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Smart Investments in Sustainable Food Production: Revisiting Mixed Crop-Livestock Systems

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crop improvement programs (*23*, *24*) (Box 1). It is important, therefore, that we expand the scope of and access to new marker platforms to provide efficient, cost-effective screening services to the breeders. Communication and mechanisms for delivery of material to breeders must be developed. There is an urgent need to expand the capacity of breeding programs to adopt new strategies. The clearly documented high rate of return on such investments in the past should be kept in mind (*25*).

The concerns about food security and the likely impact of environmental change on food production have injected a new urgency into accelerating the rates of genetic gain in breeding programs. Further technological developments are essential, and a major challenge will be to also ensure that the technological advances already achieved are effectively deployed.

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PERSPECTIVE

Smart Investments in Sustainable Food Production: Revisiting Mixed Crop-Livestock Systems

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Farmers in mixed crop-livestock systems produce about half of the world's food. In small holdings around the world, livestock are reared mostly on grass, browse, and nonfood biomass from maize, millet, rice, and sorghum crops and in their turn supply manure and traction for future crops. Animals act as insurance against hard times, and supply farmers with a source of regular income from sales of milk, eggs, and other products. Thus, faced with population growth and climate change, small-holder farmers should be the first target for policies to intensify production by carefully managed inputs of fertilizer, water, and feed to minimize waste and environmental impact, supported by improved access to markets, new varieties, and technologies.

"Business as usual" investments in agriculture, although necessary (*1*, *2*), are unlikely to deliver sustainable solutions as the world rapidly changes (*3*, *4*). At the recent G8 summit in Italy, the leaders of the world's wealthiest countries promised to invest U.S.$20 billion to improve global food security. Most of that money is likely to flow to the developing world, where over the next few decades agricultural systems, already facing a variety of stresses, will be expected to accommodate a massive population surge. Even an investment of this magnitude could fail to generate food security if its deployment is not well planned and based on sound science.

The usual culprits, such as inefficient aid delivery, government corruption, and political unrest, are a barrier to progress but are not the most important problem. Rather, it involves a fundamental failure to appreciate the range of different agricultural systems that are expected to feed our planet in the coming decades and their policy needs. The diverse pressures that are acting on agricultural systems in various parts of the world include population increase, rising incomes and urbanization, a rapidly rising demand for animal products in many developing countries, and a fierce competition for land and water (*3*, *5*, *6*), all of which will have profound effects on food security (*1*). Croppers and livestock keepers the world over have steadily accumulated local experience and knowledge that will help them to adapt in the future, but the rapid rates of change seen in many agricultural systems in developing countries may simply outstrip their capacity. Yet, recent scientific assessments (*1*, *2*, *7*–*10*) and the technical and policy recommendations that flow from them have not fully captured the complex biological, social, and economic dynamics of the variety of chal-

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lenges likely to confront future crop and livestock production (*5*).

Recently, the Consultative Group on International Agriculture Research (CGIAR) considered the issues facing mixed crop and livestock production, one of the predominant forms of agriculture in the developing world (*3*). Mixed systems enable the farmer to integrate different enterprises on the farm; in such systems, livestock provide draft power to cultivate the land and manure to fertilize the soil, and crop residues feed livestock (Fig. 1). Moreover, income from livestock may be able to buffer low crop yields in dry years. These mixed systems may be used intensively close to urban markets, as well as in less productive areas with limited market access.

The synergies between cropping and livestock husbandry offer many opportunities for the sustainably increasing production (*11*) by raising productivity and increasing resource use efficiency both for households and regions. This, in turn, can increase incomes and secure availability and access to food for people while maintaining environmental services. However, during the next 20 years mixed crop-livestock farmers may not be able to stay abreast of population growth, environmental change, and the increasing demand for animal products (*1*, *3*).

According to the CGIAR analysis, the world's one billion poor people (those living on less than $1 a day) are fed primarily by hundreds of millions of small-holder farmers (most with less than 2 ha of land, several crops, and perhaps a cow or two) and herders (most with fewer than five large animals) in Africa and Asia (*3*). Furthermore, mixed crop-livestock systems could be the key to future food security; two-thirds of the global population already live in these systems, and much of the future population growth will occur there. Already, mixed systems produce close to 50% of the world's cereals and most of the staples consumed by poor people: 41% of maize, 86% of rice, 66% of sorghum, and 74% of millet production (*3*). They also generate the bulk of livestock products in the developing world, that is, 75% of the milk and 60% of the meat, and employ many millions of people in farms, formal and informal markets, processing plants, and other parts of long value chains (*3*).

Box 1. Enhancing livestock productivity through improved dual-purpose crops.

