ECOSYSTEM-BASED ADAPTATION THROUGH SOUTH-SOUTH COOPERATION

GOOD PRACTICE CASE STUDY

Greenhouse agriculture and water harvesting technologies for climate change adaptation in the Ningxia Hui Autonomous Region, China

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This case study describes the use of diverse water harvesting and water saving technologies to mitigate the effects of recurrent drought, extreme weather and general decline in moisture availability in the arid and semi-arid Ningxia Hui Autonomous Region of China. The technologies introduced include the use of 'protected' agriculture (e.g. greenhouse farming), and the use of plastic and stone-gravel mulching of farmlands. While the sand/gravel mulching has been a traditional practice of local farmers throughout history, the plastic mulch and the greenhouse farming are newly applied in the region. These technologies have been introduced mainly through government subsidies and other forms of support programs. Coupled with government's diverse environmental policies for the region such as the National Forest Conservation Program (NFCP), the Grain for Green Program (GGP), land transfer policy, and the inter-basin water transfer programs, these have resulted in an increase in the overall income of local farmers, thereby leading to their widespread adoption since 1990s.

Project outcomes

- Through the increased productivity of farms, farmers have increased their income.
- The agricultural patterns have become better adapted to extreme weather variability and droughts.
- The implementation of greenhouse farming helped in sparing of large tract of formerly cultivated, degraded land, thereby providing improved opportunities for the National Forest Conservation Program.
- Greenhouses enable longer growing season for valuable vegetable crops, helping farmers to market high value cash crops.
- An integrated result of the above has led to an overall rehabilitation of degraded land.

Key lessons

- Successful implementation of adaptation technologies requires strong government policy support, including subsidies to create an enabling environment, until communities start to adopt them voluntarily.
- Protected agriculture (e.g. greenhouse farming) has improved productivity, thereby resulting in improved income.
- Protected agriculture assures higher productivity within limited area of land, sparing more degraded land for environmental rehabilitation programs.
- The implementation of water-saving technologies such as plastic and sand-gravel mulching have resulted in improved water use efficiency ultimately increasing farmers' income.
- Sustainable adaptation and adoption of these technologies, however, require continued knowledge sharing, training and financial assurance for farmers.

GOOD PRACTICE DESCRIPTION

LOCATION: Ningxia Hui Autonomous Region of China

This case study is not part of a particular project but describes the 2 technologies that have been continuously practiced as a response to climate change adaptation.

OPERATIONAL BUDGET: Government subsidy and individual farming families' sources e.g. contributing up to 16%-23% of household income

KEY STAKEHOLDERS: Government of Ningxia Hui Autonomous Region, Chinese Central Government, local farmers of Ningxia and various research/academic institutions

Background information and climate change vulnerabilities

This case study describes two innovations aimed at reducing the negative consequences of drought and extreme variability in the Ningxia Hui Autonomous Region in China. These innovations include (1) plastic and sand-gravel mulching for reducing moisture evaporation from sandy soils in the arid and semi-arid zones, and (2) use of greenhouse agriculture for climate change adaptation. Ningxia Hui Autonomous Region is located in northwest China. It is geographically located between 35^{o}14'-39^{o}23' N and 104^{o}17'-107^{o}39' E, lying in the upper reaches of the Yellow River bordered by Shaanxi on the east, Gansu on the south and Inner Mongolia in the north. Ningxia covers an area of about 66,400 km^2, and had a population of more than 6.6 million (in 2014), many of which are Hui Muslims (36%) (Yang et al., 2015). The area is composed of grassland (22,700 km^2 or 34%); cultivated land (11,000 km^2 or 17%); and potentially arable land (7,300 km^2 or 11%). In 2006, its GDP was 71.08 billion RMB, divided between primary industry (11%); secondary industry (49%); and tertiary industry (40%).

Ningxia has an arid and semi-arid agro-ecology with the annual average air temperature of 5-10^{o}C. The annual precipitation decreases from south to north; more than 400 mm in the southern part of Ningxia, 200-300 mm in the middle and less than 200 mm in the north. The precipitation is mainly obtained during summer and autumn (80%). Annual evapotranspiration is approximately 1,214-2,803 mm.

