and planned dams in the Greater Mekong subregion. Currently the Mekong Hydropower Map and Portal database includes information on 750 dams that are completed, planned or under construction. The database and supporting maps cover the Mekong, Red, Irrawaddy and Salween basins. To better understand the potential impacts from prospective dams in these basins, WLE has also contributed to a Dam Inundation Mapping Tool to model the inundation areas of prospective dams on the Irrawaddy, Salween, Mekong and Red River basins.

Resettlement programs may provide compensation for affected households, but reconstructing livelihood opportunities can be very difficult. Impact assessments of resettlement programs conducted after communities have been resettled due to hydropower dam construction in Lao PDR reveal the importance of maintaining access to fisheries, grazing areas and farmland to sustain livelihoods and incomes. Loss of riverbank gardens and overall changes in the water and aquatic and terrestrial ecosystems immediately following the dam construction can result in both reduced and less diversified household incomes for affected communities (see, e.g., Kura et al. 2014). Dams may also adversely affect public health. For example, WLE research has shown that by providing breeding habitat for anopheles mosquitoes, 1,268 large dams in sub-Saharan Africa elevate the risk of malaria for 15 million people and cause at least 1.1 million people to contract the disease each year (Kibret et al. 2015). If mitigation measures are not improved, these numbers could triple by the end of the century as a result of population growth in combination with climate change–without even considering effects of new dam construction (Kibret et al. 2016). Small dams and irrigation schemes also increase malaria risk, but to date no systematic analyses of the cumulative impact exists.

The World Commission on Dams (WCD 2000) concluded that large dams should be a development opportunity for all, not a privileged few. New ways of conceptualizing and managing water resource systems can help achieve more sustainable and equitable outcomes. One way of achieving this is to treat river basins as interconnected systems of built (e.g., dams) and natural (e.g., wetlands and floodplains) infrastructure.

River basins as suites of complementary natural and built infrastructure

While large-scale infrastructure is an important aspect of economic development, natural systems are integral to water resources planning and management. Placing a greater emphasis on the role of natural systems means considering them to be 'infrastructure' and, conversely, considering built infrastructure to be 'novel ecosystems' (Box 2). Through the WISE-UP to Climate project, led by the International Union for Conservation of Nature (IUCN), WLE scientists are contributing to new concepts and approaches that combine built and natural infrastructure for water and food security.

Treating water resources systems, like river basins, as interlinked combinations of natural and human-built structures can bring nature to the fore and facilitate improved planning and management of water for increased resilience and sustainability. Planners and investors can then consider different 'collections' of built

BOX 2. BUILT AND NATURAL INFRASTRUCTURE

Built infrastructure (e.g., dams and reservoirs) creates new configurations of biotic and abiotic elements that interact with the landscape in which they are located, and they can be perceived as 'novel ecosystems' (Hobbs et al. 2006). These are complex, dynamic aquatic ecosystems and there is potential to direct their evolution to provide a suite of desired ecosystem services (McCartney et al. 2016).

Ecosystems (e.g., wetlands and floodplains) in many respects function like human-built infrastructure. These can be perceived as 'natural infrastructure' that, like built structures, perform desired water resources management functions (Emerton and Bos 2004).

and natural infrastructure and direct their development projects so that they jointly contribute to a suite of desired benefits, such as water for productive uses, recession agriculture, flood protection and production of hydroelectricity, floodplain grazing, and river and reservoir fisheries.

Within this construct, it is important to consider the interconnections between ecosystem services and both built and natural infrastructure. To do this, WLE researchers have classified two types of water-related ecosystem services. Type 1 are those ecosystem services that affect the technical performance (i.e., reliability, resilience and vulnerability) of built infrastructure and hence its ability to deliver the benefits for which it was built (e.g., hydropower and/or irrigation). Type 2 are those that are affected by the physical presence of built infrastructure or by changes in water, sediment or nutrient fluxes caused by the way built infrastructure is designed and operated (e.g., fisheries and/or floodplain agriculture) (Fig. 1).

WLE research on managing reservoirs as ecosystems contributes to this concept by investigating how managing reservoirs as 'novel ecosystems' can create habitat diversity, increase fisheries productivity, mitigate adverse human health impacts and improve livelihoods.

