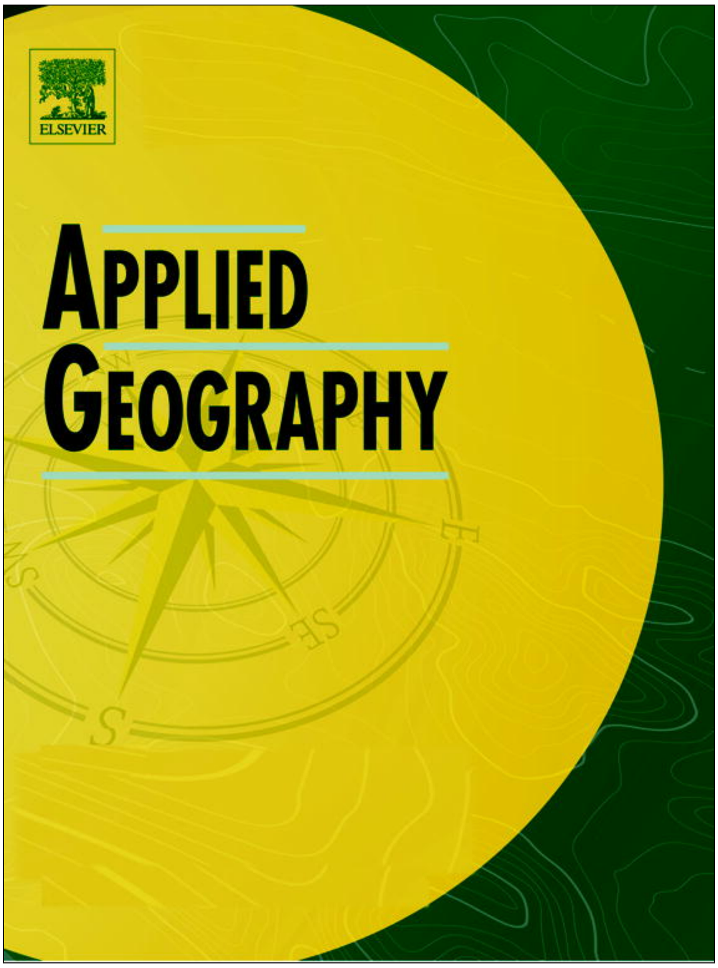

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Applied Geography 39 (2013) 128–139

Contents lists available at SciVerse ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Climate adaptation: Institutional response to environmental constraints, and the need for increased flexibility, participation, and integration of approaches

Stephanie Amaru [a], Netra B. Chhetri [b,*]

[a] Consortium for Science, Policy and Outcomes, Arizona State University, P.O. Box 875603, Tempe, AZ 85287-5603, USA
[b] School of Geographical Sciences and Urban Planning, Consortium for Science, Policy and Outcomes, Arizona State University, P.O. Box 875302, Tempe, AZ 85287-5302, USA

Keywords:
Institutions
Climate adaptation
Case studies
Top–down
Bottom–up

A B S T R A C T

Adaptation to the impacts of climate change is a dynamic process that is shaped by institutional, cultural, and socioeconomic contexts. Efforts to adapt to changing climate may occur on many scales and may be undertaken by a variety of stakeholders and do not occur in institutional vacuum. As globalization has increased the exchange of knowledge across space, a greater number of institutions have become involved in adaptation measures encompassing multiple scales. In order to gain insight into how adaptation might unfold into the future, we investigate the interactions between institutions operating at multiple levels in the innovation of new technologies on demand. From a broad sample of cases, we identify four distinct types of adaptation measures and select one corresponding case representing each type to assess the roles of institutions (and other stakeholders) in innovation. We further identify and discuss two findings that cut across all adaptation measures: (1) the need for widespread participation, flexibility, and integration of stakeholders for quick and effective response, and (2) the need to transfer leadership and responsibility from institutionally led adaptation measures to community based measures so that adaptation is sustained into the future. Together, these findings suggest that the types of adaptation measures implemented primarily from the top–down may not promote local resilience in the long term; likewise, those measures implemented from the bottom–up require some level of collaboration from the top to maximize their effectiveness.

Introduction

Until recently, adaptation – a process by which societies address the consequences of climate change – was a taboo subject in the discussion of global climate policy, where it was viewed as undermining efforts to reduce greenhouse gas emissions (see Pielke, Prins, Rayner, & Sarewitz, 2007). However, the realization that, even in the best-case scenario, emissions reductions can have little effect on social vulnerability to climate impacts over the next several decades has prompted a resurgence of interest in adaptation. This has yielded an increase in methodological frameworks and theoretical approaches to understand and assess vulnerability of society to climate, along with a focus to design appropriate adaptation strategies (Berkhout, 2012; Fresque-Baxter & Armitage, 2012; Fussel & Klein, 2006). Adaptation to the threats posed by climate change is not just a function of the threats themselves, but is shaped by the cultural, institutional, and socioeconomic contexts in which these risks occur (Hinkel, 2011).

Adaptation is an ongoing and dynamic process whereby societies continually respond to changing socioeconomic, technological, and resource regimes. For example, historically agrarian societies have learned to thrive in a wide range of climatic conditions, ranging from extreme cold to hot temperatures and from very dry to humid climates (Easterling, 1996). Variation in climatic resources across space and time has also acted as a source of technological and institutional innovation (Chhetri & Easterling, 2010; Hayami & Ruttan, 1985, p. 506), exhibiting the inherent potential for society to adapt to future climate change. The ability of a system to implement appropriate adaptation strategies is also conditioned by the context of governance and must be supported by existing policies, laws, rules, regulations, programs, and mandates unless the selected strategy is to change a law or process (Moser & Ekstrom, 2010).

Adaptation to climate change also occurs on a variety of scales, with action taken at the local or regional level in an attempt to

* Corresponding author. Tel.: +1 480 727 0747.
E-mail addresses: Stephanie.Amaru@asu.edu (S. Amaru), Netra.Chhetri@asu.edu (N.B. Chhetri).

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http://dx.doi.org/10.1016/j.apgeog.2012.12.006

make adjustments to changes (Klein, Schipper, & Dessai, 2005), and can be undertaken by a range of stakeholders including farmers, public institutions, communities, civil society (NGOs), and private sectors. Some important elements of successful adaptation measures include leadership, resources, information exchange and communication among stakeholders, and compatible views and beliefs. Moreover, monitoring and evaluation mechanisms must be implemented to manage and measure the outcomes of adaptation and changes to the environment (Moser & Ekstrom, 2010). A sustained effort to adapt therefore demands an active engagement of various stakeholders so that location-specific technology is innovated to adapt to climate change.

Macro level adaptation policy may be disconnected from the needs of marginalized communities where location specific adaptation needs exist independently from national and international policies. Local cases of climate adaptation illustrate how intricately power and authority over the global climate change debate has become more decentralized, as other actors such as nongovernmental organizations, firms, experts, international institutions, and individuals take its ownership (Rodima-Taylor, Olwig, & Chhetri, 2012). In light of this broader distribution of power over many types of actors, it is important to investigate the role of institutions in local cases of climate adaptation. An increasing number of studies demonstrate the importance of informal networks of customary institutions of mutual help in climate adaptation. For example, the mutual help among Kuria people of Tanzania involved both customary institutions as well as important innovations (Rodima-Taylor, 2012). Most importantly the adoption of a participatory approach provided the participants an innovative way to manage their livelihoods. While drawing attention to the potential limits of social innovation, Eriksen and Selboe (2012) highlight the close coupling between institutions (formal and informal) and climate adaptation. By examining how villagers in a Norwegian mountain farming community manage the increasing formalization of rural agricultural production through negotiating the traditional networks of collaboration to access equipment and labor, the authors demonstrate the continued dependence of the farmers on informal social relations that help to manage and shape that formalization. A clearly growing number of papers emphasize the need for a policy framework that better accommodates existing informal structures and local collective action.