Ningxia is generally classified into three agricultural zones, based on topography and available water sources. These are (1) the Northern Yellow River irrigation region, (2) the central arid zone, and (3) the Southern mountain area (Zheng et al., 2006). The northern part is an irrigated agricultural area, where agriculture relies entirely on irrigation; the central part comprises interlacing agro-pastoral zones; and the southern part is a rainfed agricultural area. The irrigation area along the Yellow River in northern Ningxia is the fourth largest irrigated agricultural area in China and a major grain-producing area in Ningxia (Yang et al., 2015). Ningxia is affected by frequent weather and climate fluctuations. The major types of observed climate change and climatic challenges include an increasingly warmer weather conditions and the increase in frequencies of extreme weather events. Particularly for this province, water stress has recently become more serious and recurrent (Zou et al., 2005). Studies have shown that over the last 30 years, drought has affected 14.3% of the population, and 47.6% of the total land area, causing economic loss equivalent to US$ 26.7 million (Tan et al., 2014). The affected population, land and revenue losses caused by droughts have also increased by 279,000 persons, 32,000 hectares and US$ 13.4 per decade, respectively (Tan et al., 2014). Moreover, existing climate forecast indicates that future climate in Ningxia will see higher temperatures in the summer months (especially higher minimum temperatures), while rainfall will become highly variable and frequency and intensity of extreme events will increase (Wang and Chen, 2014), making rainfed crop cultivation less and less viable and increasing more pressure on already existing irrigation sources (Wang and Chen, 2014). In the last 50 years, Ningxia has shifted from a wet period (1960-1980) to a dry period (since 1995; Du et al., 2015). Furthermore, over the past decades, the observed average annual air temperature has significantly increased by 1.4-2 ^{o}C (Yuan et al., 2011).

Besides highly variable and extreme climate, Ningxia has also been historically affected by desertification. Desertification has affected 55.8% of Ningxia's total terrain (2.89 million hectares), with additional 1.21 million hectares of grassland and 132,000 hectares of farmlands also currently threatened by desertification (PRC and UNDP 2010). Most farmers in the province are highly vulnerable to the effects of climate change, because their livelihood depends on agricultural practices that are highly sensitive to climatic conditions. For instance, the drought in 2004-2006 had a significant impact on the agricultural productivity of mixed farming, grazing and irrigated areas (Li et al., 2013). Official statistics from Ningxia's Meteorological Bureau on agricultural disasters shows that during the period 1949 to 2000, on average 23% of the province's arable land (equivalent to 480,000 ha) experienced yield losses of 10%–30 % and 17% of the area yield losses greater than 30 % (Li et al., 2013). Direct economic losses in the agricultural sector showed a steep jump in 2001 from RMB 910 million to RMB 1.27 billion per year (Li et al., 2013). The main negative consequence of changing climate is the reduced amount of water for irrigation from the Yellow River (Liu and Xia, 2004, Yang et al., 2015). The negative impacts of these challenges are also exacerbated by other challenges, including (1) limited capacity and reliability of seasonal weather forecasting services, that hindered farmers' ability to reliably predict weather and take adaptation measures; (2) flooding, which has become a new challenge by itself, to which farmers are not traditionally adapted; (3) limited or low compensation to farmers who participate in adaptation practices, which discourages voluntary adoption of technologies; and (4) inadequate cooperation between local government departments.

In light of the challenges caused by extreme weather change and recurrent drought, the construction of efficient water-saving infrastructure has become the core of drought adaptation strategy of the Ningxia government, with socio-economic sustainable development being the ultimate goal (Yang et al., 2015). Ningxia has, therefore, become the face of the Chinese government's attempt to adapt to climate change and variability in China's arid region starting in early 2000s (Yang et al., 2015). The implementation of these technologies required an integration of policies, institutional leadership, engineering, technological and social initiatives and measures. These specific coping and adaptation strategies were made to be aligned with the national macro adaptation strategies (Yang et al., 2015).

Among the many measures implemented in this perspective, two technologies are further described in this case study: the use of plastic and stone mulching as well as greenhouse farming.

