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3 AUTHORS, INCLUDING:

Anu Ramaswami
University of Minnesota Twin Cities

Julie Beth Zimmerman
Yale University

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Integrating Developed and Developing World Knowledge into Global Discussions and Strategies for Sustainability. 2. Economics and Governance

ANU RAMASWAMI,[†]
JULIE B. ZIMMERMAN,[‡] AND
JAMES R. MIHELCIC*[,§]

Civil Engineering, University of Colorado at Denver and Health Sciences Center, Denver, Colorado 80217-3364, Chemical Engineering, School of Forestry and Environmental Studies, Center for Green Chemistry and Engineering, Yale University, New Haven, Connecticut 06511-6815, and Civil & Environmental Engineering, Sustainable Futures Institute, Michigan Technological University, 1400 Townsend Drive, Houghton, Michigan 49931-1295

Knowledge transfer from the developing to the developed world is described in the domain of economics and governance for sustainable development. Three system areas are explored: the structure of commons governance institutions, the process of community-based participatory action research, and the role of microfinance and microenterprise for the development, adoption, and diffusion of sustainable technologies. Case studies from both the developed and developing world demonstrate the effectiveness of social networks and community cooperative strategies in a wide range of sectors. Developing world experiences are shown to be particularly rich in the application of local knowledge and social capital toward sustainable development.

Introduction

This two-part manuscript focuses on knowledge transfer for sustainable development from the developing to the developed world. Part 1 focused on science and technology innovations originating in the developing world that can be enhanced through further quantification and analysis in the developed world for sustainable use of water, energy, and materials (*1*). While technology innovations are critical for sustainable development, the widespread diffusion of sustainable technologies greatly depends on suitable financial vehicles (*2*, *3*) as well as robust governance for long-term management and maintenance of technologies and infrastructure that continuously adapt to the changing natural environment (*4*). As the number of scientists and engineers engaged in sustainability increases, knowledge of key governance, participation, and economic models will be critical for effective implementation and dissemination of science and technology for sustainability.

In this part 2 paper, we present three system areas critical to this successful implementation and diffusion: (1) adaptive commons governance, (2) community-based participatory action-research (PAR), and (3) leverage of microfinance and microenterprise resources. Common across all three areas is the importance of social networks, the use of cooperative strategies, and the effective leverage of social capital in achieving sustainability objectives. These strategies, primarily originating in the developing world, are highlighted through case studies, evaluated for their successful implementation, and traced to growing trends in the developed world for advancing sustainability. Just as in part 1 (*1*), insights gained from these developing world strategies can be, and in some cases are, translated or adapted for use in the developed world, bringing to bear the best innovations from all sources to achieve the common goal of global sustainable development.

System Area #1: Commons Governance

Common pool resources or "commons" are defined as those in which the exclusion of beneficiaries is particularly difficult or costly, and, exploitation by one user reduces resource availability to others (*5*). Commons include natural resources such as rivers, forests, and fisheries as well as constructed infrastructures such as irrigation canals. Commons have historically been managed by societies through three types of institutions: (1) private property and markets, (2) regulatory institutions, and (3) communal institutions (*6*). In 1968, Hardin articulated the "tragedy of the commons" (*7*) as the inevitable process by which individuals, motivated by self-interest, are inexorably driven to appropriate commons, eventually leading to resource destruction. Free market mechanisms and regulations were proposed as the only solutions to moderate such self-interested behavior (*5*, *7*) and have since been the primary focus of the developed world where communal property management is now viewed largely as a vestige of the rural past (*6*).

However, there is a growing awareness of several limitations associated with regulatory and market-based approaches to commons governance, such as cost inefficiencies to ensure compliance, and issues of coverage, monitoring, and validation (*4*). Simultaneously, human behavior studies based on game theory are providing strong evidence that, in addition to self-interest, humans also exhibit a strong preference for reciprocity and fairness (*8*). Theoretical study outcomes suggest that communications channels and institutional structures that enable reciprocal arrangements can foster voluntary cooperative solutions to commons challenges (*8*).

A major contribution of developing world knowledge systems has been to demonstrate resilient and sustainable real-world implementation of cooperative commons management over many generations and a variety of commons resources (i.e., irrigation in Nepal; rangeland management in Mongolia) (*5*, *6*). Through the pioneering works of Ostrom (*9*) and others, a collection of indigenous society case studies was synthesized and analyzed to reveal important structural features and institutional design principles that facilitate successful local self-governance of commons. The strong empirical evidence provided by the analysis of these case studies is contributing to a paradigm shift in the developed world where community-scale cooperation is re-emerging as an additional strategy for effective, sustainable governance of the commons (*5*, *6*).

