Systems-based approaches to help smallholder farmers face climate change and transition to profitable, resilient farming

More than 80% of farms worldwide have holdings of less than 2 hectares. Distributed throughout Africa, Asia, and Latin America, they produce roughly 35% of the world's food, typically using low-input, rainfed agriculture that depends mostly on family labor, with little or no mechanization or fertilizer, and mainly for local consumption. Their activities contribute little to global warming but they inordinately suffer its extremes, including rising temperatures and extended droughts. Boosting their productivity and profits are a key part of improving rural livelihoods.

Smallholder farmers in Mbingwa village, Malawi, grow tobacco for income and maize, groundnuts, sweet potato, vegetables, and bambara nut for food. Both men and women cultivate food crops.
Photo: CIMMYT/Mike Listman

Sub-Saharan Africa

Smallholder farmers predominate in sub-Saharan Africa. They face the challenges mentioned above but also contend with soils of low fertility and their farming practices extract nutrients without replacing them. Their chief crop and food source is maize, but cassava, sorghum, millet, plantain, tobacco, legumes, and farm animals are also important.

Since the early 2000s CIMMYT has studied and promoted sustainable intensification practices based on improved cereal and legume diversification, scale-appropriate mechanization, and conservation agriculture, which involves reduced tillage, keeping crop residues on the soil, and diversifying cropping.

CIMMYT and partners work has directly influenced 200,000 smallholders and conservation agriculture practices are now used by more than 3 million farmers in southern Africa. This is improving soil health and is key to climate change adaptation and mitigation by sequestering soil carbon, as shown through a unique mother and baby trial network linking long-term trials to on-farm impact across Malawi, Zambia, and Zimbabwe. As part of diversification, farmers are encouraged to grow larger areas of legumes, which add nitrogen to soils.

Given that smallholder farmers typically adopt resource-conserving system innovations slowly and in bits, a promising approach appears to be supporting a gradual, step-wise adoption of conservation agriculture – along with livestock and residue management, use of new crops, improved varieties, and appropriate mechanization.

In Zimbabwe, partners are promoting climate-smart technologies such as drought-tolerant maize seed in combination with conservation agriculture, insurance, and linking farmers to markets to achieve a transformational change towards greater resilience. "Mother" trials established near villages have shown dramatically higher yields than farmers' own practices and promoted farmer experimentation, and yields of maize and legume intercrops thrive where conventional agriculture often fails.

Recent evidence suggests that climate change can be mitigated through ecologically-sound farming practices. Long-term experiments of 10 years or more in Africa and Europe show that yields of maize and other key crops are improved when farmers use ecological intensification practices. These include crop diversity (such as intercropping and crop rotations), planting fertility-improving crops (especially legumes), and applying manure or other organic fertilizer. Ecological intensification can be high yielding, while saving on mineral fertilizer, especially nitrogen, thereby reducing greenhouse gas emissions. In places where farmers' access to fertilizer is limited, such as sub-Saharan Africa or the Central American Highlands, ecological intensification can complement scarce fertilizer resources to increase crop yields, boosting households' incomes and food security.

Don't burn that stubble!

Farmers in many areas, including South Asia and Mexico, burn residues left over from harvested crops, usually to clear plots for the next crop. This releases huge clouds of carbon dioxide and pollutants that threaten inhabitants' health downwind.

CIMMYT and partners are promoting no-burn alternatives and policies but changing involves trade-offs for farmers, so they must see some benefit in doing so. For example, the center's long-term studies and field tests in northern India found that sowing wheat directly into just-harvested rice fields without burning or removing straw or other residues will not only reduce pollution in New Delhi and other parts of northern India, but will save over $130 per hectare in farmer expenses, lessen irrigation needs by as much as 25%, and allow early planting of wheat to avoid yield-reducing heat stress, according to a **2021 study**.

The benefits of sowing wheat earlier so that the crop fills grain before the weather gets hot are well documented. In Bihar, India – a state characterized by small, fragmented farm holdings – **CIMMYT and partners successfully promoted** use of early-maturing rice varieties and climate information systems, allowing earlier rice harvesting and wheat

Burning rice straw in India. *Photo: CIMMYT*

planting. Farmers following the practice harvest nearly 1 ton more of wheat per hectare than those who plant late, a 36% increase in yield.

Mechanization on the march

CIMMYT has been working with farmers and entrepreneurs across eastern and southern Africa to test and promote scale-appropriate mechanization, partly to ease the drudgery of smallholder farmers and women but also to address mounting labor shortages in rural areas. Key to the approach is the "service provider" model, whereby farmers able to purchase farm implements and tools offer their services for hire to community members. Building on the findings of the completed ACIAR-funded project Farm Mechanization and Conservation Agriculture for Sustainable Intensification (FACASI) and Harnessing Appropriate-scale Farm Mechanization in Zimbabwe (HAFIZ), CIMMYT is working in Zimbabwe with 200+ farmers and four service providers in Murehwa and Mbire districts as ambassadors of the community through Agroecological Living Landscapes (ALLs).

Learning landscapes to accelerate innovation in rural communities and food systems

Leveraging CIMMYT leadership, science, and partnerships and the funding and research capacity of Mexico's Secretariat of Agriculture and Rural Development (SADER) during 2010-21, the program known as "MasAgro" has helped

A new vision of making profits drives mechanization service providers in Zimbabwe. *Photo: CIMMYT*

over 300,000 participating farmers to adopt improved maize and wheat varieties and resource-conserving practices on more than 1 million hectares of farmland in 30 states of Mexico. Along the way, MasAgro assembled a network of hubs and modules, documenting innovative practices adapted and taken up by hundreds of thousands of farmers, with long-term field experimentation platforms linked to sustainable production and value chains through private and public sector partnerships — a new type of research learning laboratory that directly addresses sustainable development goals. Along with MasAgro in Mexico, which is e-documenting and generating knowledge through 350,000 field logbooks and 13,000 modules with side-by-side comparisons (see this data brief), CIMMYT's geo-nutrition labs in Ethiopia and Malawi and CGIAR living labs in Zimbabwe, Kenya, Laos, Peru, Tunisia and India are operating but require a major investment to systematize and integrate them.

CIMMYT scientists co-evaluate innovations with smallholder farmers in the state of Chiapas, Mexico. *Photo: CIMMYT/Mike Listman.*

We propose investing in long-term field experiments embedded in "learning landscapes" that will leverage public-private sector partnerships through data analytics, remote sensing and model-driven early warning systems, linked systematically with long-term field experimentation and co-learning on-farm, to rapidly generate innovations in pest management, climate smart and regenerative agriculture, adapted varieties and seed system innovations, as well as informing food and environmental security policy development and change.

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