Intervention technologies

a) Greenhouse agriculture: Greenhouse construction, as an example of protected agriculture, has been promoted as a poverty reduction measure in Yellow River irrigated areas. Greenhouses enable longer growing season for valuable vegetable crops, and reduce water loss from evapotranspiration. Because of its benefit on increased productivity and farmer's income, the number and coverage of protected agriculture, particularly greenhouse agriculture, has been increasing over time. In 2006 about 30% of the cultivated land was covered by greenhouses, and the proportion has been continuously increasing. In 2011, the area under protected horticulture was 40,000 km^2 (Guo et al., 2012), and increased afterwards owing to the increased productivity of the system. This technology, where agricultural practices are mainly horticulture, crop production under greenhouse conditions has attracted the attention of farmers and policy makers due to its potential for improving productivity. A tailor-made greenhouse that fits the local environment was also designed - a groove type of greenhouse with 80m (length)*10m (width) *3.5m (height) (Guo and Li, 2013). This design contains about 1.5-2 m underground with two wind shields at each side of the greenhouse at 1m. Transparent film is used at the top of the greenhouse to let the sunshine in and the insulating layer is used to preserve the heat. A rain-collecting cellar is also constructed nearby the greenhouse to collect rain for irrigation in winter. Figure 1 below is an example of such type of greenhouse farm.

Figure 1. Farmers in Ningxia working in a greenhouse (©Tan Haishi)

b) Water conservation techniques: The most important challenge brought about by climate change is a steady decline in the amount of moisture in the soil. Therefore, conservation of water is an essential technology to assure that the available water will not be lost before it is used for important purposes. In this case study, two types of water conservation technologies are described. These include (1) the use of plastic mulch, and (2) the use of sand-gravel mulch.

(1) The *use of plastic mulch* in areas facing water shortage: Farmers in Ningxia have been using various water harvesting technologies including the use of plastic film on the land in autumn to collect rain and reduce evaporation. Thin plastics are bought in rolls and used to cover the length and width of a farmland, thereby protecting rainwater from evaporating quickly. Plants are allowed to grow through small holes made on the plastic. Any rainwater falling onto the plastic is collected and allowed to flow directly to the soil through the same holes. Plastic mulches, though very effective at increasing water use efficiency in dryland areas, however, have been blamed for their catastrophic environmental consequences, as tons of undegradable plastic is left every year on farmlands and outdoors after their use (Changrong et al., 2006). Realising this problem, biodegradable plastic mulches with similar effect on water conservation, and even better effect on soil microbial content, have been devised and are already in use by farmers (Moreno and Moreno, 2008).

(2) The *use of stone and gravel mulch* to reduce evaporation from sandy soils: When irrigation water is limited, farmers take action to reduce the amount of moisture lost

by evaporation through various measures, including the traditional use of sand-gravel mulching to protect from moisture evaporation. Typically, farmers used stones and gravel mulch to reduce evaporation of moisture from the soil, to enable them to produce watermelon (Figure 2). This technology is a prerequisite for viable production of watermelons, as growing watermelons required relatively large amount of water compared to other crops, and technologies for conserving and harvesting available moisture were a must. This technology, also called 'shatian' or 'sandy fields' in Chinese, actually emerged in the 1930s in Ningxia. This has been an indigenous practice of Chinese farmers in the Arid North-West China (Li, 2003). In 2009, the total planting area of gravel-mulched watermelon is 687 km^2 in Zhongwei City, where watermelon growing is a major industry. The "traditional wisdom" of gravel-mulched watermelon production technique was developed at a larger scale three decades ago, prior to the availability of water-saving trickle fertigation and bio-degradable plastic mulch materials.

Figure 2. Farmers harvesting watermelons growing on gravel-covered land in Zhongwei City of Ningxia ©Xinhua

Description of the results

Greenhouse agriculture

Greenhouses enable longer growing season for valuable vegetable crops and reduce evapotranspiration water losses. The use of greenhouse agriculture in the 2000s greatly increased the vegetable production, productivity and revenue produced from it. In 2005, vegetable planting area under protected agriculture was 10,733.33 ha, and that in sunlight greenhouses was 7,600 ha (Jianping et al., 2008). As a result of the greenhouse agriculture, the number of vegetable varieties exceeded 50, compared with only 10 varieties in the 1960s and 30 in the 1980s, and the annual yield reached 3.579 million tons, with per-capita share of vegetables in Ningxia exceeding 600 kilograms (Jianping et al., 2008).