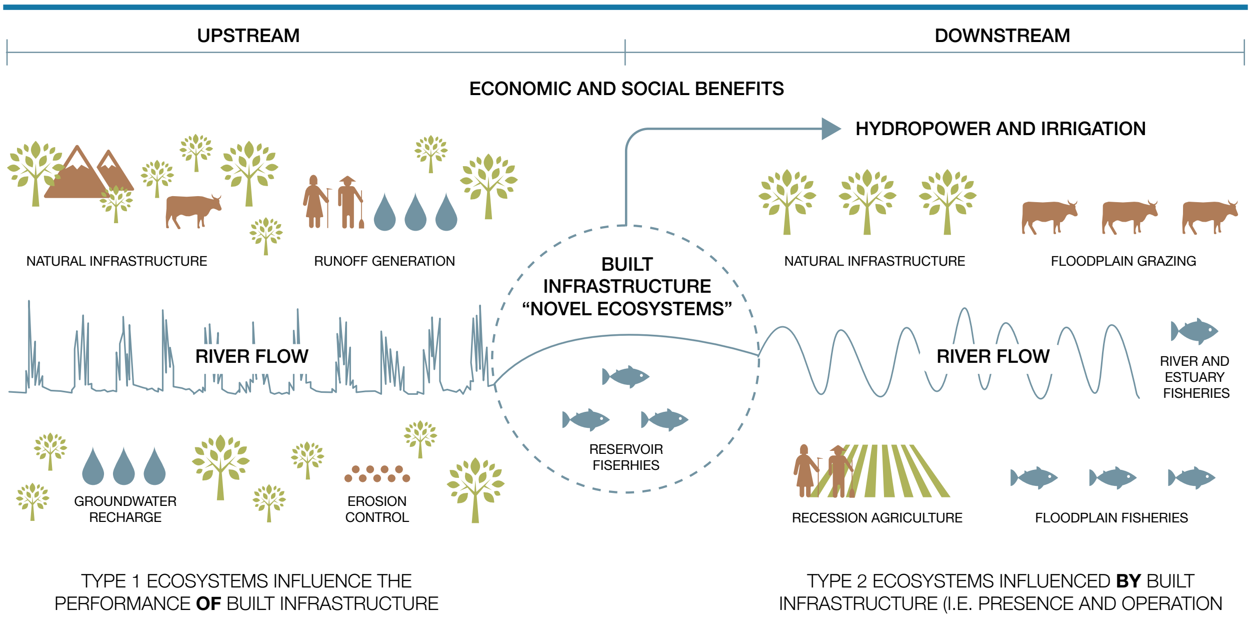
An ecosystem framework for managing built and natural infrastructure

Ecosystem management seeks to strike a balance between the generation of benefits from built infrastructure and maintaining the ability of ecosystems to sustainably provide ecosystem services. Considering a reservoir as an aquatic habitat, interconnected with the surrounding landscape, rather than simply an inert body of water, promotes the idea that beneficial ecosystem functions can be sustained and enhanced, if carefully managed. Examples from research carried out in Southeast Asia illustrate how this approach can be applied in practice.

Sustaining reservoir fisheries

Hydropower reservoirs are typically characterized by deep, standing or slow flowing water, and drawdown, which occurs when water levels drop due to

FIG. 1: CONCEPTUALIZATION OF TYPE 1 AND TYPE 2 ECOSYSTEM SERVICES



Source: McCartney and Sood 2016.

hydroelectric production, exposes barren banks that contribute little to aquatic productivity. Consequently, reservoirs are often less productive than natural environments. Moreover, the construction of reservoirs rarely offsets the loss of river fisheries and wetland habitats on which especially women and resource-poor households depend for food and nutrition security. Fisheries can be enhanced, however, through the creation of wetlands on the drawdown zones of reservoirs (Fig. 2).

WLE researchers explored the viability of reservoir wetlands, through the construction of earth dykes with a spillway, in Lao PDR's Nam Gnouang reservoir. Preliminary research indicated that non-intensive fish production in the two proposed wetlands could yield over 500 kg per ha per year. Contributions to local livelihoods could be in the form of a fish conservation area, with the fish that return to the reservoir increasing overall fish stocks, or directly as a source of food, which adds to dietary diversity and are vital sources of nutrition in households that otherwise depend primarily on rice as a food staple. The latter would directly benefit women, who are not active fishers in the main reservoir, but do collect fish and other aquatic organisms from paddy fields and close to the shore (McCartney et al. 2016).