In developing countries, some crops like maize, wheat, sorghum, and millet are dual purpose: Their grain provides food for humans and their residues are used as feed for livestock. Traditionally these crops have been bred to improve grain yield and drought and pest resistance. However, in the past decade it has been recognized that farmers in mixed crop-livestock systems value the crop residues sometimes as much as the grain owing to their importance as a feed for livestock, particularly in the dry season (*29*). Breeding programs for these crops are increasingly being adapted to include breeding for residue quality without compromising the original objectives associated with increasing grain yield.

In India, where the demand for crop residues as feed is very high, improved dual-purpose varieties of sorghum and millet have had significant impacts on the productivity and efficiency of crop-dairy systems. Small-holders have been able to increase the milk production of buffalos and cows by up to 50% while at the same time obtaining the same grain output from their crops. This has increased the demand for dual-purpose crops with relatively high-quality crop residues, and burgeoning fodder markets have developed around cities like Hyderabad (*29*).

Intensive Crop-Livestock Systems

The pressures currently acting on the so-called "high-potential," intensively farmed lands of developing countries are large enough to slow and possibly end the substantial increases in growth rates of crop production seen during recent decades. For example, diminishing water resources are becoming a huge constraint to rice and wheat production in South Asia (*1*). There, livestock numbers are projected to increase significantly: cattle and buffalo from 150 to 200 million animals by 2030 and pigs and poultry by 40% or more in the same period (*1*, *3*). Pressures on biomass to feed these animals are already high, with trade-offs in the use of resources (land, water, and nutrients) becoming increasingly hard to balance in these systems, especially as competition for biomass for food, feed, fertilizer, and fuel increases (*3*, *12*, *13*). Similar caps on natural resources in the East African highlands and other high-potential agricultural areas of Africa are appearing in the form of infertile soils, degraded lands (*13*, *14*), depleted water sources, carbon losses, shrinking farm sizes, and decreasing farm productivity (*14*, *15*). Recent research suggests that some of these areas may not respond to increased fertilizer inputs and will need a closer integration of livestock and crop production to improve productivity (*14*, *15*).

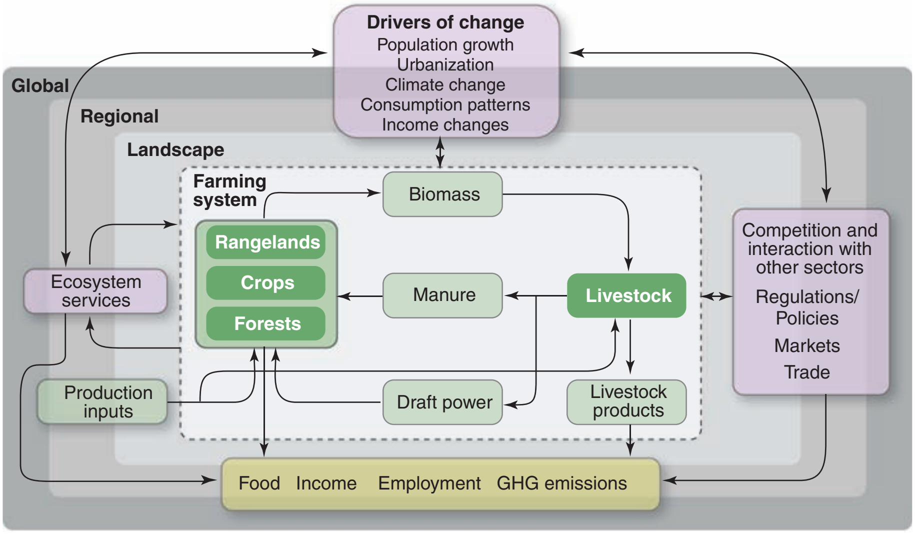

Fig. 1. Main interactions in mixed crop-livestock systems in the developing world.

The key will be to develop sustainable intensification methods that improve efficiency gains to produce more food without using more land, water, and other inputs (*3*, *16*, *17*). For example, in parts of Asia there is considerable scope to produce more meat and milk in mixed systems through more efficient production systems (Box 1). Over the past 30 years, researchers have doubled the efficiency with which chickens and pigs convert grain into meat (*6*, *16*), and this has resulted in less grain consumption per unit of poultry and pig meat produced. Although global poultry and pork prices have decreased significantly, this has been at the expense of increasing the price of cereals available for human consumption (*1*) and has promoted deforestation in the neotropics (*16*, *18*).