Following Rodima-Taylor et al. (2012) we argue for the importance of identifying different forms of climate adaptation by considering adaptation as institutional and relational innovation. We argue that institutions operating at multiple scales prepare and mediate responses to climate change while rapidly evolving and adapting to new contexts and demands. We further argue that innovations themselves are human responses to changing contexts and are embedded in social processes. So the consequences of climate event are not the function of its physical characteristics, as Rayner and Malone (2001) contend, they are the function of the way in which society has configured its relations with its resource endowments. So adaptation to climate change will often be mediated through existing social and institutional factors and may be executed by multiple actors, with a range of resources, and have the potential to transcend the bureaucracy and slowness of national and international political debate (Rodima-Taylor, 2012). An understanding of adaptation should therefore draw attention to the broader set of stakeholders, including farmers and their supporting organizations.

In an in-depth analysis of four cases, we present distinct adaptation strategies applied by farmers and their supporting institutions. By analyzing the roles and interactions of "top–down" actors, such as institutions, and "bottom–up" actors, such as local farmers, we hope to gain insight about how the adaptation process may unfold in the future. Most importantly, this study attempts to investigate the capacity and extent to which institutions may be involved in adaptation efforts. In addition to identifying the common threads across all four cases the case studies presented in this study build the argument that research on adaptation to climate change needs a greater emphasis on understanding institutional dynamics across scales. This paper outlines a need for locality-based research on adaptation that would particularly draw on social science perspectives to adapt to climate change.

The next section begins with a discussion of the relationship between institutions and climate adaptation. Section 3 describes the methodology used to select a sample of 45 local adaptation cases for analysis of institutional intervention and adaptation strategy type, and a smaller sample of 4 specific cases for in-depth discussion in Section 4. We then analyze the common threads and lessons that can be learned from these four cases in Section 5, and conclude by restating goals for strengthening future adaptation efforts in Section 6.

Institutions and climate adaptation: a case

Climate change is expected to create new climatic conditions to which society must adapt by taking measures to manage risks or by taking advantage of new opportunities. These adaptation measures vary across communities; partially because of the nature of climate change itself, and partially because of the diversity of social actors (e.g. farmers, community), cultures, and their supporting institutions (Fussel & Klein, 2006), yielding varying capacities to respond to climate change. According to Berkhout (2012), adaptive response is conditioned by the ability of social actors to perceive and evaluate a threat and their capacity to enact a response when needed. These specificities pose an analytical challenge whereby scholars need to analyze the factors that influence variation in adaptation measures (Arnell, 2010; Fresque-Baxter & Armitage, 2012).

Emerging studies suggest that adaptation is in part a function of the flow of knowledge between various institutions and communities (Agrawal, 2008; Upton, 2012), and the capacity for collective action among institutions in the private and public sectors and in civil society (Rodima-Taylor, 2012). The role of institutions in technological innovation in response to climate impacts has not been well studied or understood. While some communities and institutions may use innovative technologies or scientific research to adapt to climate change, other communities may utilize approaches based on managerial or organizational changes, increased communication and collaboration among stakeholders, or informal agricultural experimentation based on experience (Chhetri, Chaudhary, Tiwari, & Yadaw, 2012). In many cases of adaptation in rural communities, institutions are involved in implementing or strengthening the adaptation strategy in some capacity (Eriksen & Selboe, 2012; Olwig, 2012).

In addition to an increase in the mobility of people and flow of information in recent decades, there has been an increase in new ideas and resources that can facilitate adaptation. Local adaptations are thus increasingly coupled with global policy, illustrating the interconnectedness between institutions and actors across scale. Indeed, according to Rodima-Taylor et al. (2012) local response to climate is increasingly embedded in the global response and vice versa. While the institutions operating at the macro level may be able to create an enabling environment for adaptation at the national level, their levels of engagement tend to leave large gaps in adaptive responses at the local level, ignoring important actors in understanding the relationship between climate trends and adaptation outcomes at the local level. According to Crane, Roncolo, and Hoogenboom (2011), individuals (e.g. farmers), local organizations (e.g. farmers groups), and other actors (NGOs) at the local level act as pro-active agents who respond to challenges posed by climate in shorter time scales (e.g. season) and in the long term (e.g. decade). The significance of institutions in facilitating local adaptation is not in question here, but the absence of understanding local dynamics can be a major shortcoming in our ability to design robust adaption plans in response to climate change. This disconnect between actors operating at different scales can be problematic in designing robust adaptation strategies at the local level (Fresque-Baxter & Armitage, 2012).

Although cross-scale linkages are commonly asserted to be important in responding to climate change (Adger, Arnell, & Tompkins, 2005), research on the interrelationships between local and global processes shaping adaptation is still young. According to Adger et al. (2005:80) the "dynamic nature of linkages between levels of governance is not well-understood, and the politics of the construction of scale are often ignored." Research on adaptation to climate change is just the beginning of efforts to recognize the cross-scale dynamic at play. Recent work on the importance of the social aspects of climate change (e.g. Agrawal, 2010; Nielson & Reenberg, 2010; Ribot, 2010) has thus particularly highlighted the interaction between institutions and actors across multiple levels. Institutions may both limit and facilitate local climate adaptation. The roles and responses of institutions in climate adaptation are becoming more intertwined with global policy. As the world becomes increasingly globalized, discourse and ideas travel more readily across scales. National and global institutions may impose policies and programs that inhibit local adaptation, but they may also promote innovation through social and economic resource provision. This may be accomplished with resources including management strategies for livelihoods, knowledge about climate, technical skills, and new organizational frameworks (Rodima-Taylor et al., 2012). Additionally, as climate projections change institutions at all scales have been pushed to reevaluate their roles and purposes (Agrawal, 2010). This paper examines the significance of institutional involvement by analyzing a sample of 45 cases of local climate adaptation during an era of globalization and increased interaction of stakeholders across multiple scales. The following section describes our methodological approach for selecting a sample of cases, conceptualizing institutional intervention, drawing distinctions between different types of adaptation methods, and selecting specific examples for further discussion and analysis.

Methodological approach

This is a bibliometric analysis to identify the role of institutions in climate adaptation. To select and conduct the in depth analysis of the four cases, we first sampled 45 cases of adaptation utilizing several different search queries. First we began with broad search terms and started adding specificity as patterns in types of adaptation strategies began to emerge. The primary search tools utilized in selecting cases were Google Scholar, JSTOR, and publications from development organizations found to frequently surface in web searches of local climate adaptation issues. The sample size of adaptation cases was capped at 45 when further searches began to primarily yield cases that overlapped with those already in the sample or were not materially relevant to the study. The term "climate change" was utilized in our search queries in order to single out cases involving responses to extreme weather events and conditions that may be considered atypical of local regions based on written records of the last century. For example, a region may be considered historically drought-prone or flood-prone, but have only just recently be driven to a tipping-point at which communities must resettle to areas more favorable for agriculture. While authors may not know with certainty whether "tipping-points" and extreme weather events may be attributed to anthropogenic climate change, many cases do attribute these drivers of adaptation measures to be "climate change" in that they represent a departure from the status quo of a region in the context of the past few generations. Disengaged from the debate about the impact of humans on the environment, "climate change" in the broader sense is what poses a challenge to development and provokes a variety of different types of adaptation measures.

