African Insect Science for Food and Health

Climate-smart push–pull:

resilient, adaptable conservation agriculture for the future

Developing adaptable, productive agricultural systems that are resilient to the risks and shocks associated with long-term climate variability is essential to maintaining food production into the future. But resilience is not enough. Climate-smart agricultural systems also need to protect and enhance natural resources and ecosystem services in ways that mitigate future climate change.

Push–pull is a conservation agriculture technology developed for smallholder mixed farming systems. The livelihoods of 80% of the population of sub-Saharan Africa (SSA) depend on these systems. Push–pull farmers establish perennial stands of two fodder crops, one between the rows of their main cereal crop and the other around the field. The natural chemicals produced by these companion plants effectively control stemborers (insect pests) and parasitic weeds in the genus *Striga*.

When farmers adopt push–pull, as nearly 70,000 have done since 1998, they not only achieve a dramatic and sustainable increase in cereal yields, they also benefit from enhanced soil fertility and obtain year-round fodder crops. This strengthens the foundations of their farming and livelihood systems, making them both more productive and more resilient.

Although farmers have successfully used push–pull since it was first extended in 1998, in recent years they began reporting that the companion plants could not always withstand the long seasonal dry spells that were becoming more frequent. Through new research in 2011, this led to the development of a 'climate-smart' push–pull, which includes two new drought-tolerant companion plants. Building on the already formidable pest management and soil improvement characteristics of the technology, climate-smart push–pull can be extended to dryer agro-ecosystems and applied to a wider range of cereal crops.

Mary Otuoma, a widow who lives with her daughter-in-law and two grandchildren in Bondo district, Kenya, farms a single acre. She is pictured in front of her climate-smart push–pull plots with sorghum (foreground) and maize (background). "I now have enough food," says Mary, "and I have been able to buy a sheep. My poverty is alleviated."

Africa's persistent poverty…

Africa faces particular problems in feeding its population and it is the only continent in which per capita food production has been declining over the past two decades. In SSA, land degradation, pests and weeds hamper the efficient production of cereals, particularly maize, the main staple and cash crop. Low and declining yields are affecting food security, nutrition and incomes, trapping farmers in poverty and poor health. The resource-constrained smallholder farmers living in the arid and semi-arid regions who practice mixed crop–livestock production are particularly badly affected.

In addition to widespread poverty, population pressure on the land is high in many areas. In many parts of the region, smallholdings commonly amount to just one hectare or less. Soils are severely degraded and have low organic matter as a result of continuous monocropping, lack of investment in soil improvement and the removal of crop residues for livestock fodder. Most fields are heavily infested with parasitic striga weeds, while insect pests – principally stemborers – devastate cereal crops, commonly causing over half the potential harvest to be lost.

Many families remain trapped in a cycle of diminishing yields and deepening poverty. Food insecurity is already common, with a critical shortage of cereals in almost 70% of rural households. This is the backdrop to the challenge of intensifying agriculture sustainably to meet the extra demand for food from a growing population. There is an urgent need for a significant and sustainable increase in grain yields and animal production. In particular, sustainability requires ecologically sound ways of managing weeds and pests, and a strong focus on maintaining and conserving soil, crop and water resources.

…and the compounding effects of climate change

Climate change is anticipated to have far-reaching effects in Africa, threatening many of the advances made through efforts to achieve the Millennium Development Goals by 2015. Ensuring the continuity and sustainability of development in the context of climate change will be at the centre of post-2015 international development agendas.

Studies to predict the effects of climate change suggest that, by 2025, growing-season average temperatures will be warmer than those of 1960–2002 for four years in ten for the majority of Africa's maize-growing areas. This is projected to reach nearly nine years in ten by 2050, and nearly ten by 2075.

Climate models also suggest that rainfall will become progressively more unpredictable, with a decline in yearly totals and increasing incidence of floods and droughts.

These climate trends are likely to lead to worsening land degradation and pest and weed pressure, with crop failure occurring more often, exacerbating food insecurity. To adapt to these adverse conditions, many resource-constrained smallholder farmers will need to modify their farming systems to incorporate cereal crops with greater drought resistance, such as sorghum and millet, and to replace cattle with small ruminants for dairy production.