In some regions, farmers will have to change the species of livestock they keep to use their resources more efficiently, and policies to promote livestock specialization will be needed. A measurable shift is already taking place in South Asia's intensive mixed crop-livestock systems, from ruminant and crop production to intensive industrial poultry. Here, rates of growth in poultry production are projected to exceed 7% per year by 2030, which is two- to threefold higher than rates of growth for ruminants or crop production (*3*). Specialization and intensive industrial livestock production will in turn require environmental and trade regulations. For example, in parts of Asia, large numbers of pigs in unregulated intensive industrial systems pollute water sources in peri-urban areas (*19*) (Fig. 2). Concentration of animals can also increase the risk of outbreaks of emerging infectious diseases, afflicting livestock and people alike (*20*) (Box 2).

Box 2. Intensification and the risks of avian influenza.

Recent outbreaks of avian influenza in both domestic poultry and the human population have been a source of considerable concern. The disease, caused by the highly pathogenic H5N1 virus, appears to move between poultry and wild birds and to people. The virus was identified in domesticated geese in southern China in 1996 and in humans in Hong Kong in 1997. H5N1 avian influenza then spread rapidly in 2002, with outbreaks in poultry, wild birds, and other mammalian species in more than 60 countries. By the end of 2009, 467 human cases and 282 deaths had been reported to the World Health Organization (*30*). In response, more than 200 million poultry have been killed by the virus or culled to prevent its spread.

The epidemiology of the disease is not well understood because there are many vectors, including wild birds and other wildlife. However, large concentrations of birds in both backyard and intensive systems, coupled with poor disease control or underfunded veterinary services in some developing countries, could be significant risks for the spread of the disease. The risks of livestock diseases, including those associated with intensifying systems, will need to be addressed through developments in disease surveillance and early warning systems.

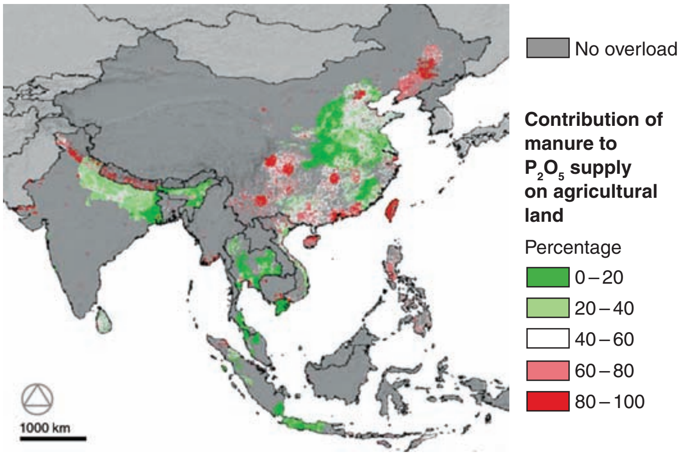

Fig. 2. Contribution of livestock to estimated nutrient overloads in Asia (*19*).

Extensive Crop-Livestock Systems

Significant contributions to future food security could be made in the more extensive mixed crop-livestock systems used in developing countries, where there is less pressure on the land and the crop productivity is far from optimal (*21*). For example, yields of dryland crops such as sorghum, millet, groundnut, and cowpea could easily be increased by a factor of three with appropriate land preparation, timing of planting, and use of fertilizers and pesticides (*21*). In specific circumstances, genetically modified (GM) crops can be an important contribution to improving crop productivity by increasing water use efficiency or reducing the impacts of pests and diseases. Policies and public investments in infrastructure and market development will be essential to create systems of incentives, reduce transaction costs, and improve risk management (*10*, *22*). Integration of production in these systems to supply agro-ecosystems services to the more-intensive systems will also be needed to ensure sustainability (*3*).

Investing in extensive mixed systems will require considerable changes in public investments. Instead of allocating most resources to highly populated areas or those with high agricultural potential, developing-country governments will have to begin investing in infrastructure and services for more extensive areas (*22*), many of which are likely to be affected by climate change in the future (*2*). With better roads, markets, health facilities, and other infrastructure and services, the rural-to-urban migration rates in the extensive mixed areas could be reduced (*10*), thus nurturing the next generation of food producers.

Conserving Agro-Ecosystems

In developing regulatory frameworks for sustainable food production, we need to define the limits to agricultural intensification (*11*, *16*). Lessons can be learned from the developed world in terms of matching efficiency gains and environmental regulation. For example, the European livestock sector grew slightly in the past decade while reducing greenhouse gas emissions by 9% (*23*). Particularly in the developing world, we need to determine criteria for defining intensification thresholds at local levels before irreversible environmental degradation occurs (*16*).

