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Tackling trade-offs in the nexus of water, energy and food

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Abstract

We explore processes that enable effective policies and practices for managing the links between water, energy, and food. Three case studies are assessed at different scales in the Mekong River basin, Sri Lanka and Zimbabwe. We find that there are considerable opportunities for improving outcomes for sustainable development by finding solutions that accommodate multiple objectives in the nexus. These include making data more publicly available, commissioning independent experts to advise on contested issues, engaging under-represented stakeholders in decision-making, sharing benefits, exploring different perspectives in forums where alternative development options can be tested and engaging decision-makers at different scales.

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1. Introduction and methods

Managing the positive and negative synergies among policies and practices for water, energy and food is a great challenge (BMU and BMZ, 2011; Falkenmark and Galaz, 2007; Hussey and Pittock, 2012; Pittock et al., 2015; SIWI,

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2014). While the academic literature is replete with descriptions of problems, there is a need to translate conceptual understanding and policy-level dialogue into practical solutions to constructively manage the linkages across these sectors.

This paper assesses three case studies presented at the workshop on *Water, Energy, Food and Ecosystem Security* at the 2014 World Water Week in Stockholm, which examined the trade-offs made in the nexus in different contexts and the means by which stakeholders are negotiating these trade-offs. The case studies are: (a) at a large river basin scale, the choices between water for energy or biodiversity and food in the Mekong River region; (b) at a meso basin scale in Sri Lanka; and (c) at the community scale in Zimbabwe. Because of the contrasts among scales in the trade-offs faced by stakeholders in these case studies, we examine whether there are common needs for processes that enable effective negotiation among sectors.

In the following sections each of the three case studies are situated. We assess the objectives of stakeholders related to water, energy and food, consider why these objectives are contested and what is at stake in these trade-offs. We then discuss how this analysis of trade-offs informs decision-making, who is involved in making decisions, whether they are able to make joint or coordinated decisions and what mechanisms are used or needed to coordinate these. Finally, we examine what has been achieved. Drawing on the cases, we assess the common needs for processes that enable effective policies and practices for managing the links across the sectors.

2. Mekong River basin

2.1 Context

The Mekong River flows for approximately 4,800 km through China, Myanmar, Laos, Thailand, Cambodia and Vietnam. Construction is underway for the first hydropower dams on the free-flowing main stem of the lower Mekong Basin (LMB). These infrastructure projects present some of the most urgent examples of the nexus and the need for considered trade-offs (ICEM, 2010; Orr et al., 2012).

Dam construction creates conflicts between energy supply and related economic interests, versus their social and environmental impacts (WCD, 2000). One recent review focussing on the decade since the end of the World Commission of Dams (WCD) report highlights undiminished controversy surrounding impacts (Moore et al., 2010). Yet, while a number of stakeholder processes have resulted in principles, recommendations, tools and protocols to minimize the impacts of hydropower dams while maximizing their benefits, few new projects have applied these principles (IHA, 2010; MRC, 2010; WCD, 2000; Ziv et al., 2012).

The strategic environmental assessment (SEA) of hydropower on the Mekong concluded that the 11 proposed main stem projects would have significantly negative net impacts on both fisheries, with losses estimated at USD 476 million per year (excluding effects on the coastal and delta fisheries), and riverbank gardens with losses calculated as USD 20.7 million/year (ICEM, 2010). There is an inherent need for better resource planning across sectors and wider recognition of the implications of poor decision-making concerning shared resources.

2.2 Contested objectives of stakeholders

In terms of fish species the Mekong is the second most biodiverse river in the world (Ziv et al., 2012). Dams are expected to significantly diminish fish species and populations by blocking migration, changing flow patterns and trapping sediments (ICEM, 2010). Today, 60 million people live in the LMB, and 80 per cent rely directly on the river system for their food and livelihoods (ICEM, 2010). Most of these households would be affected by changes in fish availability, as this is the main source of dietary protein (Baran and Myschowoda, 2009). Policymakers have often failed to recognize the crucial role of inland fisheries in providing food security (Bene and Friend, 2011).

