The ISPC mobilizes science for development by promoting international dialogue on critical and emerging issues. It works to foster partnership between the CGIAR and collaborators worldwide. The biennial CGIAR Science Forum is a meeting place for scientific exchange between CGIAR research centers and current and potential partners. It is an opportunity for scientists to come together and examine emerging challenges, identify key research issues, and establish strategic alliances to address them. To this end, the theme of Science Forum 2011 focused on the 'Environment–Agriculture Nexus'.

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Addressing research at the 'Agriculture–Environment Nexus'

Insights from the CGIAR Science Forum 2011

Historically, agriculture has focused primarily on food production. Now its contribution to food security needs to be balanced with its impact on the environment, energy supplies, human health, and development.

This 'Agriculture–Environment Nexus' was the theme of the 2011 CGIAR Science Forum, convened by the Independent Science and Partnership Council (ISPC) and the Chinese Academy of Agricultural Sciences, and held in Beijing from 17 to 19 October 2011. It united 250 researchers from CGIAR research centers, universities, national research agencies, non-governmental organizations (NGOs) and the private sector to identify the most promising scientific and technological approaches to these challenges. The meeting focused on priority research goals and how research work can be coordinated and implemented within the newly reformed CGIAR. A summary report has been published.[1] This brief highlights the key insights from the Forum to help guide future decisions within the CGIAR.

The growing global population needs to be fed. However, the overarching challenge is to increase production while minimizing negative impacts on natural resources and the emergence of environmental problems such as competition for water use and climate change. The negative impacts stem

Key issues

- Agriculture is intimately linked with the environment. Food production has widespread implications for natural resources and, conversely, the availability and integrity of natural resources strongly influence agricultural yields.
- The impacts of agricultural practices interact with ecosystems in a number of ways across spatial scales, and can have 'lag' effects that are undetectable over the short term.
- The challenge is to understand these factors, their reciprocal effects, and their geospatial scales and timeframes – including the governance and shared use of agricultural and environmental resources.

from all types of agriculture, including crops, livestock, fisheries and aquaculture, and include:

- soil degradation
- water pollution (e.g., arising from excessive use of fertilizers or disposal of wastes from intensive animal production systems)
- changes in land use, leading to loss of grazing lands and loss and fragmentation of forests or coastal habitat
- loss of biodiversity
- greenhouse gas emissions.

The discussion sessions at the Forum were dynamic and produced several conclusions:

1. We need to enhance the 'ecological intensification of agriculture' and exploit the tools of 'sustainability science' to address the multiple and varied interactions between agriculture and the environment. The Forum worked towards definitions of these concepts[2] and encouraged their refinement so that all players speak the same language and work together. Also encouraged was the appropriate measurement and benchmarking of key variables for agriculture, the environment, and human welfare.
2. Measuring the impact of large-scale sustainability science projects will require long-term data sets to be maintained for benchmark sites in major agricultural systems and their respective ecosystems. These long-term efforts are needed to elucidate various impacts across different spatial and temporal scales. Differences between the timeframes and expectations for research and resource governance can create tension between scientists, farmers, NGOs, and politicians, and these must be addressed through stakeholder interaction.
3. Trade-offs between agricultural intensification and maintenance or conservation of natural ecosystems vary according to context. Innovative methods (e.g., remote sensing, modeling) and more extensive inter-sectoral interactions will be required to promote land-use planning at the landscape level. Have we developed the skills and capacity to do this properly? There is value, for instance, in examining animal-source industries together with their feed and other input sectors, and to manage waste and disease potential along with other agricultural land use. Truly integrated approaches require systems thinking and will involve more than simple bilateral trade-offs. More integrated approaches that consider scientific options along with risks to farmer welfare and livelihoods offer the potential for a future in which overall land use will be optimized in a manner more consistent with desirable societal outcomes.

Another challenge is how to frame the global dialogue about appropriate structures and functions for agriculture in terms of sustainability science. Participants explored ways in which agricultural science can consider trade-offs more effectively and adopt integrated systems approaches in the future.

Emergence of sustainability science

Research to address the agriculture–environment nexus must make sense of dynamic linkages between biophysical and social drivers that determine trends in food security and environmental consequences. The term 'sustainability science' provides a framework to facilitate the required integration of scientific disciplines. It has been defined as "an emerging field of research dealing with the interactions between natural and social systems, and with how those interactions affect the challenge of sustainability: meeting the needs of present and future generations while substantially reducing poverty and conserving the planet's life support systems".[3]

How to bridge the agriculture–environment divide?