Any agricultural investment portfolio funded by the G8 should be sufficiently diverse to include payments for protecting water, carbon, biodiversity, and other global goods and ecosystem services where rangeland and other systems are under significant pressures and need to de-intensify or stop growing altogether (*3*, *24*, *25*). For example, implementing schemes to pay farmers for protecting water towers in the Himalayas could be key for food production in large parts of South Asia. Such schemes could be aimed at sustaining stream flow early in the growing season, when water inputs are critical for crop production (*26*).

Relatively modest extra investments could halve child malnourishment rates in developing countries (currently 27%), in spite of projected population growth to 2050 (*27*).

Nevertheless, to reduce poverty while increasing food supplies and maintaining functional ecosystems will require well-regulated and differential growth in crop and livestock production (*1*, *3*, *6*). It will require public and private investments in the more-extensive mixed agricultural systems neglected in the past (*22*). It will require higher public and donor funding for research and development in the livestock sector, which historically has been lower than those for food crops, often by a factor of 10 or more (*28*). It will require differentiated and nuanced policies able to assess the trade-offs between agro-ecosystem services and human well-being (*5*). And it will require that governments and donors, together with scientists and other stakeholders, precisely target technological, investment, and policy options to suit different farming systems and regions (*3*).

There is no doubt that agriculture as an engine for growth is regaining recognition by governments in developing countries (*10*). Together with the commendable and significant financial commitments of G8 countries to developing-country agriculture, they now need to match it with an intellectual commitment—one that embraces a new agricultural frontier and new efficiencies, incentives, and regulations in the food systems of developing countries.

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PERSPECTIVE

Measuring Food Insecurity

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Food security is a growing concern worldwide. More than 1 billion people are estimated to lack sufficient dietary energy availability, and at least twice that number suffer micronutrient deficiencies. Because indicators inform action, much current research focuses on improving food insecurity measurement. Yet estimated prevalence rates and patterns remain tenuous because measuring food security, an elusive concept, remains difficult.

The 2008 global food price crisis, which sparked riots in more than two dozen countries, rekindled political and scientific interest in food security. In their July 2009 joint statement, the G8 heads of state agreed "to act with the scale and urgency needed to achieve sustainable global food security" (*1*). To direct scarce resources to where they can do the greatest good, actions must be guided by reliable information as to who is food insecure, where, when, and why. This requires improved measurement of food insecurity and its causes and greater attention to key institutional and policy lessons learned.

An Elusive Concept

Among the various definitions currently in use, the prevailing definition, agreed upon at the 1996 World Food Summit, holds that food security represents "a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life." This high standard encompasses more than just current nutritional status, capturing as well vulnerability to future disruptions in access to adequate and appropriate food (*2*, *3*).

Food security is commonly conceptualized as resting on three pillars: availability, access, and utilization. These concepts are inherently hierarchical, with availability necessary but not sufficient to ensure access, which is, in turn, necessary but not sufficient for effective utilization (*4*). For most of human history, lives were short and unhealthy due in large measure to insufficient macronutrient (carbohydrate, fat, and protein) intake. Beginning in the 18th century, however, a succession of countries broke free of the nutritional poverty trap (*5*, *6*), thanks largely to increased food availability made possible by advances in agricultural production; hence, the common association of food security with supply-side indicators, typically measured in daily calories per person.

Adequate availability is necessary, but does not ensure universal access to "sufficient, safe and nutritious food." Access is most closely related to social science concepts of individual or household well-being: What is the range of food choices open to the person(s), given their income, prevailing prices, and formal or informal safety net arrangements through which they can access food? As Nobel Laureate Amartya Sen wrote, "starvation is the characteristic of some people not *having* enough food to eat. It is not the characteristic of there *being* not enough food to eat. While the latter can be a cause of the former, it is but one of many *possible* causes" (*7*). Access reflects the demand side of food security, as manifest in uneven inter- and intrahousehold food distribution and in the sociocultural limits on what foods are consistent with prevailing tastes and values within a community. Access also accentuates problems in responding to adverse shocks such as unemployment spells, price spikes, or the loss of livelihood-producing assets. Through the access lens, food security's close relationship to poverty and to social, economic, and political disenfranchisement comes into clearer focus. But because access is an inherently multidimensional concept, measurement becomes more difficult than with availability (*4*).

Utilization reflects concerns about whether individuals and households make good use of the food to which they have access. Do they consume nutritionally essential foods they can afford, or do they choose a nutritionally inferior diet? Are the foods safe and properly prepared, under sanitary conditions, so as to deliver their full nutritional value? Is their health such that they absorb and metabolize essential nutrients? Utilization concerns foster greater attention to dietary quality, especially micronutrient deficiencies associated with inadequate intake of essential minerals and vitamins.

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