RESEARCH ARTICLE

Climate change adaptation to escape the poverty trap: role of the private sector

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Abstract. Climate change adaptation and poverty alleviation call for an integrated strategy, because poverty exacerbates the vulnerability to climate change and vice versa. The private sector, which has traditionally been excluded from adaptation planning, may contribute greatly to the development of an integrated strategy. Here, we identify the differences in adaptation trajectories between the private sector and communities by proposing a conceptual framework and report on a case study in a dryland area of China, where the private sector led a successful adaptation and poverty alleviation project. We found that their win–win strategy achieved both climate change adaptation and development, thereby helping a disadvantaged community to escape the poverty trap and achieve sustainable development. The private sector played a dominant role in the response, as this sector can adapt in ways that are not possible for governments or communities. We suggest that participatory governance that includes private-sector stakeholders is more likely to achieve sustainable development.

Key words: *adaptation; climate change; framework; poverty alleviation; private sector.*

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Climate change has become one of humanity's greatest challenges, as it has caused profound impacts on both natural and human systems. This is especially true in rural and sensitive areas (e.g., drylands, coastland, mountainous areas), where the residents typically suffer from poverty, which greatly decreases their ability to respond to the changes. The public sector (mainly governments and international organizations) typically leads governance efforts for adaptation in most parts of the world by supporting economic diversification and by providing information, policy and legal frameworks, and financial support. However, public interventions generally confront many barriers in rural and sensitive regions, such as a lack of financial or human resources to support project planning and implementation, and this is especially true in impoverished communities (IPCC 2014). Although growing public-sector involvement is an encouraging trend, mitigation efforts—which are more relevant in international climate negotiations and macroeconomic planning—have been given much more attention than adaptation efforts, which are more immediately practical and effective, particularly as they affect the private sector's response to climate change.

As the impact of the extreme climatic events on the private sector has become increasingly obvious, some studies of the private sector's adaptation to the impacts of climate change are beginning to emerge, but they remain rare, particularly those involving small- and medium-sized companies (Goodall 2008, UNEP 2012, Linnenluecke et al. 2013, Surminski 2013). The private sector's significant contributions to climate adaptation have long been underestimated, especially in impoverished communities, which have fewer resources and options to combat the damage caused by climate change. Private-sector actors are attractive participants in partnerships with public-sector actors, which were traditionally seen as the principal agents in implementing local adaptation responses (Tompkins and Eakin 2012). This is because the private sector faces different constraints than the public sector, has access to different resources, and often has greater knowledge of local conditions.

In light of the overwhelming adverse impacts of climate change, it is becoming increasingly urgent to involve all possible stakeholders in increasing a community's adaptive capacity. Beyond seeking benefits for the private sector, our primary goal in this study was to explicitly document the role of the private sector in climate change

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adaptation, especially in terms of catalyzing new ways of thinking about the interactions among stakeholders to achieve climate change adaptation and poverty alleviation in marginalized and climate-sensitive communities. We see the private sector as a key actor that should be involved in choosing and implementing adaptations to climate change, and in helping the society in which the private sector is embedded to achieve sustainable development—that is, our goal is to seek a win–win solution to climate adaptation challenges.

The lack of insights into the private sector's role in adaptation and its benefits to society due to a lack of empirical studies has left a huge gap in our knowledge. Here, we describe an empirical case study in which the private sector led a successful climate change adaptation project in an arid region of China. We then synthesize the relationship between development and adaptation to climate change and compare the pros and cons of adaptation projects led by the community, by government, and by the private sector to reveal the importance of appropriate participatory governance.

Obstacles to Adaptation in Disadvantaged Regions

Poverty has been widely recognized as a key factor that increases the vulnerability to climate change, and vice versa (Bohle et al. 1994, Adger et al. 2003, Eriksen and O'Brien 2007, IPCC 2007). Climate variability exacerbates the poverty trap, which represents the group of self-reinforcing mechanisms (e.g., inefficient state governance, poor education, market failures) that create significant barriers to escaping poverty (Leichenko and Silva 2014). Many of the critical pillars of poverty alleviation, including investment in infrastructure to improve security, in road and transportation networks, in market access, and in access to potable water and energy sources, may be compromised by climate change (Arndt et al. 2012, Block and Strzepek 2011; Gao et al. 2014). For example, the World Bank estimates that up to 40% of the development projects that have been financed by foreign assistance, including development loans, are vulnerable to climate change (Ayers et al. 2014). Mani et al. (2013) note that poverty can affect the cognitive abilities of the poor, thereby undermining their financial decision-making ability and producing suboptimal decisions that deepen their poverty; malnutrition and a preoccupation with their severe budgetary constraints reduce the mental resources available to deal with other challenges.

