

# Evolution of models to support community and policy action with science: Balancing pastoral livelihoods and wildlife conservation in savannas of East Africa

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**We developed a “continual engagement” model to better integrate knowledge from policy makers, communities, and researchers with the goal of promoting more effective action to balance poverty alleviation and wildlife conservation in 4 pastoral ecosystems of East Africa. The model involved the creation of a core boundary-spanning team, including community facilitators, a policy facilitator, and transdisciplinary researchers, responsible for linking with a wide range of actors from local to global scales. Collaborative researcher–facilitator community teams integrated local and scientific knowledge to help communities and policy makers improve herd quality and health, expand biodiversity payment schemes, develop land-use plans, and fully engage together in pastoral and wildlife policy development. This model focused on the creation of hybrid scientific–local knowledge highly relevant to community and policy maker needs. The facilitation team learned to be more effective by focusing on noncontroversial livelihood issues before addressing more difficult wildlife issues, using strategic and periodic engagement with most partners instead of continual engagement, and reducing costs by providing new scientific information only when deemed essential. We conclude by examining the role of facilitation in redressing asymmetries in power in researcher–community–policy maker teams, the role of individual values and character in establishing trust, and how to sustain knowledge–action links when project funding ends.**

outreach | power | trust | Kenya | Tanzania

**A**lthough pastoralists and rangelands have been the subject of research study for decades around the globe, it is only recently that pastoral communities and policy makers have been part of the research process rather than the subjects of study alone or excluded altogether (1). In Africa, the current structure of academic incentives and poor research funding makes it difficult for local researchers to work closely with pastoral communities over the long term, particularly if those researchers live in cities far from pastoral lands. Researchers from outside the region rarely have the opportunity to engage at the depth and over the time required to ensure research is useful to local actors. Agricultural extension in African pastoral lands is difficult not only because of the mobility of some pastoral populations (2) but also because many extension specialists do not recognize the highly adaptive nature of indigenous pastoral management (3). Pastoral households and communities are often the subjects of postgraduate theses or larger research projects in which students and researchers collect information from households and rangelands but rarely have the funds to interpret and return this information to the communities that provided it (e.g., ref. 4). It is even rarer to find research that, from the outset, integrates

communities or policy makers in collaborative efforts for the purpose of creating “research-action arenas” (5), wherein different groups are integrated to support local action in an action research framework (6).

This lack of connection and integration of knowledge from communities, policy makers, and researchers to support action is a problem being tackled globally with some progress (7, 8). Broad reviews suggest that such efforts are most successful when teams attempt to position people or institutions along the boundaries between communities, policy makers, and researchers (7). The capacity of such people or institutions to span these boundaries tends to improve the salience, legitimacy, and credibility of the information produced for all involved. When individuals or organizations attempt boundary spanning, they face contested ways of knowing, inequities of power, difficulties brought on by the practical aspects of management, and the problems of sustaining engagement over time (5, 7, 9). Individuals that span boundaries appear to play a key role in linking knowledge with action, but we know little about how they do what they do and how to train others to do this work (8).

This paper describes the development of a model, through boundary-spanning individuals and organizations, to better integrate knowledge from policy makers, communities, and researchers of Maasailand in East Africa for the purpose of promoting action that will balance poverty alleviation and wildlife conservation. Currently, half of Maasai households live below the poverty line (10) even though they live in savannas that attract massive profits from wildlife tourism, which accrue mostly to outsiders (11) and also the pastoral elite (12). The traditional balance between pastoral land use and wildlife is growing more tenuous with the recent expansion of cropland

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(13), the privatization of land, and the sedentarization of formerly mobile herders (14). Pastoralists are also often marginalized by government policy that favors the dominant settled farming lifestyles (15) of the nearby highlands. With problems of this magnitude, one key challenge is how to bridge the gap between the available information (from local communities, researchers, and policy makers) and the actual use of this information to bring about desired action for sustainable poverty reduction and conservation of wildlife and other natural resources.

Although we focus on our new research-action model here, it is important to describe the scope of the research itself. The overall research issues tackled by this team, most of which were developed in consultation with our clients in community and policy circles, span from the global to the local level, with a major focus at the landscape and community levels. At the global level, our team addressed the dynamics and sustainability of pastoral systems in 9 sites in North America, Australia, Africa, and Asia (16, 17). At national and regional levels, the team sought to understand the distribution and trends in land use (18), land tenure, wildlife (19), and poverty (10). At the landscape level, we studied the causes of changes in pastoral household economies and land use (20), the effects of these changes on wildlife and savanna ecosystems (21, 22), the conflicts between herders and wildlife (23), the economic returns from conservation to pastoralists (24, 25), the understanding and articulation of indigenous knowledge (26) and the effects of biodiversity payment schemes on pastoral attitudes toward wildlife (27) in 4 major study areas.