Protecting recession agriculture

The drawdown zone can additionally provide important agricultural opportunities, particularly in instances where there is limited arable land for farming communities that been relocated due to dam construction. In Vietnam, the 720 megawatt Yali hydropower dam, built on the Sesan River in 2003, resulted in the resettlement of around 1,150 households, and the loss of 1,240 ha of farmland. It also created a fertile drawdown zone of about 2,600 ha, within an elevation of 512-515 m. Pilot studies were conducted to adapt local farmers' cultivation practices to suit the flooding regime in the drawdown zone, for example by replacing maize with fast-growing cassava varieties. This strategy has resulted in increased crop yields and incomes for participating households with no adverse impacts for electricity generation (Sellamuttu et al. 2014).

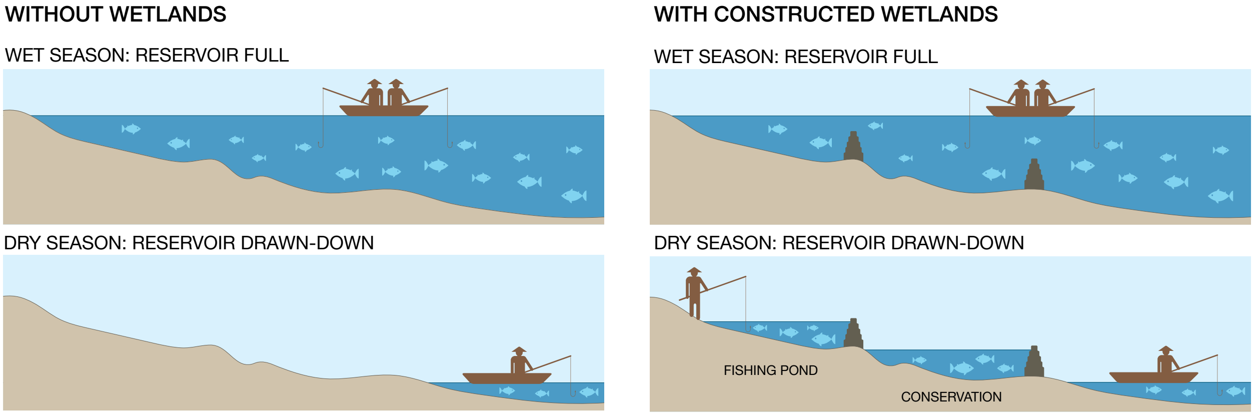
Redesigning fish passages

Dams often block migratory routes that fish use to travel up and down stream. Fish passages are intended to maintain the connectivity of upstream tributaries, the reservoir and the downstream river. In recent years, near-natural fish passages (or bypasses), which mimic the natural condition of a river, have been constructed around reservoirs on selected rivers in Europe, South and North America. Similar bypass channels are now being considered for some dams in the Mekong River basin, including the Lower Sesan 2 in Cambodia. The Lower Sesan 2 Dam has been identified as potentially having the greatest adverse impact on fish production and biodiversity in the Lower Mekong Basin, with an estimated 9.3% reduction of the migratory fish biomass basinwide (Ziv et al. 2012). WLE has conducted research on the feasibility of passages that simulate natural conditions (Gätke et al. 2014). The study found nature-based fish passages to be a viable option in this context and has recommended their construction (McCartney et al. 2016).

Managing dams in sub-Saharan Africa to mitigate malaria risks

Recognizing reservoirs as ecosystems helps identify innovative ways to mitigate adverse health impacts. For example, dams can be operated to disrupt mosquito-breeding sites. Research on the Koka reservoir in Ethiopia determined the potential of manipulating water

FIG. 2: CREATION OF WETLANDS IN THE DRAWDOWN ZONES OF RESERVOIRS TO SUPPORT ECOSYSTEMS FUNCTIONS



Source: Meynell and McCartney 2014

levels in the reservoir in such a way that it became less suited to the development of malaria transmitting mosquitoes (Kibret et al. 2012). Computer modelling confirmed that targeted implementation of this approach would have negligible impact on other dam objectives of hydropower and irrigation (Reis et al. 2011).

Investing in natural infrastructure to safeguard the performance of built infrastructure

In the Kenya, the Nairobi Water Fund is investing in natural infrastructure in the Tana River to reduce erosion and sediment deposition in downstream reservoirs. Analyses indicate that USD 10 million spent on natural infrastructure in the upper basin (i.e., buffer strips along riverbanks, terracing, reforestation, agroforestry and measures to prevent road erosion) can bring returns of USD 21 million over 30 years through increased hydropower generation and reduced water treatment costs (TNC 2015). Benefits are maintained under a range of possible future climate scenarios (Simons et al. 2017).