The relationship between climate change and poverty has an important implication: Increasing the adaptive capacity of a community may be necessary before it can attempt to escape the poverty trap. For example, increasing household income may reduce the risk of famine in case of drought, and rising household education levels may make a household more likely to benefit from early warnings (Adger et al. 2011, Gao et al. 2013, Eakin et al. 2014). The interactions among limited financial and human resources, limited integration or coordination of governance, and uncertainties about projected impacts, as well as the limited tools available to monitor adaptation effectiveness, suggest that the effects of climate change will be much stronger in the world's poorer regions (IPCC 2014).

Households and communities tend to bear risk locally and rely more heavily on local environmental knowledge, including informal norms and rules (Eakin et al. 2014). They generally disperse or reduce the risk of environmental change by means of measures such as diversification of their crop species, adjustment of cultivation and tillage regimes (e.g., changing the sowing time), and lifestyle adjustments, as in the case of nomadic Mongolian herders, who adapt to their region's harsh environment by migrating to new pastures when current pastures are adversely affected by drought and other climatic disasters (Wang et al. 2013, Chen et al. 2014). As another example, rural residents throughout the developing world have adopted flexible labor strategies and crop diversification, and rely on kinship networks to cope with drought (Mertz et al. 2011). Although their adaptation measures offer some degree of resilience, they may be insufficient to cope with the accelerated environmental change that is now occurring (Valdivia et al. 2010).

Engineering and technological options are commonly implemented as adaptive responses (e.g., irrigation facilities, wells, dams), and because of their cost, these usually involve public-sector investments. The public sector often focuses on infrastructure improvements, enhancing early warning systems, public awareness campaigns, and technological solutions to climatic threats (Eakin and Patt 2011, Bierbaum et al. 2013, Moss et al. 2013). However, these responses are increasingly costly and create a huge financial burden for the public sector, especially in impoverished regions, thereby limiting the number of projects that can be undertaken and decreasing the chance of successful adaptation (Stern 2007). The private sector becomes a valuable ally in such projects, as it faces different constraints and has financial and other resources that are unavailable to the public sector, as well as having an economic stake in a project's success.

Socioeconomic development and climate change adaptation should be integrated to achieve both social and ecological progress (Cao et al. 2009), but they are typically developed in isolation (Fankhauser and Burton 2011, Smith et al. 2011). Poverty alleviation programs concentrate on economic growth and livelihood improvement, but rarely consider the impact of climate change on their success. Planned adaptation led by the public sector is likely to follow the "command and control" path, which often fails to consider a community's unique needs due to inadequate knowledge of the local context, and results in excessively slow responses due to bureaucratic inertia.

Incentives for Climate Change Adaptation that Includes the Private Sector

The contribution of private-sector actors to climate change adaptation has long been underestimated. However, we are among the growing number of researchers who believe that the private sector cannot be isolated from the surrounding community and environment, which implies that the private sector has a strong motivation to help its community so that neither suffers unnecessarily from climate change. For example, a private-sector actor may contribute to adaptation by building a road network between their factory and the places their workers live, thereby making it easier for workers to reach the workplace. This is likely to have other benefits, such as helping farmers to bring their produce to markets along the road.

To support this study, we have proposed a framework for private-sector participation (Fig. 1). The private sector can take a variety of measures (e.g., infrastructure improvement) to increase its adaptive capacity and can thereby reduce the potential risks from climate change and maintain or even increase productivity by distributing the hazards among available coping mechanisms. By ensuring its own productivity, the private sector may become more profitable and more able to improve management of the resources that their business exploits. The local community can also benefit from these measures if they can share the new or improved infrastructure, as in the case of road networks, irrigation systems, and weather forecasts that provide early warning of drought or flooding disasters. An improved road infrastructure may provide better access to markets and re-orient the community toward exploiting these markets. If this approach increases the demand for a company's products, this will also increase employment opportunities, thereby alleviating poverty and promoting socioeconomic development.