Push–pull: a broad-based solution

Push–pull has already proven its success as a conservation agriculture technology that simultaneously addresses many of the constraints faced by smallholder farmers, dealing effectively with pests and weeds, increasing the productivity of crops and livestock, and supporting several important agro-ecosystem functions.

The new climate-smart adaptation of the push–pull technology has unrivalled potential to continue to address these problems at the same time as equipping farmers with the increased resilience and adaptability they need to deal with the additional problems associated with climate change.

What is climate-smart push–pull?

Developed by *icipe* and its partners, push–pull is a novel conservation agriculture technology designed to integrate pest, weed and soil management in cereal-based farming systems. It involves driving cereal stemborers away from the crop by using a repellent intercrop plant, desmodium (the 'push'), while at the same time attracting stemborers with a border crop of native grass trap plants (the 'pull'). Chemicals released by the desmodium roots also result in very effective control of the troublesome parasitic weed striga.

As well as controlling stemborers and striga, the push–pull companion plants provide high-value animal fodder, which farmers can sell or feed to stall-fed dairy cows and other livestock. The companion plants also increase soil fertility, prevent soil erosion and conserve soil moisture.

In Lambwe Valley, Mbita district, Kenya, this maize crop has failed due to a long dry spell, and the farmer has released his livestock into the field to graze the plants.

The technology fits well with traditional African mixed cropping systems. Based on locally available plants, rather than expensive external inputs, it is both appropriate and economical. By improving the productivity of a wide range of crops and livestock, it diversifies farmers' income sources. Through being equally accessible to female and male farmers, it contributes positively to gender equity. Perhaps most importantly, push–pull farmers commonly report a doubling and tripling of their maize yields and their food security is greatly increased.

Funding from the European Union has allowed further research to adapt push–pull to predicted drier and hotter conditions by identifying and incorporating drought-tolerant trap and intercrop plants. This has led to a new, climate-smart push–pull package being extended to farmers, comprising an intercrop of greenleaf desmodium and a border crop of Brachiaria grass. As well as directly addressing soil fertility and productivity constraints, climate-smart push–pull responds directly to the rising uncertainties facing Africa's rain-fed agriculture due to the continent's vulnerability to climate change.

How does push–pull work?

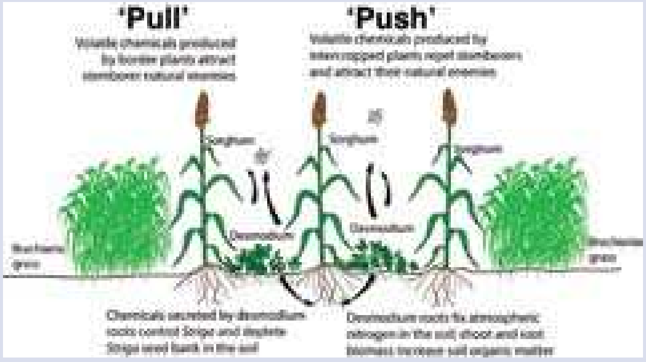
Push–pull prevents stemborers attacking cereals by intercropping with a 'push' plant, such as desmodium, and planting around this intercrop a border of a stemborer-attractive 'pull' plant, such as Napier grass or Brachiaria grass.

In addition to repelling or pushing the stemborers away from the crop, desmodium suppresses the parasitic weed, striga. It stimulates germination of the striga seeds, then inhibits the growth of its roots, thereby preventing the striga attaching itself to the host plant.

On top of dealing with stemborer and striga, the leguminous desmodium intercrop fixes atmospheric nitrogen, adds organic matter to the soil, conserves soil moisture and enhances soil biodiversity, thereby improving soil health and fertility. Additionally, it provides ground cover and, together with the surrounding grass trap crop, protects the soil against erosion.

Stemborer larvae feed first on the leaves of the maize plant, before going on to bore into the stem.

The parasitic weed *Striga hermonthica* does not make its own nutrients, instead drawing its nourishment from the cereal roots.



Conventional push–pull was developed in 1997 and introduced to farmers in 1998. It uses silverleaf desmodium (*Desmodium uncinatum*) and Napier grass (*Pennisetum purpureum*).

