The Green Wall in the heart of the Takalamakan Desert: demonstrating potential contribution to ecosystem-based adaptation and Africa's Great Green Wall initiative

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Authors: **Dr Anthony Mills**, C4 EcoSolutions, Cape Town, South Africa
Dr Jian Liu, UNEP-IEMP, Beijing, China
Boni Biagini, Global Environment Facility, Washington DC, USA
Ermira Fida, UNEP, Nairobi, Kenya
Dr Arthur Hanson, China Council for International Cooperation on Environment and Development, Victoria, Canada

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Key policy messages

The Green Wall of the Taklamakan Desert in Northwest China stretches for 436 km through the heart of the Desert. It was constructed over a period of 15 years but based on 50 year long-term ecological research. This shows how human ingenuity and science can overcome tremendous environmental barriers of fiercely dry and hot conditions to develop new, green ecosystems that provide adaptation services such as protection of infrastructure.

The total cost of investment on the Green Wall is about 1/3 of the BAU to protect the road by removing sand, plus a remarkable increase in indigenous biodiversity in desert. This is a typical example of ecosystem-based adaptation (EBA)

Long-term ecological research is of fundamental importance for forging EBA interventions. Applied research should be conducted in collaboration with both the private and public sectors to ensure that appropriate upscaling of EBA interventions is triggered

The good practices and technologies can be shared and transferred to Africa, in particular in support its Great Green Wall of the Sahara and the Sahel (GGS) which needs to go far beyond simple tree planting, but adapting climate change, securing food supply and livelihood, conserving biodiversity and exploring new value chains and generating new income. There are consequently considerable synergies between the two green walls in China and Africa.

Introduction

Over a period of more than 2500 years, China constructed and maintained its Great Wall to repel invasions from forces to the North. This wall – despite covering more than 21000 km – was often unsuccessful in holding back the northern attackers. Recently, China has built a more successful wall, a 'Green Wall', 436 km long, that is holding back thousands of hectares of sand dunes from within the second largest sand desert in the world – the Taklamakan Desert of Xinjiang Uygur Autonomous Region in northwest China. This new Green Wall comprises a dense plantation of irrigated, indigenous, desert plant species adjacent to the highway that cuts through the centre of the desert. The air temperature of the Taklamakan Desert has increased as a result of climate change and is predicted to rise by several more degrees over ensuing decades – with poorly understood impacts on the desert ecosystem and water regimes. It is, however, likely that sands will become increasingly mobile as topsoils become drier as a result of warming. The Green Wall, which protects the road infrastructure from being covered in sand, is a prime example of the ecosystem-based adaptation (EBA) approach being undertaken by China. What made this Green Wall and EBA a success?

The short answer is 50 years of scientific research conducted by the Xinjiang Institute of Ecology and Geography Research (XIEG) within the Chinese Academy of Sciences. This research, driven by the demands of communities and industry, has been conducted by numerous research stations – including those from the Chinese Ecosystem Research Network (see Annex 1) – as well as botanical gardens. China has recently started sharing its experience and research know-how in ecological restoration and climate change adaptation with developing countries via the joint UNEP-NDRC global project "Enhancing Capacity, Knowledge and Technology Support to Build Climate Resilience of Vulnerable Developing Countries" funded by the Special Climate Change Fund of Global Environment Facility (see Annex 2). The Launch Workshop for this project was held over 22-24 April in Beijing, and a field trip was conducted in Xinjiang over 25-29 April to examine how China's scientific endeavours have informed policy and catalysed EBA upscaling.

The field trip commenced with a visit to Turpan Botanical Garden where horticultural research is conducted on desert plants from across the world. Thereafter the field trip delegates travelled along the 436 kilometres of Green Wall adjacent to the Tarim Desert Highway. The intensive research required to establish this Green Wall – an ecological engineering feat rivalling the construction of China's Great Wall – was a primary focus of the field trip. Thereafter the delegates visited Cele National Field Research Station where the primary research being conducted on restoration of arid ecosystems was observed. The large-scale implementation of this research was seen on the final day of the field trip, at Hotan Wind Shelter, where thousands of hectares of desert are being reclaimed to yield verdant agricultural fields.