A case study of cooperative rice farming in Bali, Indonesia, implemented over several centuries through the institution of the nested water temples, is used to illustrate key features of successful commons governance in the developing world

* Corresponding author e-mail: jm41@mtu.edu.
† University of Colorado at Denver and Health Sciences Center.
‡ Yale University.
§ Michigan Technological University.

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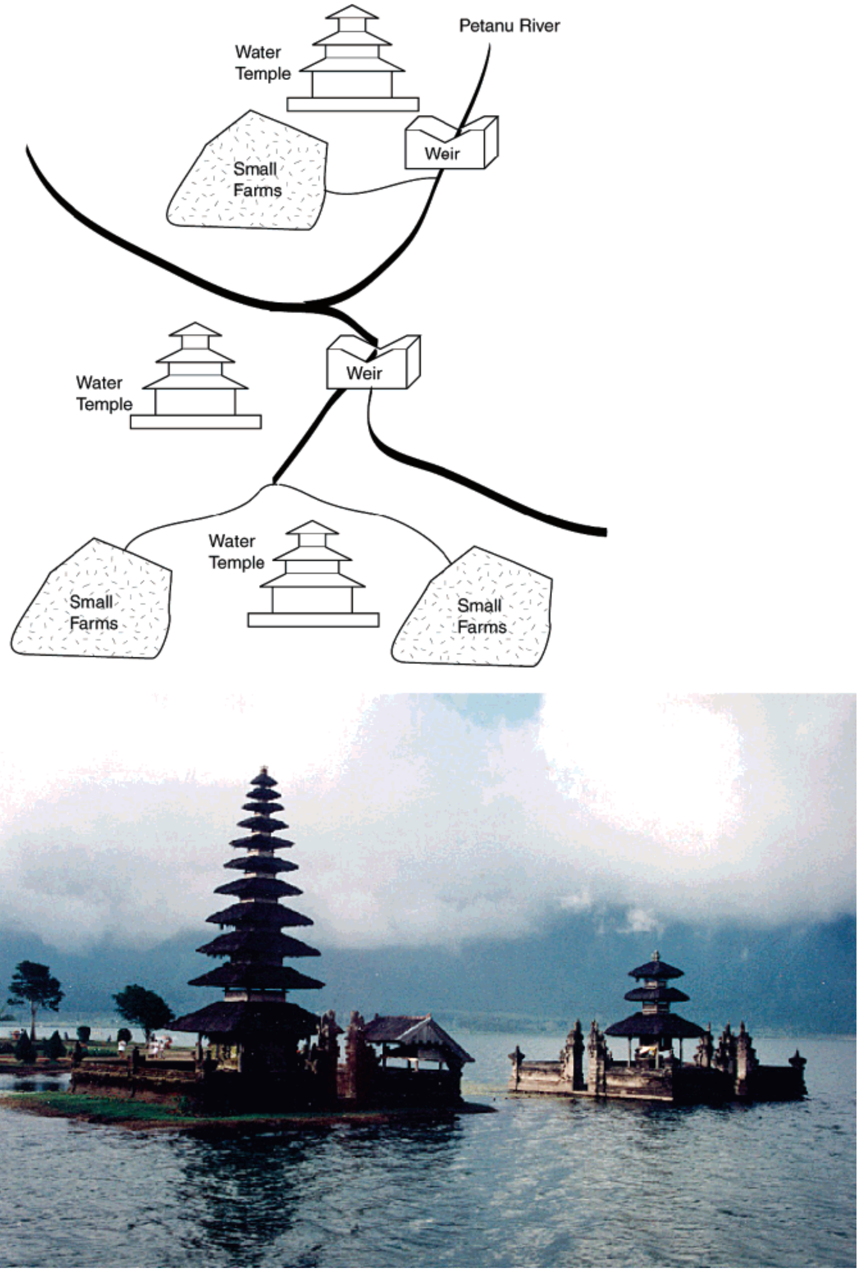

FIGURE 1. (a) Top: Hierarchy of nested water temples at different water diversion points in a small portion of the Petanu River, Bali (adapted from ref *12*). S*ubaks* are local level irrigation associations containing an average of 92 small individual farms that control water from a single dam or weir. (b) Bottom: At the highest organizational level is the Crater Lake temple.

(*10*–*12*). Freshwater is in limited supply in Bali, flowing from a central location through natural and man-made irrigation channels to terraced rice farms. This water flow is governed by small water temples at individual farms, progressing through local irrigation associations, called *subaks*, that manage individual dams and weirs to the highest-level temple at the water source (see Figure 1).

The two dominant competing externalities are (1) water shortage and cropping delays imposed on the downstream farmer if irrigation water is appropriated early in the flow and (2) pest damage imposed by rice farms that are not on the same cropping schedules (synchronous farming and fallow periods deprive pests of their natural habitat thereby limiting crop damage) (*10*). These externalities are cooperatively managed whereby upstream farmers have an incentive to share water with downstream farmers so that proximally located farms are on synchronous schedules. Concurrently, some staggering of cropping schedules across the watershed is desired and is implemented to avoid simultaneously exerting peak water demand on limited water resources.