Climate-smart push–pull was developed in 2011 and introduced to farmers in 2012. It uses two drought-tolerant species: greenleaf desmodium (*Desmodium intortum*) and Brachiaria grass (*Brachiaria cv mulato II*).

See www.push-pull.net for more information.

The climate-smart push–pull demonstration plot at Mbita Point.

The sorghum plot on the left is infested with the purple flowers of striga, while the climate-smart push–pull plot on the right is completely free from the weed.

Why climate-smart push–pull?

The trap plants and intercrops used in conventional push–pull were developed to suit the current average rainfall (>800 mm per annum) and moderate temperatures (15–30°C) of Western Kenya. The rising uncertainties of rain-fed agriculture for farmers in this region and those in warmer, drier agro-ecosystems led *icipe* scientists to begin the search for new trap plants and intercrops.

Working with Rothamsted Research, UK and national partners in Ethiopia, Kenya and Tanzania, *icipe* scientists tested a total of 500 potential grasses, identifying 21 that were suitable for controlling stemborers. They then worked with farmers to select the trap plant of their choice.

The grass that farmers selected, Brachiaria, controls stemborers effectively by supporting a parasitic wasp which feeds on their larvae. Crucially, it can also withstand periods of up to four months with no rainfall, and temperatures in excess of 30°C. In addition, the grass is extremely palatable to livestock.

At the same time, the team worked to identify new species of desmodium. They needed species that not only had the desirable characteristics of silverleaf desmodium – controlling striga, emitting volatiles to repel stemborers, fixing nitrogen, producing high biomass and spreading on the ground – but were also drought tolerant. Forty-three accessions of 17 species were collected from arid regions across Africa, and greenleaf desmodium was selected. In addition to its known ability to control striga and stemborers, it fixes more atmospheric nitrogen and produces more fodder than silverleaf .

Both Brachiaria and greenleaf desmodium seed are commercially available, which meant that the new climate-smart push–pull package could be rapidly disseminated to farmers. Scientists have also identified two native African desmodium species (*D. ramosissimum* and *D. repandum*) that are even more drought tolerant than greenleaf (*D. intortum*), but for which there is no commercially available seed at present. Looking to the future, *icipe* is building partnerships with farmers and seed companies to address this constraint.

Desmodium ramosissimum, shown here controlling striga in a plot of sorghum, is highly drought tolerant, but seeds are not yet commercially available.

The *icipe* team and Rothamsted scientists are continuing their work to more fully understand the chemistry behind desmodium's ability to suppress striga, by isolating and purifying the active compounds in exudates from drought-tolerant desmodium roots. Similarly, they are examining the full mechanism of stemborer control in Brachiaria grass. This will ensure the future sustainability of the climate-smart push–pull technology and allow its wider adaptation.

Partnerships in implementation

While push–pull is in many ways an elegantly simple technology, it is based on a set of complex ecological and chemical relationships between plants, insects and soil. Scientists at *icipe* have found that push–pull works best in practice when farmers understand clearly how it works. This has made disseminating push–pull a knowledge-intensive process, with a strong emphasis placed on building farmers' capacities.

District-based *icipe* field workers usually deliver training by working with farmer groups established for mutual support and self-help, but also often visit individual farmers to oversee the establishment of push–pull plots. They also train farmer teachers, many of whom have now become experienced peer educators.

A hallmark of the successful spread of push–pull has been *icipe*'s capacity to identify and work in harmony with the many groups and organizations it meets in the field. Exploiting synergies with other active research and development organizations has created new channels for spreading push–pull. Particularly important is *icipe*'s

Testing potential push–pull border crop grasses for drought tolerance at *icipe*'s Thomas Odihambo Campus, Mbita Point, Kenya.

These farmers are members of a Heifer International group in Kenya's Rachuonyo district, and have planted a climate-smart push–pull plot with sorghum.

partnership with Heifer International, a non-governmental organization (NGO) whose livestock-focused work has proved to be a good fit with the technology, and which is now the formal implementing partner for climate-smart push–pull in Kenya and Tanzania.