Knowledge exchange between the private sector and communities can help both to increase adaptive capacity and to alleviate poverty. For example, local environmental knowledge can reveal suitable places to construct certain types of infrastructure, whereas the private sector can teach the community how to use various technologies to improve their productivity. The success of cooperation between the private sector and communities depends on building positive relationships between them in which both benefit from the relationship.

When the private sector invests in adaptations it can share with the local community (e.g., flood-control infrastructure that also captures water for reuse, environmental restoration to improve the welfare of employees), this shifts part of the cost from the community to the private sector. For individuals and households, the availability of low-cost, high-quality services such as cellular phone service and timely access to weather information makes it possible to provide earlier warnings of extreme weather, even in poor countries and remote regions. This is possible due to the private sector's investments and technologies transferred to communities. Private-sector actors may also find ways to benefit economically from climate change by identifying potential resources, as in the example of capturing flood water. Adaptation can therefore represent an investment that protects or increases the private sector's profits.

Based on these principles and the framework in Fig. 1, we describe a case study in arid northern China, where a private-sector adaptation is helping an impoverished community to escape the poverty trap and increase its resilience against climate change.

Case Study: Yangguan Town

Yangguan Town, in Dunhuang County of Gansu Province, lies at the edge of the Kumtag Desert. The annual average temperature is 9.3°C, ranging from

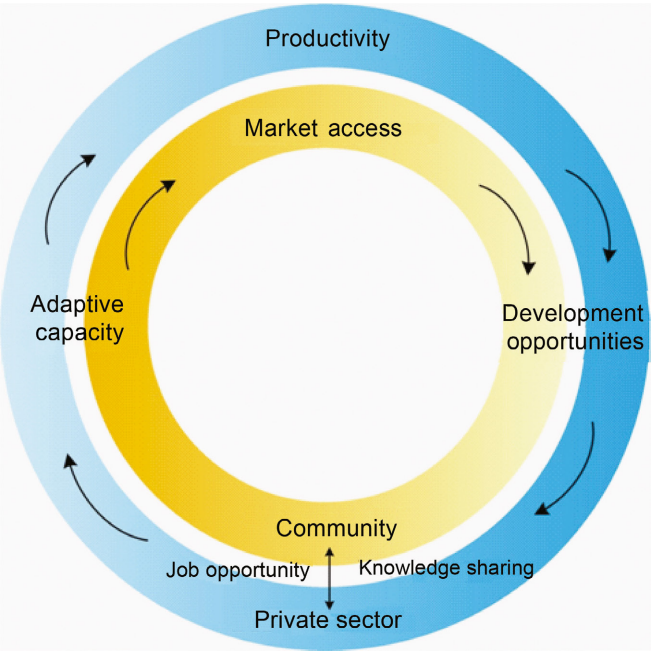

Fig. 1. The private sector provides development opportunities for their community that benefit both the sector and the community by facilitating adaptation to climate change. The blue circle shows how the private sector's profit motive promotes investments in adaptation that will also enhance their productivity by stabilizing the environment and creating new development opportunities that result from increased productivity. The yellow circle shows the benefits that the community receives from the private sector's adaptations, which can be shared with the community. Creating robust infrastructures such as an improved road network can increase community access to markets and promote the adoption of a market economy. The private sector's adaptations increase adaptive capacity both for them and for their community, as the infrastructures can be shared. With a more stable environment, the private sector and its community are both more likely to seize new development opportunities.