The yield from greenhouse farms ranged from 4.5 – 6 kg/m^2, a value that is higher than the yield from conventional agriculture (Guo and Li, 2013). Another important impact of the greenhouse agriculture is that, due to its implementation, many less productive farmlands have been abandoned and converted into forest land, resulting in an increase in forest cover in the province (Restrepo et al., 2017).

Water harvesting and conserving technologies

a) *Plastic mulching*: Plastic mulches are widely used in arid and semi-arid areas of China for various purposes. For instance, 87% of farmers in Minqin County of Gansu Province use plastic film to conserve rainwater and that has improved crop productivity by 53% (Ingman et al., 2015). The use of plastic mulching has been increasing from time to time in different districts of the Ningxia region. The advantages of using plastic mulches are various - including increasing water use efficiency, plant growth rate and productivity, increasing mineral or fertilizer availability, controlling runoff, and reducing weeds in farmlands (Li et al., 2004, Yan et al., 2010). Plastic mulching (Figure 3) can be of ordinary mulching, which is the use of mulching plastic film on the surface layer of soil at regular intervals, and full-film mulching, which covers the entire soil surface with a plastic film. It is also sometimes combined with sand-gravel mulching.

Figure 3. A villager lays plastic mulches on bare ground (Right) and then stamps down the plastic mulch (left) in Jiatang Township of Haiyuan County, Ningxia. (©Xinhua)

b) *Gravel and stone mulching of sandy soils*: This technology was introduced in Ningxia in 1930s. Farmers put stones on sandy land to protect water and regulate temperature and reduce evaporation of limited moisture from the sandy soil. Carboniferous limestone gangue sand/gravel containing selenium minerals is typically used for mulching purpose, especially in watermelon farming. Rainwater leaches the minerals deposited in the sand/gravel. Then, watermelons absorb the selenium. The selenium-rich watermelons grown in this fashion are therefore called selenium sand melons. The sand/gravel serves three purposes (Yang et al., 2015): (1) to reduce surface runoff and make full use of limited precipitation, (2) to conserve moisture in the soil and decrease evaporation, and (3) to increase mineral components of the soil. Sand-gravel mulching irrigation is a combination of sand-gravel mulching and supplementary irrigation unique to the Ningxia region. In sand-gravel mulching, a layer of sand and gravel is placed on the soil, and then a mulch plastic film is layered over the sand and gravel at intervals of about 80 cm (Figure 4). A study by Li (2002) proved that mulching sandy soils with gravel and stone resulted in 32% more dew deposition than unmulched soil. Since dew deposition reduces evaporative moisture loss, the mulching improves the availability of moisture for crop production (Monteith, 1957). Dew can help horticultural crops such as cucumber, watermelon and pumpkin from drying as a result of extreme temperature and drought (Stone, 1957), which in turn also improves their growth rate and productivity under moisture stressed condition. Gravel-mulching was effective in conserving moisture and increasing yield and water use efficiency at about 1.9 times more than conventional flat soil cultivation in semi-arid regions of China (Li, 2002). Similarly, in an experiment undertaken at the semi-arid Loess Plateau, China, gravel-sand mulching produced results in the production of higher biomass yield of maize than plastic-mulching or straw-mulching (Wang et al., 2009). A combination of plastic mulching with sand-gravel mulching (Figure 5), in an experiment in dry semi-arid China, also resulted in an average runoff efficiency (runoff/rainfall) of 87% and a twofold increase in crop yield and 1.8-fold increase in water use efficiency (Li et al., 2000). The only drawback of sand-gravel mulching is its high labour intensity and associated labour costs. Since sand gravel/stone mulching is very labour intensive (around 6,000 RMB/ha), it only applied to high-value crops such as watermelon (Li et al., 2013).

