Eco-Efficiency: From Vision to Reality

Key Messages from a Publication Describing Advances and Options in Eco-Efficient Agriculture
From the Neolithic Revolution to the Green Revolution, farmers have always sought to use their land, labor, and other resources more efficiently. But in recent years, this abiding concern has become especially urgent and worrisome. Farming communities and whole societies have awakened to the huge costs of over-using chemical inputs and mining earth’s resources unsustainably to raise agricultural productivity in response to rapidly growing demand.

Under mounting pressure, tropical agriculture has arrived at a defining moment in its history. It can either continue along its current course, thus forfeiting the huge potential of the tropics for sustainable development. Or it can rise to the challenges of climate change, resource scarcity, and deteriorating food security by rapidly pursuing multiple paths to eco-efficiency.

Convinced that eco-efficiency can serve usefully as a guiding principle for research, the International Center for Tropical Agriculture (CIAT) decided several years ago to incorporate this concept into its mission:

To reduce hunger and poverty, and improve human health in the tropics through research aimed at increasing the eco-efficiency of agriculture

The challenge now – for our organization and others – is to translate the vision of eco-efficiency into reality.

Pathways to Eco-Efficiency

The Global Footprint Network calls attention to unsustainable use of natural resources each year by marking “Earth Overshoot Day.” In 2012, it fell, by rough estimation, on 22 August. For the rest of the year, the human race lived beyond its means, demanding more from the Earth – including the capacity to grow food – than it was able to replenish.
Such warnings ominously signal the need for eco-efficiency in agriculture and other sectors. But it is less clear how best to achieve this aim and to measure progress.

Agricultural experts agree that there is no single magic formula for achieving eco-efficiency in agriculture. They view this concept rather as a practical tool that can help us better understand emerging challenges for agriculture, analyze technological and policy options, and weigh difficult tradeoffs.

To foster debate and action, CIAT is launching a new publication series (Issues in Tropical Agriculture) whose inaugural volume is titled Eco-Efficiency: From Vision to Reality.

The publication charts six distinct but complementary pathways for progressively achieving a more eco-efficient agriculture:

1. Large-scale adoption of better crop varieties and management practices, based on sound agronomic advice
2. Increased investment in best practices that offer large enough gains to compensate farmers for greater risks

Eco-Efficiency and Climate Change

While clearly contributing to the climate change problem, farming must also be part of the solution.

Agriculture accounts directly for 10-12% of global greenhouse gas emissions. The figure reaches 30% when emissions closely related to farming are included, particularly forest destruction for crop and livestock production. Agriculture must reduce its emissions while boosting carbon sequestration to help achieve the 50-85% reduction required by 2050 to avoid a dangerous global temperature increase of more than 2.4 °C over pre-industrial levels.

Farmers must face the additional challenge of adapting to climate change impacts, which will burden them with greater uncertainty than ever about temperatures, rainfall, and extreme weather. This is an especially daunting prospect for poor farmers in developing countries, who are least able to cope.

Making agriculture climate smart is closely intertwined with the challenge of boosting food production to meet rapidly rising demand over the next several decades. The task is further complicated by limited and increasingly contested access to land, water, and energy resources. Together, these pressures make eco-efficiency in agriculture, not just a desirable end, but an urgent necessity.

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* Available at: http://ciat.cgiar.org/new-publications/
3. Reduced investment in inputs that are being over-used
4. More efficient use of all resources to obtain greater returns at lower cost
5. Spread of technologies that make possible quantum leaps in agricultural productivity
6. Protection against future losses in productive capacity

Some of these pathways are already well traveled, while pioneering farmers continue to explore others, with the aid of agricultural research for development.

Eco-Efficiency: From Vision to Reality provides guidance and inspiration for these efforts by documenting recent advances in research on key production systems and crops. As described on pages 6-11 of this brochure, the publication also explores new avenues by which agricultural research can help achieve further gains in eco-efficiency.

Achieving Eco-Efficiency: How and for Whom?

Achieving eco-efficiency in agriculture requires a profound shift in our development vision – from farmers’ fields to the corridors of political power. The 1992 Earth Summit represented an important early step in the right direction, which coincided with an incipient revolution in sustainable agriculture. But the movement lost momentum, as global support for agriculture began to wane.

Renewed food price volatility, vulnerability to climate change, and rampant natural resource degradation are the costs of past neglect. To reduce those costs drastically and fulfill the promise of tropical agriculture will require, apart from better technologies, revised policies, reformed institutions, and renewed investment, which make it attractive and feasible for rural people to adopt new practices.