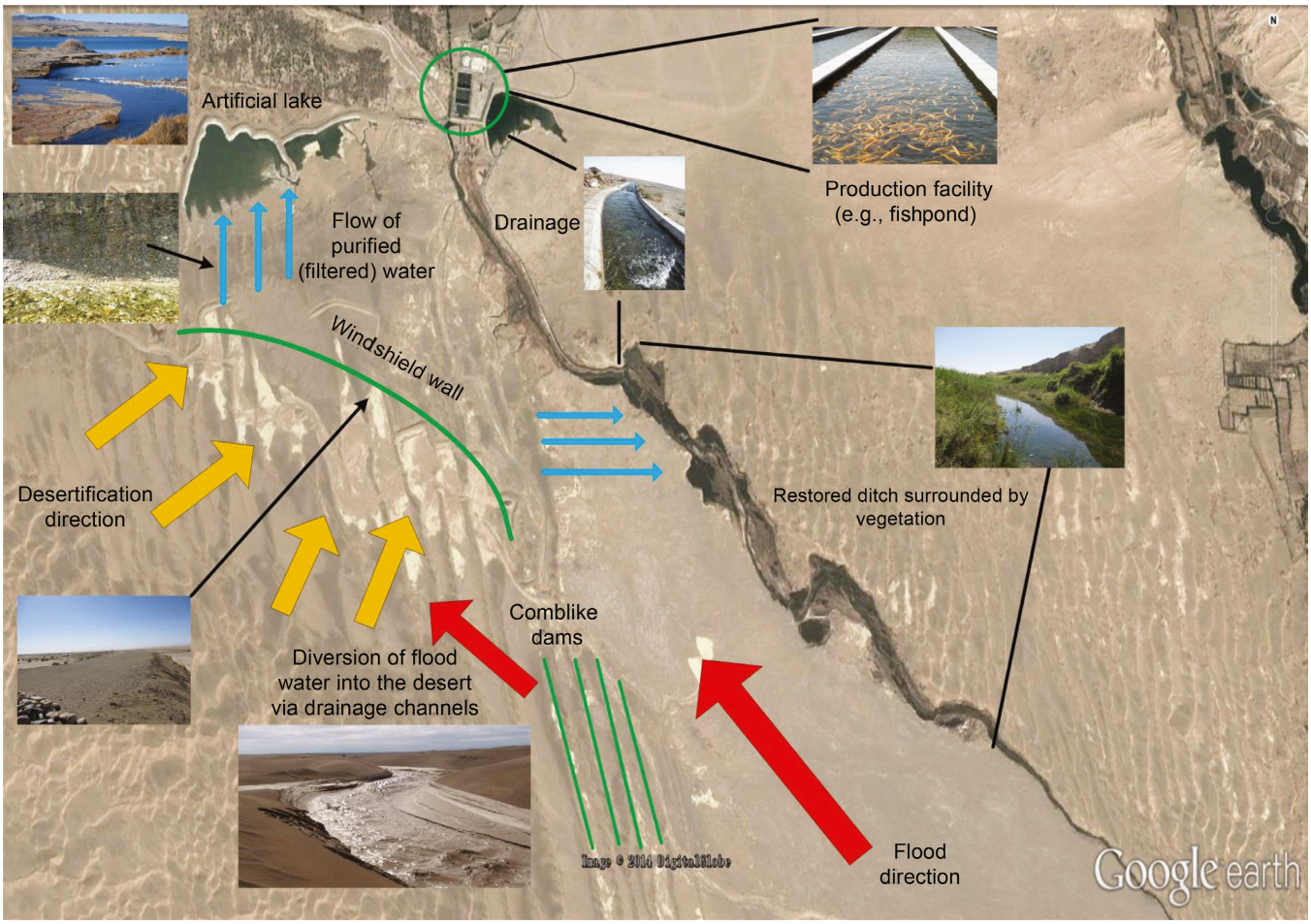

Fig. 2. Illustration of the adaptation project initiated by an aquaculture firm in Yangguan.

24.7°C in July to −9.3°C in January. Due to the low mean precipitation (39 mm/yr) and high potential evapotranspiration (2480 mm/yr), meltwater from the Altun Mountains is the main water source for the environment and local residents. Like many impoverished regions in the world's drylands, serious poverty exists due to the combination of low fertility, limited water availability, and the area's remoteness (Reynolds et al. 2007), and the town is already experiencing the impacts of climate change. Historically, desertification and flooding have threatened Yangguan. For example, the ancient Yangguan City was an important stop along the Silk Road, but was destroyed by the desert. Meteorological data suggest that precipitation during the rainy season has increased from 32.4 mm in the 1960s to 54.8 mm in the 2000s and that the number of days with precipitation greater than 0.1 mm has been increasing. This suggests an increasing risk of floods, as the desert soils cannot absorb this much water in a single rainfall event. The consequences are dramatic. For example, 18 floods occurred in 2007, causing 2×10^9 RMB in economic losses.

