A Planet for Life 2012 focuses on agriculture and its relation to development, food and the environment. At the end of the 2000s, a consensus has emerged and points to the urgent need for massive investment in the agricultural sector, which is (once again) viewed as one of the prime engines for development and food security, as well as for poverty reduction. But what exactly does this consensus cover? While the idea of investing in agriculture is gaining ground and although several countries or regions appear to be offering opportunities for investment in agricultural land, debates are ongoing as to which agricultural models to choose and how agricultural policies should be implemented.

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Even before the political mobilization embodied in the World Bank’s 2007 World Development Report on agriculture and the international initiatives that followed the surge in agricultural prices in 2008 (G8, G20, etc.), the scientific community had already grasped, by the early 2000s, the issue of the future of global agriculture and food. Agriculture foresight exercises such as IAASTD1 (led by Bob Watson, former chairman of the IPCC) and books such as Michel Griffon’s (Feed the Planet, 2006) have raised a typically Malthusian question: in a context of scarcity of natural resources, biodiversity degradation and climate change, by 2050, will the food supply be sufficient to feed the growing world population?

While subject to criticism, the Malthusian perspective has merit in its ability, in situations of scarcity and global change, to open the debate on the various projections that can be made regarding innovation and the future pace of progress in science and techniques. Will these advances enable global agricultural production to increase more rapidly than the rates of resource depletion and growth in demand? Depending on whether one answers yes or no this question, it becomes essential to either liberate the full potential for innovation to increase agricultural productivity, or to aim for a fundamental redesign of the functioning of food chains to act on both the demand and supply (Freibauer et al., 2011).

In both cases, the ability to innovate is central. Technological trajectories in agriculture are closely linked, and will remain so, to the economic and social transformations

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1. International Assessment of Agricultural Science and Technology for Development
of production systems and territories. Even if rapid innovation is necessary, it is essential to discuss the technological choices and available options in a transparent way, and their impacts on our societies. While the challenge is global, agricultural situations in different regions of the world are very diverse: innovation systems must therefore reflect this diversity. For this to occur, the research systems in different regions of the world must have sufficient capacity. For some countries, mainly in the South, research and innovation systems are as yet underdeveloped and are largely dependent on other agricultural research structures at the international level: cooperation in public research in the North, private research, coordination of an international research system, etc. This article provides a brief history of the role of this international research system in implementing a type of agricultural modernization, known as the “green revolution”, in many developing countries since the 1960s. Decisions regarding the research priorities that govern the innovation capacity of this system are then examined, both for the subject areas for research (what are the technological options?), and for the organization of research practices (how can researchers be encouraged to work alongside those in the field?). The debate over the priorities of the international system for agricultural research for development is one of the strategic environments where decisions on global socio-technical issues are made, which will shape the ability of humanity to feed itself tomorrow.

AGRICULTURAL INNOVATION: HISTORICAL AND EMERGING ACTORS

The international agricultural research institution that crystallizes the debate today is the CGIAR (Consultative Group on International Agricultural Research), which was established in 1971 under the auspices of the World Bank. At the end of World War II, the Ford and Rockefeller foundations were major funders of four agricultural research centres (CIMMYT in Mexico, IRRI in the Philippines, IITA in Nigeria and CIAT in Colombia), which allowed these countries to increase their agricultural production through the breeding of major crops (wheat, maize and rice).

**BOX 1 THE GREEN REVOLUTION**

The green revolution was based on massive external inputs (chemical fertilizers, pesticides, herbicides, improved seeds, irrigation and, often, mechanization). This modernization was based on a coherent package of technologies and focused solely on maximizing yields, and in doing so allowed the simplification of traditional agricultural systems, which through their great diversity – due to the wide variety of crop and livestock species and their combinations – had provided a way to limit many climate and biological risks. The green revolution enabled a 2.5 multiplication in global agricultural production between 1960 and 2005, while the population “only” doubled during the same period. Its techniques were predominantly accessible only to farmers with sufficient capital and the transfer of these technologies to farmers required accompanying agricultural public policies, subsidies for the purchase of inputs, the construction of infrastructure, changes in land tenure, etc. Although widely criticized for its social and environmental impacts, the green revolution remains a reference model for institutions such as AGRA1, for the modernisation of agriculture in Africa.