Options to replace the protein, in particular lysine (an amino acid essential for children's brain development), from the lost fish supply in the LMB were assessed following the proposed construction of 88 hydropower dams by 2030 for Cambodia, Laos, Thailand and Vietnam (Orr et al., 2012; Pittock et al., in review). There are five options for managing loss of fish supplies due to hydropower dams, namely, do nothing, import food or replace with livestock, other fish or crops. The options for replacing protein and lysine with domestic livestock, fish and crop production involve significant resource trade-offs. Diverting a third of Thailand's marine fish exports or half of Vietnam's freshwater fish exports to regional consumption is one option. To replace lysine with vegetables 6–59 per cent more cropland is required per country. To replace it with livestock, 7–155 per cent more pastureland is required (Pittock et al., in review). The projections show that Cambodia and Laos are much more vulnerable to reduced food security from the loss of freshwater fish than Thailand and Vietnam.

From an energy perspective, there is undoubtedly a need to improve energy access for the rural poor. However, the proposed hydropower dams will mainly export electricity to cities and neighbouring countries. The extent to which the people of Cambodia and Laos will benefit from the generated electricity or how the benefits from the hydropower dams will finance sustainable development is unclear (ICEM, 2010; Molle et al., 2009). In this context, mechanisms are weak or absent for sharing the benefits of hydropower development with people in impacted rural areas, with many case studies highlighting the difficulty of providing fair compensation to rural people for loss of access to land and other natural resources (Sayatham and Suhardiman, 2015).

The construction of the dams cannot be separated from regional politics and power relations between neighbours (Grumbine et al., 2012; Hirsch, 2011). Since the 1990s, the governments of the region have prioritized economic integration and growth through investments in infrastructure, including through the Greater Mekong Sub-region Program of the Asian Development Bank. Other drivers include changing demographics, energy security concerns and policies favouring lower carbon energy sources.

The choices among hydropower development, biodiversity conservation and food security are contested due to mismatches in information, scale and influence. Large dam development is currently favoured by wealthy nations and companies in China, Thailand and Vietnam who stand to benefit most from business and energy supplies (Grumbine et al., 2012; Hirsch, 2011). The hydraulic bureaucracy drives hydropower development, which transfers wealth from rural natural resources to the hands of national governments and key companies (Molle et al., 2010). In contrast, the advocates for conservation of biodiversity or of the traditional rice and fish livelihoods of rural villagers lack ready access to information and financial and political influence. Benefit-sharing mechanisms for impacted people in rural areas are weak or missing.

2.3 Making decisions

The Mekong River Agreement between the LMB states has provided a platform for sharing information, developing a common understanding of some issues and undertaking assessments of key issues, notably the SEA (ICEM, 2010). Contracting external experts to provide technical advice has greatly improved trust in the information generated. Limited civil society participation in decision-making has also been facilitated. However, the Mekong River Commission has not succeeded, thus far, in developing consensus among its member nations on water allocation and development. This is because key aspects of the Agreement are poorly defined and open to a range of interpretations; there are differing national interests; consensus decision-making results in no or lowest common denominator decisions; and other institutions, such as the Greater Mekong Sub-region Program, have more influence on the outcomes. Consequently, sound technical advice on how to transparently access and optimize benefits from development options has been poorly used resulting in ad hoc projects and conflicting outcomes (MRC, 2010; Ziv et al., 2012).

Current research to better quantify the trade-offs (Pittock et al., in review) is intended to communicate the implications of development options for other sectors such as agriculture and health, and engage them in decision-making. This highlights the importance of better public access to data, greater clarity on governance arrangements and involvement of a broader range of sectors in decision-making to maximize the benefits for people and the environment.