Yangguan's poverty trap arises from a combination of vulnerability to climate hazards and poverty. To respond to the increasing flood risk, the community constructed some simple flood-defense structures and shelter forests and has attempted to take advantage of the region's abundant radiation and dramatic daily temperature swings to develop a fruit industry. Unfortunately, these efforts were compromised by climate change, as flash floods destroy the flood-defense structures with increasing frequency. In addition, with no way to receive warnings of such floods, the flash floods that originate in the Kumtag Desert threaten people's security and often destroy essential infrastructure, including farmland (mainly orchards), road networks, and even villages. Under such circumstances, it is not possible for the community to alleviate its poverty long enough to improve its defenses or allow additional development.

In 2000, a private firm that mainly produces *Salmo gairdneri* (a kind of fish that can only survive in cold and flowing water) came to Yangguan to gain access to its meltwater resource, which is suitable for fish production. However, it was difficult to secure fish production because the unpredictable flooding often destroyed the ditches used to collect the meltwater. The firm therefore invested in an extensive adaptation project in cooperation with the local community (Fig. 2). In contrast, with the traditional goal of defense against floods, the project attempted to collect

Table 1. Comparison between the period before (2001–2007) and after (2008–2015) implementation of the Yangguan flood management project.

	Construction			Constructed								
	2005	2006	2007	2008	2009	2010	2011	Average	2012	2013	2014	2015	Average
Investment ($\times 10^9$ RMB)	13.000	28.000	17.000	11.000	4.000	2.500	1.500	11.000	6.000	2.000	3.000	1.000	3.000
Flood frequency (per year)	5	13	18	2	3	4	3	7	4	4	2	4	4
Economic damage ($\times 10^6$ RMB)	12.00	86.04	114.01	0	0	0	160.00	53.15	0	0	0	0	0
Available surface water ($\times 10^6$ m^3)	7.88	9.62	11.04	20.50	26.81	30.90	36.26	20.43	28.38	26.18	33.74	37.21	31.38
Depth to water table (m)	23	20	18	16	5	5	5	13	4	4	3	3	3
Income from agriculture ($\times 10^6$ RMB)	44.75	52.42	61.76	70.23	78.00	85.77	95.30	69.75	126.04	14.079	153.72	167.77	147.08

the flood water and transform it into a resource for fish farming. To disperse the flood and divert its water into the desert, the firm established 20 km of comblike channels. The water captured by these channels is diverted into the desert soil, and it gradually filters through the soil before emerging in low-lying areas as purified water that can be used directly. To combat desertification and dust storms, a series of artificial lakes was created in low-lying areas to conserve and store the filtered water. The purified water flowing from the desert forms wetlands and increases the soil moisture, thereby improving the survival of the shelter forest and allowing the establishment of nonforest vegetation that protects the wetlands. The increased water availability and vegetation cover have decreased gully erosion and generated more stable flows of water. For example, based on our observations, the flow rate in the channels has increased from 0.35 to 0.65 m^3/s between 2001 and 2012. This filtered water flows continuously through the fishponds, as *Salmo gairdneri* needs flowing water. The water leaving the fishponds, which contains significant levels of organic fertilizer, is diverted to irrigate the village's farmland and orchards along the drainage channel. In addition, a 21-km windshield wall was constructed to prevent mobile sand dunes from entering the inhabited areas; it also provides shelter to a belt of shrubs and trees that further reduce blowing sand.

The firm provides part-time employment for local people and encourages them to participate in construction and maintenance of these infrastructures when they are not engaged in farming. By 2011, the adaptation system was well developed and the community has benefited from a significantly improved water resource, while decreasing their exposure to a hazard (i.e., flooding) created by climate change. The firm has created a transportation network to carry its primary product (fish) to distant markets. Because this infrastructure has more capacity than is required to carry the firm's fish, the firm allows local farmers to lease its vehicles so they can carry their crops to markets.