25 April, 2013. Turpan Botanical Garden

Turpan Botanical Garden (TBG) is located 10 km southeast of the center of the town Turpan in the arid desert of the Turpan Basin. Temperatures can exceed 45 ^{o}C and annual average precipitation is only 16 mm. The purpose of establishing the garden in 1976 was to collect and display a wide variety of desert flora from around the world. More than 400 species of

desert plants grow in the TBG and, as a result of this propagation, the garden has become a research base for conserving the germplasm of many Chinese desert plant species. The horticultural research conducted in TBG provides a basis for selecting plant species to be used in EBA interventions in Xinjiang. The rate of growth, water use and survival of hundreds of different desert plants species under different environmental conditions have been analysed in these gardens (Figure 1). Effects of the following environmental parameters on plant growth are tested: salinity levels, soil type, water supply and irrigation methods. The results of this horticultural and ecological science have been used to select the most appropriate species for the Green Wall.

Figure 1: Irrigation of desert plants in Turpan Botanical Garden. A Calligonum species is in the foreground.

26 April, 2013. The Green Wall Protecting the Taklamakan Desert Highway

The Taklamakan Desert is the world's second largest shifting sand desert (after the Sahara), covering 337000 square kilometres, and lying in the rain shadow of the Himalayas. The Tarim Desert Highway that dissects the desert from north to south was completed in 1995 to transport the oil and gas from the centre of the desert. Sand persistently encroached on the road and the XIEG consequently undertook research for the oil and gas industry to determine how indigenous plants could be used to create a barrier to the sand movement. The Taklimakan Desert Research Station (TDRS) was established in 2003 to build on the scientific research undertaken at the Turpan Botanical Garden. Applied research at this station – which has the harshest climate, in terms of heat and aridity in the world – was undertaken to determine which species could tolerate the extremely saline groundwater of the Taklamakan Desert. In certain places of this desert, the groundwater has a salinity approaching that of seawater, and irrigation with such water would prohibit the growth of most plants on earth. The TDRS overcame this problem by testing the growth of 173 species of plants under the desert climate and under irrigation with saline water. Of these, only 88 species were able to grow well under the harsh environmental conditions. Three plant genera from the 88 species were selected as having optimal characteristics for the construction of the Green Wall, namely *Calligonum, Haloxylon* and *Tamarix*. These characteristics include

extreme drought tolerance, rapid growth, capacity to withstand damage from wind-blown sand and capacity to grow using saline water.

The Green Wall, which stretches for 436 km through the heart of the Taklamakan Desert was constructed over a period of 16 years from 1991 to 2006 and entailed *Calligonum*, *Haloxylon* and *Tamarix* being planted in rows, alongside drip irrigation pipes, in belts of 72-78 meters wide on each side of the road (Figure 2).

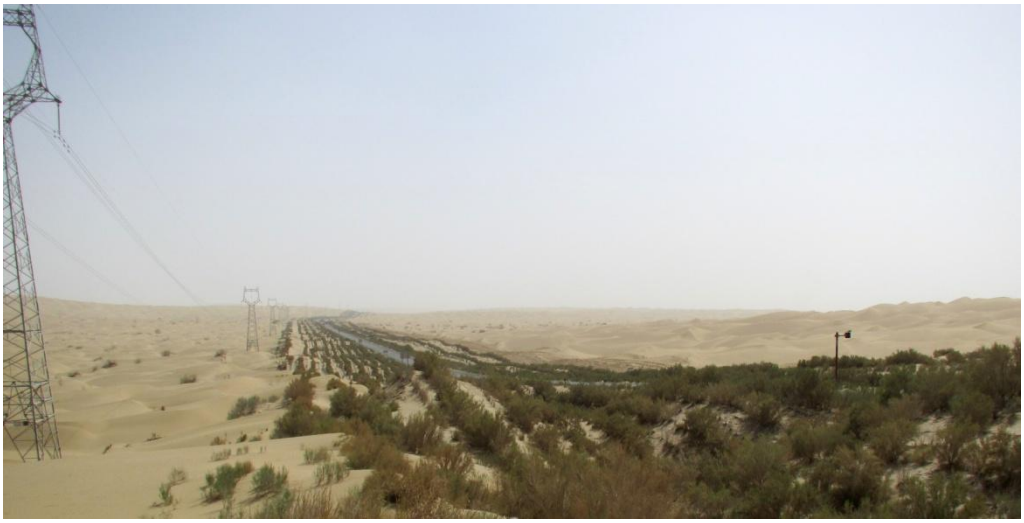

Figure 2: The Green Wall of irrigated desert plants that runs for 436 kilometres through the heart of the Taklamakan Desert.