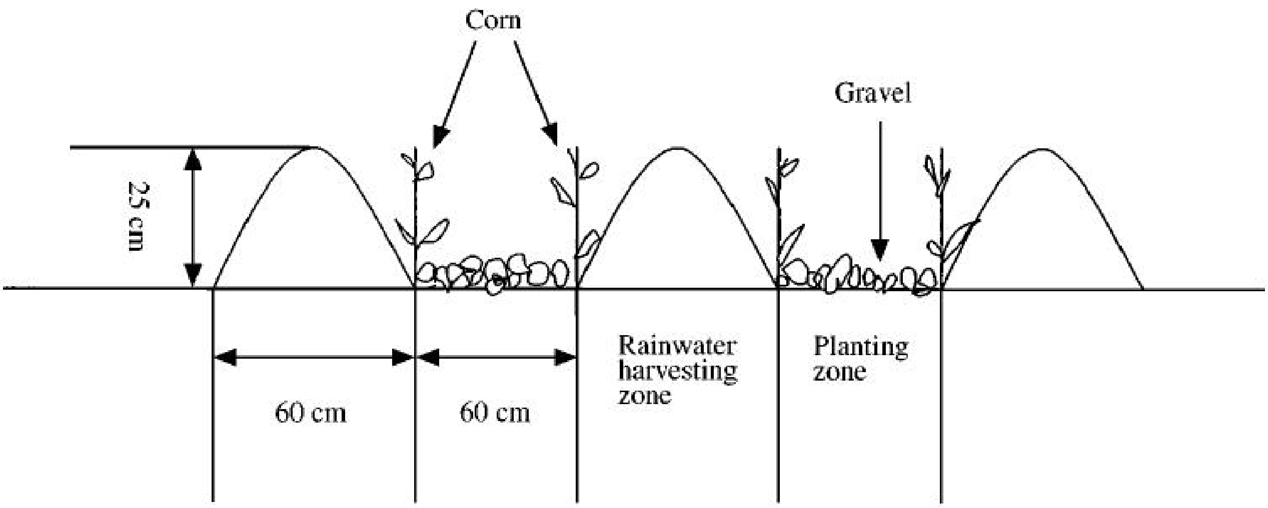

Figure 4. Schematic diagram of in-situ rainwater harvesting combined with gravel mulch system (© Li et al., 2000)

Figure 5. Combination of gravel and plastic mulching in Ningxia (© Yang et al., 2015)

GOOD PRACTICE ANALYSIS*

Knowledge building

How has the project built upon or applied the findings of specific research projects? How has the project actively contributed to international understanding on Ecosystem-based Adaptation?

The technologies described in this case study are specific examples and practices within the overall land rehabilitation and poverty reduction policy of the government of the People's Republic of China. At the beginning, though some of the technologies were indigenous (e.g. sand-gravel mulching), many of the technologies were initially derived from the experience of other countries where these technologies performed well (Bennett, 2008).

Through the 1,000 villages poverty alleviation program, the government helped in not only construction and provision of the different technologies such as the provision of greenhouse farming equipment, but also included labour skills training to foster adoption of new farming technologies and train farmers to seek employment in urban areas.

Hundreds of studies have also been undertaken on the issues of climate change adaptation, including the technologies described in this case study. Nonetheless, so far there is no formal channel for transferring the knowledge generated from these studies to the farmers who use the knowledge. Educated farmers, however, are still using the internet and other sources to obtain information for their newly adopted technologies. Moreover, because of the economic returns, there is very active farmer-to-farmer information sharing and dynamic feedback environment.

Transfer of knowledge within farming communities was also supported and orchestrated by the Ningxia government, an effort which required coordination of various social sectors and economic systems, improvement of the social security system and involvement of different stakeholder and a scientific decision-making.

Community participation and inclusiveness

Has the project consulted with local communities in the formulation, implementation and decision-making process? How were gender issues incorporated? Explain how the project mobilized local interest and ownership in order to ensure its activities responded to the needs of local beneficiaries.

Not only experiences from foreign countries have been obtained, local experience and indigenous knowledge on the different practices were also taken into consideration. The technologies described in this case study were part of national and provincial policies of environmental rehabilitation and poverty reduction in Ningxia. Some of the policies, including the restriction of grazing, inter-basin water sharing, land rights transfer, grain for green policies, resettlement programs, have all been implemented with direct involvement of the local people. Participation in many of these programs (e.g. resettlement) was also on a voluntary basis. Also, the implementation of these technologies was undertaken through local dialogue and engagement.

