FARMER Rhoda Mang'yana has vastly increased the yield of maize crops on her land in Malawi by planting trees whose fallen leaves and roots rebuild the soil.

A CURE FOR AFRICA'S SOIL

By growing trees, shrubs and other perennial plants among crops in the field, African farmers can revitalize some badly depleted soils while raising food yields

By John P. Reganold and Jerry D. Glover

Mariko Majoni in Malawi has dramatically changed how he farms. Like many small-scale African farmers, he could not afford fertilizers, and over the years his maize yields plummeted. When he learned about "fertilizer trees" that capture nitrogen from the atmosphere, he planted seedlings between his rows of maize. Six years later he was harvesting 10 times as much food, enough for his family and a surplus to sell. At first his neighbors thought he had gone mad. Now many of them have adopted the same practice.

Across much of sub-Saharan Africa, temperatures are warm, and days are long and sunny. Crops should grow well there, but as with Majoni, farmers are struggling mightily, even when they use chemical fertilizers. Yields of maize, a staple cereal, average around one metric ton per hectare—barely one tenth of maize yields that farmers in the U.S. Midwest enjoy. The reason is simple: A large proportion of soil in the lands south of the Sahara Desert is depleted. It

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lacks the organic matter and nutrients needed by plants. Applying extra chemical fertilizer alone is not always enough to raise yields significantly and in some cases can actually harm the soil further. Soil degradation continues at alarming rates, causing already low yields in some regions to stagnate or fall still lower.

The situation is troubling because about 220 million of the world's 800 million undernourished people live in the sub-Saharan region. And recent studies indicate that the population of roughly one billion people will double by 2050 and will be hard hit by climate change. Without a significant upgrade of the soil, hunger is sure to increase. Restoring soils, scientists agree, is the number-one priority to raising agricultural productivity.

In principle, the solution is straightforward. The soils need to be rebuilt with decomposed plant and animal material. This organic matter adds nitrogen and carbon, helps to retain water and nourishes microbes that keep the earth productive. In practice, though, challenges abound. A majority of African farmers cannot create or afford to buy enough crop residue, compost or animal manure to rebuild their land. And restoration has to occur while the land continues to be farmed; families cannot stop planting while croplands are repaired. Farmers also face the daunting task of increasing yields while avoiding overuse of water and chemicals and earning enough money to maintain the financial and social stability of their families and communities.

The approach Majoni adopted belongs to a set of strategies known as perenniation, which could make a huge difference in Africa. The methods rely on raising trees, shrubs or perennial grasses right among or alongside food crops to renew soils, thereby boosting crop yields and improving the long-term sustainability of food production. The perennial plants supply carbon and nitrogen to the ground, help to retain water, reduce erosion, fight off pests and raise crops' uptake of chemical fertilizers. The techniques work well with modern management practices, including no-till agriculture and organic farming, and with modern crop cultivars that have been bred for better drought tolerance and disease and pest resistance. The perennials can also provide farmers with feed for livestock and wood for fuel.

Three perenniation methods illustrate how farmers can sustainably increase the yields of important staples such as maize and sorghum and so enrich soils. Although other approaches exist, these three have succeeded in sub-Saharan Africa and have great potential to be more widely adopted there. They can help increase cereal grain yields from one to three metric tons per hectare over several years. And lessons learned could benefit other areas of the world with nutrient-poor tropical and subtropical soils, including countries in South Asia and South America.

TREES AND PEAS

THE PERENNIATION STRATEGY most widely employed by African farmers, including Majoni, is known as evergreen agriculture. Farmers establish certain kinds of trees in the fields of annual crops. Their nitrogen-rich leaves drop and fertilize the soil surface, and the activity of their deep roots adds nitrogen and carbon to the soil. Often farmers use *Faidherbia albida,* an acacia-like species native to the continent. It grows primarily in the months between the harvest and planting of crops, so it does not compete with them for water, nutrients or sunlight. In regions where crops are harvested by hand, farmers may plant the trees randomly, but they can also space the trees evenly and far enough apart that tractors and combines can navigate through. In recent decades more than 100,000 farmers in Zambia have integrated these leguminous fertilizer trees into their maize fields. In Niger and Mali, farmers have protected naturally growing tree seedlings on more than five million hectares of millet and sorghum fields, creating seminatural parklands. Several other tree species are working well, too.

PLANT BREEDER Albert Chamango shows how peanuts and taller pigeon peas can flourish together while also enriching the soil.

The trees, some reaching 30 meters high, also draw up other nutrients such as phosphorus and potassium because their roots mine much deeper soil layers than those used by the crops. As with nitrogen, these nutrients are made available to the crops through decomposing leaf litter and root activity. In addition, the trees protect the crops from hot, dry winds and thereby reduce the amount of water evaporating from the ground. These

IN BRIEF

Soils in many regions across sub-Saharan Africa are so depleted that simply adding fertilizer will not improve them and may even make them worse. **Growing perennial plants** such as trees, shrubs and legumes among food crops can rebuild soils and reduce pests while the crops grow, ultimately raising yields. **More than a million** African farmers have used the three leading "perenniation" techniques, but millions more need technical or financial help to exploit them.