Lansing et al. (*11*) studied the nested water temples and found that meetings were held at each level—individual farm, subak, and intersubak—on a schedule relevant to the spatial scale being managed, to coordinate water-allocation and pest-management strategies congruent with environmental observations. In a follow-up study supported by the U.S. National Science Foundation, ecosystems modeling of the study area showed that the most optimal water allocation occurred through the self-governance mechanisms of the communal water temples at the spatial scale of organization of the *subaks* (*11*), thus illustrating the effectiveness of local-scale governance when it matches the spatial scale at which the externalities occur. A survey of farmers in the subak system revealed that both upstream and downstream farmers recognize their competing concerns can be effectively

TABLE 1. Ostrom's Eight Design Principles for Cooperative Self-Governance of Environmental Resources Adapted from Refs *4* and *9*[a]

Ostrom's principles	Bali: Oos and Petanu Rivers	Tampa Bay
Clearly define the boundaries of resources and user groups.	Delineation of *subaks*—irrigation associations with about 90 farms that control water from one dam. Larger *subaks* are subdivided into munduks of 40−50 farms each.	Scientific studies define water resources. Users are defined as urban and rural with separate usages of municipal, agricultural, and industrial.
Devise rules that are congruent with ecological conditions.	All homes in a *subak* have equal water rights. Irrigation and pest control regimes (rules) are congruent with water availability and pest characteristics.	Collective water management system that increases lake and wetland levels and reduces saltwater intrusion into coastal groundwater.
Involve resource users in developing and modifying rules (collective choice arrangements and analytic deliberation).	Formal (written) and informal rules on water withdrawals, cropping, and pest management are developed by *subak* members at temple meetings and reinforced by temple rituals.	Series of workshops held over a 2-year period with various water authorities and government officials.
Devise accountability mechanisms for monitors.	Monitoring by individual farmers working in the field every day, reporting to the head of each *subak*.	Permit system regulates water withdrawals.
Apply graduated sanctions for violations.	Water rights temporarily suspended as per rules, but water stealing rarely occurs due to social norming.	State of Florida can apply fines through Southwest Florida Water Management District.
Establish/use low-cost mechanisms for conflict resolution.	Meetings within *subaks* and across *subaks* to mediate conflicts and allocate water across the river.	Use independent expert peer review and mutually acceptable third-party mediation.
Allocate authority at multiple levels from local to global (nesting).	Authority scales up from *munduks* or *subaks* (of 40−50 farms), to inter*subak* councils (of 172 *subaks*) culminating at the Crater Lake temple that feeds the rivers.	Counties and cities represented on a 9-member board.
Employ a mixture of institutional types, with local collective choice arrangements not challenged by larger government agencies.	The government of Bali now encourages the *subak* system, after opposition and failed experimentation with privatized farming during the 1980s.	Collective choice arrangement at county and city political level overseen by state and federal government.

[a] Case studies from Bali (*10*, *12*) and Tampa Bay (*14*, *15*) illustrating their application for water management.

managed through cooperation to achieve sustained, improved, and equitable rice yields without centralized control or harmful pesticides (*10*). In contrast, water appropriation and pest management decisions made on an individual basis in modern development projects in Bali during the 1970s and 1980s lead to chaotic water sharing and severe crop failures of nearly 100% (*10*). The government of Bali has since encouraged a return to the communal resource management through the water temples.

Analogous to this water management case study, the effectiveness of communal governance by traditional Mongolian herders has been visually demonstrated in satellite images that showed about 10% degradation of their common-property grasslands compared to nearly 75% degradation observed in state-owned lands in neighboring Russia and more than 33% degradation observed in privatized small pastures established more recently in China (*5*). Similar community-based commons governance institutions in many parts of Asia and Africa have been documented to sustainably manage a variety of natural resources (water, grasslands, and forests) and infrastructures pertaining to irrigation and agriculture as summarized in refs *5*, *6*.

Analyses of these and other case studies of indigenous resource management systems revealed important common structural elements or institutional design features that facilitate local-scale self-governance (*5*, *6*) of which eight design principles developed by Ostrom (*5*, *9*) are commonly cited and are listed in Table 1. Several researchers are evaluating how the design principles for cooperative self-governance, derived primarily from community-scale demonstrations in indigenous societies, can be applied to developed nations and to the global arena, which differ structurally in terms of the large-scale of infrastructure and resource systems as well as the sparseness of rich social networks (*4*).