3. **Walawe River Basin, Sri Lanka**

3.1 Context

The 132 km long Walawe River originates in the central hills of Sri Lanka and flows towards the drier parts of the country. The Kalthota Irrigation Scheme (KIS) is an ancient river diversion scheme in the upper reaches of the Walawe River, which provides water for 920 ha of land, benefitting over 1,600 subsistence farmer families. The 278 Mm^3 capacity Samanalawewa Reservoir was constructed in the upper catchment of the river in 1992 (Figure 1), primarily to generate 120 MW of hydroelectricity. Until impoundment of the reservoir, the farmers enjoyed unrestricted access to irrigation water to cultivate water-intensive rice crops twice a year. The hydropower project obstructs the free flow of water to KIS, as the outflow from the power plant bypasses KIS. However, since impoundment, unexpected water leakage from the dam has made approximately 55 Mm^3 of reservoir water available for KIS without any control throughout the year, but it does not always correspond to the timing of water use in agricultural activities.

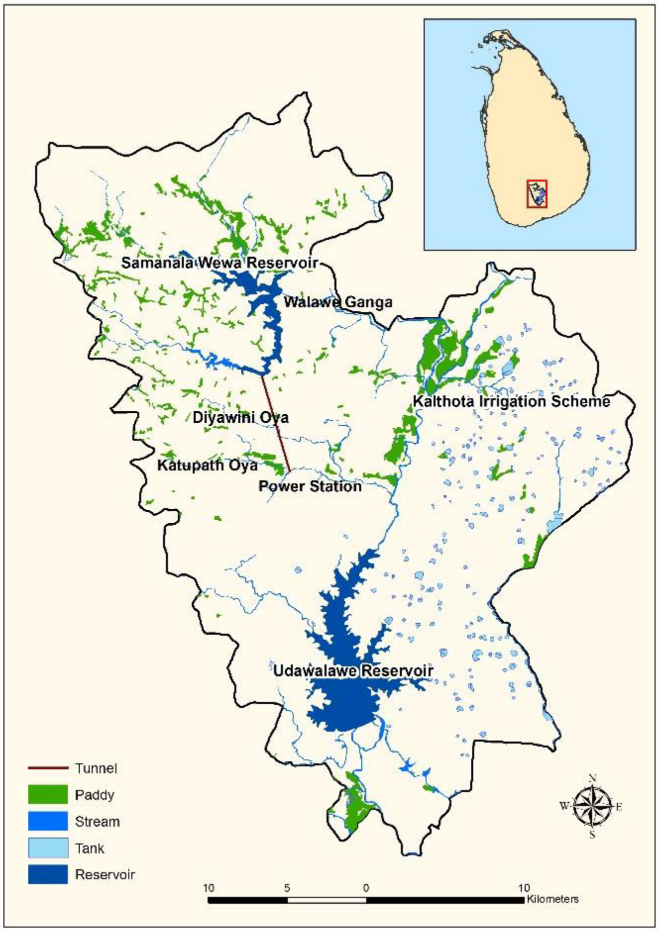

Figure 1. Map of the Kalthota Irrigation Scheme area. Source: Aheeyar et al. (2008).

3.2 Contested objectives of stakeholders

The hydropower development has deprived downstream farmers of a large portion of the water they previously received and created a conflict with the Ceylon Electricity Board (CEB). However, in consideration of the historical rights of the Kalthota farmers, the CEB had agreed with the Irrigation Department (ID) to share the water (40 Mm^3 per annum). Each stakeholder has their own agenda and different mandates in utilizing available water resources. The CEB and the ID have to meet the national- and provincial-level (macro-level) requirements, but the KIS farmers are interested in micro-level outcomes, ensuring that their traditional water-use rights are tied up with social, economic, political and cultural perspectives.

Although the Samanalawewa power plant was constructed to generate 300 GWh of electricity annually, it has only produced 220–235 GWh per annum due to dam leakage and high water consumption for rice cultivation. The country faces a power supply crisis and depends on environmentally unsustainable fossil fuels for much of its energy requirements, so the underutilization of the hydropower plant during the dry season has negative economic and environmental consequences.

To inform decision-making on the trade-offs, the gross water productivity for both rice cultivation and hydropower generation was calculated based on the following assumptions:

- Total amount of water released for irrigation was 40 Mm^3 per year
- Average annual paddy (un-husked rice) yield was 5,187 kg/ha
- The foregone value of water released for irrigation equals the cost of fuel in thermal power generation.