In recent years, many novel tools and concepts have emerged that can help, including product life-cycle analysis, green value chains, and carbon footprint measurement. Putting those options to better use is largely a matter of capacity development. In this arena as well, many approaches show promise, such as new forms of participatory research and dynamic knowledge sharing techniques.

Skillful capacity building at every level will be especially necessary for ensuring that new pathways to eco-efficient agriculture don’t bypass smallholder farmers. This should also help create gender-sensitive options, which provide an exit from the absurd dichotomy between women’s huge burden of responsibility for food production and their limited access to all types of resources.
Eco-Efficiency and Rio+20

The World Business Council for Sustainable Development first used the term “eco-efficiency” in its 1992 publication, Changing Course. It defined the term as “creating more goods and services, with ever less use of resources, waste, and pollution.” The 1992 United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil, endorsed this concept, calling on private industry to embrace Agenda 21 – the conference’s action plan for achieving sustainable development.

Some years later, agricultural experts in the public sector took up the eco-efficiency banner as well. A 2009 report from CIAT suggests that eco-efficient agriculture is competitive and profitable as well as sustainable and resilient and that by harmonizing the economic, environmental, and social dimensions of development, it generates multiple benefits for the poor, particularly when it offers new options and roles for women.

The event held in 2012 to mark UNCED’s 20th anniversary, referred to as Rio+20, reaffirmed the sustainable development agenda. Eco-efficient agriculture is more important than ever for turning the green growth agenda into action.

A rice farmer speaks with scientists near Caranavi, Bolivia.
Toward Eco-Efficient Agricultural Systems

From Adversaries to Allies
A new development formula for the Brazilian Cerrado

The Brazilian Cerrado is a vast tropical savanna, occupying nearly a quarter of the country’s total land area. Expanding crop and livestock production in this ecoregion has contributed significantly to Brazil’s agribusiness development, accounting for a third of grain production and half of meat output. But this has incurred high environmental costs as well, including extensive degradation of sown pastures, which cover nearly a third of the Cerrado.

Recent research on a new, eco-efficient cropping system – part of an ambitious government program to promote low-carbon agriculture – demonstrates impressively that intensive agriculture and environmental quality can be compatible in the Cerrado. Bringing together activities that have traditionally competed with one another, the new formula integrates cereals and grain legumes with forages for livestock grazing and tree species for lumber and fuel.

This approach has already gained favor as a means to recover degraded pastures. It boosts output of grains, livestock products, and agro-energy; while also showing potential to lower vulnerability to climate and economic change as well as reduce greenhouse gas emissions, enhance carbon sequestration, and discourage deforestation. The new system offers a compelling, eco-efficient alternative to the common practice of leasing Cerrado land to ethanol processing plants for unsustainable sugarcane production.

System Solutions
Building agricultural momentum in West Africa’s savannas

In response to steadily rising population and market pressures – 4% annual growth in demand for livestock products, for example – farmers have intensified agricultural production across West Africa’s dry savannas. While opening new pathways to development, this has also created significant challenges to the sustainability of the region’s cropping and livestock systems.

In search of solutions, agricultural researchers have developed measures that address specific problems effectively. To cope with declining soil fertility, for example, they have introduced drought-tolerant maize varieties that use nitrogen efficiently for grain production in combination with moderate use of chemical fertilizers and planting of herbaceous legumes – an approach referred to as integrated soil fertility management. Scientists have also devised integrated strategies for managing the parasitic weed Striga. These combine tolerant cereal...
Maize in Ghana's Upper West Region.

varieties with improved practices, such as rotation with soybean, which acts as a “trap” crop, stimulating “suicidal” germination of *Striga* under conditions in which its seeds cannot survive.

Deploying such technologies more widely and integrating them into new systems that employ resources more efficiently – such as relay or strip cropping of improved cereals with food-forage legumes – would go far toward realizing the savanna belt’s large potential for sustainable agricultural development.

**Stepwise Change**

**Strengthening food security in Central Africa**

With up to 70% of rural households suffering from chronic food shortages, the densely populated Great Lakes Region of Central Africa urgently needs to intensify agriculture sustainably as part of a wider effort to combat rural poverty and recover from years of conflict. Recent agricultural research has demonstrated that two key steps are essential for achieving this end.

The first entails a “seeds and fertilizer” strategy, through which farmers widely adopt disease- and insect-resistant varieties (especially banana/plantain, beans, cassava, and maize) that are locally adapted and whose improved performance justifies the investment in moderate amounts of fertilizer.