#### Four Study Areas in Pastoral Ecosystem

**Tarangire–Simanjiro–Manyara Pastoral Ecosystem.** Located in northern Tanzania, the main conservation-development issues in this landscape are ensuring food security and land access for growing pastoral families and maintaining large migrations of wildlife between pastoral village land in Simanjiro and Monduli, and Tarangire and Manyara National Parks. Village land is accessed and used communally subject to customary tenure negotiations (9). New wildlife management areas (WMAs) were designed to devolve some management of wildlife to the local level through village titling of land and land-use planning (9). During our project, our research-for-action team responded to requests from village members and policy makers for information about livestock veterinary issues, livestock marketing, wildlife trends, gender issues, local tourism-benefit-sharing mechanisms, and pastoral inclusion in wildlife policy.

**Amboseli–Longido Pastoral Ecosystem.** The Amboseli–Longido pastoral ecosystem rings the northern and western slopes of Mt. Kilimanjaro and straddles the border between Kenya (Amboseli) and Tanzania (Longido). Amboseli is dry, so the dynamics of pastoral families are highly dependent on a series of swamps for livestock-watering and -grazing purposes, and the cultivation of onions and tomatoes. In Amboseli National Park, wildlife alone similarly depend on these swamps for survival. These swamps and the wet slopes of Kilimanjaro attract in-migrants and, consequently, road and water development and expanded settlement on farms (13, 20). In Longido, Tanzania, pastoral families face issues of access to land and water and implementation of WMAs. Some families stopped cultivating here because of repeated loss of crops to elephants and other wildlife (28). During our project, our team worked on issues of livestock breeding, access to livestock vaccines, water development, and the effects of land subdivision on pastoral livelihoods and wildlife.

**Kitengela Pastoral Ecosystem.** This ecosystem, also called the Athi–Kaputiei, is just south of Nairobi National Park and Kenya's teeming capital of Nairobi. Here, urbanization is a major

issue, with the expansion of flower farms, export processing, and small towns. Since land privatization in the 1980s, rapid expansion of these land uses and fencing have increasingly restricted the movement of pastoral livestock herds and seasonal migrations of wildebeest and zebra from pastoral lands to Nairobi National Park (29). A land leasing program, which pays residents not to fence their land and to monitor poaching, is changing local attitudes toward wildlife and is in high demand with pastoral families (30). Even so, wildlife populations plummeted in the last decade (29), so the local communities and others are now expanding the leasing project. Our project team experimented with the efficiency of various livestock breeds, mapped land use and analyzed wildlife land-use interactions, and assessed the economic returns to the land (30).

**Mara Pastoral Ecosystem.** The Mara ecosystem in Kenya is the northern dry-season grazing reserve for the migrating Serengeti wildebeest population and one of the wettest pastoral savannas in East Africa. Recently, wildlife populations also plummeted in this ecosystem (22, 31–33) and most of the tourist revenue from wildlife flowed to wealthy elites, not the poorer herders living near the wildlife (12). Here, the main issues revolve around the adoption of private land ownership, new public–private partnerships that will allow local landowners to share more fully in tourism revenues, and rapid expansion in crop cultivation and settlement. Our project team assessed the economic returns to land use (24, 34), effects of settlements on wildlife, human–wildlife conflicts (23), livestock health and breeds, causes of changes in wildlife and livestock populations (33), and the effects of protected areas and pastoralism on wildlife (22).

**Evolution of Boundary Spanning Models in Pastoral Lands.** Over the last 25 years, the senior author of this paper was a member of a succession of research teams working on pastoralism and conservation in East Africa. These teams evolved their model of boundary spanning; starting by closing gaps and integrating knowledge among scientific disciplines, they progressed to link policy makers, communities, and researchers by using boundary-spanning agents, teams, and organizations, and by integrating their efforts from a local to a global scale. At the outset, these were some of the first scientific teams to work at a systems level to integrate the social and ecological science of pastoralism (35–38). This and related work led to a major shift in the paradigm of rangeland science, from equilibrium- to nonequilibrium-systems thinking, which is still debated in scientific and development circles (39). Two decades ago, these research teams used Model 1 (Fig. 1), where community members participate as field guides and interview subjects. At that time, the research questions were largely academic, grappling mostly with interdisciplinary integration and systems understanding but always with an eye to influence science and policy over time. When looked at from today's perspective, students on these teams built their careers by using an extractive research model based on information taken from (and willingly given by) pastoral communities. This method was the norm at that time.