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benefits can double grain yields and help to triple them when combined with modern crop varieties and fertilizers.

More than 30,000 farmers in East Africa have adopted a second type of perenniation called the push-pull system. They plant specific perennial plants among the maize fields, as well as around the edges. The plants suppress insect pests and weeds but can also mitigate erosion, produce animal feed and lessen the need for fertilizers. For example, farmers in East Africa use push-pull systems to manage both stem-borer larvae that chew into maize stems and African witchweed, which steals nutrients from maize roots. Farmers plant desmodium (*Desmodium uncinatum*), a perennial legume usually cultivated to feed livestock, in between rows of maize. It produces a smell that repels, or "pushes out," the stem-borer moths that want to lay their eggs. And a chemical from its roots suppresses witchweed.

To further reduce pest damage, farmers may grow perennial Napier grass (*Pennisetum purpureum*), also a valuable livestock feed, around the edges of the maize field to "pull in" the stem borers. The grass provides an attractive place for the stem borers that are repelled by the desmodium to lay their eggs, yet it produces a sticky resin that traps the hatched larvae.

Push-pull systems can more than double maize yields when both stem borers and witchweed are problems and increase yields by 25 to 30 percent when only stem borers are an issue. The livestock feed and increased soil nitrogen are added benefits.

Malawian and U.S. scientists developed the third approach—the "doubled-up" legume system—adopted on more than 8,000 farms in Malawi. In its simplest form, a farmer plants a low, fast-growing legume such as peanut or soybean and adds pigeon pea, another legume that grows taller but much slower and is deeper-rooted. The peanuts or soybeans mature in a few months, just when the pigeon pea is surpassing them in height and would block the sun. After the peanuts or soybeans are harvested, their leaves fall and enrich the soil. The pigeon pea matures in another month or two and is harvested, and its leaves drop, continuing the enrichment. Because the two crops grow at different rates and tap different depths of the soil, they generally do not compete for nutrients or water. This system boosts the amount of protein-rich plants a farmer can harvest in a year and enhances soils while requiring less labor than two separate crops would. And it broadens the farm family's diet.

Pigeon peas regrow after being harvested. Thus, in the second season farmers can plant maize among the regrowing pigeon peas and subsequently harvest the maize and a second crop of the peas. Across two seasons this system produces three harvests of legumes and one harvest of maize, providing 50 percent more protein than the traditional maize-legume rotations.

OPTIMIZING CROPS TO LOCAL CONDITIONS

FOR MORE THAN A MILLION African farmers who have integrated perennials into their routines, the rewards have been great. They have rebuilt soils while sustainably increasing food production and dramatically improving their livelihoods. But millions more farmers in sub-Saharan Africa do not even know the techniques exist, or they need technical or financial help to exploit them. Good practices, however, are less straightforward than applying fertilizer or pesticide. Farmers must learn how to grow perennial and annual crops together, manage longer crop rotations and devise marketing strategies for a diversified harvest. Also, many farmers do not own the land they work or lack firm leases, which can dissuade them from investing in longer-term solutions.

To help, the international community should expand its investments in perenniation development, supporting efforts to scale up the successful techniques and backing research into others that farmers and scientists have not tested widely. Some efforts are well under way. The World Agroforestry Center, an international research institute that has led the development of evergreen agriculture, is in the final year of a four-year project called Trees for Food Security, in partnership with the governments of Ethiopia, Rwanda, Burundi and Uganda. The Program for Sustainable Intensification, run by the U.S. Agency for International Development, is supporting all three of the techniques we have described in regions of sub-Saharan Africa.

Scientists at the International Crops Research Institute for the Semi-Arid Tropics, the University of Malawi and Michigan State University are helping farmers in East Africa further improve doubled-up legume systems. They are developing more types of pigeon peas suitable for different climate conditions and farmer needs. Other experts have managed to create perennial versions of traditional annual crops such as sorghum, wheat and rice, and they are now trying to raise the yields and other desirable characteristics of these novel plants. Washington State University, Michigan State and the Land Institute in Salina, Kan., are breeding perennial grains that could thrive in diverse farmlands.

These efforts are good starts. But researchers are not yet certain which perenniation techniques would work best in various environments, in sub-Saharan Africa and beyond. An in-depth analysis is needed. To do that, scientists at Rutgers University and a Chinese company's department of agriculture and bioenergy have proposed a global network of 27 to 45 research stations, including in Africa. The stations would study the suitability of a range of trees, shrubs and other perennials for local climate, environmental and cultural conditions. The scientists estimate that $540 million to $1.8 billion could endow the network with sustainable programs. The losses of nitrogen, phosphorus and potassium from cultivated fields in sub-Saharan Africa alone have been estimated at $4 billion annually. Considering that perenniation can significantly stem those losses, tap into new sources deeper in the soil and, when legumes are involved, reduce nitrogen fertilizer use, the investment seems worthwhile.

Africa's farmers face a host of difficulties, yet many have successfully used perenniation in challenging environments. Expanding perenniation will help more of them feed their families and neighbors and create incomes for themselves and workers, raising their communities' standards of living. SA

MORE TO EXPLORE

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