Knowing little about how the dataset of 45 adaptation cases would take shape by the end of the selection process, vague search phrases were used to gather an initial set of cases (e.g. "climate adaptation X region," "climate adaptation rural community"). Because our focus was on adaptation method and region, no specific range of years was applied to searches. While some of the cases discussed adaptation methods that may have been used for decades or centuries, all of the sampled cases were focused on modern adaptation efforts. As most of the cases resulting from general searches were concentrated in few regions, such as Asia and Africa, a secondary search sought to pinpoint cases in other regions by searching more specifically by location (e.g. "climate adaptation Y country in region underrepresented in initial dataset"). As certain sources appeared more frequently than others in general searches for climate adaptation strategies, these specific sources were browsed further for additional cases (e.g. *Applied Geography, Global Environmental Change, Institute of Development Studies, Tiempo*). Lastly, as new adaptation strategies surfaced in surveys of different cases, these strategies were entered into the search to see if they were implemented elsewhere in other variations (e.g. "climate adaptation drought resistant crop," "climate adaptation information network"). From these searches, we selected 45 cases from which we could analyze degree of institutional intervention and type of adaptation strategy.

The cases utilized in this study vary in the degree to which formal institutions intervene in climate adaptation measures and in which methods are used to adapt to climate change. For the selected dataset, classifications for institutional intervention and type of adaptation strategy were assigned to each case. Institutional intervention was classified on a scale ranging from mostly "top–down" implementation by institutions, such as IGOs, large NGOs, national governments, and research institutions; to mostly "bottom–up" implementation, by small NGOs, individuals, and local communities. This study considers a strategy implemented by a combination of actors, not heavily weighted toward top–down or bottom–up action, to be "mixed". This simple method of classification helped us to pinpoint the balance of actors spearheading adaptation efforts in a given case.

As there was wide variety among types of adaptation strategies, each type was classified into one of four groups created prior to searching the literature: *science based, technology or information based, experience based, and managerial or organization based*. A *science based* approach is defined as one rooted primarily in formal experimentation in a research-oriented setting, conducted with the intention of contributing to the body of knowledge on agriculture, adaptation, or whatever subject is at hand. *Technology or information based* strategies involve the development or use of technology, information networks, and other infrastructure to meet a practical goal. An *experience based* strategy is defined as a strategy rooted primarily in individual goals and human interactions, and may include educational programs or experimentation through trial-and-error. Lastly, a *managerial* or *organizational* strategy is an adaptation measure that, at its core, is based on the creation or restructuring of programs, resource allocation schemes, or governance. Table 1 details the adaptation measures falling into each category.

A conceptual sense of which types of adaptation strategies would fall into each category of adaptation type was established by brainstorming as many potential adaptation strategies as possible, and then reflecting on their similarities and differences before the sample of cases was selected. The resulting four categories for adaptation approaches are distinguishable based on their required resources, methodologies, goals, and intents. Having constructed this general framework, we took a deductive approach and categorized specific strategies on a case-by-case basis as we collected them. While many cases sampled involve a balance of activities falling into more than one of the aforementioned four categories, each case was classified

Table 1
Descriptions of adaptation measures within each of the four categories.

S #	Measures of adaptation	Description
1	Science based	• Traditional science: experimentation by formal scientific method; done through a credible research institution or scientist; published scientific research
2	Technology or information based	• Information networks: dissemination of information such as climate data; predictive modeling • Increased communication: collaboration among different stakeholders or levels of governance; natural disaster warning systems • Developing infrastructure: implementation of changes to irrigation or agricultural infrastructure
3	Experience based: experimentation or informal communication	• Informal experimentation: trial-and-error, unofficial experimentation by farmers or communities in an attempt to develop effective agricultural techniques • Change of agricultural techniques: implementation of new agricultural methods in an attempt to increase yields or cope with drought (this may be classified as a "2" on Index B if the technique requires use of new technology or infrastructure) • Focus groups or interviews: facilitating experience-based communication within communities to help set developmental goals and develop climate adaptation strategies • Education: teaching communities about agricultural techniques and methods for producing high yields in less favorable climactic conditions; providing individuals with skills and knowledge to pursue alternative livelihoods (this may be classified as a "2" on Index B if the education is intended to teach a community how to use new technology or infrastructure)
4	Managerial and organizational	• Land redistribution or resettlement: changes to the management of land; migration of communities or individuals to places with more favorable environmental conditions for agriculture or with new opportunities to earn livelihoods • Funding: financial aid for development and climate adaptation efforts • Creation of new programs: planning programs to aid in a community's ability to cope with drought and natural disaster, diversify livelihoods, or set future goals • Agenda setting: prioritizing a particular goal or problem in governance or in the development of programs • Diversification of livelihoods: seeking new income-generating activities to compensate for a loss in profits from agriculture as a result of climate change

into a single category based on which adaptation strategy type seemed the most prominent or exerted the most impact. It is worth noting that some adaptation strategies lend themselves to the involvement of certain actors and institutions. However, we must examine the actors involved and the adaptation methods themselves separately, because the two factors may not always be associated with one another. For example, while some adaptation strategies, such as laboratory science or managerial changes, are more likely to be implemented primarily from the top down, this is not always the case. A small NGO might lead laboratory research but still be considered a bottom–up actor based on its scale and its supporters. Likewise, restructuring governance in a local community may involve the transfer of small-scale leadership from one individual to another and thus be considered more "bottom–up" than "top–down".

In order to select cases corresponding to each of the four adaptation types for analysis, we first considered the frequency of specific adaptation measures within each category of adaptation type. For example, if the *technology or information based* category included x cases primarily using climate modeling, $x + 1$ cases primarily involving the adoption of new technologies, and $x + 2$ cases primarily involving development of information or assessment based infrastructure, the latter cases were considered to be the most frequent adaptation measure within the category. Of the smaller samples of cases utilizing the most common adaptation strategy within each category, we selected those cases demonstrating the most detailed discussions of adaptation measures used and institutional involvement. Thus, the four cases selected for further discussion illustrate the most common adaptation strategies within each of the four types and represent the most detailed accounts of adaptation. *Case I* exemplifies a science and technology based adaptation strategy involving the research of drought resistant wheat cultivars. It is an illustration of a top–down approach to adaptation. *Case II* reflects a technological solution to climate adaptation involving development of infrastructure for coastal management and water supply. It is also an example of a top–down approach. Serving as an example of a bottom–up approach to adaptation, *Case III* illustrates the measure of informal experimentation in resource management by farmers at the local level in Burkina-Faso. Lastly, *Case IV* is an example of a top–down, adaptive change in management and organization involving the replacement of traditional seed distribution systems with community-oriented seed fairs in Kenya. The following section includes discussion of each of these cases, with a focus on institutional involvement and adaptation measure used.

Discussion of four cases

Case I: Scientific approaches: Testing rice cultivars in India

This case study is based on a research experiment conducted to develop drought resistant cultivars of rice in Asia. It is based on information presented by Ouk et al. (2006), describing the attempt of a research station to select drought resistant rice genotypes using a drought response index (DRI) to measure plant responses to stressful conditions similar to drought. This case is a top down approach in response to climatic constraints, because scientists in a state-affiliated research institute conducted the DRI research without involvement of individual farmers or the community. The research presented in this case contributes to climate adaptation by examining the extent to which DRI may be used to select parents for drought resistant population development in breeding programs. Growing drought resistant genotypes may help farmers sustain yields during seasons with unfavorable drought conditions.

In Southeast Asia and Eastern India, drought is a major climatic constraint hindering the production of rice. Yield during drought is affected by phenology, drought tolerance, and yield potential. Ouk et al. (2006) posit that genotypes that generate high yields experimentally may not have traits for drought tolerance in actual conditions. If these genotypes are screened only for traits such as potential yield, it is difficult to see if they are actually drought tolerant, because there are differences in crop phenology among genotypes. While this uncertainty can be reduced by grouping certain genotypes into different maturity groups, a more practical way to select for drought tolerance, according to Ouk et al. (2006), is to measure the yields of genotypes under stressful conditions that resemble drought, and represent this information in an index. This provides an integrative measure of the complex traits influencing tolerance to heat and drought conditions (see Terra, de Barros Leal, Rangel, Barros, & dos Santos, 2010; Verulkar et al., 2010).