Applying estimated water productivity values at 2014 prices (Table 1), shows that reducing the amount of water used for cultivation in favour of producing hydropower is 4.1 times more economically valuable. This estimation excludes the benefit of a reduction in the carbon footprint due to the use of hydroelectricity. Molle et al. (2005) made similar estimates for water productivity in the area and found that producing electricity is around three times more beneficial than paddy cultivation. Reducing water use in irrigation increases hydropower generation. This limits fuel import costs, which has broader benefits to society.

Table 1. Water productivity vales for rice production vs thermal power

Value of water for irrigating rice at 2014 prices	
Total land extent cultivated in KIS	865.5 ha
Total yield (two seasons) = 5,187 kg/ha × 865.5 ha × 2 seasons	8,978.7 mt
Average selling price of paddy (year 2014, dry season)	LKR. 40/kg
Average production cost per season	LKR 103,740/ha
The gross value of total yield (GV)	LKR 359,148,000
The net value of total yield (NV)	LKR 179,574,060
Value of 1 m^3 of water for irrigation	LKR 4.48
Value of water for thermal power substituting for hydropower at 2014 prices	
Total release for irrigation	40 Mm^3
The amount of energy unit lost due to irrigation release (40 Mm^3)	30 GWh
Average fuel cost per unit of energy (1 KWh)	LKR 24.65
The value of the thermal power generated = 30 GWh × LKR. 24.65 ×1,000,000)	LKR 739,500,000
Value of one m^3 of water for thermal power	LKR 18.48
Ratio of the value of water for irrigation vs thermal power	1 : 4.1

3.3 Results

Competing demand for irrigation and unexpected water leakages from the dam have diminished hydropower generation. Water consumption for rice cultivation in KIS is in the range of 30,468–39,608 m^3 per hectare per season, which is more than double that of most of the well-performing irrigation schemes in Sri Lanka. Habitual use of water due to farmers' traditional attitudes, poor condition of irrigation infrastructure and other problems in water management has contributed to the higher water use (Imbulana, 2006). The irrigated area consists of alluvial soil with high sand content and low water-holding capacity (ibid.). As the KIS is located upstream and plenty of water is available throughout the year due to historical water rights, farmers are not utilizing seasonal rainfall for cultivation through timely preparation of their land. Although groundwater is a potential source of irrigation, farmers have not attempted to use it due to the cost of pumping compared to gravity-fed irrigation.

The CEB, in collaboration with the ID, made various efforts to reduce water use at farm level through building awareness and introducing various water-management techniques, but without much success. Finally, the CEB introduced a compensation scheme for farmers' water rights during dry seasons. Under this programme, owners of paddy land received a cash payment once per season as compensation; this was equal to the estimated average foregone income from rice cultivation (LKR 35,000 per hectare per year at 2004 prices). Farmers received the customary irrigation water quotas during the wet season. Although the compensation programme was a win–win solution and seemed to be more economically attractive than the income earned from irrigated paddy farming, it was rejected by the farmers after 2 years for various reasons.

The compensation programme led to the loss of household income for smallholders (75 per cent of farmers), as they were less able to raise additional income by working as farm labourers. The lack of compensation to tenant farmers, who were not the registered landowners (14 per cent of the population), created social unrest. Further, there were administrative problems in the compensation payment mechanism, such as delays in payment, cumbersome procedures, and alleged corruption.

In addition, there were other financial, cultural, and environmental issues. The majority of the beneficiaries had problems managing the lump sum payment throughout the season to meet their expenses. Households involved in paddy farming are used to earning income through the selling of surplus paddy stocks in stages whenever the need arises. In most households, the traditional role of fund management shifted from women to men after the compensation programme was introduced. The men, who had little experience in financial management, spent most of the funds at once, and were left with little money at the end of the season. Receipt of a lump sum also prompted beneficiaries to purchase inessential food items and household consumer durables.

