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 insect pests (stemborers and fall armyworm) and parasitic weeds in the genus *Striga*.

When farmers adopt push–pull, as more than 236,000 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 used push–pull successfully since it was first disseminated, in the mid-2000s some began reporting that the companion plants could not always withstand the long seasonal dry spells that were becoming more frequent. After new research, this led (in 2011) to the development of a 'climate-smart' push–pull, with two new drought-tolerant companion plants. Such plants are being identified and tested in an extended range of agro-ecosystems and 2020 will see the launch of 'third-generation' push–pull. This builds on the already formidable pest management and soil improvement characteristics of the technology to include its use in much dryer agro-ecosystems and a wide range of cereal crops.

Mary Otuoma, a widow who lives with her son and four grandchildren in Siaya County, Kenya, farms just three quarters of an acre (0.3 ha). She is pictured in front of two of her climate-smart push–pull plots with sorghum (foreground) and maize (background). Her four push–pull plots provide 410 kg of maize and sorghum per season. Sales from her push–pull have funded the construction of two houses for her family.

Africa's persistent poverty…

Africa faces particular problems in feeding its population and it is the only continent in which per capita food production is still declining. 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 smallholders living in arid and semi-arid regions who practise mixed crop–livestock production are particularly badly affected.

In addition to widespread poverty, population pressure on the land is often high, with smallholdings commonly amounting to just one hectare or less. Soils are severely degraded and contain little 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 and fall armyworm – devastate cereal crops, frequently 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 Sustainable Development Goals (SDGs) by 2030. Ensuring the continuity and sustainability of development in the context of climate change is at the centre of international development agendas.

Studies 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 falling yearly totals and increasing cases of floods and droughts.

These climate trends are likely to exacerbate land degradation, and pest and weed pressure, with more frequent crop failures and worsening food insecurity. To adapt to these adverse conditions, many resource-constrained smallholders will need to modify their farming systems by incorporating drought-tolerant cereal crops, such as sorghum and millet, and replacing dairy cattle with small ruminants.

Push–pull: a broad-based solution

Push–pull has proven its success in simultaneously addressing many of the constraints faced by smallholders: dealing effectively with pests and weeds, increasing the productivity of crops and livestock, and supporting several important agro-ecosystem functions.

Second-generation, climate-smart push–pull continues to address these problems while also 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 conservation agriculture technology designed to integrate pest, weed and soil management in cereal-based farming systems. It involves driving cereal stemborers and fall armyworm 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 eliminate the troublesome parasitic weed striga.

As well as controlling stemborers, fall armyworm 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, Homa Bay County, 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.

How does push–pull work?

Push–pull prevents stemborers and fall armyworm 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.