Certainly we need more detailed understanding of the current status of agriculture and its impact on ecosystem services, including the ecological basis of many of the agricultural practices we take for granted. We need to increase yields of crops and animal-source products through the 'ecological intensification' of agriculture – namely "harnessing the power of knowledge of ecological processes to increase yields and enhance ecosystem services and sustainability". While it was acknowledged that this definition, which emerged from the Science Forum discussion, needs to be further debated and refined, it represents a good start in placing emphasis on the 'ecological' component. And although more efficient use of inputs is key, efficiency in itself is not enough to make agricultural systems satisfy both production and environmental goals.

Agreed measures (metrics) that can be objectively applied to help understand, benchmark, and quantify changes taking place in the quality of natural resources and environmental services are required to: a) identify emerging trends at an early stage; b) measure the progress of systems in which improvements are being sought through new management approaches, and; c) properly measure the impacts of research.

We also need to better estimate the value of different ecosystem services to enable transparent assessment of trade-offs between agricultural productivity and other services, to aid mutual understanding in discussions for improving governance, and to properly measure the impacts of research to improve natural resources management. One example would be to measure the success of payment schemes that seek to maintain or enhance ecosystem services, through resource, financial, and human welfare indicators.

We need to measure better, and be able to predict, carbon dioxide and other greenhouse gas emissions from a whole range of resource systems and agricultural practices, to inform the debate over climate change as well as decisions on how to minimize agriculture's contribution to global warming. We also need to quantify the degree to which agriculture can help mitigate the effects of climate change and develop appropriate best-management practices.

A similarly complex measurement issue concerns biodiversity. Despite the fact that negative impacts on biodiversity are one of the most talked-about effects of the intensification and malpractice of agriculture, we have been constrained in arriving at clear conclusions on some of the underpinning issues because different definitions and scales are applied by different practitioners. These issues need resolution. We need to conduct research at several levels (plant/organism, commodity, farm, landscape, agroecological zone, sector and market) and to have means of relating cause and effect across scales. Only on the basis of such understanding can landscape- and regional-level planning be explored.

Another consideration is the extent to which land saved by intensification of agriculture on existing farmland (thus reducing pressure for conversion of non-agricultural land to food production) can contribute to the conservation of biodiversity in untouched ecosystems. Answers to this question are critical to inform the development of conservation strategies as the world struggles to meet future food security targets with limited land and water reserves. The work presented at the Forum suggested that effects were different if Green Revolution approaches for major staple crops were considered (potential for land saving) versus plantation agriculture for products like oil palm grown in forest-rich countries (where new technology further increases the already large economic returns and encourages expansion of production into the forest). Thus the consensus was that intensification will help, but alone it will not be able to prevent forest loss. Research will be required to further increase the efficiency of agriculture and to help governments foresee the consequences of national choices about the exploitation of landscapes for multiple purposes.

The ecological intensification of agriculture, and the broader ambitions of sustainability science, both require inputs from scientists across a range of disciplines. To enable such interdisciplinarity, scientists must understand each other; hence the precision of definitions is particularly important. As noted above, it was agreed that ecological (or sustainable) intensification means much more than simply improving agronomic efficiency of input use.

An important realization is '*the future is not what it has been*'. As climate change moves the goalposts for management of agricultural systems through traditional knowledge, and the rate of yield gain expected from our key development-related crops has to increase despite resource constraints, new models for prediction and management will have to be developed – not simply extrapolated from previous experience.

Scientific versus civil society approaches to agriculture

How can we move toward a harmonization of different agricultural practices? We have to measure the impacts of agricultural practices both on the immediate agricultural setting and on the landscape, including higher-scale ecosystem services and biodiversity.

We need consistent frameworks to assess the environmental impacts of existing and alternative agricultural systems. We also need to assess the value of environmental goods and services, and to factor in the risk to farmers of adopting practices that have fewer negative impacts on the environment – and the risks to ecosystems if farmers do not adopt them.

Scientific and governance frameworks need evidence to decide how best to manage landscapes and take action, even in the face of uncertainty (i.e., sometimes on the basis of probable if uncertain outcomes, and on the basis of available but often incomplete information).

We need to continue to challenge existing assumptions about land saving and its associated conservation opportunities. For example, evidence was produced at the Forum that crop rotation can be just as advantageous as intercropping for the biological management of pests. Under what conditions can the forest–agriculture interface be managed through mosaics to optimize outcomes? Can we really expect resource-poor, smallholder farmers to play a central role in farm-level conservation of biodiversity? What kind of science and social organization is required to manage forest–agriculture transitions in an optimal way? What should the balance of our farming systems be in relation to major and minor crops for food and climate security, and improved nutrition?