Members of these teams gradually became more actively involved with policy makers and pastoral communities in an effort to create scientific information more relevant to their needs. Researchers first directed their work toward issues of concern for policy makers and pastoral communities (40) as shown in Model 2, and then did so more fully by consulting communities and policy makers on problems at the outset of the research (Model 3). In the 1990s, some members of the wider team connected Models 2 and 3, identifying problems together with communities or policy makers, feeding initial research findings back to communities and interpreting these findings together (4, 41–43) as shown in Model 4. In the project described in this paper, this progression evolved further into a new model

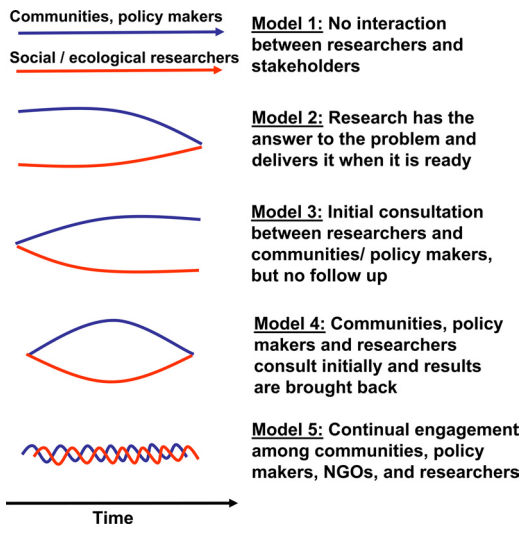


Fig. 1. Evolution of our models to link knowledge with action in pastoral systems of East Africa over the last 3 decades.

of continual engagement through facilitation and full integration—in all aspects of the information generation, interpretation, and action—of traditional producers and consumers of information. Project members created knowledge-action arenas (5) and facilitated boundary agents to blur the boundaries between these groups (Model 5) by using an action research process. This was a natural progression as our understanding of human–ecological systems expanded, new tools like ecosystem- and agent-based models became available, and our ability to integrate spatial and social scales into conceptual and analytical models increased. This model builds on the philosophy and process of participatory action research (6) and focuses on a new method by which to integrate different knowledge systems through facilitators in a multicultural setting.

**A New Model of Boundary Spanning Across Level and Scale.** The new continual engagement Model 5 (described later in this section) was embedded within a philosophy and practice of boundary spanning (44) at nested individual (agent), team, and organizational levels to create strong back-and-forth connections among scientists, policy makers, and communities. At the organizational level, we doubt we would have attempted ambitious boundary spanning if we had not been embedded within an organization [the International Livestock Research Institute (ILRI)] and a research system [Consultative Group on International Agricultural Research (CGIAR)] that view boundary spanning (even if not so named within the institutions) and partnership strengthening as major institutional goals. Even though ILRI rewarded scientists less for building partnerships than for publishing papers, it fostered a culture of openness to experimentation with new models and the creation of safe spaces (44) by scientific managers to encourage innovation. And the CGIAR rewarded teams for partnership innovation, bestowing on our team its “Best Innovative Partnership” award in 2006. Another crucial catalyst for the team was the Sustainability Science Program based at Harvard University, which both expressed an interest in this project and brought refined “knowledge-to-action” concepts to bear upon it.

We then constructed a boundary-spanning team of members, each of whom had a responsibility to span boundaries between institutions at different, nested scales (Fig. 2). At the global level, we asked each of the international scientists on the core team to connect the team’s work with international conservation and development organizations and teams [like the United Nations

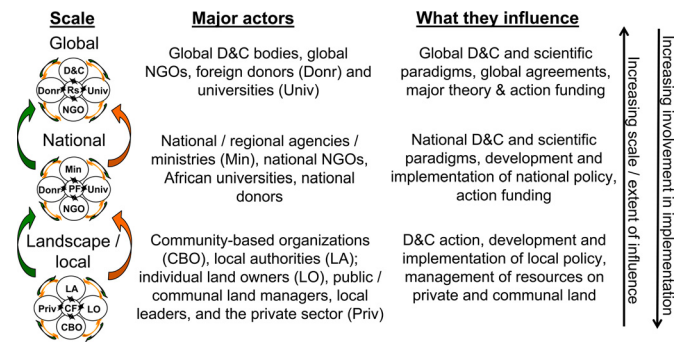


Fig. 2. Roles of the researchers, policy facilitators, and community facilitators in the spanning of boundaries among different actors and what those actors influenced at different scales. D&C, development and conservation; Rs, researchers; PF, policy facilitator; CF, community facilitator.