1. Alliance for a Green Revolution in Africa
These research centres made major contributions to the modernization movement through the dissemination of scientific innovation, that was later to be coined the “green revolution” in Asia and Latin America (see Box 1), and which focused on increasing crop yields to meet the rapid growth in demand. Implicitly, these centres also provided a way to appease the political protests demanding land redistribution. The four centres differed from former colonial centres by their emphasis on genetics and hybridization of high-yielding varieties.

Faced with a need to broaden the funding base of these centres and the on-going risk of hunger, FAO, the World Bank and UNDP\(^2\) set up the CGIAR, a structure for the coordination of research at the four agricultural research centres, to oversee the improvement in the functioning of an international agricultural research system that was gradually becoming established and to mobilize international donors.

Between 1980 and 1990, the number of CGIAR centres expanded from 4 to 18, and there are 15 today (see figure 1). These centres, which are located throughout the world, specialize in specific types of agricultural production: some on particular crops, others on production techniques or systems (irrigation, livestock farming, agroforestry...) or ecosystem types and climatic zones (arid areas, tropical agriculture...).
The development of CGIAR centres in countries that lacked efficient national agricultural research centres remains controversial. Although the CGIAR centres have enabled the development of research programmes, thus overcoming the absence of national research systems, they did not however encourage the emergence of such institutions in the least developed countries, rather seeming to substitute them in the long term.

In 2010, CGIAR had 65 members (international organizations, member states and private foundations), which financed its 15 research centres with a total global annual budget of $696 million and rising. For the last 20 years, the CGIAR has been required to provide a better platform to allow the voices of stakeholders to be heard, particularly representatives of farmers from the South who criticize the green revolution in the excessive importance it attaches to technological developments, despite the increasing recognition for the negative social and environmental consequences arising from this strategy. In 2007 this process culminated in a phase of reform for the organization, focusing on its funding and fields of research, which also aims to adapt research to new challenges such as climate change, to further expand the research themes, to ensure the CGIAR operates more transparently and to improve the efficiency of its use of donor funds.

As a response to the CGIAR, the GFAR\(^3\) was launched under the leadership of IFAD\(^4\) in 1996 with a mission to help the national agricultural research systems in the South and to enable producer associations to be heard in the community of international agricultural research. As an international platform for the discussion of strategic options for agricultural research, involving all stakeholders concerned with the future of agriculture, GFAR represents six regional forums. It is financed by the FAO, IFAD and a group of donors that, in 2009, provided the GFAR with a budget of $2.8 million. Its ability to influence the direction of CGIAR research is growing.

In this overview of public agricultural research systems for development, we must not forget the role of research institutes for the development of developed countries (including the former USSR), whose networks of researchers and strategic decisions have contributed to the gradual changes of the CGIAR.

Furthermore, Brazil, India and China are now rapidly entering onto the stage of this international agricultural research system: the extensive development of their national agricultural research systems is attributed to intellectual property rights (patents, the rights of breeders...) and the driving role of private actors and NGOs to guide investment (James et al., 2008). These three countries accounted for 42% of public agricultural research spending in developing countries in 2000 (compared to 25% in 1981).

Private foundations are increasingly becoming engaged in public international agricultural research programmes. For example, private foundations accounted for an 11% share of the budget of the CGIAR in 2010. In particular, in 2010 the Bill and

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3. Global Forum on Agricultural Research
4. International Fund for Agricultural Development
Melinda Gates Foundation (in addition to its financial support for AGRA and GAFSP\(^5\), the latter being created in late 2009 in response to the soaring agricultural prices of spring 2008) became an official funding member of the CGIAR, committing to becoming one of its major donors by 2013. In addition, private research by agricultural supply companies is also considerable: in 2005, private agricultural research accounted for nearly 40% of the total expenditure. However, these investments are not homogeneous across the globe, with public research remaining the main form of research in the majority of developing countries (see Figure 2).

The CGIAR reform process constitutes one of the major arenas for all stakeholders to discuss the strategic priorities for agricultural research on a global scale and, in particular, to consider a new model to potentially succeed the green revolution. Today, this debate predominantly forms around two controversial candidate models: a new green revolution or agroecology.

**A “NEW GREEN REVOLUTION” OR AGROECOLOGY: TWO CONTROVERSIAL MODELS**

The debate on the direction of CGIAR research is organized around two main reference models, each derived from a particular type of response to the criticism of the green revolution. The models differ in the crop management and agricultural practices they envisage, in the responses they provide to the limited availability of resources, and in the limitations or challenges they raise.