A DRI was developed for the identification of both genotypes with drought susceptibility and tolerance. The DRI isolates drought tolerance traits and has been used for rice, bean, and chickpea crops. The index is based on yield and also accounts for flowering date and yield variation. The system produces varied results due to the variability in environments in which it is used. This study was conducted to determine whether variability was due to water availability to the genotype or to drought tolerance, and to assess variation in genotype for DRI and consistency under a variety of water stress conditions in a rice-breeding program in Cambodia.

A four-year-long field experiment was conducted at the Cambodian Agricultural Research and Development Institute (CARDI) and at Prey Veng province, which have soil that is physically and chemically poor. Flooded, well watered, and water stressed treatments were applied to paddies with a bund separating each treatment. From 80 genotypes, samples were selected yearly for this experiment and randomly arranged in blocks within the water treatments. When plants were mature, they were harvested and planted, and paddy water tables were weighed. A relative water level (WLrel) was calculated by measuring the variation among treatments in paddy water level (WL). This calculation was used as an index to represent water-deficit and show how much drought reduced yield.

It was found that performance of plants under drought conditions is significantly affected by potential yield. The DRI varied across the genotypes in 7 of the 9 treatments, and there was significant interaction between genotype and environment for DRI. It was also found that DRI genotypic variation may be unrelated to water availability, and that DRI reflects drought tolerance. Additionally, mean grain yield under water stressed (WS) treatments and all genotypes' DRI were found to be positively correlated across all environments (Ouk et al., 2006).

As drought treatments were used to determine DRI of many different genotypes, DRI was relatively consistent across all treatments. This shows that DRI could potentially be used to identify drought tolerant genotypes. Managing drought conditions by draining rainfed paddies allows for the selection of drought tolerant genotypes by farmers (Ouk et al., 2006). High DRI and high grain yield genotypes demonstrated consistent performance across a variety of water environments. As Ouk et al. found that high DRI is related to drought tolerance, selection of high DRI genotypes as parents will aid in the development of more drought tolerant rice varieties. Two high DRI genotypes were identified and used in a Cambodian breeding program after this study was conducted. The DRI will become more valuable as the measure of drought tolerance becomes more developed, and as traits and mechanisms explaining variations are further studied.

The benefit of a *science based* approach such as the experiment conducted by Ouk et al. is that it broadens our knowledge about questions relevant to climate adaptation, such as performance of certain plant genotypes under varying conditions of drought. The findings of experiments can be applied to practical adaptation practices or indices, such as using the drought response index (DRI) to pinpoint genotypes for a breeding program. However, because of the resources and expertise required by scientific research, studies such as this are often so top–down in their implementation that they may yield results that are inaccessible to farmers or irrelevant to local circumstances. Thus, because scientific experiments are often conducted in controlled environments that are removed from local contexts, collaboration efforts and adoption of additional types of adaptation may be required to make a *science based* adaptation measure effective.

Case II: Technical approaches: Enhancing coastal adaptation and water supply management capacities in Fiji

This is an example of a technology or information based approach to adaptation involving the establishment of six projects intended to increase the capabilities of island communities to manage, assess, and monitor coastal adaptation and water supply. The strategy used in this case was implemented from the top down by the University of the South Pacific (USP), as mandated by the Fiji Department of Environment, but focused on engaging local Pacific Island communities from the bottom up. This case falls into the category of a *technology or information based* adaptation measure, because it is based primarily on implementing new infrastructure for assessment and monitoring of resources, and involves an exchange of information between top–down and bottom–up stakeholders. The UN Framework Convention on Climate Change (UNFCCC) recognizes the small island developing countries of the Pacific to be among the countries that will be most impacted by climate change, in the form of weather events such as cyclones. Traditionally, people have adapted to these events using their own mechanisms such as preserving emergency food supplies and building lightweight houses that can be rebuilt easily. Population growth, economic development, urbanization, and other factors have made traditional adaptation methods less viable, and countries such as Fiji do not have the financial resources to adapt to climate change on their own by adopting sophisticated technologies. As a result, it is important to identify and develop strategies suitable for climate adaptation in Pacific communities (Limalevu, Aalsbersberg, Dumaru, & Weir, 2010).

In addition to the University of the South Pacific, the Australian government aided in climate adaptation efforts by contributing to the funding of pilot projects in six communities, and Fiji Provincial Councils helped suggest rural communities having already expressed a need for assistance. The project advisory board selected three sites for coastal management study, and three for water supply. With strong emphasis on implementation and the involvement of bottom–up actors within the community, the project sought to increase community awareness about climate change and adaptation, increase the assessment capacity and ability for local communities to address climate impacts, mainstream and locally internalize adaptation, employ sustainable and discrete measures for adaptation, and to monitor beyond the year of 2009 (Limalevu et al., 2010).

According to Limalevu et al. (2010), the methodology used to assess adaptation based on both climatic and non-climatic factors was developed by the Pacific Centre for Environment and Sustainable Development (PACE-SD) at USP. This method involves a combination of approaches based on community participation and assessment approaches based on rigorous scientific methods. The coastal management plans at each site were discussed in communities with the extra process of considering climatic impacts on Fiji and community resilience. New actions adopted in these community plans included measures such as infilling eroded parts of a river bank, building new structures to protect ecosystem services, planting grass to stabilize the river banks, improving drainage, rainwater harvesting, planting coastal mangroves and trees, and other measures.

Following Limalevu et al. (2010), the assessment of six villages, as described in this case study, led to several conclusions about climate adaptation in Fiji. In order to improve adaptation plans in rural communities, it is necessary to involve all community members, who are best acquainted with their own needs, in planning and in implementation. Additionally, the plan should be consistent with the work program within the community and its structure. It is also important to utilize support from groups outside of the community, utilize expert opinions to avoid costly technical mistakes, and to coordinate with other expert organizations, local government, and NGOs. In order for efforts in coastal and water management to be effective, information about climate adaptation must be shared in a simple and straightforward manner with the community to increase awareness and promote thorough adaptation planning and strategies. Monitoring, evaluation, and maintenance are also necessary to the success of adaptation plans requiring effort and resources into the future. The merit of this type of *technology and information based* case is that the transfer of information between top–down and bottom–up actors and consistent monitoring and maintenance may help build adaptive responsive in communities by enabling them to effectively and flexibly adjust to changes in the system.

Case III. Experience-based approaches: Improved traditional planting pits (zai pits) and FMNR in Burkina Faso

This case describes an experience-based adaptation measure in Burkina Faso involving the evolution of adaptive agricultural practices, including improved traditional pits (zai pits) and farmer managed natural regeneration (FMNR). This case of adaptation can be described as *experience based*, because it originated in contextualized, trial-and-error action from the bottom–up.

Soil and water conservation efforts of the 1960s failed due to a lack of involvement of farmers. For example, foreign aid donors initiated a project in the Yatenga Province of Burkina Faso after a drought that lasted from 1968 to 1973. This project involved use of machinery to build bunds, or "embarkment[s] of stones" built along the land to limit overland flow and lessen erosion (Morgan, 1995), over catchments. This bunding project faced opposition from farmers, who would deliberately destroy or not maintain the earthen bunds (Marchal, 1979). When the Rural Development Fund began new construction of bunds to lessen erosion (Reij, Tappan, & Smale, 2009), farmers resisted these bunds because they interfered with the access of their crops to water by preventing runoff into their fields (Reij, 1983). As the barren Central Plateau spread over more fields, killing important tree species and subjecting more people to drought, families migrated to coastal countries to earn their livelihoods. Between 1975 and 1985, many wells became dry (Reij et al., 2009), yields of millet and sorghum declined dramatically (*see* Dugue, 1989; Matlon, 1990; Matlon & Spencer, 1984), and most farmers faced dramatic food deficits (Broekhuyse, 1983). However, innovative agricultural techniques, such as zai pits, prevailed in Yatenga and helped revive the degraded land. These methods were initiated and developed by farmers themselves, with some preliminary support from nongovernmental technicians.