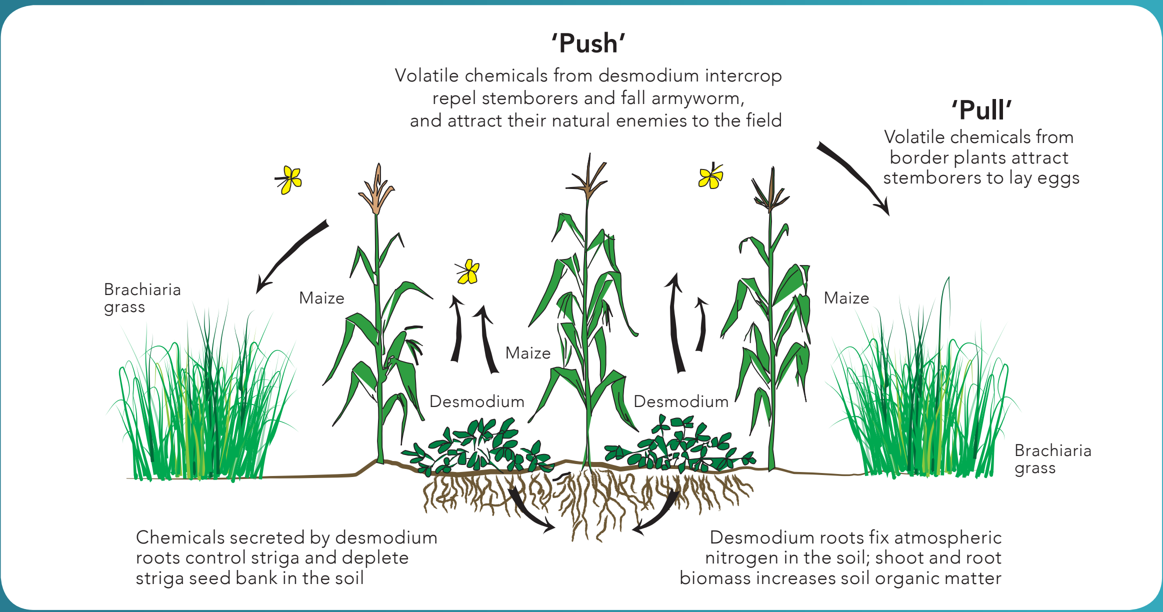
In addition to repelling or pushing the stemborers and fall armyworm away from the crop, desmodium suppresses the parasitic weed, striga. It stimulates germination of the striga seeds, then inhibits the growth of their roots, thereby preventing striga from attaching to host plants.

Besides dealing with stemborers, fall armyworm 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. It also provides ground cover and, together with the surrounding grass trap crop, protects the soil against erosion.

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 (*Brachiaria* 'Mulato II').

See www.Push-pull.net for more information. ■



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

Fall armyworm caterpillar on maize cob.

A climate-smart push–pull demonstration plot at *icipe*'s Thomas Odihambo Campus, Mbita Point, Kenya.

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

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. First, and perhaps most importantly, push–pull farmers commonly report a doubling and tripling of their cereal yields, greatly increasing their food security. 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.

Funding from the European Union enabled research to adapt push–pull to predicted drier and hotter conditions by identifying and incorporating drought-tolerant trap and intercrop plants. Support from Biovision, the Norwegian Agency for Development Cooperation (Norad) and the Department for International Development (DFID, UK) led to the 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 climate change.

Why climate-smart push–pull?

The trap plants and intercrops used in conventional push–pull were developed to suit the average rainfall (>800 mm per year) and moderate temperatures (15–30°C) of western Kenya at the turn of the century. 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.

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

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

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 *icipe* scientists selected with farmers, brachiaria 'Mulato II', controls stemborers effectively by supporting a parasitic wasp that 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 that not only had the desirable characteristics of silverleaf desmodium – controlling striga, emitting volatile chemicals 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 desmodium.

Both brachiaria and greenleaf desmodium seed are commercially available, which greatly helped rapid dissemination of the climate-smart push–pull package to farmers in new countries. However, greenleaf desmodium does not flower or set seed in equatorial or tropical Africa and, while seed is being made available by an increasing number of commercial enterprises, it would be more beneficial if farmers could produce their own to expand their plots and supply their neighbours. *icipe* has identified *Desmodium incanum* and *D. ramosissimum*, both collected from Africa and both of which flower and set seed in the target environment.

Members of a Heifer International group in Kenya's Homa Bay County have planted a climate-smart push–pull plot with sorghum.

Moreover, brachiaria 'Mulato II' has succumbed to spider mite *Oligonychus trichardti*, which has become a major pest of the grass. *icipe* has subsequently identified two cultivars of brachiaria that are not only mite resistant, but also more drought tolerant and produce more biomass than 'Mulato II'. Consequently, *Desmodium incanum* and *D. ramosissimum* together with brachiaria (*Brachiaria brizantha*) 'Piatã' (piatã grass) and 'Xaraes' (Xaraes grass) are now being disseminated and promoted as 'third-generation' push–pull options. *icipe* scientists are continuing to work towards developing a better performing third-generation Push–pull technology.