Research is showing that large populations and/or resource sizes are not a barrier as long as the resource can be readily monitored and/or stored (*4*, *6*). Examples include the effective self-governance of irrigation water by several thousand rice farmers in the Balinese case study and the pooling of groundwater rights in the Los Angeles area of the U.S. in the 1960s, which avoided costly litigation while preventing overdraft and salt water intrusion (*9*). Accurate measurement, monitoring, and reporting of groundwater withdrawals and open access to this data by all parties has built trust, fostered enforcement, and sustained this cooperative arrangement over several decades. More recently, Ostrom's institutional design principles (*9*, *13*) have been effectively applied to the 2+ million water users in the Tampa Bay area of the U.S. for cooperative water management (*14*, *15*) during a period of rapid urbanization that resulted in serve water shortages across several political jurisdictions and also resulted in a well-publicized loss of high-water usage industry. Details of this study are shown in Table 1, exemplifying how each principle applies. These examples demonstrate effectiveness of voluntary cooperative approaches alongside governmental regulations as well as private market forces in the developing world.

While the U.S. model has several modifications from the Bali subak model, including the use of computerized shared visioning modeling and less direct engagement of water users, there are many common threads including the participation of stakeholders who are closely engaged with the resource on a daily basis and the notion of nested institutions such that information can flow between local stakeholders, policy- and decision-makers, and technical experts. This is a departure from the traditional approach to water management in the U.S. Historically, water managers viewed the public as a client. Today, water managers are attempting to

TABLE 2. Comparison of Underlying Philosophy and Processes in Community-Based Participatory Action Research versus Conventional Research[a]

	participatory action research	conventional research
What is the research for?	action	understanding with perhaps action later
Who is the research for?	local people	institutional/personal/professional interests
Whose knowledge counts?	local people's facilitated with scientists'	scientists'
Topic choice influenced by?	local priorities	funding, institutional/professional interests
Methodology chosen for?	empowerment. mutual learning	disciplinary conventions, "objectivity" and "truth"
Who takes part in the stages of research?		
problem identification:	local people	researcher
data collection:	local people	researcher, enumerator
interpretation:	local concepts and frameworks	disciplinary concepts and frameworks
analysis:	local people	researcher
presentation of findings	locally accessible and useful	by researcher to other academics/funding body
action on findings	integral to the process	separate and may not happen
Who takes action?	local people (with or w/out external actors)	external agencies
Who owns the research?	shared by local people/researcher	the researcher
How are results disseminated to the community?	through local institutions and empowered locals	by external agency directly
What is the feedback mechanism?	build on local knowledge for next action	at discretion of individual researcher or external agency
What is emphasized?	process	outcomes

[a] Adapted from ref *20*.

facilitate a more sharing environment where management decisions incorporate collective choice arrangements (*13*, *14*).

Cooperative commons governance is also being evaluated to solve several trans-boundary groundwater allocation problems in North America and Europe (*14*). As the scale of the challenge increases, it is being recognized that along with nesting, the organizational scale of governance institutions must match the spatial sale at which the environmental externalities occur. Several applications of multiscale adaptive comanagement of natural resources have emerged in Sweden, building upon resilient indigenous community models that foster and "scale up" local knowledge (*16*, *17*). For example, in a successful adaptation for resilient, multiscale management of wetlands in Sweden, a new municipal organization was formed at the intermediate scale specifically to serve as a bridge between local actors and larger governmental agencies (*16*). Other adaptations in industrialized nations include the use of low-cost monitoring of commons resources and increasing the use of structured analytic deliberations between communities, scientists, and decision-makers to build trust and social capital, with the goal of achieving consensus for sustainable solutions to commons management challenges (*4*).

Systems Area #2: Community-Based Participatory Action Research (PAR)

As studies of commons governance continued into the 1990s, researchers found that successful indigenous resource management systems were also complex adaptive social-ecological systems that exhibited a high degree of resilience, i.e., an ability to respond and adapt to unexpected environmental changes, a feature critical for sustainability (*17*). Folke and others describe adaptive comanagement as a robust feedback process between local knowledge of the environment updated continuously through monitoring activities and societal decision-making undertaken by flexible local institutions that are able to engage all stakeholders (*17*). Consensus-based decision-making is often used, which can spark consideration of a broader range and a more creative set of solution strategies to accommodate minority dissenting views (*18*).

In recent years, formal processes to empower such local knowledge have been developed and refined through the cumulative works of practitioners from Europe, India, Africa, and South America (*19*) resulting in the rich field of participatory action-research (PAR), variously referred to as community-based participatory research (CBPR) and participatory rural appraisal (PRA), depending upon the application (*20*). The codevelopment of the techniques of PAR/CBPR through knowledge-sharing across developed and developing world boundaries is well-documented in ref *19*. While the design principles in Table 1 largely address the *structure and organization* of existing (in situ) governance institutions, PAR focuses on the *process* by which external actors—governmental agencies, nongovernmental organizations (NGOs), and international aid agencies—can interact with communities as equals, engaging community members in data-gathering through mapping and other formal techniques and, as co-learners, gain understanding of the system dynamics and relevant solution strategies. As shown in Table 2, PAR represents a transformation in attitude and dynamics between researchers and their host communities (*20*). Knowledge, familiarity, and practice of PAR are essential to ensure external agents do not impose top–down solutions that are inappropriate and unsustainable.