Involvement of local communities

Infrastructure projects often include resettlement action plans, which provide compensation or asset substitution for affected households. However, it can be difficult to estimate who will actually benefit, and how, in advance of the resettlement. Understanding nuances in livelihoods, land and water use as well as the determinants of adaptation, and using this information as a basis for negotiating fair and equitable deals with communities, is critical for providing viable livelihood opportunities.

The notion of benefit sharing has evolved from that of compensation to a situation in which local people directly and substantially benefit from infrastructure projects. A benefits-sharing partnership enables the local population to have ownership over the project and to strive for more socially just project outcomes for villagers (Buechler et al. 2016). Involving local communities in the decision making on, and development of, appropriate compensation packages can help ensure that the needs of smallholder farmers are taken into account. Nepal's run-of-the-river Andhikhola hydropower project offers an example of how a well-designed, multi-purpose project that incorporates the needs of local communities can offer wide-ranging benefits.

While similar examples exist elsewhere, in general, the benefits from hydropower projects continue to be skewed in favor of urban populations. Strengthening and expanding the use of participatory engagement tools with farming communities can help overcome this imbalance and ensure that the voices of smallholder farmers are taken into account in decision making. The use of participatory tools and simulations is one means to foster an exchange of views among stakeholders and develop relations between actors that normally do not interact with each other. This was the conclusion from a recent WLE project in Burkina Faso's Bagre Dam region, where a role-playing game—jointly designed by researchers, irrigation and water management agencies—allowed a diverse set of actors to collectively discuss, design and practice adaptation strategies in a virtual 'game' environment (Daré et al. 2016).

CONCLUSION

Dams are renowned both for the positive changes they bring about, such as flood control, irrigation and hydropower, and for their negative impacts, including displacement of people, changes in water and sediment flows, and disruption to environmental services and livelihoods.

The solution to this dichotomy is not to forego investment in built infrastructure, which remains essential for socio-economic development, but to give greater consideration to the role of nature in planning and operating large, built infrastructure. Conceptualizing water resource systems as collections of natural and built infrastructure operating synergistically can present options to reduce negative impacts and achieve more equitable and sustainable outcomes. Research shows, for example, that reservoirs can be designed and managed to create better fish habitats, and farmers can be supported to adapt farming techniques to new flooding regimes. These environmental services and livelihoods benefits can be achieved without compromising energy generation. WLE will continue its research on the combined role of natural and built infrastructure to support water and food security, reduce floods and droughts, and enhance environmental and equitable outcomes.

Reservoirs can also be controlled to disrupt mosquito breeding and thereby reduce the spread of malaria. WLE will carry out a systematic analysis of impacts and risks of malaria from small reservoirs and irrigation schemes in the coming phase of work. Finally, natural and agricultural systems can be managed to reduce sedimentation of reservoirs. Combining such approaches with an understanding of local livelihoods and utilizing participatory approaches to negotiate outcomes will maximize benefits.

REFERENCES

Baran, E.; Guerin, E.; Nasielski, J. 2015. *Fish, sediment and dams in the Mekong.* Penang, Malaysia: WorldFish; and CGIAR Research Program on Water, Land and Ecosystems (WLE). 108p.

Buechler, S.; Sen, D.; Khandekar, N.; Scott, C.A. 2016. Re-linking governance of energy with livelihoods and irrigation in Uttarakhand, India. *Water* 8(10): 437.

Daré, W.; Gérard, F.; Venot, J-P.; Kaboré, E.; Idani, D.; Carboni, S.; Tapsoba, A.; Napon, K.; Kaboré, P.; Ouedraogo, Y.; Traoré, R.; Gnouma, J.; Yaméogo, H.; Kambiré, Y.; Guissou, C.; Arnaldi di Balme, L.; Botta, A.; Diallo, C.; Hochet, P.; Mul, M. 2016. *Managing water infrastructure and equitable land compensation schemes in irrigation projects for social and environmental benefits.* Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE). 4p. (WLE Briefing Series No. 8).

Emerton, L.; Bos, E. 2004. *Value - Counting ecosystems as an economic part of water infrastructure.* Gland, Switzerland and Cambridge, UK: International Union for Conservation of Nature (IUCN). 88p.

FAO (Food and Agriculture Organization of the United Nations). 2007. *Dams and agriculture in Africa.* Prepared by the AQUASTAT programme. Rome, Italy: FAO. 14p. Available at http://www.fao.org/3/a-bc815e.pdf (accessed on April 19, 2017).