Labour sharing in paddy cultivation during the peak periods of demand for planting and harvesting enhanced social harmony in Kalthota village. Cessation of irrigation practices resulted in a lack of purpose and loneliness among the people, many of whom resorted to drinking alcohol, domestic violence and gambling (Aheeyar et al., 2008). Non-cultivation in the dry season negatively impacted suppliers and purchasers in the agricultural value chain. Moreover, the village-level officers in the agriculture sector lacked significant work, which diminished their status. Reduced water flow through irrigation channels also impacted flora and fauna, and diminished recharge of ground water leading to the localized drying up of wells. Detrimental effects were observed for livestock production due to limited access to drinking water and reduced hay production (Imbulana, 2006).

Thus, compensating farmers for losing their water and livelihoods is a complex matter because the different values gained from farming cannot be readily replaced with money. Consequently, the CEB agreed to the release of customary irrigation water. The negative consequences of paying compensation to farmers in lieu of their water entitlements in the KIS clearly shows that maintaining social and cultural values in a society may be more important than the realized economic gains. Therefore, more refined methodologies, incorporating the full range of values are needed to improve allocation decisions. Transparent, integrated and multi-objective planning is vital in order to maintain public trust ensure fair and equitable access to water by different users.

4. Zimbabwe

4.1 Context

Electrification rates in Zimbabwe remain poor in both urban and rural areas, with those who are connected to the grid (around 31-41 per cent of households) suffering from frequent power cuts. The situation in rural areas is especially challenging, with only 13 per cent of households connected (SE4ALL, 2012). Despite a lack of widespread access, there are no plans to extend the national grid, as supplying remote areas would be much more expensive per household than for more densely settled areas close to the existing grid.

Decentralized solutions will be vital in securing sustainable development in the future. The potential of hydropower, the community approach, and institutions required to make it a feasible solution were examined. Large-scale hydropower is already a major source of energy for the Southern African power pool, and Zimbabwe generates 32 per cent of its own power through large-scale hydropower. Despite an estimated 120 MW of potential for small- and micro-hydropower installations, only a few are utilising a tiny fraction of this potential to date (Liu et al., 2013). The reasons for this include a lack of trust in these systems by government, institutions, which are focussed on large hydropower plants and large investments, and a lack of private sector players prepared to risk investing in an uncertain regulatory environment and in systems with lengthy pay-back periods.

Due to their topography, the Eastern Highlands of Zimbabwe are especially suited to micro-hydropower, with five key micro-hydropower plants installed in this area over the last 14 years. As with many other installations around the world, the initial projects were focussed almost exclusively on addressing energy, demonstrating that the technology could work in this context, and gaining wider acceptance. This was despite the central importance of agriculture in this region. Apart from one early scheme in Nyamarimbira, there have been few deliberate attempts to make connections between the use of water for energy and for irrigation pre-implementation. Most of the energy produced by the existing micro-hydropower installations is used by households and in the community (for schools, clinics and some small business ventures, often connected to agriculture). These failed to take a nexus approach, namely that the "solution for any one problem, like energy, must give equal consideration to others in the nexus, finding interconnected solutions that maximize synergies and manage trade-offs" (Best, 2014:7).

Recent discussions on the economic viability of decentralized energy solutions, and mini-grids in particular, have promoted the A–B–C model: from Anchor, to Business, to Community. Irrigation is a business opportunity that could develop to be the anchor, a large, reliable, and credit-worthy customer. Often mobile phone companies requiring power for their towers are identified as the best anchor customers. Others tend to focus more on off-farm enterprises (EUEI-PDF and GIZ, 2014).

Our field experience has shown that where there are no clear links between water use, energy supply and mainstream agricultural livelihoods, important opportunities for development are missed, putting at risk the performance and sustainability of the energy scheme (Stevens and Gallagher, 2015). In Zimbabwe, it was the strength of community institutions and the ownership and management structures put in place that meant these trade-offs could be effectively managed.