The main techniques in PAR are exemplified in a sanitation case study from Bangladesh where three decades of effort from a number of donor agencies proved to be ineffective, while a participatory approach that engaged communities in action-research resulted in 400 villages becoming free of open defecation through adoption of latrine use, without any financial subsidies (*21*). The facilitators used techniques such as transect walk (walking with community members to create an ecological transect), participatory mapping of community defecation locations and homes, community meetings quantifying fecal pollution load in local terms, using visual tools and flow maps to enable the villagers to explore disease transmission pathways, and if mobilized to action, empowering the villagers to research and design their own low-cost toilets while adopting consensus-based monitoring strategies to address defecation violations in the villages.

In this manner, a behavior established over centuries was altered, and the resulting human health and ecosystem improvements translated to economic gains for all villagers. Additionally, the villagers innovated with local materials and design, developing more than 20 latrine designs, many of them costing less than the limited number of models available through government subsidies. The designs used local materials and resulted in a unique offset pit latrine design suitable for areas with high water tables (*21*). Local microfinance methods (discussed next as the third system area) were used by village women to ensure that all households could construct the latrines. In this manner, all stakeholders were involved, and a dynamic loop between local knowledge and relevant decision-making institutions was established. The PAR techniques as well as the community-developed latrine designs have since diffused to more than 5000 villages in Bangladesh and have successfully transferred to parts of India, Nepal, Indonesia, and Africa. As demonstrated by this case study, local knowledge, a participatory environment, and microfinance methods created an atmosphere for innovation and sustainable design resulting in greater success than had been previously realized by marketing or subsidizing developed world knowledge and technologies.

PAR techniques are now being recognized as important tools to supplement existing urban participatory planning in developed nations; a review of these with a juxtaposition of PAR applications in urban settings in Venezuela and the U.S. are provided in ref *22*. Community-based shared visioning to advance urban sustainability goals (*23*) has emerged in several cities across the U.S. and Australia under the broad heading of "new urbanism" (*24*). New urbanism initiatives attempt to counter the negative environmental and social impacts of urban sprawl by developing compact, vibrant, livable, pedestrian-friendly, mixed-use neighborhoods that enhance community interactions (*24*–*26*). Urban planning and design with the "new urbanism" mandate requires strong multistakeholder participation in visioning alternative physical forms for neighborhoods and cities, often facilitated by a design charette, an intensive shared visioning process that occurs over periods of 2–5 days, involving large numbers of stakeholders in sequential feedback sessions (*27*, *28*).

In cohousing developments, the social networks common in the developing world are being recreated in urban residential neighborhoods that couple private homes with community-managed commons areas in a manner that intentionally creates community while also attaining environmental sustainability goals (*29*, *30*). Cohousing developments are visioned, designed, developed, and managed by the community itself in a nonhierarchical, collaborative, and consensus-based manner (*31*), offering one of the strongest examples of sustainable community-based property management and participatory action in urban areas of the developed world. Developing rural common property frameworks nested within federal and state governance structures was initiated recently in Australia in 2003 (*32*), modeled directly after the resilient common pool resource governance successes of indigenous societies.

In the sector of community health, CBPR techniques have been used successfully for asthma management, children's health assessments, HIV prevention, and occupational exposure management in the U.S. (*33*, *34*). The U.S. Department of Health and Human Services is currently evaluating processes and outcomes from CBPR case studies across the U.S. to further develop the technique for wider public health application.

Specific case study examples representing each of the sectors listed above are compared and contrasted in Table 3. The table shows the wide range of resources and environmental challenges that communities are addressing in both the developed and the developing world, the successful outcomes achieved, and the varying degree to which community citizens are involved in the long-term governance of common resources. These trends indicate that social networks, community interactions, and local-scale governance, after being underutilized in the developed world for several decades, are becoming increasingly relevant to advancing sustainability. The next section examines the role of social networks as they impact private enterprises and the financing of sustainable technologies and infrastructures.

System Area #3: Peer Lending, Microfinance, and Microenterprise

Microcredit and peer lending programs were pioneered by Mohammed Younnis when he set up the Grameen bank in Bangladesh in 1976 (*35*). While conventional lending practices either reject or impose high interest rates when lending money to the poor, the Grameen Bank started lending small amounts of money to individuals organized voluntarily in peer groups that provide mutual, morally binding group guarantees in lieu of the collateral required by conventional banks. At first only two members of a group are allowed to apply for a loan. Depending on their performance in repayment, the next two borrowers can then apply, and, subsequently, the fifth member. Social capital is thus used in lieu of physical capital to secure credit and to encourage timely repayment. The loans are used to support income-generating microenterprises such as paddy husking, lime-making, and basket-weaving, that enable the very poor to rise above poverty.