Environment Programme (UNEP) and the Food and Agriculture Organization (FAO)], academic institutions and researchers outside Africa (like University College London, University of Louvain, and Colorado State University), international NGOs (like the African Wildlife Foundation), and international granting organizations [like the Belgian Directorate General for International Cooperation (DGIC), the United Kingdom’s Department for International Development (DFID), and the United States’ National Science Foundation (NSF)]. The goal of this global boundary spanning was, in the first instance, to harness the ideas and worldwide experience of scholars of transdisciplinary theory and practice in the areas of pastoral household economics, poverty mapping, large mammal conservation, biodiversity payment schemes, agent-based and savanna ecosystem modeling, and land-change science (e.g., ref. 16). Our aim was to attract and focus national and international intellectual talent on issues that mattered to pastoral families and other local land managers facing real problems on the ground in East African savannas. It was also to harness the power of the global scientific peer review system to ensure that our research was credible from a scientific point of view. Critically important here was finding a donor agency that would support a project with a strong, transdisciplinary research component and an equally strong linking-knowledge-with-action component, which we found in the Belgian government’s DGIC.

We asked scientists at the national and regional levels and a new team policy facilitator (Fig. 2) to span boundaries between our core team and national NGOs [like the Resource Conflict Institute (RECONCILE)], regional and national donors (e.g., the Belgian and U.S. embassies), academics at universities in the region (like the universities of Nairobi and Dar es Salaam) and government ministries and parastatals (including Tanzania National Parks and the ministries responsible for livestock, environment, and land). The policy facilitator’s jobs were to work directly with decision makers at various levels within ministries in both Kenya and Tanzania to understand the issues they face, to make sure the wider team contributed to policy discussions, task forces, and policy revision efforts, and to connect relevant scientific findings from the core team (or other teams with relevant information) to issues of policy importance. This was such a large task that the community facilitators (described later in this section) also played a large role here. The scientists focusing on the national level were responsible for working with technical staff on data analysis in government ministries, working with national academics and their students, summarizing scientific findings at policy fora, serving on task forces to revise government policy, and accessing funding opportunities through targeted national and regional donors.

At the outset of the project, we felt weakest in our ability to

span boundaries at the local level, and thus this was where we attempted continual engagement (Model 5 in Fig. 1). Here we established a team of community facilitators—full-time boundary agents (7, 45) whose entire function was to create research-action arenas (5) to better connect researchers, communities, and policy makers. The community facilitators' goal was to span the boundaries between these different ways of knowing and acting by knitting together land owners, land managers, development and conservation NGOs, churches, local authorities, and scientists on issues concerning land, water, tourism, wildlife, and livestock (Fig. 2). Our objective was not only to establish these links but also to integrate lessons from different geographical areas by working with these stakeholders from the 4 different pastoral ecosystems in Kenya and Tanzania. This facilitation team was the centerpiece of the team of transdisciplinary national and international scientists described earlier in this paper. All of the facilitators were themselves Maasai and all were raised within the communities they served. This integration allowed us not only to create an end-to-end system linking knowledge with action (44) but also to integrate this effort across scales in a reinforcing manner. The core project team consisted of 5 community facilitators, 1 policy facilitator, 2 anthropologists, 2 veterinarians, 3 ecologists, 1 agricultural economist, and 1 geographer. This team worked with approximately 80 communities, more than 1,500 community members, 21 other scientists, and approximately 25 policy makers on high-priority issues articulated together. This core science-for-action team was connected to a much wider team of advisors and colleagues in the academic community from 4 continents, as well as to practitioners in conservation and development both inside and outside of East Africa.

**Making the New Model Work in Practice.** By using this continual engagement model and boundary spanning at several scales, the team tackled a range of issues concerning conservation and development that they identified with communities and policy makers (for more detail, see Table S1). Here we highlight particular strategies and tools that we developed to foster trust, ensure relevance, and increase efficiency while implementing this model.

To develop initial trust at the community level, the facilitation agents first focused on issues that were not controversial and were at the core of herding livelihoods: livestock markets, health, and breeding. This initial focus on livelihood issues allowed the facilitators to establish trust and a record of engagement before tackling more controversial issues like wildlife conservation (45). With policy makers, the team focused on upcoming policy issues and paid close attention to the incentives and power structure of democratically elected leaders.

We found one tool, “outcome mapping” (46), particularly useful in ensuring that the problems tackled by the research team were useful to communities and policy makers. The team began the project with a visioning exercise that elicited what actions and behavioral/institutional change, on the part of key partners, the team wanted to promote. Team members then worked backwards to plan the information that would help to achieve these goals. This meant that the scientists needed to be more flexible about what questions they asked, what science they conducted, and how they would integrate local knowledge with scientific knowledge. It also required that community members articulate their needs for scientific information, a new experience for them.