4.2 Contested objectives of stakeholders

Although micro-hydropower schemes have great potential in Zimbabwe, the variable climate and recurrent periods of drought mean that water supply can be contentious. Competing community needs and trade-offs around water use have been evident in the development and use of all of the micro-hydropower schemes, and have implications for how the benefits are shared. There is less conflict and fewer trade-offs over the use of the available electricity where the challenge is more about how to make the most of the productive potential of the power as well as using it to provide energy services for households and community facilities.

Although community micro-hydropower is in its infancy, the most synergistic scheme is situated in Zimbabwe's Mutare District. The Himalaya community consists of 87 households scattered over a wide area. Villagers were inspired by, and learned from, the experiences of a neighbouring scheme at Chipendeke. They wanted a power plant that would supply community services and households, and enhance the agricultural livelihoods crucial to the survival of the community. As a result, an irrigation component has been included as part of the design of the 80 KW micro-hydropower project. The electricity is being used to pump water for the irrigation scheme and a cold-storage facility is being set up to help keep produce in a better condition for sale.

This integrated approach was made possible by a sophisticated and organized community structure. While problems were not completely avoided, consensus was more easily reached on compromises and solutions. With capacity building and technical support, the community learnt from other micro-hydropower schemes and took ownership of their scheme. Trained members of the community are responsible for all future maintenance of the plant and delivery of energy. The community has developed two additional co-operatives, one that takes advantage of the plentiful supply of wood in the area to make fencing and electricity poles (which are sold at a significant profit in the region) and the other is implementing the irrigation scheme.

This dual irrigation and community services approach is a conscious improvement on the Chipendeke scheme, which though benefitting farmers through the provision of such services as power for grinding mills and workshops for fixing tools, failed in the early stages to recognize the long-term needs of farmers. The financial benefits of the scheme were less widespread, and there has been conflict between the objectives of the community users of the electricity, such as those who use the newly powered clinic, shop and school, and farmers who need water for irrigation systems that pre-date the construction of the plant. The farmers were paying for electricity (which increased their overall energy costs slightly), but not benefitting from increased incomes through greater agricultural productivity.

The Chipendeke micro-hydropower scheme functions by diverting and channelling water to the plant before returning it back to the river. While this process has little impact on downstream farmers, basic mistakes during the planning and design phase meant that the water needs of the farmers close to the plant were not considered. Consequently, during the dry season, it is necessary to ration water between farmers and the plant, so the micro-hydropower plant is switched off for short periods. There were clear incentives to resolve the tension and come to this compromise: all community members stood to benefit from improved community services and electricity to houses. It was possible to deal with the unpredicted trade-offs because the community owned and ran the plant.

Similarly, tensions occurred in another scheme, Ngarura, between the urgent needs of the farmers and the energy generation potential of the scheme. While the micro-hydropower development received widespread community support in its initial design phase, delays in construction undermined the confidence of some farmers. As a result, they returned to practices which damaged the plant, such as cultivating the steep riverbanks. When heavy rains did come in 2013/14 these farming practices caused significant siltation of the system. Urgent work was required to clear the weir.

While it is possible to incentivize farmers to avoid destructive practices (in this case through penalties and the influence of local leaders), successful management of trade-offs resulting from the project is dependent on the community having a high degree of continued trust in the scheme itself. This was eventually achieved through continued community negotiations and participatory planning. This experience highlights the importance of both understanding competing needs and trade-offs and gaining local community acceptance.

4.3 Important externalities

There are many additional factors that influence the water–food–energy nexus and the success of new energy initiatives. In particular, the political economy in a given context has a significant role in the success or failure of a new power plant. In Ruti, for example, Oxfam worked with the government and Practical Action to install a 60 ha irrigation scheme using solar-powered pumps. The project was initially very successful with farmers receiving 0.25 ha of irrigated land along with start-up support in the form of seeds, tools, fertilizers, pesticides and training. Household incomes increased by 286 per cent for the very poor and 173 per cent for the poor (Magrath, 2014).

However, the scheme was dependent on a national resource, the Gutu reservoir that the community did not control. When the water levels behind the dam dropped below expected levels, there was a crisis. The government prioritized the supply of water to the nearby sugar plantation at the expense of the irrigation project. During the course of a 2-year long drought, water levels dropped even further than predicted and when the water finally did return it caused damage to the irrigation pipes.