* This analysis is based on the "principles of good practice" developed by the EU/FP7-funded project AfriCAN Climate (2011-2014). These principles represent critical cross cutting issues shared by the majority of climate change projects, regardless of focus, scope and scale. They are intended to encourage critical reflection and help project developers and decision-makers draw out relevant lessons. Source: http://africanclimate.net/en/good-practice/8-principles-good-practice

Apart from these approaches, the Ningxia government strengthens the development of farmers' associations in different districts to enhance market access, technology extension and risk mitigation. Village Mutual Financial Cooperative, as a new type of financial initiative, has also enhanced the adoption of the different technologies.

The government also provides credit services for enabling the poorest part of the communities to participate in the activities. So far, Ningxia has established a rural credit and lending system with Agriculture Development Bank, Agricultural Bank, Rural Credit Cooperatives, and Postal Savings Bank as its main channels. The rural small-amount credit loans have become the primary source of credit funds for farmers to boost production. In 2008, Ningxia Rural Credit Cooperatives issued 430,000 "green loan notes", accounting for 46% of the total number issued to farmers in Ningxia. Farmers can use the note to draw money for emergencies, and deal with matters of great urgency in their daily life. The "green loan notes" are used by the method of "examination for once, control of balance, granting the loan on demand, set a record for each loan, no limitation on the number of issuances, and revolving use", to meet farmers' demand for loans. With the loan note, farmers can apply for loans once in need, and the highest amount of the loans can be as high as 5,000 RMB (Min et al., 2008).

Political ownership, collaboration and approval

How has the project secured support from political-level stakeholders and aligned its activities with wider development agendas to trigger further collaboration opportunities?

In response to increased drought and other negative consequences of climate change, the Chinese government has implemented a number of adaptation planning and mitigation actions and policies since the 1980s. These policies described below, assured the direct participation of local people, the government and other external partners. The most important policies included the following:

1. Grazing restriction: Appreciating the effect of sheep grazing in causing grassland degradation and thereby exacerbating the effect of climate change, in 2003 a grassland grazing prohibition was implemented throughout Ningxia region (Yang et al., 2015). All sheep were kept in captivity through governmental subsides. Artificial alfalfa grasslands were also developed to support pastoralists who were prohibited from grazing.
2. Grain for Green Program (GGP): The government also put the policy of grain for green in order to return farmlands (that were originally grasslands) back into grasslands (Yang et al., 2015). This policy was meant to increase pasture availability for the sheep that were restricted from grazing. The grain for green scheme resulted in reduced amount of land for farming, thereby encouraging farmers to adopt the greenhouse crop production (Sjögersten et al., 2013).
3. The National Forest Conservation Program (NFCP): The government also supported the efforts to introduce climate change adaptation technologies though forestation, artificial fencing and grassland self-rehabilitation. The program aimed to afforest 31 million hectares by 2010 (Sjögersten et al., 2013).
4. The Land Transfer Policy: The Ningxia government has implemented the land transfer policy issued by the central government in 2004. Land transfer refers to the transfer of land-use rights, such that farmers can voluntarily transfer the use right of the arable lands they operate to other farmers or economic organizations. This policy was implemented in order to create suitable conditions for the implementation of the described technologies. Under the traditional system, land ownership of households is very small (approximately 0.17 hectare). Moreover, the land belongings to families were found to be scattered at different places, because the land was allocated to cover different levels of fertility, productivity etc., for every household. This, however, created a problem in the implementation of water saving and other technologies, as the lands were too fragmented to implement any working technology. For this reason, the land transfer policy was issued, implemented and supported the adoption of the different water saving and conserving technologies.

5. Inter-Basin Water Transfer: The government also implemented an inter-basin water transfer from the Yangtze River in anticipation that the project will greatly increase the region's adaptive capacity and resolve the water shortage problem (Yang et al., 2015). This has enabled the acquisition of enough water for implementing the technologies such as the greenhouse farming that require a considerable amount of water.
6. Financial subsidies: All levels of government strongly promote various dry-farming and water-saving agricultural technologies through financial subsidies in Middle and South Ningxia. The financial subsidies enabled poor households, who would otherwise be unable to adopt the technologies.

Financial sustainability

How has the project secured financing for sustaining and/or expanding its impacts beyond the initial project lifetime? Explain how the project secured national (e.g. government) and international (e.g. international donors) support for sustaining its impacts.