In total, 3128 hectares of sandy desert have been converted into the Green Wall, which is now a well-established *Calligonum/Haloxylon/Tamarix* (CHT) shrubland. Twenty million plants were planted over a 2 year period to form this green infrastructure, at a cost of ~$10000 per hectare, with total maintenance cost of ~$4.7 million per year. The investment has been deemed very cost-effective because the cost of removing sand manually from the road on a daily basis is estimated at $15 million per year. The total cost of investment – including establishment and maintenance – of the Green Wall over a 20 year period is estimated to be ~$125 million. By comparison the total cost of removing sand from the road – including all expenditure on equipment – has been estimated to be more than double this cost (~$300 million). The benefits of the Green Wall go beyond merely stopping sand from moving onto the road. There has, for example, been an increase in indigenous biodiversity (including mammals and birds) in the CHT shrubland.

The Green Wall will also soon be generating an income stream, based on research by the TDRS into the production of a medicinal plant, the desert ginseng (*Cistanche deserticola* and *Cistanche tubulosa*). These plants are root parasites that live off the shrubs of the Green Wall. Their roots are chipped, dried and then sold into the large domestic market across China. TDRS is conducting trials on the desert ginseng to determine how to maximise the income from this agricultural production. The research has shown that it is feasible to produce desert ginseng across the entire Green Wall and this upscaling is in the process of being rolled out (Figure 3a and b). It is anticipated that between $1500 and $7500 per hectare per annum will be generated through sales of the desert ginseng once it is in full production across the Green Wall.

(a)  (b) 

Figures 3a and b: Irrigation of Cistanche species - the desert ginseng

27 April, 2013. Cele National Field Research Station

The Cele National Field Research Station (CNFRS), located 100 kilometres from Hotan City, was established in 1983 to address environmental degradation in desert and oasis ecosystems. Research undertaken here focusses on determining how to manage the oasis and desert ecosystems in a sustainable manner in order to reduce the process of desertification which is being exacerbated by climate change. The research focuses in particular on developing technologies to control desertification and movement of sand dunes into urban and agricultural areas. To this end, the root structure and water demand of a range of desert plants are investigated in detail below ground to determine how to irrigate and on which soils to plant particular species.

CNFRS scientists are also experimenting with a range of desert species to increase agricultural production. This includes growing species used for desertification control such as *Tamarix* and *Calligonum* with agricultural and medicinal crops such as Jujuba, walnut and *Cistanche*.

The ultimate objective of the research is to guide development of the region such that agricultural production is increased, desertification is controlled, and surface and groundwater are managed in a sustainable manner, especially given the expected climate change conditions of greater temperatures and associated evapotranspiration.

The achievements of the CNFRS scientists were recognised internationally by UNEP in 1995, when the station won two UNEP awards, one for desertification control and one for restoration of vegetation. A further achievement of the station is its admission into the Chinese Ecosystem Research Network in 2003 (see Annex 1).

28 April, 2013. The Hotan Wind Shelter: shielding desertification and expanding the oasis

The technologies developed at Cele National Field Research Station (CNFRS) are used to promote agriculture in the Hotan prefecture on the northern slopes of the Karakorum Mountains on the southern border of the Taklamakan Desert. Drip irrigation systems, using groundwater, are being installed into the desert over thousands of hectares, and new, agriculturally productive landscapes are being created out of barren landscapes (Figure 4).

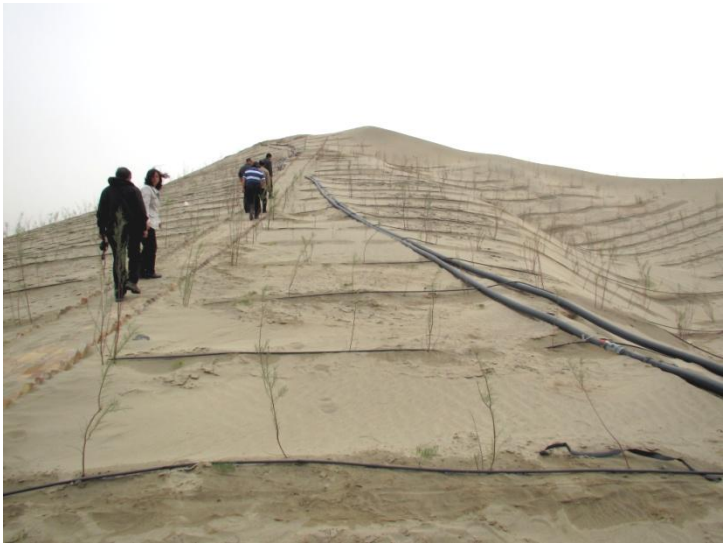

Figure 4: Ecosystem based adaptation at the Hotan Wind Shelter - rehabilitation of the desert into verdant agricultural land.