Initially conceiving the project model as one of continual engagement—wherein the large team would meet very frequently—we discovered that strategic and periodic engagement was more efficient. This strategy involved working with different groups at different times (forming subarenas) and only convening the entire research-action arena to work on

major issues or discuss larger implications. Facilitator engagement was often continual, with daily meetings with small groups of community members, policy makers, and researchers (together or separate) but was also periodic, with monthly or annual large-group meetings, field tours, peer-to-peer learning visits, training sessions, and other activities. One key practice was a meeting of the facilitator and researcher teams every 1–2 months for 1–2 days to discuss progress, new issues, and ideas, and to plan the next work period.

The facilitators and researchers soon found that the information needs of communities and policy makers far outstripped our ability (in time and resources) to create that new knowledge, so we developed a strategy to distinguish the different levels of knowledge that we would provide. The simplest level was “no knowledge provided,” wherein the facilitator or researcher had no experience with the problem (e.g., the economics of horticulture, legal land instruments) and said that he or she had no information to offer. The second level was “knowledge trading,” wherein the facilitator connected community members or policy makers to existing knowledge from traditional, research-based, or other sources. In Longido, the facilitator helped community members to understand the efficacy of existing East Coast fever vaccines for livestock, referring them to regional veterinary experts. Next was “knowledge synthesis,” wherein the facilitator combined existing research findings and traditional knowledge in new ways for community members or policy makers. In the Tarangire–Simanjiro–Manyara ecosystem, the facilitator found big price differentials along the livestock marketing chain, with large profits flowing to local middlemen who paid low prices to herders but received high prices at distant markets. The facilitator then helped the herders and local leaders form a marketing cooperative to jump the middleman and get better prices for their livestock. He also informed national policy makers of the success of the cooperative and sought their help to spread this innovation to other communities across the region.

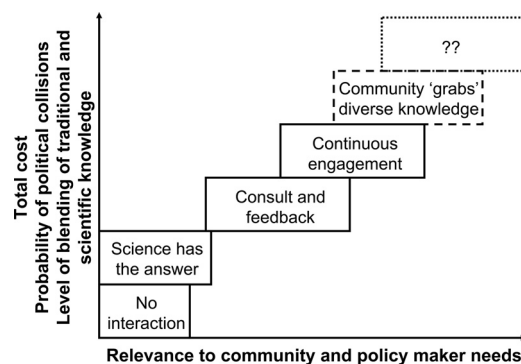
The next level was “knowledge generation,” initiated by researchers when no information existed about an issue. In the town of Kitengela, economists created information on household returns to different kinds of land use to help determine fair payments for a program that provides pastoral families with incentives to avoid fencing land and keep land corridors open for wildlife and livestock movements (30). In Amboseli, researchers worked with communities and local policy makers to adapt a spatial ecosystem–household simulation model to estimate the effects of land subdivision (47). This model helped change the discussion of the merits of land subdivision in this region at the community and policy levels. The most sophisticated level, and the most rarely implemented, was “hybrid knowledge creation,” wherein the facilitator, community members, and researchers created hybrid information together (policy makers were sometimes consulted in this process). From a community and policy perspective, this hybrid knowledge brought the reliability of scientific information into the community and policy decision-making processes. From a scientific perspective, this hybrid knowledge ensured relevance of the science and allowed a wider and deeper interpretation of the information collected. In the Mara region, information about the financial benefits of conservation at the household level catalyzed a discussion among community members and encouraged communities to form community wildlife conservancies in the pastoral lands. This joint community action created an interest among local and international NGO officials who joined the community to encourage national policy makers to develop a policy framework (called the Community Conservation Planning Framework) for conservation outside the protected area. In the Kitengela, a joint team mapped 6,741 fencelines to create a fine-resolution land-use map (29). This map was presented to the local district commissioner, who worked with the Ministry of Lands to

conduct a land-use planning exercise with community groups and county councilors and then presented the results to multiple ministries at the national level. This map is now the basis for Kenya's first land-use plan for a privatized rangeland (30).