While climate variability and change was at the heart of the problems faced by both communities during this period, in contrast to Ngarura, the community in Ruti had little power to adapt and become resilient to those changes. While new rains and technical solutions (such as sourcing water from deeper wells) offer hope for farmers in this area, their continued dependence on government-controlled resources requires further capacity building and improved institutions if their livelihoods are to be more sustainable.

4.4 Making decisions

Zimbabwe’s experience of micro-hydropower schemes illustrates the importance of approaching energy supply using a nexus approach which integrates the range of community needs and links to mainstream agricultural practices. This experience also highlights the vital role of communities themselves in decision-making concerning power supply. While there can be significant difficulties in reaching compromises at large scales should trade-offs occur, where the capacity of local institutions can be built (as in these cases), it is more likely that a mutually acceptable decision can be reached. Conflicts can be greater where the economic benefits to the majority of households are smaller. However, they will inevitably occur, even if local productivity is raised and the benefits widely shared. The priority is to ensure that robust institutions and systems are in place so that compromises and solutions can be agreed.

The International Energy Agency estimates that 55 per cent of new generation capacity needs to be from off-grid or mini-grid solutions. There needs to be a significant shift away from “business as usual” approaches to achieve this. Decentralized energy provision has a huge potential to deliver poverty reduction in more ways, more quickly and more equitably than is generally possible through larger schemes. To optimize their potential requires work to ensure that nexus issues are well understood by communities and that the right kinds of institutions are in place to negotiate trade-offs as they arise.

5. Discussion

These three cases from the Mekong, Sri Lanka, and Zimbabwe help to: (1) quantify what is at stake in practical nexus-relevant problems; (2) understand which trade-offs are most important to stakeholders and how these vary with scale; and (3) identify key resources and institutions needed for stakeholders to manage trade-offs collaboratively.

We show that data is emerging to better quantify and understand the trade-offs in the nexus. The Mekong case highlights that unanticipated displacement effects on food supply from hydropower development have significant impacts on land use, food supply, and health that have not previously been considered, highlighting the importance of engaging independent technical advisers. The Sri Lankan example shows that a purely economically rational approach that ignores important social values can cause poorly planned measures to fail. In the Zimbabwean case, considering the competing needs of the community at the design, construction, and delivery phases was crucial to success. This, in turn, needs the right institutions and ownership structures.

Conflicting interests at different scales influence how the trade-offs are prioritized in the three contexts, and are summarized in Table 2. In the Mekong, the Commission's collaborative process across the four nations was diminished by the conflicting decisions of institutions at the smaller national scale and at the larger South-East Asian regional scale. In Sri Lanka, the national need for hydropower generation conflicts with the local objectives of the rice farmer, and this is exacerbated by inadequate processes for mediating the unequal power relationship between stakeholders. Unequal power relationships were also evident in Zimbabwe in the Ruti case. A more even power relationship between different interest groups at the community scale in the Ngarura case made it easier to manage trade-offs over water use as they arose.

Table 2. Trade-offs between economic investments, ecosystems, and rural livelihoods in the Mekong, Sri Lanka, and Zimbabwe case studies.

Place	Economic growth sectors benefitting	Impacted ecosystems and rural livelihoods	Potential benefit sharing to manage the trade-offs
Lower Mekong	Hydropower	Aquatic and forest ecosystems, fisheries and agriculture	Potentially, hydropower sites with smaller ecological and social impacts on tributaries could be developed. Potentially there could be direct transfers from hydropower revenues to enhance rural livelihoods; however, these efforts have not been effective to date. Ecological impacts and displacement of food supplies is an inevitable consequence of large hydropower development.
Sri Lanka	Hydropower	Irrigation ecosystem and peasant's livelihoods	Compensating traditional farmers for loss of access to their water and agricultural livelihoods is complex. Simple financial transfers overlook other economic and social values of agriculture.
Zimbabwe: Chipendeke	Development sectors such as schools, clinics and households using electricity	Farmers close to the hydropower plant with reduced access to irrigation water during the dry season	Everyone in the community benefits from an improved service at the clinic, and from access to electricity at home. This needs to be balanced against the needs of some farmers. The agreed compromise was to switch off the hydropower plant for short periods.
Zimbabwe: Himalaya and Ruti	Wider economic growth from increased farming productivity and incomes	No direct negative impacts on ecosystems or rural livelihoods; all struggle with reduced water availability during the dry season or periods of drought	There are minimal trade-offs with the Himalaya scheme. In a drought, there may be difficulties for both power generation and irrigation. In Ruti, during the drought, water use was prioritized for the export sector. There could have been compensation for farmers or an agreement on sharing the water during dry times.