While practicing these adaptation measures, farmers also participate in non-farm economic activities in order to support their income. 50% respondents studied by Li et al. (2013) indicated that they practice off-farm income generating activities. Off-farm employment has been an important risk aversion strategy, lest the different adopted technologies fail to work. Moreover, the Ningxia government provides subsidies for plastic mulches, gravel mulches, greenhouse agriculture and others. Such subsidies and off-farm employment opportunities provided basis for sustaining the adopted technologies.

The overall increased income of farmers following these technologies, assures the future sustainability of these. For instance according to a study by Sjögersten et al. (2013), farmers said they were 'much better off than 10 years ago'. Income levels averaged around 3,000 RMB per head of population. Even with such increased income and availability of government subsidies, farmers' adoption of these technologies will depend on funding and expertise available to support change in practice (Sjögersten et al., 2013).

Building local capacities

How has the project ensured that local capacity was built during implementation phase? Explain how training programmes were integrated into core project activities and the measures taken to assure that built human capacity is maintained beyond the project's lifetime.

In order to improve the awareness of climate change and its negative impacts among government officials at all levels, and decision makers in enterprises and public institutions, and gradually foster a contingent of cadres who have better understanding of global climate change, different awareness-raising programs were undertaken by the government (Min et al., 2008).

Prior to the introduction and implementation of the different technologies, the Ningxia government undertook training of local technicians, farmers, farmers' agents, processing enterprises of agricultural products, members of rural specialized cooperatives, and village cadres. This personnel was trained in the technical and management skills to apply the selected techniques at demonstration sites, in the ultimate objective of disseminating these technologies to larger scale increasing the income of farmers and processing enterprises of agricultural products (Min et al., 2008).

Monitoring and Evaluation

How has the project demonstrated its impacts in terms of achieving objectives, outcomes, and outputs? Explain how M&E plans were developed, and how effectively they have been applied.

The Ningxia government actively encourages the participation of researchers from different local research institutes to continuously undertake studies that evaluate the impact of the different technologies, with the goal of identifying potentials for scaling up and limitations for corrections. The research institutes include: Ningxia University, Academy of Agriculture and Forestry Sciences, Academy of Social Sciences, Meteorological Research Institute, etc. The findings from the different evaluative studies undertaken by researchers help as formal tools for evaluating the impact of technologies.

References

BENNETT, M. T. 2008. China's sloping land conversion program: Institutional innovation or business as usual? *Ecological economics,* 65**,** 699-711.

CHANGRONG, Y., XURONG, M., WENQING, H. & SHENGHUA, Z. 2006. Present situation of residue pollution of mulching plastic film and controlling measures. *Transactions of the Chinese Society of Agricultural Engineering,* 11**,** 058.

DU, L., SONG, N., WANG, L. & NAN, L. 2015. Characteristics of drought variations in Ningxia from 1960 to 2012 under background of climate change. *J. Nat. Disasters,* 24**,** 157-164.

GUO, S.-R., SUN, J., SHU, S., LU, X.-M., TIAN, J. & WANG, J.-W. 2012. Analysis of general situation, characteristics, existing problems and development trend of protected horticulture in China. *China Vegetables,* 18**,** 1-14.

GUO, W. & LI, B. 2013. Design and evaluation of a novel type of greenhouse for Ningxia's windy-sandy-dry belt vegetable production. *2013 Kansas City, Missouri, July 21 - July 24, 2013.* St. Joseph, MI: ASABE.

INGMAN, M., SANTELMANN, M. V. & TILT, B. 2015. Agricultural water conservation in China: plastic mulch and traditional irrigation. *Ecosystem Health and Sustainability,* 1**,** 1-11.

JIANPING, L., GUANGFEN, Z., HUI, L., LIPING, W., ZHIHAI, T., HAIXIA, S., WENFENG, G. & HUIRONG, W. 2008. Situation Analysis of Ningxia Province. *Journal of comparative economics.* China Climate Change Partnership Framework - Enhanced strategies for climate-proofed and environmentally sound agricultural production in the Yellow River Basin (C-PESAP).

LI, F.-M., WANG, J., XU, J.-Z. & XU, H.-L. 2004. Productivity and soil response to plastic film mulching durations for spring wheat on entisols in the semiarid Loess Plateau of China. *Soil and Tillage Research,* 78**,** 9-20.