In order for this to happen, farmers need simple information on the technologies available (explaining, for example, how to identify and avoid soils in which improved seeds cannot respond to fertilizer) as well as better access to inputs, produce markets, and credit. Meeting these requirements, though hardly easy, is both feasible and beneficial, as demonstrated by the recent experience of Malawi.

The second and even more demanding step involves improved management of organic matter together with other relatively complex changes that are needed to ensure sustainable productivity growth. Since the solutions vary from one location to another, farmers must interact quite intensively with qualified extension agents and other service providers, using proven methods such as farmer field schools.

A bean farmer tends her crop in the Democratic Republic of the Congo.
Stepping Stones to the Future
Intensifying conservation agriculture in South Asia

The cereal-based cropping systems of South Asia’s Indo-Gangetic Plains constitute a key pillar of global food security and rural development. The predominantly rice-wheat rotation alone produces food for about 400 million people. The pressures on these systems will increase dramatically toward 2050, as population growth and rising incomes drive up demand for food, feed, fiber, and bio-energy.

Cereal-based systems in the northwestern and central areas of the Indo-Gangetic Plains are already showing signs of strain—reflected in stagnating crop yields and brought on by natural resource depletion as well as by the rising costs and overuse of agrochemicals and nonrenewable energy. Meanwhile, crop yields and income from more traditional cropping systems in the eastern areas remain quite low.

Research has shown in recent years that intensive conservation agriculture can address these problems successfully. It mimics the resource-conserving features of natural ecosystems through a combination of zero tillage, maintenance of crop residues as a permanent soil cover, and crop rotation and diversification. Farmers across the region are already adopting a variety of technologies that represent stepping stones toward intensive conservation agriculture.

In India and Pakistan, for example, farmers using laser-assisted land leveling, zero tillage, and drill seeding of wheat (with rice straw left in the field) obtained three times more income than with conventional tillage because of higher crop yields and lower costs. These practices offer environmental benefits as well, particularly water savings and greater carbon sequestration.
Crop Options for Eco-Efficient Agriculture

**Uncommon Bean**
Adapting to adversity with help from wild relatives

Common bean is the most important food legume of tropical America and eastern and southern Africa, where it contributes to the food and nutrition security and incomes of millions of people. Because bean’s ancestors evolved in mostly favorable environments, the domesticated crop is not naturally adapted to extreme conditions. Climate change will deepen its vulnerability by increasing pest and disease attacks, while intensifying drought.

Bean researchers have made striking progress in the improvement of resistance to diseases and its tolerance to drought. Developing more eco-efficient beans for the future will require bolder steps to enhance those and other traits, building on recent progress in the exploitation of genetic variability from some of the crop’s wild “sister” species.

**Rambo Root**
Enhancing the appeal of a reliable and versatile staple

Cassava, a high-yielding root crop of tropical American origin, has risen from relative obscurity in recent decades to become the world’s third most important source of dietary energy after maize and rice. In contrast with many other staples, nature has conferred on this crop a clear competitive edge in the face of physical stresses, such as drought and low soil fertility.

Having originated in a remarkably wide range of growing conditions, these wild plants offer a wealth of genetic solutions to the problems that bean farmers will face in the coming decades. The tepary bean, for example, which evolved in hot, dry climates, possesses a unique root system, which enables it to cope with drought.

Drought-tolerant beans also need to obtain and use nutrients more efficiently, since well-nourished plants better withstand stress. Recent progress in breeding for higher bean yields under low phosphorus and in acid soils suggests this is achievable.

Mainly for that reason, cassava has earned esteem as a vital crop for poor farm families living on marginal lands. In addition to consuming or selling the roots fresh, many of them also have the option of boosting their incomes by catering to markets for a wide variety of food, feed, and industrial products derived from cassava. One challenge for growers, however, is the range of pests and diseases that can attack cassava throughout its long growing cycle, a problem that will most likely worsen as a result of climate change.

Despite cassava’s relatively low priority in global crop research, the last 3 decades have seen major triumphs in biological pest control, remarkable advances in genetic improvement for root yield, disease and pest resistance as well as starch quality, and significant innovations in crop management. These achievements provide a solid foundation for further technological and policy developments aimed at making cassava-based systems more beneficial and eco-efficient.

Beans conserved in the CIAT genebank.

A cassava root.
Grassroots Action
Tropical forages for climate change mitigation and more

Livestock rearing uses 70% of all agricultural land and provides livelihoods for nearly 1 billion people. But livestock are also estimated to be responsible for about half of agriculture’s total greenhouse gas emissions. Sowing improved forages may offer the single most effective option in agriculture for offsetting these emissions while delivering other benefits as well, including higher meat and milk output.