This revolutionary concept was demonstrated to be fiscally viable as Grameen Bank reported a large and growing customer base (4.04 million in 2004), loan repayment rates in excess of 92%, and steady profits ($7.16 million in 2004) as well as a decreasing reliance on external subsidies (*35*). Despite controversies on appropriate measurement techniques (*36*), social impact assessments generally indicated success both in terms of poverty alleviation as well as the empowerment of women entrepreneurs whose successes typically translated to broader community benefits (*37*). The success of Grameen's unconventional banking principles led to a great explosion of similar banks in the developing world, including the Bank Rakyat of Indonesia and the BankoSol in Bolivia.

In 1988, The Good Faith Fund of Arkansas was established in the U.S. based directly upon Bangladesh's Grameen Bank model, followed by more than 100 small microcredit institutions in several large cities across the country (*38*). An outcomes assessment found that the exact replication of the Grameen model to the U.S. was unsuccessful due to several structural differences, chiefly easy access to credit cards and the lack of effective social networks both for screening borrowers as well as enforcing loan repayments (*38*). However, several useful adaptations of the basic microcredit model were also revealed. For example, participants in the Working Capital Group in Massachusetts (*39*) identified peer support, business training, and the opportunity to develop entrepreneurship networks, i.e., social capital, as highly beneficial. The provision of low-cost savings services (rather than credit) was identified to be important, and, higher interest rates, commensurate with borrower default risk, were recommended for microfinance institutions (MFIs) in the U.S. to become fiscally self-reliant (*38*).

These insights from the U.S. mirror similar trends that have since emerged in the developing world. For example, researchers have learned that loan repayment peer-pressures in developing nations can sometimes result in an endless cycle of micro*debt* (*40*), which can be mitigated by the provision of a strong, low-cost microsavings program. Microcredit and microsavings together result in the provision of microfinance services. A greater emphasis on savings and fiscal sustainability principles has resulted in the growth of several successful MFIs globally, such as the Bank Rakyat, which grew out of subsidies in only 3 years and has since

TABLE 3. Comparing and Contrasting the Process of Participatory Community-Based Governance in Developing and Developed Nation Case Studies

	indigenous governance system	participatory action-research for sanitation	participatory action-research for community health	cohousing developments	design charrette and new urbanism	water management
Case study location and refs	Oos and Petanu rivers in Bali, Indonesia (*10, 11*)	Villages in Bangladesh (*21*)	New York City, NY, U.S. (*33*)	Wild Sage Boulder, CO, U.S. (*29, 30*)	Jindalee, Australia (*27*)	Tampa Bay, U.S. (*14, 15*)
Goal	Share water and coordinate cropping schedules in cooperative farming to achieve optimal and equitable rice yields.	Improve sanitation and hygiene by promoting acceptance and use of latrines.	Assess asthma prevalence rates and design interventions for a disadvantaged urban population.	Design and operate small residential neighborhoods that create community while also promoting environmental resource conservation.	Design the physical form of cities and regions to counter the negative energy, environmental, and social impacts of urban sprawl.	Resolve conflicts associated with trans-boundary water management and implement sustainable water management plan.
Community size	>15 000 farmers	400 villages	16 000 residents	34 homes	100+ regional stakeholders	>2.1 million users in 3 counties and 3 cities
Goal definition	for and by community	external agents with community	external agents with community	for and by community residents	local/regional planning authority with stakeholders	regional political leadership with water utilities
Field data gathered by community?	always	always	always	always	modeling of alternative urban forms by experts	no, regional water authority assumes this role
Iterative decision process with feedback loops?	yes, in monthly intra-subak meetings and annual intersubak meetings	recommended as needed	recommended as needed	frequent with regular community meetings in place	through periodic 3–5 day charettes with community and stakeholders	17 workshops and several technical and legal reviews held over 2 years
Implementation/ oversight	by community	community with external agents	external agents with community	by community	local/regional planning authority	regional water authority
Decision-making by consensus?	typical	variable	variable	typical	no	variable
Long-term monitoring	typical, by community	typical, by community with external agents	typical, by external agents with community	typical, by community	infrequent/ atypical	typical, by water authority
Sanctions to ensure rule compliance?	typical, by community	desirable, by community subgroups	atypical	typical, by community	atypical	state government
Demonstrated successes	Optimal water sharing; Less than 1% crop losses with coordinated pest management; Equitable rice yields with intrasubak variability <5%; Resilient system over hundreds of yrs.	Successful self-governance resulting in 400 villages free of open defecation for first time in Bangladesh, without use of external subsidy.	Reduction in rates of asthma hospitalizations from nearly 1166 cases in 1997 to 484 in 1999 after CBPR intervention.	In general, cohousing residents drive 30% less, pay 50% less in utility bills, and use 40% less water than the typical suburban.[a]	Reduction in travel demand (*27*); Enhanced aquifer recharge (*25*); Social and community iteractions are unclear.	Reduced salt water intrusion by decreasing groundwater pumping. User cost now equal for all users and all water resources (groundwater, surface water, desalination).
Strategy and processes successfully disseminated and replicated	all across island of Bali and in numerous indigenous societies worldwide.	participatory processes are now required by all International Aid Agencies.	CBPR has been accepted and is being evaluated by the U.S. Dept of Health & Human Resources as a new technology to promote health.	Originating in Denmark, more than 100 active cohousing developments are presently in the U.S.	More than 500 new urbanism designs in the U.S; form based development codes ratified by CA with other states likely to follow.	Being evaluated for several trans-boundary water problems in the U.S. and Middle East.