**Power, Trust and Sustainability.** One of our most important lessons was that asymmetries of power and access to information must be recognized and explicitly addressed (48). The scientific team was surprisingly naïve about the strong role that facilitation would play in leveling the differences of power among the 3 actor groups. Scientists themselves were initially unaware of the extent of their own power and were surprised at how deliberate they had to be in sharing the power of information with communities. The team found that power became more symmetrical when the community and scientific teams (this was not seen as needed as much with powerful policy makers) worked jointly throughout the information-generation process, including developing research questions, collecting data, and analyzing and interpreting information. All members of this team acknowledged in action as well as word that they were simultaneously both experts and students. This served to create a collaborative learning culture (49) that empowered all team members. Another issue was the potential for 1 part of the community to manipulate information to enhance their power; the team as a whole countered this by providing information widely through many outlets to avoid monopolization by any 1 part of the community. These efforts ultimately led to greater inclusion of the wider Maasai community in government policy discussions on land use, pastoral development, and wildlife.

We also learned that trust plays a critically important role in allowing actor groups to integrate quickly and sustainably (44). But what do we really mean by trust? We certainly mean that the knowledge itself must be fair, unbiased, and respectful of different knowledge sources (7), also called “legitimate knowledge” (44). But even more important in our work were the characteristics of the actors in engendering trust, particularly the facilitators and researchers. The effectiveness of the facilitators in creating trust was greatly enhanced when they actively listened and learned, respected, and were curious about different ideas, were humble in word and action, came from the communities they served and spoke their dialect, had a long personal and family history of community service, and were willing to admit when they did not know something (45). Facilitators gained the trust of policy makers by highlighting their critical role in project success when meeting with their constituents. On the part of scientists, one key characteristic, humility, was repeatedly cited by communities as one of the most important traits that helped the groups develop trust so they could work effectively together. Here, actions were exceptionally important: It mattered what type of vehicle the scientific team members arrived in (small), how long they stayed (full meetings), what they wore on their feet (shoes ready to walk or local sandals made from car tires), and whether they walked with community members (and how far). Another action that helped establish trust was scrupulously keeping commitments and supporting one another's actions when speaking and working with other groups. We suggest that the strength of this trust will determine the sustainability and magnitude of the ultimate impact of the project because this trust creates social incentives that can be more long-lasting than economic ones (50).

Perhaps the largest concern of the facilitator–researcher team was this: How sustainable will our efforts be when the funding is gone? We recognized the important role our considerable funding and institutional resources played in allowing the group to work together and the facilitators to be effective (Fig. 3). Flexibility in spending allowed the core team to learn and adapt our resource allocations. The financial resources for this project came from a donor interested not only in science but also in



**Fig. 3.** Relationships between the relevance of each boundary-spanning model to the total cost of the spanning, probability of political collisions, and level of blending of traditional and scientific knowledge.

assisting development and conservation at the community level. The donor thus fully supported communication, facilitation, and other outreach activities normally neglected in research grants, as well as scientific data collection (by the integrated team) normally neglected in development and conservation grants.

Although there were significant advantages to this approach, there were also significant costs (Fig. 3). There is no question that Model 5, one of continual engagement, produces science that is relevant to community and policy maker needs. But full engagement comes with large and long-term costs in human, social and financial resources. Full engagement also raises the likelihood of political collisions, as information—and the scientists behind that information—became a tool to wield as an instrument of power among different community groups and policy makers.

Our strategy to sustain the progress achieved by the project over time included building capacity of all participants (ourselves especially), empowering community actors, and building institutions likely to last well beyond the end of the project. Clearly, certain projects requiring active and intensive participation of researchers and community members were not maintained after the funds were exhausted in 2007. But other, more durable parts of the partnership require no more resources to remain vibrant. These include the major shift in how the members of this team do science to support action, the training of the policy and community facilitators, the empowerment of local community voices, the strengthening of community-policy maker dialogues, and the learning model described here. For example, before this project, government ministers often arrived in these communities and made pronouncements about new programs and policies. Now the community neither allows government officials to do this nor participates unless they are consulted from the beginning of the development of the program at hand, and government officials now willingly oblige (our project is not the only reason this happened). In retrospect, we are seeing the largest impacts of the facilitation on decision making after 2007, with good indications that these impacts will only grow, particularly through a new local NGO established by the core project team that just received its first external grant.

**Future Work.** Our team developed this approach out of frustration with the poor impact of science on local and national decision making. The next step in the evolution of this model, which we are already beginning to see, is active recruitment of researchers by community members and policy makers to help them clarify, understand, and solve problems (5). In Kenyan vernacular, we are seeing communities now beginning to grab information for themselves from diverse knowledge sources (Fig. 3) as they tackle new challenges to provide healthy and profitable livelihoods for

their families and conserve the rich heritage of wildlife they have lived with in East African savannas for several millennia.