The *icipe* scientists are continuing to analyse the chemistry behind desmodium's ability to suppress striga and control fall armyworm, and the full mechanism of stemborer control in brachiaria grass to ensure future sustainability of the climate-smart push–pull technology.

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 among plants, insects and soil. Scientists at *icipe* have found that push–pull works best 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.

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 organisations it meets in the field. Exploiting synergies with other active research and development organisations has created new dissemination channels. Particularly important is *icipe*'s partnership with Heifer International, a non-governmental organisation (NGO) whose livestock-focused work has proved to be a good fit with the technology, and which is now a formal implementing partner for climate-smart push–pull in Kenya and Tanzania.

Another major dissemination partner is the community-based Sigomere Organic Agriculture Program (SOAP). Supported by US-based NGO Sasa Harambee, and in receipt of an *icipe* grant, SOAP recently established push–pull with 514 new farmers in Busia, Kakamega and Siaye counties in western Kenya in just three months (September to November 2019). SOAP's successful dissemination model relies on word of mouth – contacting individual farmers, teaching them and sending them out to recruit others. While this is a relatively labour-intensive approach, the results speak for themselves. Farmers are particularly attracted to hay (fodder) as a cash crop. SOAP also helps with hay aggregation and marketing.

By November 2019, the efforts of all partners meant that almost 138,000 smallholder farmers living in the drier parts of SSA had taken up climate-smart push–pull.

Spreading benefits, increasing impact

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

Eunice Omondi, who lives in Kenya's Siaya County, 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 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."

Professor Zeyaur Khan, principal scientist and leader of the push–pull programme at *icipe*, says "the 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."

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 farmers and results in a range of positive impacts on the livelihoods of farm households.

Improving food security and health

On-farm research confirms that, thanks to the rapid action of 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. Experience has shown that the yield gains that underpin this increased food security can be maintained over time.

Miriam Sureri in Migori County, Kenya, planted her first push–pull plot in 2010, and then 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, it doubled to six. Two litres a day are kept for Miriam's eight children, and the rest is sold to pay school fees.

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. *icipe*'s recent research has shown that dietary diversity of push–pull farmers has also increased, with many farmers being in a better position to purchase foods that they cannot produce for themselves.

Providing nutritious fodder

Livestock have 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 school fees.

Most of the members of the St Mary's Women's Group in Kenya's Homa Bay County 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.

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 milk yields. Widespread reports from adopting farmers suggest that the greenleaf desmodium of climate-smart push–pull has 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.

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 primary schools for orphans, and the inclusion of push–pull in the portfolios of income-generating activities conducted by many self-help groups in eastern Africa and beyond.

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 such as 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.

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.

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 Homa Bay County 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 that 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 the lean season.

His Excellency Lodewijk Briët, former ambassador of the European Union to Kenya, chats with Robert Atieng'a, a farmer–teacher in Siaya County, during his visit in July 2013.

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 conventional, climate-smart and third-generation variants widens the range of planting material that farmers can use to tailor their cereal cropping practices to local climatic conditions.

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 into research and dissemination, contextual changes encountered in the field can be communicated, discussed and responded to. Achieving

Samuel Ong'ou had been cultivating a conventional push–pull plot for two years before he added a new climate-smart plot in 2012. His approach to the variable climate is diversification: he grows potatoes, cassava, fruits and vegetables as well as maize and millet, and he feeds goats, cattle and poultry with push–pull fodder crops. He is funding his children through school, and even provides the school with chickens and drumhead cabbages.

Professor 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's farm in Kisumu County, Kenya. A close relationship between farmers and scientists is at the heart of the push–pull success, and is essential to its future adaptation and spread, particularly in light of new challenges such as attack by fall armyworm. The development of third-generation push–pull is one facet of the continuing evolution of this highly adaptable technology.

this level of adaptability 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 organisations 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. Climate-smart push–pull is being extended in 16 countries in SSA. Thus, the profile of the technology is rising steadily far beyond its origins in 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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