By June 2013, the efforts of all partners meant that more than 10,000 smallholder farmers living in the drier parts of Ethiopia, Kenya and Tanzania had taken up climate-smart push–pull. According to Dr Charles Midega, Senior Scientist in the push–pull programme, more than 50,000 farmers will be planting climate-smart push–pull by the end of 2014.

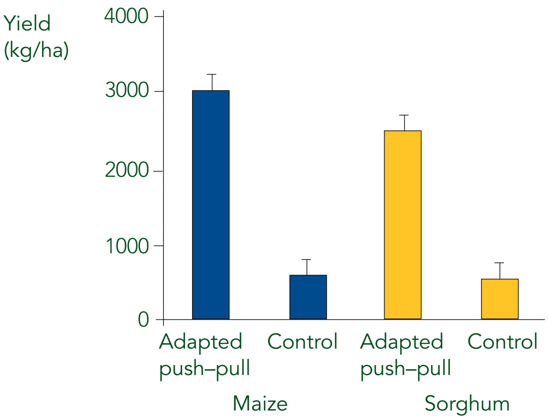
Spreading benefits, increasing impact

Conventional push–pull, usually practiced with maize, has already had significant impacts on food security, human and animal health, soil fertility, income generation, the empowerment of women and the conservation of agro-biodiversity. Climate-smart push–pull is spreading these benefits more widely, to additional crops and regions with different agro-ecosystems.

Dr Zeyaur Khan, Principal Scientist and Leader of the push–pull programme at *icipe*, says "the new trap plants and intercrops of climate-smart push–pull have met farmers' and scientists' expectations. Yields of maize and sorghum have increased significantly, sometimes as much as five-fold when compared with control plots".

The chart below presents yield data for the 2012 long rainy season for 60 climate-smart push–pull adopters, half growing maize and half growing sorghum. Their push–pull yields are compared with control plots of the same crops, grown without companion or intercrop plants.

As well as increasing cereal yields, the new companion plants have provided ample, good-quality livestock fodder, producing enough to allow farmers to make hay for the dry season. For most dairy livestock – cattle and goats, improved and local breeds – a diet of push–pull fodder results in more milk. In all, through the range of benefits it provides, the system gives high economic returns to the farmer and results in a range of positive impacts on the livelihoods of farm households.



Yield data for 2012 long rains, 60 push–pull farmers

Eunice Omondi, who lives in Kenya's Siaya district, added a climate-smart push–pull plot to her farm in 2012, and reports a six-fold increase in her maize yield. As well as being a farmer, Eunice is also a community health worker. When she goes from door to door in the villages, she explains the connection between diet and health and talks about push–pull as a way of getting more food. As she says, "having enough food helps in healing".

Improving food security and health

On-farm research confirms that, thanks to the rapid action of the greenleaf desmodium in dealing with striga, yield increases from climate-smart push–pull routinely result in cereal harvests doubling over the course of a single season.

According to Jimmy Pittchar, Social Scientist in the push–pull programme, "having enough grain to meet household needs from one season to the next is the most common local definition of food security in this region". Most push–pull farmers report that since adopting the technology, they are now mainly food-secure. On-farm results from three seasons have shown that the yield gains that underpin this increased food security can be maintained over time, thanks to the combined effect of eliminating pests and weeds and improving soil fertility.

In many cases, push–pull farmers say that the diet and therefore the health of their families have improved since adopting the technology, particularly through drinking more milk. Dietary diversity has also increased, with many farmers reporting that they are in a better position to purchase foods that they are not able to produce for themselves.

Most of the members of the St. Mary's Women's Group in Kenya's Suba district are widows. They planted a communal climate-smart push–pull plot in 2012, using the fodder to feed the dairy goats they received after working with the Italian NGO, European Committee for Agriculture and Training (CEFA). They aim to save enough money from milk sales to fence their push–pull plot and so protect it from free-grazing livestock.

Providing nutritious fodder

Livestock fulfil many purposes in the livelihood systems of farming households. They provide milk, meat, manure and draught power. Well-fed, healthy animals play an important part in maintaining soil fertility, providing dietary protein for farm households, and generating income to pay for school fees.

Push–pull farmers use their fodder crops to feed goats, sheep, cattle, pigs, poultry and even rabbits.