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- Bayer W, Waters-Bayer A (2002) *Participatory Monitoring and Evaluation (PM&E) with Pastoralists: A Review of Experiences and Annotated Bibliography* (GTZ, Eschborn, Germany).
- Barrow E (1991) Evaluating the effectiveness of participatory agroforestry extension programmes in a pastoral system, based on existing traditional values. *Agrofor Syst* 14:1–21.
- Allsopp N, Laurent C, Debeaudoin LMC, Samuels MI (2007) Environmental perceptions and practices of livestock keepers on the Namaqualand Commons challenge conventional rangeland management. *J Arid Environ* 70:740–754.
- Smucker TA, Campbell DJ, Olson JM, Wangui EE (2007) Contemporary challenges of participatory field research for land use change analyses: Examples from Kenya. *Field Methods* 19:384–406.
- Van Kerkhoff L, Lebel L (2006) Linking knowledge and action for sustainable development. *Annu Rev Environ Resour* 31:1–33.
- Reason P, Bradbury H (2001) *Handbook of Action Research: Participative Inquiry and Practice* (Sage, London).
- Cash DW, et al. (2003) Knowledge systems for sustainable development. *Proc Natl Acad Sci USA* 100:8086–8091.
- McNie EC (2007) Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. *Environ Sci Policy* 10:17–38.
- Goldman M (2003) Partitioned nature, privileged knowledge: community-based conservation in Tanzania. *Dev Change* 34:833–862.
- Okwi PO, et al. (2007) Spatial determinants of poverty in rural Kenya. *Proc Natl Acad Sci USA* 104:16769–16774.
- Norton-Griffiths M (2003) in *World Parks Congress* (World Parks Congress, Durban, South Africa).
- Thompson DM, Homewood K (2002) Entrepreneurs, elites, and exclusion in Maasailand: Trends in wildlife conservation and pastoralist development. *Hum Ecol* 30:107–138.
- Campbell DJ, Gichohi H, Mwangi A, Chege L (2000) Land use conflict in Kajiado District, Kenya. *Land Use Policy* 17:337–348.
- Coast E (2002) Maasai socioeconomic conditions: A cross-border comparison. *Hum Ecol* 30:79–105.
- Horowitz MM, Little PD (1987) in *Drought and Famine in Africa: Denying Drought a Future*, ed Glantz M (Cambridge Univ Press, Cambridge, UK), pp 59–82.
- Galvin KA, Reid RS, Behnke RH, Hobbs NT, eds (2008) *Fragmentation in Semi-arid and Arid Landscapes: Consequences for Human and Natural Systems* (Springer, Dordrecht, The Netherlands).
- Hobbs NT, et al. (2008) Fragmentation of rangelands: Implications for humans, animals, and landscapes. *Global Environ Change* 18:776–785.
- Defries R, Hansen A, Turner BL, Reid R, Liu J (2007) Land use change around protected areas: Management to balance human needs and ecological function. *Ecol Appl* 17:1031–1038.
- Said MY (2003) Multiscale perspectives of species richness in East Africa. PhD dissertation (International Institute for Geo-Information Science and Earth Observation, Enschede, The Netherlands).
- BurnSilver S, Worden J (2008) in *Fragmentation in Semi-arid and Arid Landscapes: Consequences for Human and Natural Systems*, eds Galvin KA, Reid RS, Behnke RH, Hobbs NT (Springer, Dordrecht, The Netherlands), pp 225–253.
- Lamprey R, Reid RS (2004) Expansion of human settlement in Kenya's Maasai Mara: What future for pastoralism and wildlife? *J Biogeog* 31:997–1032.
- Ogutu JO, Bhola N, Reid R (2005) The effects of pastoralism and protection on the density and distribution of carnivores and their prey in the Mara ecosystem of Kenya. *J Zool* 265:281–293.
- Kaelo D (2007) Human-elephant conflict in pastoral areas north of Masai Mara National Reserve, Kenya. MSc thesis. (Moi Univ, Eldoret, Kenya).
- Norton-Griffiths M, et al. (2008) in *Serengeti III: Human Impacts on Ecosystem Dynamics*, eds Sinclair ARE, Packer C, Mduma SAR, Fryxell JM (Chicago Univ Press, Chicago), pp 379–416.
- Homewood K, Trench P, Kristjansson P (2009) *Staying Maasai? Livelihoods, Conservation and Development in East African Rangelands* (Springer, London).
- Goldman M (2007) Tracking wildebeest, locating knowledge: Maasai and conservation biology understandings of wildebeest behavior in northern Tanzania. *Environ Planning D* 25:307–331.