While there were contrasts in the issues prioritized, in all three cases, resolution of the way forward depended on making cross-sectoral information more readily available and convening platforms for negotiation in which different sectors' interests were represented and incorporated into agreements. The adopted or potential benefit-sharing mechanisms for each case are set out in Table 2. In the Mekong example, the Mekong River Commission has played a key role in generating information and providing a negotiating forum, but it has not succeeded in adequately influencing additional sectors, such as health, or more powerful, conflicting institutions, such as those of the Asian Development Bank. Further, mechanisms are not adequate to enable rural people to share in the benefits of hydropower development. In Sri Lanka, comparison of the economic benefits of rice farming versus hydropower generation has enhanced the dialogue between stakeholders and benefit-sharing mechanisms have been tested. In Zimbabwe, smallholder farmers could appreciate the mutual benefits that were possible once they saw the reality of the water links between agricultural and energy in a neighbouring hydropower scheme. Negotiating nexus issues at this community scale does not necessarily involve greater complexity, but it may mean technical teams from supporting organizations working in an inter-disciplinary way and listening effectively to what communities are telling them about their context and potential from agriculture and energy perspectives.

All of the measures we suggest to manage trade-offs emphasize the importance of better water governance. We have focussed on the nexus between water, energy and food, because it is a tractable set of key issues and a subset of integrated water resources management (IWRM), obviating some of the challenges of implementing IWRM or sustainable development as a whole (Pittock et al., 2015). Development proponents may argue that enhanced governance is costly and may delay projects. In the context of the overall cost of large schemes, we argue that these measures are not costly. They may take time at the outset, but will often reduce time later on, reduce the chance of harming people's livelihoods, minimize duplication of activities among agencies, and improve the long-term sustainability of project investments.

6. Conclusion

Lack of integrated and multi-objective planning of available water resources seriously affects the fair and equitable access to water for different users, and leads to crises and conflicts in the allocation of water. Re-allocation of existing water shares is socially, culturally, economically, and politically very sensitive. Therefore, integrated and multi-objective planning and transparent processes are vital in order to avoid public distrust in implementing new projects, and also to ensure fair and equitable access to water by different users.

There are contrasts among scales and in focus in the trade-offs over water, energy and food faced by stakeholders in these cases. Yet, there are also common needs for processes that enable more effective negotiation among sectors. These include:

- Making the relevant data to inform stakeholders publicly available, including measures to ensure that the technical language and metrics used are understood across sectors
- Commissioning apex organizations or independent experts to provide technical advice on contested issues so as to generate greater trust in the information base
- Engaging under-represented stakeholders in decision-making processes, including, for example, rural people (especially smallholder farmers) and sectors such as health and the environment
- Assessing benefit-sharing opportunities, for instance, that may sustain rural livelihoods while enabling some level of development of new energy or other resources
- Exploring different stakeholder and sectoral perspectives in forums where standard approaches can be challenged, alternative development options tested and more common views developed on the best options for more inclusive and sustainable development
- Engaging decision-makers at different scales and from different sectors in processes of working together to identify trade-offs and to negotiate and collaborate in resolving them.

The cases assessed here demonstrate that there are extensive opportunities for improving outcomes for sustainable development by finding solutions for infrastructure development, natural resource use and ecosystem management that accommodate multiple objectives in the nexus.

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