This adaptation system provides services such as a clean water supply, security (i.e., protection against floods and desertification), and job opportunities to the community, while the private firm protects their production chain and takes advantage of previously unused or underutilized local resources (e.g., sunlight, flood water, labor). With sufficient water and increased stability of the water supply, the fruit tree plantations (mainly grapes), which are mainly managed by the local community, have become a keystone of the local economy, and exhibit synergies with the aquaculture industry by utilizing its wastes (which would otherwise require expensive treatment), thereby enhancing resident livelihoods and incomes. As a result of the above-mentioned projects, the per capita income has increased from 4000 RMB in 2005 to 16 000 RMB in 2015 (Table 1). There have been many additional benefits of the projects (Table 1). In summary, average annual investments of 110×10^6 RMB during the construction period and 30×10^6 RMB afterward have decreased flood frequency by nearly half, decreased flood damage from an average of 53.15×10^6 RMB annually to zero, increased the available volume of surface water by more than 50%, decreased the depth to the water table by 10 m, and more than doubled the agricultural income. The fruit industry has been so prosperous that grape cultivation accounted for 98% of the total farmland in 2015, reaching 1300 ha, and the sales of grapes has reached 100×10^6 RMB per year. The private sector's production increased from 5×10^6 RMB in 2001 to 20×10^6 RMB in 2011. In addition, 600 ha of wetland was created by the water-retention lakes and 1750 ha of land was revegetated, thereby increasing the community's resilience against drought (Fig. 3).

Discussion

There has been growing recognition of the role of socioeconomic development in managing the adaptation to climate change and other stresses, leading to the