In Burkina Faso, local farmers' livelihoods are very much impacted by local climate conditions such as the severe drought inhibiting agriculture in the region. In the early 1980s, farmers in the capital of Yatenga began experimenting and innovating techniques "out of despair" (Reij, Tappan, & Belemvire, 2005). The farmers began to plant pits and then innovated them by increasing their diameter and increasing concentrations of moisture and nutrients within the pits. Farmers created grids of pits, adding organic matter to the basins, in an attempt to reclaim their impermeable, degraded farmland (Kaboré & Reij, 2004; Ouedraogo & Sawadogo, 2001). These pits, called "zai pits," improve soil fertility by capturing soil and organic matter from the wind, attract termites which enhance soil nutrients (Ouedraogo & Sawadogo, 2001), increase water retention, and increase the cost-effectiveness of manure and fertilizer application (Kaboré & Reij, 2004). The uses of zai pits vary from farm to farm, ranging from agricultural intensification to reforestation when used in conjunction with sowing the seeds of desired tree species (Reij et al., 2009).

When farmers began to add manure to their zai pits, they experienced increased yields and the unanticipated result of tree growth between rows of crops such as millet and sorghum. These trees were found to further increase crop yields and enhance degraded soil, increasing food security. Scientists refer to the mixture of crops and trees as "farmer-managed natural regeneration" (FMNR), or agro-forestry. As a Malian government in the 1990s passed a law granting farmers ownership of trees on their land, FMNR has become both a legal and inexpensive way to increase yields and enhance the quality of the land. Farmer-managed natural regeneration has since spread throughout the region, as farmers share their knowledge with other farmers, and even with officials visiting from other countries (Hertsgaard, 2011).

FMNR benefits agricultural production by providing shade and bulk, which helps mitigate the effects of heat and wind and drastically reduces the amount of sowing required by farmers. Additionally, leaf litter acts as mulch, which increases the fertility of soil, and fodder may be used to feed livestock and, in emergencies, people. This technology and other simple technologies allow for more water infiltration in the soil and likely contribute to the recharging of once rapidly falling water tables. Additionally, farmers sell wood from the trees they plant in FMNR for cooking, furniture, and construction to diversify their incomes, and also as a source for natural medicine (Hertsgaard, 2011).

FMNR is recognized as one of the most successful and positive environmental transformations in Africa, as an estimated 12.5 million acres of land in the Sahel have been rehabilitated. Farmers themselves manage and "own" the technology, because they possess the experience-based knowledge of the effects of planting trees alongside crops (Reij, 2009). Additionally, in 2005–2006, Nigerian researchers found that FMNR has been significant, extensive, conducive to the soil in the south-central agricultural plain, and farm-based (Adam et al., 2006). After over three decades, farmers continue to dig zai pits without external influence or support, thus demonstrating the strategy's continued success within communities (Reij et al., 2009). Farmers in the 1980s disseminated information about zai techniques in a variety of interactive ways, including providing samples of their zai-cultivated crops, holding market days revolved around the planting pits, beginning "zai schools" to train farmers to rehabilitate land, and utilizing a student–teacher model (Ouedraogo & Sawadogo, 2001). While zai pit techniques were at first implemented in simple ways by farmers scattered across villages, other institutions and organizations on national, local, and international scales enabled diffusion of improved practices by disseminating knowledge, providing capital, and enhancing technical conditions (Reij, 2009).

While FMNR has positively transformed many villages, there are still villages in which the technology is not a viable solution and agriculture continues to depend on fertilizer and monetary inputs (Hertsgaard, 2011). Farmers, donor agencies, and government have made great strides against land degradation and poverty, but most donor agencies have reduced or stopped funding for the rehabilitation of land, which is essential to sustainable agricultural growth, food security, and livelihoods (Reij et al., 2009). The benefit of *experience based* adaptation is that it is directly responsive to local conditions and contexts and may be developed and managed by those implementing the adaptation measure. This may lead to decreased dependence on outside aid in local adaptation efforts. Although farmer managed natural regeneration cannot solve all agricultural and economic problems in Africa, the adaptation measure has demonstrated multiple positive and long-term effects on the environment and on communities.

Case IV. Managerial approaches: Seed shows in Kenya

This case describes a method of adaptation in Kenya arising from managerial and organizational changes initiated by NGOs from the top down, but intended to engage the farming community from the bottom up. In Kenya, agriculture contributes to 26% of the GDP and comprises 60% of export earnings. The most lucrative crops grown in Kenya include sugarcane, coffee, tea, pyrethrum, and maize as a primary food crop. Agricultural productivity has been declining along with life expectancy and infant survivorship. Moreover, HIV/AIDS poses a major health problem in Kenya, and over 50 percent of the country's population is impoverished (Orindi & Ochleng, 2005). Under these economic and social hardships, institutions implemented an effective adaptation strategy by organizing seed fair, with the bottom–up participation of farmers, to manage drought, a serious problem in the dryland areas of Kenya.

In Kenya, the dryland areas have experienced over 15 severe droughts since 1950, leading to major losses of crops and livestock. El Nino flooding has ruined infrastructure, property and crops, increased disease in plants and animals, and killed many people. This has negatively impacted many sectors of the Kenyan economy. Some major environmental threats to Kenya include: sea level rise that might negatively impact tourism and increase poverty and unemployment; precipitation that might ruin infrastructure and homes, increasing dryness of Arid and Semiarid Lands and hindering food production and nutrition; increasing extreme weather events; and increasing mean temperature. As a result of these severe climate conditions exacerbating preexisting economic and social hardships in Kenya, aid and development agencies have attempted to help Kenya by providing the country with seed aid and food aid distributed in many ways, including seed fairs, which give farmers the ability to acquire and maintain seeds. While many assume that these recovery efforts are unsuccessful due to a scarcity of seeds, in actuality, their lack of success is more due to inadequate access to seeds. Farmers in the Tharaka district have stated that a major limitation to food production is a lack of timely access to quality seeds. In times of drought, the government has called upon donor agencies to provide seeds sourced from companies to needy homes via government or administrative institutions to needy households (Orindi & Ochleng, 2005).

Traditional systems of seed relief buy and distribute seeds following institutional and government structures, with seeds stored in local government offices until tenders bid on them and commercial seed companies distribute them later. This system has hindered the ability of communities to recover after drought by enabling seed recipients and communities to be passive and nonparticipatory. This approach frequently ends in poor crop performance, as farmers plant cereal grains that should not be planted (Omanga, 2002). The seeds that are appropriate local varieties are not available to commercial seed companies, so relief agencies instead buy "improved" varieties that local farmers do not like and that may not be adapted to certain communities. The standard seed types provided by seed companies cannot always meet the diverse needs of farmers operating under difficult socio-economic and ecological conditions. Usually, farmers rely on local seeds or seeds from previous seasons for high quality seeds that will lead to long-term productivity in dryland areas. However, under traditional systems of seed relief, aid agencies "misdiagnose" inaccessibility to seeds with scarcity of seeds, and resource poor farmers don't have access to the seeds they need because they are given inappropriate seeds at inappropriate times during institutional interventions. In this system, affected households and communities are passive, as government and NGOs control and distribute these seeds and hinder these communities with their decisions rather than helping them (Orindi & Ochleng, 2005).