A wide variety of tree species and crop species are planted. Poplar plantations produce timber. A range of agro-forestry plantations produce fodder. Walnut plantations are underlain with a wheat crop (Figure 5), producing food crops for local consumption and for export. Vineyards produce grapes for consumption and production of wines. To capitalise on the investment to reclaim the desert, novel techniques are used to maximise the agricultural productivity per unit area. Wheat is grown on the verges of roads, and vineyards are grown over roads. Indeed, the latter 'grape corridors' extend along 1500 kilometres of road in the Hotan prefecture. New technologies presently being tested by CNFRS scientists in the expansion of the Hotan Wind Shelter include the use of hydrophobic sand – treated using nano-technology methods. This treated sand is used to prevent water loss, keeping the water within the root zone of the soil profile.

Figure 5: Reclamation of the desert in Hotan prefecture to yield lush agricultural fields of wheat and walnut trees.

In new desert reclamation projects that are expanding the Hotan Wind Shelter, drip irrigated *Tamarix* plantations are used to control movement of sand from the desert (Figure 6), and are also used to produce roots of the valuable medicinal plant, *Cistanche*, for export. The production of *Cistanche* is undertaken by local villagers, providing them with a new income stream that is boosting the local economy. This is an example of EBA, whereby a drought-adapted plant species, *Tamarix*, is being used to combat the increasing threat of desertification as a result of climate change, and a drought-adapted income-generating plant, *Cistanche*, is being used to provide alternative livelihoods for local communities.

Figure 6: Drip irrigation of Tamarix species to control sand movement in the Hotan prefecture.

This economic transformation highlights how science conducted by CNFRS has catalysed new public sector investments in green infrastructure which in turn are benefiting local communities.

29 April, 2013. Xinjiang Institute of Ecology and Geography, CAS

Xinjiang Institute of Ecology and Geography (XIEG), which emerged in 1998 from a former Xinjiang Institute of Biology, Soil and Desert established in1961 and Xinjiang Institute of Geography in 1965, has provided the research platform – built over 50 years of continuous work – for catalysing EBA implementation and upscaling across Xinjiang. This multi-disciplinary institute comprises 8 research departments, 9 field stations, a scientific library and natural science museum. The staff contingent of the institute comprises 132 resident professors, 46 visiting professors and 334 graduate students. On 28 April, the field trip delegates visited the XIEG natural science museum which has a wide range of modern displays depicting the knowledge that XIEG has developed in desert, grassland and alpine ecosystems of Xinjiang. These displays are visited regularly by school children, as part of XIEG's commitment to improving public awareness and ultimately society's responses with regards to managing ecosystems and adapting to climate change.

Beyond the Green Wall: EBA in the 21st Century

The Green Wall of the Taklamakan Desert shows how human ingenuity and science can overcome tremendous environmental barriers of fiercely dry and hot conditions to develop new, green ecosystems that provide services such as protection of infrastructure. This ingenuity and science was provided by the XIEG over many decades. The development of the Green Wall has triggered many other green infrastructural developments, and numerous lessons have been learned through the XIEG's long-term, applied research. Firstly, it is evident that the XIEG's knowledge can be used to manage the new climate change risks – such as greater temperatures and more intense and frequent droughts – that Xinjiang, China and the entire world face. Indeed, an EBA approach using green infrastructure designed by XIEG has already started in the Hotan prefecture. In this region, the success of the Green Wall has catalysed public sector expenditure to reclaim the desert and develop highly productive agricultural landscapes, despite climate change-induced diminishing water resources. Secondly, XIEG's work shows that long-term research is of fundamental importance for informing EBA interventions. This is because ecosystems respond slowly to restoration efforts, and in many cases, decades of research are required before the optimal protocols for EBA can be identified. And thirdly, the XIEG experience has shown that applied research should be conducted in collaboration with both the private and public sectors to ensure that appropriate upscaling of EBA interventions is triggered. The XIEG research on appropriate EBA interventions started at a plot scale in the Turpan Botanical Gardens, for example, and then reached thousands of hectares through the collaboration with the industrial sector on the Green Wall, and finally, after influencing public policy, it has been upscaled to tens of thousands of hectares in the Hotan prefecture.