Forages encompass an extraordinary variety of plants selected mostly from undomesticated grass and legume species and grown either as perennial pastures or in diverse combinations with crops. Superior pastures are extremely effective in sequestering carbon while restoring degraded marginal land. With adequate management, the potential of sown forages to capture carbon is second only to that of forests.

Some Brachiaria grass species also show a remarkable ability to reduce nitrification – the microbial process responsible for emissions of nitrous oxide, a greenhouse gas that is 300 times more potent than carbon dioxide. Through a process called “biological nitrification inhibition,” Brachiaria grasses suppress this activity by means of a substance released from their roots. Rotations of annual crops like maize with Brachiaria pastures are one option for recovering more nitrogen and reducing nitrous oxide emissions from fertilizer applied to crops.

Determined action now to realize the potential of these uses of improved forages will help ensure that agriculture contributes effectively to climate change mitigation while also combating hunger and poverty.

Exporting Success
Rice advances for tropical America and the world

While currently contributing less than 4% of global production, the rice sector of Latin America and the Caribbean (LAC) is poised to offer much more. A series of recent scientific advances, together with the region’s abundant land and water resources, make it feasible for LAC’s rice sector to eventually export surplus production globally while also benefiting growers worldwide through South-South technology transfer.

During the 1960s and 70s, the rapid spread of new rice technology in LAC boosted production tremendously – raising average yields in Colombia, for example, from 1.5 tons per hectare in 1965 to 4.4 tons a decade later. Since then, while rice yield potential has essentially stagnated, researchers have still registered important efficiency gains by developing new generations of improved rice that are especially well suited to the region’s diverse rice-growing environments and predominant practices. In recent years, they have also developed varieties that show potential for significantly higher yields.
Over the last decade or so, researchers have further demonstrated the feasibility of an agronomic revolution, in which farmers can raise average rice yields by as much as 2 tons per hectare through more precise crop management, permitting more efficient use of resources such as nitrogen fertilizer and water.

These advances in rice improvement and resource use are underpinned by significant institutional innovations, particularly the creation of a successful regional rice consortium that unites public and private sector organizations with farmer associations.

Nourishing the Future
Fruits and vegetables for global nutrition security

While nearly 1 billion people endure chronic hunger, about twice that number suffer from malnutrition. Fruits and vegetables have a major role to play in ensuring that growing human populations are not just fed but also nourished.

Rich in vitamins, fiber, minerals, and other micronutrients, these crops can help fight malnutrition indirectly as well by fetching higher prices and creating jobs, thus boosting incomes and bringing more diverse diets within poor consumers’ reach. Highly attractive to smallholders, fruit and vegetable production can particularly benefit women, who already figure importantly in these crops’ value chains.

With the benefits come heavy constraints, however, including myriad pests and diseases, which are likely to get worse as climate change alters their dynamics through shifts in temperature and relative humidity. Dealing effectively with these constraints involves a combination of improved lines of key horticultural species, safer practices for disease and pest management, and more judicious handling of water and fertilizers.

The value of such interventions is evident from many success stories across the developing world – such as disease-resistant tomatoes and integrated management of a major eggplant pest in South Asia. Translating these successes into eco-efficient fruit and vegetable production worldwide will require increased investment in innovative research, which engages development agencies and the private sector effectively, while also actively involving growers in the development of new technologies.
This brochure summarizes the key messages from a CIAT publication titled *Eco-Efficiency: From Vision to Reality* – the first in a new series called *Issues in Tropical Agriculture*. The book was prepared under the guidance of a distinguished expert panel by various CIAT scientists together with colleagues from Bioversity International; the Brazilian Agricultural Research Corporation (Embrapa); Central Rice Research Institute (CRRI) in India; Colombian Corporation of Agricultural Research (CORPOICA); Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia; E3 Asesorías; Grains Research & Development Corporation (GRDC) in Australia; Institute for Climatic and Atmospheric Science (ICAS) in the UK; Institutional Learning and Change (ILAC) Initiative in Italy; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); International Institute of Tropical Agriculture (IITA); International Livestock Research Institute (ILRI); International Rice Research Institute (IRRI); Japan International Research Center for Agricultural Sciences (JIRCAS); Latin American Fund for Irrigated Rice (FLAR); Swedish University of Agricultural Sciences (SLU); University of Agriculture, Makurdi, in Nigeria; and World Vegetable Center (AVRDC).

**Eco-Efficiency for a Better World**

In response to the multiple crises besetting agriculture in recent years, the sector has received renewed attention but not enough. The time has come to make a better world than the one we know today through more concerted efforts to achieve eco-efficiency in agriculture.