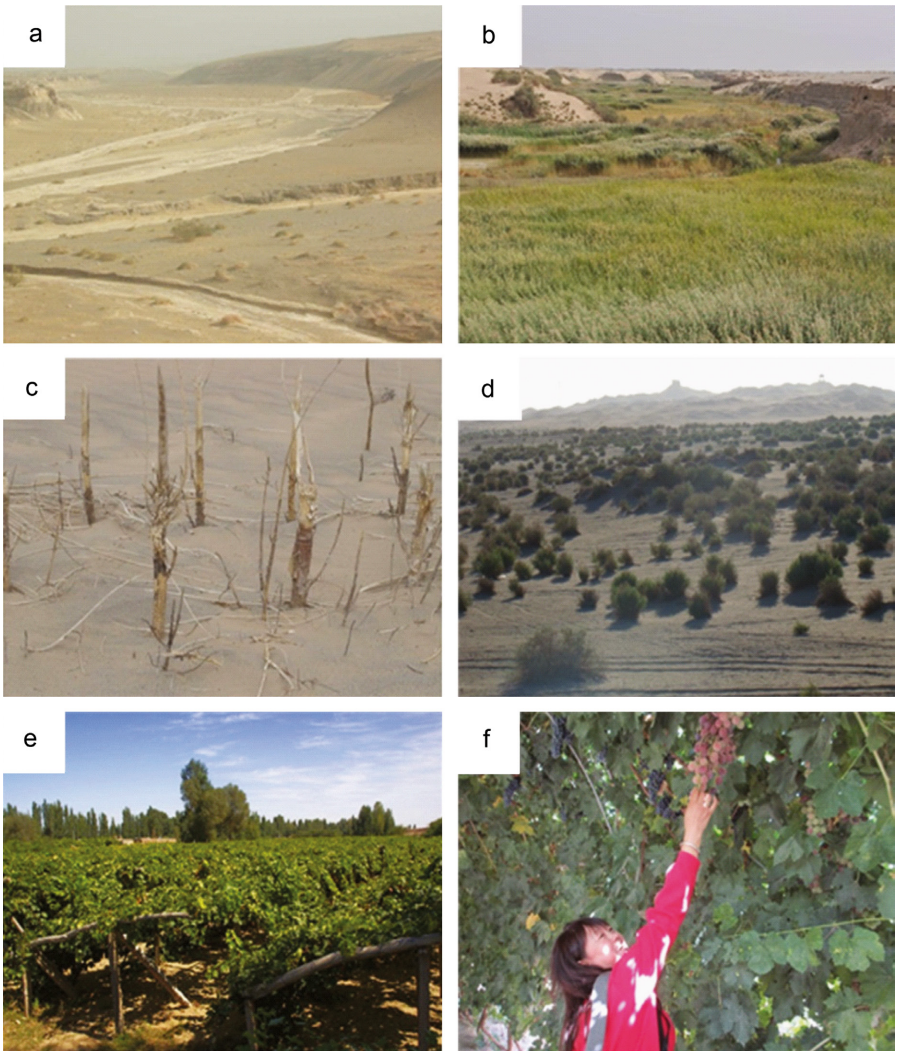

Fig. 3. Changes in the landscape of Yangguan as a result of participation in local ecological restoration by the private sector: (a, c) in 2000; (b, d) in 2011. The ditch in (a) is now surrounded and protected by vegetation (b), and the sheltered area created by shrubs and trees (c) has increased vegetation survival (d) by taking advantage of flood water captured by the desert. The booming grape industry (e) improves the local people's livelihood and (f) attracts many tourists for recreation.

development of scientific and policy guidance by organizations such as the Intergovernmental Panel on Climate Change (IPCC 2014) and the United Nations Framework Convention on Climate Change. Development and adaptation have been regarded as mutually dependent strategies (Ayers et al. 2014). The connections among climate change, adaptation, and poverty are complex and context-specific (Leichenko and Silva 2014). Some researchers have found that development is the best pathway toward adaptation (Fankhauser and Burton 2011), whereas others have argued that development is contingent upon adaptation, as the accumulation of capital and increases in welfare that are associated with development are only achieved after successful adaptation (World Bank 2010). These conflicting opinions reveal how climate change adaptation is deeply embedded in socioeconomic processes, including institutional and technological innovation, resource production and consumption patterns, and the actions of the different stakeholders.

The poverty trap will deepen, exacerbated by climate variability and the shocks caused by the destruction of assets during extreme weather events, and the diversion of resources toward costly adaptation measures such as coastal defense structures may permanently reduce economic output in affected regions (Leichenko and Silva 2014). The poverty trap cannot be escaped without combining improved adaptation to climatic hazards with socioeconomic development to solve the dilemmas facing disadvantaged communities (Tallis et al. 2008, Cao et al. 2009, Chen et al. 2014). And it is almost impossible for society to build the resilience with the sustainable economy and environment. Unfortunately, in many regions, and especially in impoverished regions, climate change is often treated exclusively as an environmental problem by government agencies that act at a community level,

rather than as one component of a broadly integrated social issue that affects the community's development and welfare (Conway and Schipper 2011), thereby leading to biased or incomplete views and projects. This may undermine the system integrity and make the local communities hard to adjust to the changing circumstance, jeopardizing the resilience and resulting in the poverty–environment vicious trap.

Our case study represents what seems obvious in hindsight: Convert a resource that is overabundant at certain times (such as water during heavy rainfall) but precious and in short supply at other times into a socioeconomic asset. Although our case study has clear implications for other arid regions that experience flash floods, such a success will only be possible under a specific hydroclimatic regime and local social and environmental conditions. Elsewhere, more ingenuity may be required to determine what adverse consequences of climate change can be reimagined as valuable resources.

To achieve effective climate change adaptation in a specific local context, it is necessary to seek solutions that go beyond the conventional community-based or government-led approaches. If adaptation can be embedded within socioeconomic development through institutional and technological innovation, the result can help communities to achieve sustainable development (World Bank 2010, Fankhauser and Burton 2011). As our case study showed, converting what was formerly a hazard (flash floods) into a resource created opportunities for the local community to develop specialty industries, while also improving their access to market, which is a particularly meaningful consequence for those remote communities.

Our case study shows how the private sector is a key stakeholder that can propose innovative adaptation strategies that are highly adapted to the local context, and that provide both necessary services and sustainable business models that will make current and future investments more resilient against climate change (Biagini and Miller 2013). Unlike conventional development projects driven by the community alone or led by the government, funding is less constrained because the private sector is willing to make investments that will be repaid through increased profits or decreased losses. In addition, they may be better equipped than governments to study the scope of the project and provide adequate resources to design a successful project that accounts for community perspectives; as a result, the private sector needs to be incorporated more comprehensively in future adaptation projects to break the poverty trap (Stringer et al. 2014).