Many farmers report positive changes in the health and productivity of their animals, particularly thanks to the nutritional qualities of desmodium. Because it is rich in protein, desmodium fodder frequently doubles or even triples existing milk yields. Widespread reports from adopting farmers suggest that the greenleaf desmodium of climate-smart push–pull appears to have an even more positive impact than silverleaf desmodium.

Generating income

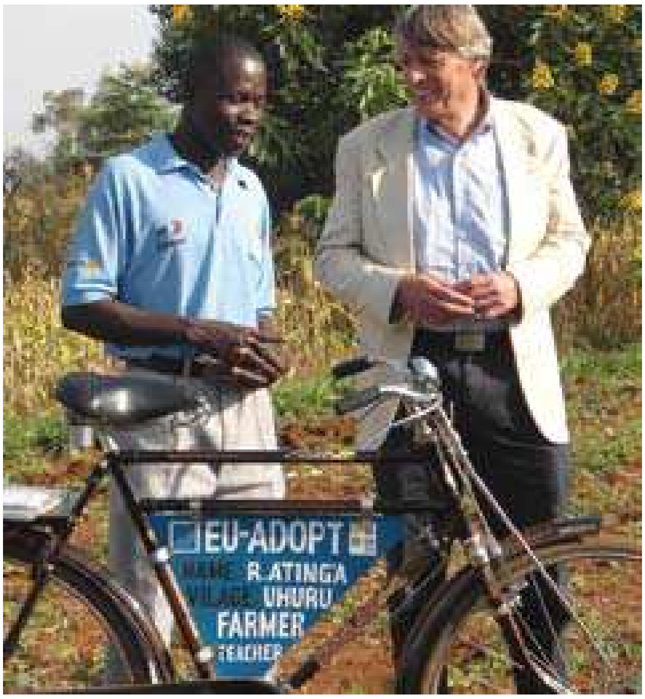
There are a number of ways that push–pull generates cash income, including the sale of cereals, milk and fodder. Within the household, this increased income is most often spent on school fees, but also used for improvements to housing and investment in livelihood diversification.

But there are also many examples of income being used to strengthen the social safety nets that protect vulnerable community members, particularly those affected by HIV/AIDS. These include the construction of a primary school for orphans using profits from climate-smart push–pull surplus, and the inclusion of push–pull in the portfolios of income-generating activities conducted by many self-help groups in Kenya and Tanzania.

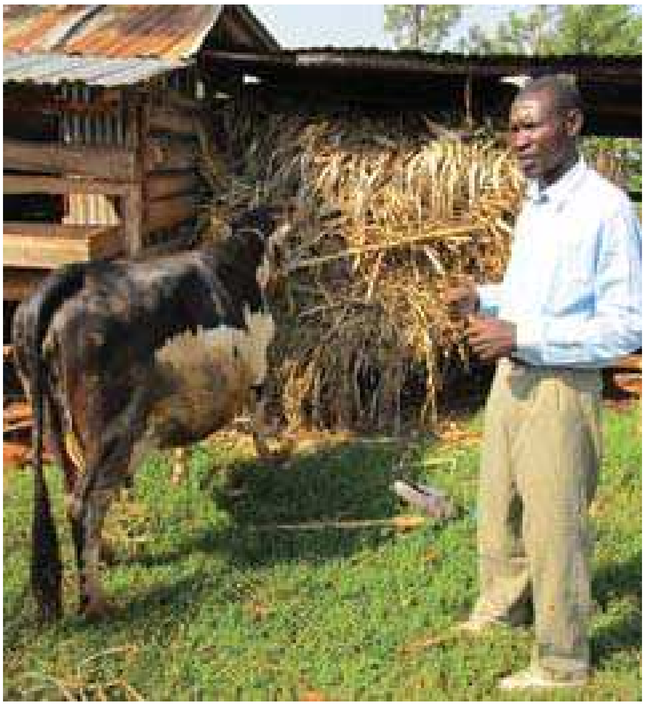
Miriam Sureri in Kuria district, Kenya, planted her first push–pull plot in 2010, and more than doubled the original area with a climate-smart plot in 2012. Before adopting push–pull, she got two litres of milk a day from her local breed cows. With silverleaf desmodium and Napier grass, this went up to three litres, but with fodder from her climate-smart plot, her yield doubled to six. Two litres a day are kept for Miriam's eight children, and the rest is sold to pay school fees.