[a] Specific estimates of 320 tons of CO_2, 1 ton of SO_2, and 0.6 tons of NO_x emissions avoided per year due to sustainable building design adopted at Wild Sage Co-housing when compared to a conventional building.

TABLE 4. Project Description, Outcomes, and Impact of Adopting or Marketing Sustainable Technologies through Microfinance

	location, reference	loan details/ unit cost	financing vehicle
Sanitation, Water Supply and Water Treatment Technologies			
Construction of low-cost locally designed household latrines successful with entire village adopting low-cost toilets savings from health improvements enabled full loan repayment	Bangladesh (*21*)	\$1−\$4 per unit	community self-help groups offered credit to members
Rehabilitation of two boreholes & funds for electricity to pump water community repaid loan within 6 mos from water revenues reliable water supply for 1200 homes since 1992	Nderu (*45*)	\$4500 paid back in 6 mos	community schools provided initial credit
Purchase of household filter for arsenic removal from water ongoing study with and w/o consideration of 50% external subsidy	Nepal (*3*)	∼\$20 per unit, lasts 2 yrs	local MFI to provide credit
Construction of lake for rainwater harvesting on marginal lands profits from dual harvests per year led to diversification to cash crops and to fish farming, enabling loan repayment and employment of 10 landless laborers	Gujarat, India (*44*)	\$4000 at 5% paid over 5 yrs	microenterprise loan from Ecselance International
Construction of a large piped water infrastructure MFI K-Rep-Bank bridges the financing gap between Nairobi Water Utilities and the Community Water Project	Nairobi, Kenya (*45*)	pilot in development	project cost shared by community (20%), MFI loan (40%), and utility (40%)
Renewable Energy Technologies			
17W solar photovoltaic system to support small sawmill business improved cash flow by 50% enabled loan repayment in 5 years first success led to diffusion of more than 1000 solar PV units more than \$750 000 invested locally in solar energy	Bangladesh (*43*)	\$270 per unit	Grameen Shakti MFI: finance and technical assistance for energy projects
Microhydro unit to power milk refrigeration at a local dairy coop profits increased to \$671 per month, allowing loan repayment diffusion of 15 additional units installed in the area turbines used to also grind grain and support local businesses	Peru (*43*)	\$35 000 at 8% pa over 5 yrs	Intermediate Technology Peru financing and technical assistance
Initial project set up a dairy with 10 cows profits from dairy operation and milk products led to construction of a biogas unit for energy recovery from animal waste	Gujarat, India (*44*)	\$4000 at 5% paid over 5 yrs	microenterprise loan from Ecselance International

been reporting exceptionally high rates of return. Currently, more than 10 000 MFIs are serving more than 13 million people globally, with more than \$7 billion in outstanding loans, with an average loan repayment rate of 97% (*41*). While continued research is needed to ensure that the globalization of microfinance does not exploit the poor (*42*), the concept itself is revolutionary and has improved the lives of millions of people in Bangladesh, for which its founder Mohammed Younnis, received the 2006 Nobel Peace prize.

In recent years, microfinance has been actively explored to support the adoption and diffusion of sustainable technologies and infrastructures in the developing world. This can occur via four distinct mechanisms. First, with community members themselves generating small loans in a revolving fund, e.g., small groups of women previously mentioned in the Bangladesh sanitation case study offered very small loans to other group members on a rotating basis to fund the construction of low-cost (\$1.30−\$4) latrines. Savings from improved household health enabled timely loan repayments over a period of a few months, after which the groups disbanded (*21*). In a second model, existing MFIs focused specifically on financing sustainable technologies with full loan recovery, resulting in the rapid diffusion of these technologies. For example, the Grameen Bank, recognizing that solar energy technologies require larger loans as well as trained technicians to ensure effective use of the technologies, established a separate entity specifically to finance energy technologies (*43*). This entity facilitated the spread of more than 100 000 photovoltaic units in rural Bangladesh. In a third model, donors are not focused on a specific sustainable technology, rather, microentrepreneurs seeking profits choose to invest in a variety of sustainable technologies such as biogas, rainwater harvesting, and wind-powered pumps, yielding economic and social benefits (*44*).