One of the key aims of the Forum was to help make the debate between the scientific community and civil society over agriculture and the environment more rational and evidence-based. Many of the positions held by some participants lead us in opposite directions (e.g., while organic farming may have some environmental benefits, it is less productive in terms of yield and land use). Better metrics, consistently applied, will help frame this debate.

Organizing scientific research at the agriculture–environment nexus

Agricultural research has to strengthen its systems perspective to take account of environmental impact. This will require farm-level research to be properly integrated with landscapes and users from other sectors. Science has to adopt a research-for-development perspective. However, integrating everything before we have sufficient understanding of the individual elements is not helpful and can lead to poor policies and research prioritization. Reductionist science may still have its place, but results should feed into the broader stakeholder discussion in an appropriate fashion. There needs to be continuing research on environmental (bio-geochemical and ecological) cycles to improve the evidence base and to identify the most powerful and cost-effective metrics for gauging system performance, as well as to establish a common currency for evaluating research priorities and policy options.

Local farmers and stakeholders in landscapes are key to the adoption of improved methods and the long-term trajectory of ecosystem health. Livelihood perspectives will have to be incorporated into advice to governments about environmental use at the landscape level.

The inevitable pressures to intensify (or increase catch or product off-take per unit area and time) must be led by rational estimation of consequences and trade-offs. Such understanding will likely not be derived from the farming sector itself, but from effects on other competing sectors (such as input markets for grains and fish meal), or from the human health sector (pollutants, zoonoses), or for climate mitigation and adaptation (managing carbon stocks or water). Science will have to enter into a continuously reactive mode. Research must bring groups of scientists and stakeholders together, periodically test the efficiency and impacts of current practices, and create suitable understanding so that alternative and improved practices can be properly evaluated.

What does this mean for the CGIAR and its role in the global research network?

The CGIAR should be urged to continue its transition and the development of globally integrated research programs that link effectively to other science providers (e.g., in the land use management, climate change, and environmental communities) and to the stakeholders in the sites chosen for on-the-ground research.

The emphasis on yield improvement must be woven into a *sustainability science* perspective. Achieving this integration will require appropriate foresight studies of how farming will develop (given for instance the move towards greater urbanization), where and under what circumstances smallholder or plantation/monocropping farming systems will predominate, and what the environmental consequences and responses will or should be. Clear vision about trajectories in farm size and farmer education is critical to underpin such assessments.

Research at the nexus of agriculture and environment should include large-scale field studies that are well connected to end-users, in order to accommodate interactions and innovation at different spatial scales. In its selection of sentinel sites for CGIAR Research Programs, the CGIAR has an exciting opportunity to establish collaborative, measured approaches to sustainability science, and to provide progressive evidence that can elucidate spatial-scale interactions, refine research prioritization, and inform policies. The CGIAR has found success in biophysical (particularly crop improvement) research and policy. It needs to bring those attributes together and consider the appropriate emphasis for its efforts. Contributors to the Science Forum suggested that in addition to scientific research, equal investments must be made in partnership strategies and in the science–policy interface to ensure real impact of research at the agriculture–environment nexus.

The CGIAR needs to challenge existing dogmas in a constructive way by researching the scientific consequences of actions and providing, where needed, the metrics, models and frameworks by which consequences – and the results of its own programs – can be judged. Indeed, identifying the most appropriate metrics (i.e., those that are robust, low cost, and replicable) is an important international public good, and one in which the CGIAR has a comparative advantage to lead, in partnership with other invested actors.

For a robust science–policy dialogue, the CGIAR may need different types of people and institutions represented in its research consortia – those who can undertake discussions with other sectors on the basis of scientific evidence and join the debate about the best use of landscapes, resources, and climate management. We need a balanced approach to funding not only our research, but also the management of partner and policy interactions. Through these partnerships, we can achieve development outcomes that meet both production and environmental goals.

Notes

1 The program and a comprehensive summary of meeting outcomes are available at www.sciencecouncil.cgiar.org

2 See the discussion of Science Forum Session 1, page 4, and Session 2, page 6, at: www.sciencecouncil.cgiar.org/fileadmin/templates/ispc/documents/Mobilizing_science/Science_Forum/SF11_Summary_Final_15Dec.pdf

3 Proceedings of the National Academy of Sciences: www.pnas.org/site/misc/sustainability.shtml

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