In 2002, the Global Environment Facility (GEF) enabled Kenya to communicate its commitment to climate change issues to the UNFCCC. Multiple international aid and development institutions have helped research climate change in Kenya. Kenya's National Environment Authority (NEMAS), working under the Ministry of Environment and Natural Resources, has governed all of the country's climate change related activities by working with other national ministries and departments. Government and development partners view assisting Kenya with both food and seed provision to be a superior approach than simply providing food to households affected by climate change, because it could lead to long-term improvements in resilience and agriculture (Orindi & Ochleng, 2005).

After the Kenyan government requested seed aid from donor agencies during a severe 2-year drought in 2000, the government and many NGOs sourced seed administratively from seed companies to households. Other organizations, including the Catholic Relief Services (CRS) and the Food and Agricultural Organization (FAO), attempted a new approach: seed fairs and vouchers to distribute seed over seven districts. The Seed Voucher and Fair system, or SV&F, was implemented by CRS to promote crop technologies to help with drought tolerance and to promote information sharing about local seeds, which were used by about 90% of Kenyan farmers. Seed shows have helped the community by providing a market for local seeds, enabling seed display for farmers, enabling access to choice of seeds of needed crop varieties, helping pinpoint beneficiaries, improving local economies through local sales, exposing farmers to new types of crops, enabling information sharing, and promoting quick distribution of seeds. Additionally, seed shows helped poor farmers by providing alternatives to money for seed purchase, with options such as loans, trading for labor, sharecropping contracts, and small gifts. SV&F is therefore not only an emergency response measure, but also a measure to recover from drought (Orindi & Ochleng, 2005). Preparation for seed fairs includes determining the location and date of the event, finding exhibitors, identifying judges, identifying those households who need seeds through direct participation, and distributing vouchers. Seed fairs are planned such that farmers and companies can exhibit seeds a few weeks prior to projected rainfall so that seeds will be planted at an opportune time (CRS, ODI, & ICRISAT, 2002). Seed fairs have successfully provided quality seeds and information to farmers faster and at a lower cost than commercial seed companies, and the system is now used for emergency seed relief in a variety of areas (e.g. Uganda and Sudan). These fairs are flexible, inexpensive, and better-suited adaptive systems than blanket seed distribution. Additionally, SV&F systems have promoted diversification of communities' crops, which will help protect against total crop failure in cases of extreme climatic events (Orindi & Ochleng, 2005).

Because the SV&F system may be very decentralized, it is more effective than traditional seed distribution as local conditions may shape which crop varieties are chosen for adaptation (Sperling, 2002). Seed fairs enable farmers to share their agricultural experiences, consult with other farmers about selecting seeds, and increase communication with government agricultural teams. Additionally, because the seed fair strategy promotes use of the community's unique seed resources and established adaptation measures rather than use of hybrid seeds farmers may not know how to properly grow, SV&F promotes biodiversity in rural communities. This biodiversity may serve as "insurance" against failure of all crops when there are harsh environmental conditions such as drought (Orindi & Ochleng, 2005).

Seed fairs have proven to be successful and demonstrate the resilience of local seed systems, as seed supply has been adequately maintained through these fairs despite consecutive crop failures. As local sources were able to supply enough seeds during an extensive drought, it is clear that local supplies should be the primary focus in responding to the stresses of climate change. Because seed fairs are very participatory, even the most needy communities and families attain access to seeds in the seed fair system.

A benefit of a *managerial or organization based* adaptation measure such as the SV&F system is that it may not require many resources beyond a restructuring of leadership or relations among actors. Additionally, seed fairs have created an opportunity to bridge communication between government from the top down and farmers from the bottom up, as institutions such as the Kenyan Agricultural Research Institute (KARI) and the Kenya Plant Health Inspectorate Services (KEPHIS) have been more able to reach out to farmers and educate them. To improve the SV&F system, better organization and more publicity is required for broadening the scope of the program. Local institutions and resources are vital to capacity building and to providing resources to those who need them most. Seed fairs have been shown to be more successful than formal seed aid systems because they are less expensive, faster, more likely to reach the needy, promote equity, and strengthen long term coping strategies. Additionally, informal seed fairs maintain crop diversity and provide market incentives for traditional seed growers. The authors of this case study call for increased participation of government institutions and national seed banks, who should both preserve local varieties and introduce new varieties that may be better adapted to drought and changing climate conditions (Orindi & Ochleng, 2005).

Analysis of common threads across the cases

That growing recognition of the role of multiple stakeholders to mediate local climate adaptation has drawn attention to the institutions. However, it frequently remains challenging to account for the growing diversity of institutions and their multi-scale connectedness. For example, by treating communities as homogenous unit bounded by norms and values, the community-based approaches to climate adaptation often obscures the fact that adaptation, especially to date, is a dynamic process, involving a multitude of complex social actors with specific interests and agendas. The four distinct cases chosen for this study represent approaches to adaptation involving a variety of different methods and stakeholders. Although the adaptation methods, institutional involvement, and other circumstances vary greatly among all cases, there are common observations and goals that may apply across cases.

In an attempt to synthesize the analyses of all four types of case studies and extract recommendations that may be applied to all types of future climate adaptation efforts, this study identifies two common features across all four types of climate adaptation that pertain to institutional intervention and may be integral to future success: (1) the need for widespread participation, flexibility, and integration of top–down and bottom–up stakeholders for effectiveness, and (2) the need for a transfer of leadership and responsibility from institutions to farmers and individuals in order to sustain the effectiveness of adaptation measures into the future with less dependence on distant institutions. An in-depth discussion of the four cases selected for this study demonstrates that these two findings may serve as valuable goals for adaptation in the future across a variety of contexts.

The need for widespread participation, flexibility, and integration of multiple stakeholders

Although adaptation efforts are context-specific in nature and entail knowledge that is specific to location, they impact a range of different stakeholders. It follows that broadly including many actors in adaptation strategies "has both ethical and practical value" (Few, Brown, & Tompkins, 2007). The collaboration of multiple stakeholders may help address the future goals and present deficiencies of different kinds of adaptation strategies. Moreover, collaboration at multiple levels helps enable adaptive comanagement systems, which allow for dynamic and flexible problem solving and responses to change (Folke, Hahn, Olsson, & Norberg, 2005).

Actors involved in climate adaptation efforts, may range from individuals, to different scales of government and firms, to international agencies. Some adaptation measures are simple operational decisions, but others take the form of policy intended to build adaptive capacity (Adger, Brooks, Bentham, Agnew, & Eriksen, 2004). While a farmer or community may only be interested in immediate operational adaptation out of necessity, institutions such as seed companies and governments are likely be more interested in long-term goals. A farmer's method for climate adaptation may be more locally contextualized so as to preserve his livelihood, whereas a larger organization's method may broadly encompass economic, social, political, and resource considerations. The activities of these very different stakeholders overlap, so climate adaptation cannot be focused solely on top–down or bottom–up adaptation. Because unintentional adaptation by individuals may interfere with the effectiveness of the intentional adaptation efforts executed by institutions on a broader scale, cooperation and integration of adaptive activities are necessary among stakeholders and across sectors (Adger et al., 2004).