The XIEG is now sharing its considerable EBA expertise with developing countries across Africa and Asia. This is primarily taking place through the joint UNEP-NDRC global project "Enhancing Capacity, Knowledge and Technology Support to Build Climate Resilience of Vulnerable Developing Countries" (see Annex 2) and the National Development Reform Commission (NDRC) of China's South-South Cooperation Initiative on Climate Change and Ecosystem Management (see Annex 3). Under these projects, scientists from XIEG will be working in Mauritania to develop EBA interventions that will build climate resilience in its desert ecosystems, and other CERN scientists from across China will be working in Nepal and the Seychelles to build climate resilience of a range of forest and mangrove ecosystems. The lessons learned from these international collaborations will be disseminated to other developing countries via regional networks in Africa and Asia Pacific.

The Great Green Wall of the Sahara and the Sahel (GGS) is one pertinent example of how XIEG's research knowledge could be applied to great effect. This green wall was initiated by the African Union and the Community of Sahel-Saharan States to address the detrimental social, economic and environmental impacts of land degradation and desertification in the Sahel and the Sahara. The lessons learned by XIEG during the construction of China's Green Wall through the Taklamakan Desert and the transformation of thousands of hectares of desert into productive agricultural landscapes in the Hotan prefecture are likely to be of great benefit to the GGS developers. This is because Africa's green wall will also go far beyond simple tree planting. It will be exploring ways to generate income, adapt to climate change, develop new livelihoods, establish new value chains and provide food security for vulnerable local communities. There are consequently considerable synergies between the two green walls in China and Africa.

Annex 1. The Chinese Ecosystem Research Network

The Chinese Academy of Science (CAS) established the Chinese Ecosystem Research Network (CERN) in 1988 under the auspices of the Chinese government and World Bank (www.cern.ac.cn). CERN has developed into an innovative scientific and technologically advanced facility that integrates monitoring, research and demonstrations into long-term research frameworks to assist China, address ecosystem management, environmental protection, agriculture, disaster reduction and natural resource management. Demonstration activities of CERN include long-term ecological and economic research for investigating the effectiveness of ecosystem management technologies. This includes a range of demonstration models across China, including soil and water conservation activities, revegetation of hilly regions, protection and recovery of natural vegetation in arid areas and alternative cropping systems. Good practices derived from the results from these demonstrations are used to inform Chinese regional conservation and socio-economic development plans. At present, CERN consists of 40 field stations, 5 sub-centres and 1 synthesis centre, with over 2000 scientists, technicians and graduate students engaged in its activities. Over the next 10 years CERN will focus its activities around six core research areas: i) ecosystem processes; ii) responses and adaptation of ecosystems to global climate change; iii) biodiversity conservation and use of biological resources; iv) ecosystem restoration and sustainability; v) impacts of human activities on ecosystem structure and functions; and vi) application of ecological monitoring, modelling and eco-informatics.

CERN provides technical support to UNEP's International Ecosystem Management Partnership (UNEP-IEMP). These two institutions work closely together to synthesise research findings for use in policy and ecosystem management decision-making. The SCCF project will work closely with UNEP-IEMP and CERN to efficiently use the knowledge, technologies and good practices developed in China as well as in other developing countries. The expertise of CERN will be drawn upon for developing long-term research frameworks for measuring the effects of using climate resilient approaches for mangrove restoration in the Seychelles, community based watershed-restoration in Nepal and multi-use desert greenbelt establishment in Mauritania. CERN already has strong links in Mauritania through the Xinjiang Institute of Ecology and Geography which focuses on desertification control. The SCCF project will furthermore build on CERN's partnerships with other research networks including United Kingdom Environmental Change Network (UKECN), US-LTER, LTER-Europe and South African Environmental Observation Network (SAEON) through its membership in the International Long Term Ecological Research (ILTER) multilateral platform.

Annex 2. The UNEP-NDRC global project "Enhancing Capacity, Knowledge and Technology Support to Build Climate Resilience of Vulnerable Developing Countries"

The joint UNEP-NDRC global project "Enhancing Capacity, Knowledge and Technology Support to Build Climate Resilience of Vulnerable Developing Countries" funded from SCCF resources was successfully endorsed by the GEF CEO on 15 January 2013. The overall goal of the SCCF project is "*to reduce the vulnerability of LDC and developing African and Asia-Pacific countries to climate change impacts by providing capacity, knowledge and technology support"*. This SCCF project comprises three components to be implemented over four years (2013-2016), namely: i) **Inter-regional coordination and capacity building** for African and Asia-Pacific developing countries to plan and implement EBA; ii) **Inter-regional online EBA knowledge support**; and iii) The transfer of **EBA technologies** to pilot African and Asia-Pacific countries supported by national and local level capacity building and knowledge support. The SCCF project's three components include both inter-regional activities, delivered through Component 1 and 2, and national level activities (in the Seychelles, Nepal and Mauritania) delivered through Component 3.