FAO. 2015. *The impact of natural hazards and disasters on agriculture and food security and nutrition: A call for action to build resilient livelihoods.* Rome, Italy: FAO. 15p. Available at http://www.fao.org/3/a-i4434e.pdf (accessed on April 19, 2017).

Gätke, P.; Baran, E.; Fontes Jr, H.M.; Makrakis, S.; Makrakis, M.C.; Räsänen, T.A.; Saray, S. 2014. Fish passage opportunities for the Lower Sesan 2 Dam in Cambodia - lessons from South America. Chapter 3.2 in: *On optimizing the management of cascades or system of reservoirs at catchment level.* Hanoi, Vietnam: International Centre for Environmental Management (ICEM). 27p. Available at http://www.optimisingcascades.org/wp-content/uploads/2014/03/FE-4.-Fish-passage-opportunities.pdf (accessed on April 19, 2017).

Hobbs, R.J.; Arico, S.; Aronson, J.; Baron, J.S.; Bridgewater, P.; Cramer, V.A.; Epstein, P.R.; Ewel, J.J.; Klink, C.A.; Lugo, A.E.; Norton, D.; Ojima, D.; Richardson D.M.; Sanderson, E.W.; Valladares, F.; Vilà, M.; Zamora, R.; Zobel, M. 2006. Novel ecosystems: Theoretical and management aspects of the new ecological world order. *Global Ecology and Biogeography* 15: 1-7.

ICEM (International Centre for Environmental Management). 2010. *Mekong River Commission strategic environmental assessment of hydropower on the Mekong mainstream.* Hanoi, Vietnam: ICEM. 145p.

Katus, S.; Suhardiman, D.; Senaratna Sellamuttu, S. 2016. When local power meets hydropower: Reconceptualizing resettlement along the Nam Gnouang River in Laos. *Geoforum* 72: 6-15.

Kibret, S.; Lautze, J.; Boelee, E.; McCartney, M. 2012. How does an Ethiopian dam increase malaria? Entomological determinants around the Koka reservoir. *Tropical Medicine & International Health* 17(11): 1320-1328.

Kibret, S.; Lautze, J.; McCartney, M.; Glenn Wilson, G.; Nhamo, L. 2015. Malaria impacts of large dams in Sub-Saharan Africa: Maps, estimates, predictions. *Malaria Journal* 14: 339.

Kibret, S.; Lautze, J.; McCartney, M.; Nhamo, L.; Glenn Wilson, G. 2016. Malaria and large dams in sub-Saharan Africa: Future impacts in a changing climate. *Malaria Journal* 15: 448.

Kura, Y.; Joffre, O.; Laplante, B.; Sengvilaykham, B. 2014. Redistribution of water use and benefits among hydropower affected communities in Lao PDR. *Water Resources and Rural Development* 4(C): 67-84.

McCartney, M.P.; Smakhtin, V. 2010. *Water storage in an era of climate change: Addressing the challenge of increasing rainfall variability.* Blue paper. Colombo, Sri Lanka: International Water Management Institute (IWMI). 14p.

McCartney, M.P.; Sood, A. 2016. *Understanding the link to water and quantifying Ecosystem Services in the Tana Basin, Kenya.* Ecosystem Services Partnership Conference, 21-25 November, Nairobi, Kenya.

McCartney, M.P.; Kura, Y.; Meynell, P.; Senaratna Sellamuttu, S.; Matthews, N. 2016. Hydropower reservoirs as novel ecosystem: Adopting an ecosystems based approach for management. *Proceedings of the Sixth International Conference and Exhibition on Water Resources and Hydropower Development in Asia, Vientiane, Lao PDR, March 1-3, 2016.* Wallington, UK: The International Journal on Hydropower & Dams.

Meynell, P.; McCartney, M. 2014. *Constructing wetlands within reservoirs to improve fisheries.* Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE). 2p. Available at https://cgspace.cgiar.org/handle/10568/35099 (accessed on April 19, 2017).

Mille, G.; Hap, N.; Loeng, N. 2016. *Economic value of fish in Cambodia and value added along the trade chain.* Phnom Penh, Cambodia: Inland Fisheries Research and Development Institute (Fisheries Administration) and WorldFish. 62p.

Nam, S.; Phommakone, S.; Vuthy, L.; Samphawamana, T.; Hai Son, N.; Khumsri, M.; Peng Bun, N.; Sovanara, K.; Degen, P.; Starr, P. 2015. Economic value of Lower Mekong fisheries: Lower Mekong fisheries estimated to be worth around $17 billion a year. *Catch and Culture* 21(3): 4-7.