Promoting gender equity

Once established, push–pull reduces the drudgery of digging and weeding, tasks most often performed by women, freeing up their time and labour for more productive tasks like selling milk or starting a poultry enterprise. Diversified farm income means there is more money available to buy medicines, household goods and other essentials. Feeding dairy cattle in stalls also frees women and children from the task of herding cattle to graze.



His Excellency Lodewijk Briët, Head of the European Union Delegation to Kenya, chats with Robert Atieng'a, a farmer teacher in Siaya district, during his visit in July 2013.



Evelyn Otunge's husband died in 2003, and since then she has been raising their six children alone. She adopted push–pull in 2008 and planted a climate-smart plot with sorghum in 2012. "I used to work alone on a big portion of land, for very little produce," she says. "But now I work a small area. It takes less labour, and produces more income."

More stable and resilient agro-ecosystems

As far as possible, climate-resilient agro-ecosystems maintain the functions and services provided by natural systems. This means integrating instead of segregating, closing water and nutrient cycles, increasing biological and genetic diversity, and regenerating instead of degrading bio-resources. Push–pull technology contributes to stable and climate-resilient agro-ecosystems by providing farmers with a tool for on-farm diversification that is in line with these underlying principles.

Farmers have for many years habitually diversified the crops they plant as an insurance strategy against climate uncertainty. Push–pull reinforces this strategy, because it can be equally useful when applied to maize, sorghum, millet and rice. Furthermore, having both conventional and climate-smart variants widens the range of planting material that farmers can use to tailor their cereal cropping practices to local climatic conditions.

Samuel Ong'ou had been cultivating a conventional push–pull plot for two years before he added a new climate-smart plot in 2012. He grows bananas, sweet potatoes and vegetables as well as maize and sorghum, and he feeds goats, cattle and poultry with push–pull fodder crops. In the long rainy season of 2013, the area of Rachuonyo district where Samuel lives experienced heavy rain at the onset followed by a long dry period, which finally ended with a hailstorm. Given these unfavourable climate events, Samuel was not expecting much cereal to be harvested this season. But he was nonetheless confident that the diverse enterprises on his farm, which all rely directly or indirectly on his push–pull fodder, were resilient enough to see his family through this lean season.

Dr Zeyaur Khan, Principal Scientist and Leader of the push–pull programme at *icipe*, and Remjius Bwana, a farmer, inspect a climate-smart push–pull field planted with sorghum on Remjius' farm in Kisumu West district, Kenya. A close relationship between farmers and scientists is at the heart of push–pull's success, and is essential to its future adaptation and spread.

Looking ahead

One of push–pull's strengths is the way the programme has been managed as a learning process. Because farmer participation is built in to research and dissemination, contextual changes encountered in the field can be communicated, discussed and responded to. Achieving this level of reflexivity to contextual change is a vital aspect of the climate-smart qualities of push–pull, and is thanks in no small part to the flexible approaches of the many donor organizations that have funded its development and spread. Both the technology and its model for dissemination represent a substantial resource for the future.

The development of climate-smart push–pull has made it possible for the technology to travel to new areas with lower rainfall, and to increase the potential number of farmers who might find it a useful and profitable addition to their livelihood strategies. In addition to the work that has begun to extend climate-smart push–pull in Ethiopia, Tanzania and Uganda, trials are being carried out in Nigeria and the technology has been adapted for use in South Africa. The profile of the technology is rising steadily far beyond its homeland of Western Kenya.

The need for adaptive agricultural practices that can cope with increasingly variable climatic conditions and still produce food for people and livestock has never been greater; neither has the need for development pathways that respect ecological limits and restore ecosystem health. Experiences with push–pull offer important lessons about developing and implementing the kind of climate-smart technologies that are needed to meet these challenging goals.

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icipe—International Centre of Insect Physiology and Ecology
P.O. Box 30772-00100
Nairobi, Kenya
Tel: +254 (20) 8632000
Fax: +254 (20) 8632001/8632002
E-mail: icipe@icipe.org

icipe
African Insect Science for Food and Health