Historically, most adaptation efforts have been designed to develop a specific capacity rather than a more holistic capacity. Examples include the dissemination of climate forecasts, drought-tolerant crop varieties, and water storage projects. However, in the context of significant poverty and political marginalization, these activities have had limited success in reducing climate vulnerability, at least in part because the project represented a single, static intervention rather than a more dynamic and holistic approach, thereby compromising these efforts. Local people and the public sector may find it difficult to maintain the effectiveness and sustainability of these measures because of the huge financial burden; once a project has been implemented, the community usually receives no ongoing funding to maintain it. In contrast, the private sector designs projects to obtain ongoing revenues that can be used to maintain their projects. Enhancing adaptive capacity must therefore go beyond simple physical measures to include a consideration of how a development opportunity can be created.

The private sector seeks growth strategies and opportunities to obtain a competitive advantage. Their investments are viewed through the economic lens of benefits and risks, and require them to build sustainable relationships with other stakeholders and transferrable capabilities (London and Anupindi 2012). The profit motive can lead the private sector to invest and provide infrastructure that will also benefit its community. This is particularly significant for remote and disadvantaged communities. The successful adaptations in our case study resulted from the benefits acquired from a sustainable business model that provides an ongoing incentive to the private sector to increase and protect their investments. The case study also shows a fundamental shift in thinking about hazard—from a short-term, reactive, disaster-focused view of climate change as a hazard to a long-term view that focuses on active disaster prevention, impact reduction, and a resource-focused perspective that emphasizes economic opportunities. This approach will work if it attacks the underlying causes of chronic poverty and food insecurity.

Although the private sector may play a more important role in adaptation, profits are the foundation of its motivation for adaptation. This implies that uncertainty of benefits and costs may discourage the sector from investment activity, especially for small- and medium-sized enterprises. Activities conducted by private sector may fail to achieve the adaptation or development goals if high transaction costs emerge related to policy development, implementation, distribution of the benefits, and sharing of risk. In most cases, private-sector initiatives therefore cannot succeed without government support because the private sector depends on the government for information and for supportive policies and regulations, and the government's resources are generally greater than those of individual enterprises. For example, access to weather and climate information is sometimes tightly controlled by governments and only available for a fee, which can add substantial transaction costs for the private sector. Without access to these data, many companies will fail to objectively evaluate the magnitude and impacts of climate change, and this may lead

to losses beyond their expectation during the early stages of adaptation. This would decrease the likelihood of subsequent private-sector investment. Surveys by the Organisation for Economic Co-operation and Development have also revealed that most businesses believe that it is unnecessary to account for the risk of climate change in their investments and their business plans, in part because they see this as technically difficult and perhaps premature (Biagini and Miller 2013). Companies may also find that they have few options to develop and implement adaptation strategies, or may believe that much of what could be done is within the realm of government responsibility.

Although there are few cases to date of the private sector acting as a supplier of climate change adaptation, our case study suggests that this sector can play an important role in adaptation. However, this adaptation is context-specific and heterogeneous, which implies that approaches based on cooperation with the private sector will vary greatly among industries (e.g., agriculture vs. manufacturing), organization sizes, and perceptions of risks and opportunities. Different economic structures and development levels will also change the potential impact of climate change. Furthermore, aspects of communities, such as education levels, access to public transportation, and the availability of public services, will affect the community's role. The communities most strongly affected by climate change may be more strongly motivated to cooperate with the private sector to find opportunities for mutual benefit. An additional challenge will be finding ways for the private sector to work effectively with the public sector, as these sectors have very different goals, governance structures, constraints, and powers. In particular, governments will need to re-examine policy development to identify potential roles for the private sector, and encourage the private sector to participate in the policy implementation. For example, providing long-term loans at low interest rates will help the private sector afford expensive construction activities such as those described in our case study.

Although our results are promising, they are only a single study and there have been insufficient studies of this approach to allow generalization to other contexts. It will therefore be necessary to replicate our framework in similar contexts to confirm that it achieves similarly good results, and to test it in different contexts to determine its generalizability to different ecological, cultural, and socioeconomic contexts. Much more work will be needed to improve our framework and harmonize adaptation to climate change, participatory governance, and poverty alleviation. This also suggests that the generation of adaptation strategies and selection of the most effective adaptation measures should be assessed in the broader context of linked social and ecological issues rather than focusing only on climate change.

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