Last, large banks and development institutions are now recognizing that microfinance can be a vehicle to leverage local financial resources to bridge the large infrastructure funding gap in developing nations (currently estimated at \$7−\$70 billion globally for water infrastructure), while also fostering community participation in large infrastructure projects (*45*). This simultaneously addresses the challenge of effective local governance of water and sanitation infrastructures, while partially meeting the financing gap. To explore this potential, the World Bank has recently initiated a pilot study combining local microfinance with conventional funding vehicles for a large water infrastructure project in Kenya with long-term sustainability goals.

Lessons learned from the above case studies (see details in Table 4) show that the microfinance-microenterprise model can facilitate the diffusion of sustainable technologies provided a steady demand exists or can be created (e.g., demand for sanitation in rural Bangladesh), a diversity of low-cost products are available, a credible and experienced local MFI is present, and regional policies are supportive of leveraging local initiatives (*3*, *43*, *45*). Most important to the success of this model for supporting the development and diffusion of sustainable technologies is that entrepreneurs often require training in evaluating and using alternative technologies, developing a business plan, and leveraging profits (*43*−*45*). The use of microfinance-microenterprise specifically for disseminating sustainable technologies has yet to be explored in the developed world, although opportunities exist, for example in the provision of rolling funds to finance energy efficiency improvements in low-income households. With the recent (November 2006) opening of the *New Resource Bank* in San Francisco as the first bank in the U.S. created specifically to support the development and diffusion of resource-efficient technologies, microfinance ideas may gain further traction for sustainability applications in the developed world.

Discussion

Case studies have been used to demonstrate the effective application of social capital in the developing world for long-term cooperative governance of common pool resources and for the development of local ecological knowledge through participatory action research. For more than two decades, developing world knowledge in these two system areas has sparked important dialogue and furthered the fields of cooperative community-based commons governance and PAR/CBPR in developed nations (*4*, *5*, *19*). The practical experiences of many traditional communities in governing their commons has been distilled into Ostrom's eight design principles (*9*) that guide the structure and arrangement of institutions for managing commons resources. These principles along with concepts of adaptive comanagement have been successfully applied for cooperative resource management in many industrialized nations such as the U.S., Sweden, and Australia. Structural differences, particularly the lesser emphasis on social networks and local knowledge in many industrialized nations, are being overcome through the use of nested multiscale governance institutions connecting local actors to larger agencies, and, through the use of structured analytical dialogue and shared visioning between technical experts, communities, and regulatory agencies to build social capital for commons governance (*4*).

More recently, the revolutionary idea of peer-lending and microfinance, pioneered in Bangladesh, was translated to the U.S. Differing financial structures posed a challenge to this first translation in the developed world. However, as more communities engage in local-scale sustainable development initiatives, suitable adaptations of microfinance may find success in the developed world. The three system areas of cooperative commons governance, participatory action research, and microfinance demonstrate the significant knowledge sharing that has occurred from the developing to the developed world. Case studies from both the developed and the developing world show that social networks and voluntary cooperative actions occurring at the local community-scale can contribute significantly to the goal of global sustainable development in a wide range of sectors ranging from natural resource management, water, sanitation, energy, infrastructure development, urban planning, and community health. Innovative microfinance-microenterprise models can be used to leverage social capital for poverty alleviation as well as to fund the diffusion of a host of sustainable technologies and infrastructures in the water, energy, and sanitation sectors.

Important questions remain and are the subject of ongoing research, regarding the spatial scale at which community networks are most effective (*4*, *6*), the interaction and the interface of communal property management with free markets and with federal regulatory frameworks operative (*4*, *6*), and the interface of local microfinance initiatives with conventional financing vehicles (*45*) as well as the impact of technological advances in promoting or inhibiting community-based commons governance (*6*).

Understanding the governance, finance, market, and social structures necessary to create an environment that actively supports the development and diffusion of sustainable technologies is critical to advancing the goal of global sustainable development. Innovative technologies with great potential to advance sustainability often have little impact due to socially or structurally incompatible governance, management, and finance mechanisms that inhibit technology diffusion. Continued broad knowledge sharing ranging from science and technology to governance structures and market mechanisms between developed and developing nations is essential in creating an expanded tool kit and a richer experiential base with which to address the challenge of global sustainable development.

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