A reason to integrate top–down and bottom–up stakeholders is to enable the benefit of shared resources, information, and aspirations. While some successful climate adaptation measures may not require scientific or technical knowledge, integrating top–down and bottom–up actors may help communicate and deliver the benefits of science and technology to communities with adaptation measures rooted in bottom–up action. For example, the presence of companies that sell seeds from drought-resistant seed breeding companies at seed fairs could enrich the selection of seeds sold at seed fairs by collaborating with local farmers. An initiative requiring or incentivizing laboratory scientists to observe and communicate with rural farmers to supplement their research on adaptable crop genotypes could promote the development of seeds that are more appropriate for the specific environments and agricultural techniques of rural communities. A balance of a variety of actors with different roles and strengths may compensate for the shortcomings of a program that is exclusively top–down (e.g. DRI research in Case I) and science-based or exclusively bottom–up. Additionally, polycentric institutional arrangements uniting actors at different scales can help bolster adaptive governance, as local and national institutions "gain strength" from the support of institutions operating at the regional and global scale (Folke et al., 2005).

In some cases, for an individual to benefit from a climate adaptation effort, others must support and invest in adaptation efforts as well (Adger et al., 2004). For example, the seed fairs described in Case IV (Kenya) would not have led to successful outcomes had entire communities not become actively involved in the exchange of seeds, monetary incentives, and information. Participation by many farmers in the community challenged the traditional seed distribution system that had previously failed to serve as an effective adaptation measure. In other cases, individuals might be able to gain benefits from adaptation efforts without dependence on the intervention of outside institutions or changes in policy, but only if the adaptive activity is permitted by the regulatory framework in that society (Adger et al., 2004). This is apparent in Case III (Burkina Faso), which involved the implementation of zai pits and FMNR by individuals from the bottom up. While the widespread use of FMNR did not require the intervention, resources, or expertise of institutions, this practice would not have been possible had the Malian government not passed a law allowing farmers legal ownership of trees. Similarly, had Kenya not communicated its commitment to climate change issues to the UNFCCC, it might not have received as much attention or support from the Food and Agricultural Organization or the Catholic Relief Service. Lack of incorporation into the UNFCCC network might have therefore constrained the evolution of traditional seed distribution into seed fairs in Kenyan communities. These examples illustrate the need for widespread participation of both individuals and institutions, and regulatory flexibility in rural climate adaptation efforts.

Another important element that was present in these case studies was a need for the integration of and cooperation among stakeholders at multiple scales, even in adaptation efforts that appear to be strongly top–down or bottom–up in their execution. For example, in Case III (Burkina Faso), zai pits and FNMR practices were developed independently by farmers in Africa. However, the success of this case in reviving so much of the degraded lands in the Sahel can be largely attributed to the continued spread of these practices. This was enabled on the large scale by the influence of overseas governments and NGOs, which may take part in promoting policy changes in Africa or encourage the sharing of grassroots information. Additionally, the spread of FMNR would not have been possible without the top–down influence of the permissive regulatory framework established by the Malian government in the 1990s.

In contrast, Case I (Cambodia) demonstrates an adaptation strategy that is lacking in integration of stakeholders. In Case I, scientists tested the ability of a drought response index (DRI) to serve as a measure of drought tolerance across different crop genotypes. While the genotypes identified as high DRI were used in a Cambodian breeding program, the research represented in this case study was performed without involvement of rural farmers and communities directly effected by drought. A breeding program may work toward the improvement of crops growing under certain broad conditions such as drought stresses, but developments may not be accessible to rural communities or appropriate for a community's specific environmental or socioeconomic context without direct involvement of rural farmers. The shortcoming of this exclusively top–down approach is demonstrated by the weaknesses of traditional seed distribution systems as described in Case IV (Kenya). If researchers and communities collaborate and use the DRI to select for the most drought resistant genotype of those crops that may be grown in a certain area, this might increase communities' capacity to adapt to drought conditions. Use of DRI could help communities expedite the process of adaptation to changes in climate by helping them quickly select the most drought-resistant genotypes to plant rather than leaving farmers to select for crops by trial-and-error while losing yields.

Cases II (Fiji) and IV (Kenya), while initiated and implemented from the top–down, both demonstrate the benefit of adopting a balance of top–down and bottom–up actors in their continued executions. Case II was implemented by the Fiji government and the University of the South Pacific, but it directly involved community members, whose participation and education were vital to the mission of the program. Additionally, leaders of the project cited an increase in cooperation among governments, NGOs, community members, and other stakeholders as a continued goal. In Case IV, the status quo prior to the establishment of seed fairs was a passive distribution system of inappropriate seeds by seed companies. While the SV&F program in Kenya was founded upon the initiative and creativity of the FAO and the Catholic Relief Service, the program also would not have been possible without the thorough participation of farmers in the community. This participation is what provided the distribution of seeds and knowledge required to stimulate a market for local seeds. The SV&F program might be further enriched by collaboration with researchers investigating drought-resistant genotypes or seed breeding organizations, as this could increase the robustness of the local seed market and increase the incentive for those developing new crop genotypes to take local contexts into account. As different actors fill different niches of knowledge and call for different aspirations in adaptation (Few et al., 2007), adaptation efforts may benefit greatly from increased collaboration and communication among government, local institutions, communities, and seed companies.

If we examine the potential shortcomings of all four of the cases we have discussed, it is clear that deficiencies in adaptation efforts spearheaded by one type of actor (e.g. top–down) may be addressed by the increased involvement of another type of actor (e.g. bottom–up):

1. *Science based*: Controlled research experiments conducted by researchers (top–down actors) may not be effective, because they are limited to controlled environments that are removed from specific, local contexts. This may be addressed through collaboration with seed companies and farmers in local areas of interest (mixed/bottom–up actors).
2. *Technology or information based*: The governments or research institutions (top–down actors) implementing adaptation efforts involving continued monitoring, management, or assessment may not have the resources to sustain a project into the future. This may be addressed by efforts to train, educate, and collaborate with local organizations, leaders and citizens (mixed/bottom up actors).
3. *Experience based*: Adaptation efforts, such as agricultural practices arising from trial-and-error at the individual level (bottom–up actors), may be geographically limited if actors do not have the ability or incentive to communicate their practices to other communities. This may be addressed by efforts of regional organizations or outside institutions (mixed/top–down actors) to increase communication among local leaders or create educational programs.
4. *Managerial or organizational*: An organizational change to seed distribution such as the implementation of market-based seed fairs by NGOs (top–down actors) will not help distribute seeds if there is too little participation within the community. This may be addressed by giving farmers and seed companies (bottom–up/mixed actors) notice of the event, making participation inexpensive and convenient, and incentivizing the exchange of information and goods.

As we think about the strengths and weaknesses of each case of adaptation, it is important to recognize that each of the four adaptation "types" includes elements of the other adaptation types as well. For example, while seed shows in Kenya represent a successful *managerial or organizational* adaptation strategy in this study, the introduction of drought resistant genotypes is science based, the sharing of information among stakeholders at seed fairs is information based, and adjusting seed exchange according to local market demands and immediate environmental conditions is experience based. While research using a drought response index (DRI) to identify drought resistant rice cultivars is primarily *science* based, its use by seed breeding programs can be classified as technical or information based, as the fruits of the experiment are applied to the technology of seed breeding. Although the Ouk et al. experiment did not encompass experience based or managerial or organizational measures, consideration of farmers' experiences of local conditions and collaboration with local organizations would have strengthened the success of this case of adaptation. The program to enhance coastal adaptation and water supply management capacities in Fiji may have been primarily *technical* in nature due to its focus on assessment of local resources, but its assessment methods are based on rigorous scientific methods, its employment of local perspectives is experience based, and its focus on giving the community the tools and knowledge to lead future adaptation efforts may be considered managerial and organizational based. The development of zai pits and FMNR in Burkina Faso is primarily *experience* based, but its widespread success is largely due to managerial and organizational efforts to spread the practice to other communities, and could further be strengthened by science based and technology based efforts to develop or discover tree cultivars and fertilizers best suited for these practices. Thus, while each of the four cases discussed in this study fit best into a certain adaptation category, these categories are not mutually exclusive and should be utilized together for success.