Through the above components, the SCCF project will address capacity, knowledge and technological needs to implement EBA in vulnerable African and Asia-Pacific developing countries by i) building a **scientific evidence base** for EBA; ii) implementing concrete, on-the-ground EBA interventions in three countries (Seychelles, Nepal and Mauritania) representing three different vulnerable ecosystems (coastal, mountains and arid/semi-arid respectively) within **institutionalised, long-term research frameworks**; iii) developing and disseminating **detailed EBA implementation protocols** (including information on cost-effectiveness) applicable to a range of countries, ecosystems and economic sectors; iv) developing EBA **planning tools** for decision-makers and project managers; v) conducting **capacity building, policy strengthening** and **inter-regional coordination** to assist existing adaptation networks and initiatives that provide regional and national level EBA knowledge support; and vi) providing inter-regional knowledge support through an **interactive web-based platform**, including documentaries, research funding guidance, policy briefs as well as access to information and planning tools.

Activities will be implemented by building on and linking with existing African and Asia-Pacific regional networks and initiatives on EBA. The project will collate, synthesise and disseminate outcomes and lessons learned from GEF and non-GEF projects including expertise from China using a standardised methodology. A rigorous scientific approach will be used to build an evidence base for EBA across a range of ecosystems, including coastal, mountain and arid/semi-arid. The projects' concrete, on-the-ground EBA interventions will focus on climate-resilient interventions for mangrove restoration (550 ha) in the Seychelles, community-based watershed restoration (495 ha) in Nepal, and multi-use desert greenbelt establishment (450 ha) to control desertification in Mauritania. The interventions will *inter alia*: i) regulate water quality, flow and storage thereby improving fresh water provision and food security; ii) increase the supply of non-timber forest products (NTFPs) such as fruits, nuts and fibre; iii) conserve biodiversity; iv) provide protection from extreme weather events, in particular shoreline protection from coastal storm surges; and v) increase fisheries production by protecting spawning grounds. Research on the effects of these interventions and information from other GEF and non-GEF projects will provide an evidence-base for future EBA up-scaling.

In summary, the SCCF project will assist local communities in developing countries in Africa and Asia-Pacific to adapt to the impacts of climate change by enhancing their capacity to plan, finance, implement, research and legislate in support of EBA. The project will be implemented by UNEP which will bring to this project its extensive experience gathered for many years as capacity builder, knowledge mobiliser and ecosystem manager. The project will be executed by the NDRC of China through the Institute of Geographic Sciences and Natural Resources Research (IGSNRR) – Chinese Academy of Sciences (CAS) in parallel with and by complementing other on-going initiatives as part of its South-South Cooperation Programme. Besides this, the project will build upon on-going regional and national baseline initiatives.

Annex 3. China's South-South Cooperation Initiative on Climate Change

The SCCF project has been identified as a flagship project for the National Development Reform Commission (NDRC) of China's **South-South Cooperation Initiative** on Climate Change, which includes initiatives currently under development in collaboration with UNEP, IEMP and the Chinese Academy of Sciences (CAS) to promote capacity building and adaptation technology transfer in developing countries of the southern hemisphere, in particular Africa and Asia-Pacific. China's commitment to South-South Cooperation was initially made in 2011 at COP17 where Xie Zhenhua, Vice Chairman of the NDRC, announced China's South-South Cooperation Initiative on Climate Change. More recently in 2012, this commitment was reiterated at the Rio+20 Earth Summit 2012, where the Chinese Premier Wen Jiabao announced that China will: i) allocate ~US$31.7 million (200 million RMB) to assist Least Developed Countries, Small Island Developing States (SIDs) and African countries in addressing climate change over the next three years; and ii) contribute ~US$6 million to a UNEP Trust Fund to enhance the capacity of developing countries to plan and implement appropriate ecosystem management activities including desertification control, forest protection and restoration. The NDRC through the IGSNNR is the Executing Agency of this SCCF project and is also responsible for the development of the SSC. The NDRC through the SSC initiatives is providing US$5 million in co-financing to the SCCF project.