Reis, J.; Culver, T.; McCartney, M.; Lautze, J.; Kibret, S. 2011. Water resources implications of integrating malaria control into the operation of an Ethiopian dam. *Water Resources Research* 47(9): W09530. doi:10.1029/2010WR010166.

REN21 (Renewable Energy Policy Network for the 21st Century). 2016. *Renewables 2016: Global status report.* Paris, France: REN21 Secretariat.

Sadoff, C.W.; Hall, J.W.; Grey, D.; Aerts, J.C.J.H.; Ait-Kadi, M.; Brown, C.; Cox, A.; Dadson, S.; Garrick, D.; Kelman, J.; McCornick, P.; Ringler, C.; Rosegrant, M.; Whittington, D.; Wiberg, D. 2015. *Securing water, sustaining growth: Report of the GWP/OECD Task Force on Water Security and Sustainable Growth.* Oxford, UK: University of Oxford. 180p.

Sellamuttu, S.S.; Phuong, N.D.; Bouahom, B.; Joffre, O.; Pant, J.; Keophoxay, A. 2014. Hydropower development and livelihoods: a quest for a balanced approach through research and partnerships. In: *Aqua-Media International.* Fifth International Conference on Water Resources and Hydropower Development in Asia, Colombo, Sri Lanka, 11-13 March 2014. Wallington, Surrey, UK: Aqua-Media International. 9p.

Simons, G.; Buitink, J.; Droogers, P.; Hunink, J. 2017. *Impacts of climate change on water and sediment flows in the Upper Tana Basin, Kenya.* FutureWater Report 161. Wageningen, Netherlands: FutureWater.

TNC (The Nature Conservancy). 2015. *Upper Tana-Nairobi Water Fund Business Case.* Version 2. Nairobi, Kenya: TNC.

WCD (World Commission on Dams). 2000. *Dams and development: A new framework for decision-making.* London, UK and Sterling, VA, USA: Earthscan. Available at http://awsassets.panda.org/downloads/wcd_dams_final_report.pdf (accessed on April 19, 2017).

WLE (CGIAR Research Program on Water, Land and Ecosystems). 2014. *Ecosystem services and resilience framework.* Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE). 46p.

Ziv, G.; Baran, E.; Nam, S.; Rodríguez-Iturbe, I.; Levin, S.A. 2012. Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin. *Proceedings of the National Academy of Sciences* 109(15): 5609-5614.

RESEARCH PROGRAM ON Water, Land and Ecosystems

CGIAR

LED BY: IWMI International Water Management Institute

About the Towards Sustainable Intensification: Insights and Solutions Briefs

WLE's series of Towards Sustainable Intensification: Insights and Solutions Briefs synthesizes the research findings and solutions generated during the program's first phase, which was composed of more than 140 projects across 48 countries in Africa, Asia and Latin America. Each brief is focused on a topic of strategic relevance to sustainable intensification of agriculture and provides analysis of and recommendations on how to place sustainability at the heart of agri-food systems. The series aims to guide and support decision and policy makers, investors, and others working to achieve poverty alleviation and livelihood improvements through sustainable intensification of agriculture.

CGIAR Research Program on Water, Land and Ecosystems

The CGIAR Research Program on Water, Land and Ecosystems (WLE) combines the resources of 11 CGIAR centers, the Food and Agriculture Organization of the United Nations (FAO), the RUAF Foundation, and numerous national, regional and international partners to provide an integrated approach to natural resource management research. WLE promotes a new approach to sustainable intensification in which a healthy functioning ecosystem is seen as a prerequisite to agricultural development, resilience of food systems and human well-being. This program is led by the International Water Management Institute (IWMI) and is supported by CGIAR, a global research partnership for a food-secure future.

CGIAR Research Program on Water, Land and Ecosystems (WLE)
International Water Management Institute (IWMI)

127 Sunil Mawatha
Pelawatta, Battaramulla
Colombo, Sri Lanka

Email: wle@cgiar.org
Website: wle.cgiar.org
Thrive Blog: wle.cgiar.org/thrive

ISSN 2521-1528 (Print)
ISSN 2521-1536 (Online)

IN PARTNERSHIP WITH:

Bioversity International, CIFOR, CIAT, CIP, FAO, ICARDA, ICRISAT, IFPRI, ILRI, RUAF Foundation, World Agroforestry Centre, WorldFish