- Nkedianye D (2003) Testing the attitudinal impact of a conservation tool outside a protected area: The case for the Kitegela Wildlife Conservation Lease Programme for Nairobi National Park. MSc thesis. (Univ of Nairobi, Nairobi, Kenya).
- Trench P, Kiruswa S, Nelson F, Homewood K (2009) in *Staying Maasai? Livelihoods, Conservation and Development in East African Rangelands*, eds Homewood K, Trench P, Kristjansson PK (Springer, London), pp 217–256.
- Reid RS, et al. (2008) in *Fragmentation in Semi-arid and Arid Landscapes: Consequences for Human and Natural Systems*, eds Galvin KA, Reid RS, Behnke RH, Hobbs NT (Springer, Dordrecht, The Netherlands), pp 195–224.
- Nkedianye D, Radeny M, Kristjansson P, Herrero M (2009) in *Staying Maasai? Livelihoods, Conservation and Development in East African Rangelands*, eds Homewood K, Trench P, Kristjansson P (Springer, London), pp 115–150.
- Ottichilo WK, de Leeuw J, Skidmore AK, Prins HHT, Said MY (2000) Population trends of large non-migratory wild herbivores and livestock in the Masai Mara ecosystem, Kenya, between 1977 and 1997. *Afr J Ecol* 38:202–216.
- Homewood K, et al. (2001) Long-term changes in Serengeti-Mara wildebeest and land cover: Pastoralism, population, or policies? *Proc Natl Acad Sci USA* 98:12544–12549.
- Ogutu JO, Piepho H-P, Dublin HT, Bhola N, Reid RS (2009) Dynamics of Mara–Serengeti ungulates in relation to land use changes. *J Zool* 278:1–14.
- Thompson DM, Serneels S, Kaelo D, Trench PC (2009) in *Staying Maasai: Livelihoods, Conservation and Development in East African Rangelands*, eds Homewood K, Kristjansson P, Trench P (Springer, London), pp 77–114.
- Coughenour MB, et al. (1985) Energy extraction and use in a nomadic pastoral ecosystem. *Science* 230:619–625.
- Little MA, Leslie PW (1999) *Turkana Herders of the Dry Savanna* (Oxford Univ Press, Oxford).
- McCabe JT (1990) Turkana pastoralism: A case against the tragedy of the commons. *Hum Ecol* 18:81–103.
- Ellis JE, Galvin KA (1994) Climate patterns and land-use practices in dry zones of Africa. *BioScience* 44:340–349.
- Ellis J, Swift DM (1988) Stability of African pastoral ecosystems: Alternative paradigms and implications for development. *J Range Manage* 41:450–459.
- Ellis JE, Coughenour MB, Swift DM (1993) in *Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Savannas*, eds Behnke RH, Scoones I, Kerven C (Overseas Development Inst, London), pp 31–41.
- Boone RB, Coughenour MB, Galvin KA, Ellis JE (2002) Addressing management questions for Ngorongoro Conservation Area, Tanzania, using the SAVANNA modelling system. *Afr J Ecol* 40:138–150.
- Galvin KA, Boone RB, BurnSilver SB, Thornton PK (2009) in *Wildlife and Society: The Science of Human Dimensions*, eds Manfredo M, Vaske JJ, Brown PJ, Decker DJ, Duke EA (Island Press, Washington D.C.).
- Galvin KA, Thornton PK, de Pinho J, Sutherland J, Boone RB (2006) Integrated modeling and its potential for resolving conflicts between conservation and people in the rangelands of East Africa. *Hum Ecol* 34:155–183.
- Clark WC and Holliday L (2006) Linking knowledge with action for sustainable development. (National Research Council of the National Academies, Washington DC). Available at [www.nap.edu/catalog.php?record\\_id=11652](http://www.nap.edu/catalog.php?record_id=11652).
- Nkedianye D, et al. (2008) in *Joint CID Graduate Student and Research Fellow Working Paper 25 and ILRI Working Paper* (Harvard Univ, Cambridge, MA and International Livestock Research Institute, Nairobi, Kenya).
- International Development Research Centre (2004) *Outcome Mapping: "Those Who Dream Make a Difference"* (International Development Research Centre, Ottawa).
- Boone RB, BurnSilver SB, Thornton PK, Worden JS, Galvin KA (2005) Quantifying declines in livestock due to land subdivision. *Range Ecol Manage* 58:523–532.
- Kristjansson P, et al. (2009) Linking international agricultural research knowledge with action for sustainable development. *Proc Natl Acad Sci USA* 106:5047–5052.
- Walker GB, Daniels SE (2001) *Working through environmental conflicts: The collaborative learning approach*. (Greenwood, Westport, CT).
- Pretty J, Smith D (2004) Social capital in biodiversity conservation and management. *Cons Biol* 18:631–638.