The potential for future success with less dependence on outside institutions

The discussion of institutional roles in four rural climate adaptation cases reveals that the involvement of many different types of institutions may be vital to the success of adaptation measures. Institutions provide resources and expertise to which rural communities do not immediately have access. Despite the importance of institutions in adaptation, it is important to consider the longevity, context, and scale of climate adaptation measures. Intensifying agriculture and obtaining livelihoods in the face of climate change entails improvements to and investment in soil, water, and agroforestry (Reij, 2009). As most donor agencies have limited or ceased funding for land rehabilitation, it is important to consider the ways in which individual farmers can rehabilitate land from the bottom up, without as much need for continued institutional intervention or aid. For this reason, the success and widespread dissemination of farmer-managed natural regeneration and use of zai pits serves as a valuable lesson for donors and farmers alike. In the 1980s, no one would have conceived of once degraded lands in the Sahel becoming dense with trees and people after such a descent into drought, poverty, "invisibility" to government and donors, and despair (Reij, 2009). Because landowners manage and maintain FMNR themselves, outside institutions are not required to fund recurrent expenses. Additionally, changes to agricultural management such as FNMR are much less expensive than subsidization of fertilizer and other strategies requiring institutional involvement (Reij, 2009).

The success of zai pits and FMNR in case III demonstrates that "barefoot" or informal science can be as important as traditional science in rural communities, as the most successful innovations may begin as simple and inexpensive changes to existing, local practices (Reij, 2009). This informal experimentation and innovation may be useful for climate adaptation in communities that are overlooked by government and donor agencies, as institutional intervention is not required at the small scale. Case III also demonstrates that a single idea may act as a catalyst for more widespread innovation, as farmers simultaneously tinker with a technique and explore changes and synergies of environmental, agricultural, and economic components of the system. Additionally, this case shows that a widely adopted technology or technique should be flexible and quickly adaptable for application under a variety of different environmental, economic, and social conditions and needs (Reij et al., 2009). The ability of farmers to innovate at the local scale while immersed in the context of their communities' complex needs is an adaptive mechanism that prevails with or without institutions, monetary aid, or complex technology. While Case III is appealing because it does not require many resources or depend upon institutional intervention, it is important to recognize that institutional and organizational innovations were vital to the success of FNMR on the large scale. Promotion of local leadership and dissemination of information is what led to more significant environmental and economic improvements in many communities. A multitude of models were used to diffuse the practice, demonstrating flexibility and cooperation. Additionally, the government played an important role in public education, supporting initiatives led by farmers, and supporting legal frameworks that provide rights that are vital to farmers (Reij et al., 2009). Thus, even a case implemented from the bottom—up, at the level of the individual farmer or community, might require institutional support for significant success on a larger scale.

While Case II (Fiji) and Case IV (Kenya) were both adaptation efforts initiated from the top—down, their objectives and characteristics are such that efforts can continue into the future without dependence on institutions. This is apparent in both the missions founding these cases and in the resources required to sustain these adaptation efforts into the future. In Case II, the project intended to bring about the following results in each of the six targeted communities: increased awareness within the community about climate change and climate adaptation; increased capacity to assess and act in response to the impacts of climate change and adapt locally; internalizing and mainstreaming climate adaptation at the level of the community; implementing measurable and sustainable adaptation measures; and monitoring adaptively into the future (Limalevu, 2010). These goals alone demonstrate the intention of those executing the project to enable each community to continue climate adaptation without dependence on institutions. Additionally, the project involved the community not by simply teaching information about adaptive measures, but by ensuring that the community gained experience implementing these measures and would take ownership of the adaptation process (Limalevu, 2010). While the community is supposed to gain the experience to continue the process of adaptation on its own, outside support, analysis, and recommendations from experts may be vital to continued adaptation efforts involving technical information (Limalevu, 2010). The community might depend on outside NGOs or experts to fulfill this need, but that does not mean that the community cannot still be in control of the process. Local leadership may influence even the work of those providing technical information from outside of the community by choosing which experts and organizations to involve, maintaining relationships with these experts, and understanding which expert services or advice may be needed in a given situation.

In Case IV, seed shows in Kenya were initially implemented by Catholic Resource Services and other collaborators, such as the Food and Agricultural Organization (FAO) and local dioceses. As opposed to traditional seed distribution systems, seed fairs enabled the opportunity for farmers to show their seeds and to access seeds of the varieties they need, in addition to other benefits such as increasing communication among farmers and other stakeholders. Seed fairs require some complex organization, as judges, exhibitors, and needy households must be identified and involved. A venue must be determined, a date a few weeks prior to rainfall must be set, and vouchers must be distributed to needy households prior to the seed fair. While seed fairs may involve research organizations and require coordination, publicity, and communication among different participants, they are fast and inexpensive (Orindi & Ochleng, 2005). The strengths of the seed fair system are intended to benefit the community in a sustainable manner by promoting the exchange of seeds, incentives, and information. If a protocol for organizing seed fairs is streamlined by local leadership and relationships with local seed companies are maintained, seed fairs could potentially be organized locally without being so dependent on the intervention of outside organizations or institutions. In fact, the SV&F system may even perform more efficiently without any institutional intervention (Orindi & Ochleng, 2005).

The SV&F system is considered to be more cost effective and less bureaucratic than traditional seed distribution systems, partly because it places much of the responsibility on farmers to make their own arrangements to participate in a locally-based seed fair rather than farmers waiting for slow or inefficient distribution from government (Orindi & Ochleng, 2005). The SV&F system is intended to develop local capacities, contain assistance within the affected area, and develop local institutions. The seeds sold in seed fairs are local and remain within the system, as local traders buy seeds during harvest time from households and then sell them to farmers to be planted later. This system of replanting improves seeds over time, gives them a market through which they can be exchanged, and keeps seeds in areas to which they are better suited than commercial seeds (Orindi & Ochleng, 2005). As agricultural teams associated with the government take the opportunity to use seed fairs to discuss soil conservation, drought management, and other issues with farmers, knowledge becomes more widespread in the community and increases the capacity of the community to deal with these issues independently (Orindi & Ochleng, 2005). The continued implementation of seed fairs may perpetuate this positive relationship between government and farmers, and the participatory nature of the system may give the community the power to determine how and to what extent a community organizes its own seed fairs without as much dependence on institutional assistance.

Conclusion

As climate change continues to impact rural communities by threatening agricultural practices, productivity, and livelihoods, there is an increasing need to implement climate adaptation strategies more efficiently and effectively. Surveying and analyzing climate adaptation case studies has revealed the variation among climate adaptation strategies, in terms of adaptation measures, which actors are involved, and degree of institutional intervention. Analyzing four exemplary case studies has helped to identify common strengths, shortcomings, and requirements for future sustainability and improvement.

Some common goals that apply to case studies across the spectrum include: (1) widespread participation, flexibility, and integration of stakeholders, and (2) sustainable success into the future with less dependence on institutional intervention. These goals suggest that those cases implemented from the top–down require the involvement of some bottom–up actors for continued success, and those implemented from the bottom–up require the involvement of some top–down actors for optimal effectiveness. Additionally, the goal of including a wider variety of actors may help extend the benefits of resources such as science and technology to those communities that have not had access to the aid of outside institutions. This study reveals that, while cases of climate adaptation differ significantly in terms of institutional involvement and strategy used, adaptation efforts may be strengthened by increasing participation of a variety of actors, increasing flexibility, considering local contexts, improving sustainability, and decreasing dependence on outside intervention.

Acknowledgments

We would like express gratitude to the ASU/NASA Space Grant Program for providing funding and support for this project. We also would like to recognize and thank Daniel Sarewitz and Mary Jane Parmentier for their constructive support.

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