LI, X.-Y. 2002. Effects of gravel and sand mulches on dew deposition in the semiarid region of China. *Journal of Hydrology,* 260**,** 151-160.

LI, X.-Y. 2003. Gravel–sand mulch for soil and water conservation in the semiarid loess region of northwest China. *Catena,* 52**,** 105-127.

LI, X.-Y., GONG, J.-D. & WEI, X.-H. 2000. In-situ rainwater harvesting and gravel mulch combination for corn production in the dry semi-arid region of China. *Journal of Arid Environments,* 46**,** 371-382.

LI, Y., CONWAY, D., WU, Y., GAO, Q., ROTHAUSEN, S., XIONG, W., JU, H. & LIN, E. 2013. Rural livelihoods and climate variability in Ningxia, Northwest China. *Climatic Change,* 119**,** 891-904.

LIU, C. & XIA, J. 2004. Water problems and hydrological research in the Yellow River and the Huai and Hai River basins of China. *Hydrological Processes,* 18**,** 2197-2210.

MIN, A., HAN, Q. & JIA, Z. 2008. China climate change partnership framework-enhanced strategies for climate-proofed and environmentally sound agricultural production in the yellow river basin (C-PESAP). *Situation Analysis of Shaanxi Province, Northwest Agriculture and Forestry University, Yangling*.

MONTEITH, J. 1957. Dew. *Quarterly Journal of the Royal Meteorological Society,* 83**,** 322-341.

MORENO, M. & MORENO, A. 2008. Effect of different biodegradable and polyethylene mulches on soil properties and production in a tomato crop. *Scientia Horticulturae,* 116**,** 256-263.

RESTREPO, A. M. C., YANG, Y. R., HAMM, N. A., GRAY, D. J., BARNES, T. S., WILLIAMS, G. M., MAGALHÃES, R. J. S., MCMANUS, D. P., GUO, D. & CLEMENTS, A. C. 2017. Land cover change during a period of extensive landscape restoration in Ningxia Hui Autonomous Region, China. *Science of The Total Environment,* 598**,** 669-679.

SJÖGERSTEN, S., ATKIN, C., CLARKE, M., MOONEY, S., WU, B. & WEST, H. 2013. Responses to climate change and farming policies by rural communities in northern China: a report on field observation and farmers' perception in dryland north Shaanxi and Ningxia. *Land Use Policy,* 32**,** 125-133.

STONE, E. C. 1957. Dew as an ecological factor: I. A review of the literature. *Ecology,* 38**,** 407-413.

TAN, C., YANG, J., QIN, D. & LI, M. 2014. Climatic background of persistent drought in Ningxia Hui Autonomous Region. *China. J. Desert. Res,* 34**,** 518-526.

WANG, L. & CHEN, W. 2014. A CMIP5 multimodel projection of future temperature, precipitation, and climatological drought in China. *International Journal of Climatology,* 34**,** 2059-2078.

WANG, Y., XIE, Z., MALHI, S. S., VERA, C. L., ZHANG, Y. & WANG, J. 2009. Effects of rainfall harvesting and mulching technologies on water use efficiency and crop yield in the semi-arid Loess Plateau, China. *Agricultural water management,* 96**,** 374-382.

YAN, C., HE, W. & MEI, X. 2010. Agricultural application of plastic film and its residue pollution prevention. Beijing, China: Science Press.

YANG, J., TAN, C., WANG, S., WANG, S., YANG, Y. & CHEN, H. 2015. Drought adaptation in the Ningxia Hui Autonomous Region, China: Actions, planning, pathways and barriers. *Sustainability,* 7**,** 15029-15056.

YUAN, H.-Y., ZHANG, X.-Y., XU, H.-J. & YANG, X.-G. 2011. Changes of China agricultural climate resources under the background of climate change. . Change characteristics of agricultural climate resources in Ningxia. *Chinese Journal of Applied Ecology,* 5**,** 024.

ZHENG, G., CHEN, X., SUN, Y., ZHANG, Z. & NA, L. 2006. The changes of temperature, precipitation, evaporation and their response to the climate warming. *Sci. Meteorol. Sin,* 26**,** 412-421.

ZOU, X., ZHAI, P. & ZHANG, Q. 2005. Variations in droughts over China: 1951–2003. *Geophysical Research Letters,* 32.