The “new green revolution” theoretically integrates the social criticism that was aimed at the first green revolutions, which bypassed the poorest farmers (Dorward et al., 2004). While the original green revolution was capital intensive (access to inputs, mechanization...), the new green revolution intends to be knowledge intensive. It is mainly based on advances in genetics to achieve similar goals: to improve yields and to improve plant resistance to disease, drought and pests. In addition, it requires the establishment of strong public intervention mechanisms that would focus particularly on the diffusion of technological advances to the poorest farmers.

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\( ^5 \) Global Agriculture and Food Security Program

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**Figure 2** Public and private expenditure in agricultural research in 2000

Despite the high stakes, funding for research in agriculture and agricultural science has for decades only represented 7% of government research budgets. While Southern countries have made a greater effort (20% of their research budgets), most funding is provided by Northern countries, which dedicate only 5% of their research budgets to the subject. In recent years, many commitments have been made to reverse this trend, which are awaiting realization.
This model promotes major investment in the development of diverse research methods for varietal improvement. By focusing on laboratory-produced knowledge, this “new green revolution” model, similarly to the previous agricultural modernization, positions farmers downstream of research results, agricultural development services and input suppliers, according to a strictly top-down rationale. It seems to ignore the works of the sociology of scientific knowledge, which show the importance of forming associations with the beneficiaries of research, well in advance of the innovation process, for successful implementation (Latour, 1989).

Moreover, while this new modernization project targets small family farms, the productivity gains sought would entail the substitution of labour with capital, and would thus greatly reduce the agricultural workforce, even though this workforce is still important (involving 1 billion people in Asia and 200 million in sub-Saharan Africa), without even accounting for the large population growth that will continue in these rural areas. Unless one anticipates an extraordinary economic boom in another sector of the economy, this path of modernization in Africa may lead to the phenomenon of mass unemployment. The model of the new green revolution should therefore be questioned regarding its ability to develop practices that are sufficiently productive and labour-intensive, and that draw in particular from the modernization trajectories in Asia that had a lesser reliance on mechanization compared to those of Latin America, for example.

Finally, though the technologies of the new green revolution are based on the objective to maximize the agricultural productivity from all inputs (land, water and fertilizer) and thus to reduce the environmental impact, they remain largely dependent on fossil fuels and are vulnerable to other types of resource depletion (phosphorus, for example) or socio-political crises and the ecological risks that could be linked the use of biotechnology.

In contrast to this adjustment plan, which represents the continuity of the green revolution paradigm, agroecology offers a completely different perspective for agricultural innovation. A commission chaired by Gordon Conway for the CGIAR in 1996 launched the concept of a “doubly green revolution”, but it was actually the IAASTD (McIntyre et al., 2009) that provided the best expertise base to form the foundations of the proposal of an agroecological model as an alternative to the green revolution and its new incarnation. It is based on a fundamental critique of the modernization project that was at the heart of previous technological changes. While the green revolution sought to modernize traditional agriculture by simplifying traditional systems and opening them to the use of external, often synthetic, inputs, agroecology instead puts the ecological functions at the centre of agricultural systems, which are regarded as agro-ecosystems, where the optimization of natural cycles (energy, carbon, nitrogen, phosphorus, water...) would enable the design of systems that are more productive and also more autonomous, that are

**WHILE THE ORIGINAL GREEN REVOLUTION WAS CAPITAL INTENSIVE (ACCESS TO INPUTS, MECHANIZATION...), THE NEW GREEN REVOLUTION INTENDS TO BE KNOWLEDGE INTENSIVE.**
better able to cope with future environmental issues, benefiting from the complexity and knowledge of traditional systems, and producing not only biomass but also a set of goods and services (protection of water resources, biodiversity, for example). By combining the scientific expertise of ecology and agronomy, agroecology constitutes a separate innovation path, exemplified today by various techniques such as no-till farming (zero tillage), integrated biological control for crop protection, crop rotation, and forming associations between crop species (cereals/legumes, trees/annual crops...) or between cropping and livestock systems. In this innovation model, farmers themselves become producers of knowledge, since innovative agricultural systems must be designed appropriately to suit environmental conditions (as well as socioeconomic ones) that are specific to the local context.

It is likely – with the exception of techniques, such as conservation agriculture, that are fully compatible with large mechanized farms – that innovative agroecologically-designed systems will be more labour intensive, thus providing employment opportunities for the large agricultural labour force (as indicated by the agricultural chapter of the UNEP Green Economy report, 2011): it remains to be seen whether these jobs can be sufficiently remunerated. Indeed, the future success of the agroecology model will be partly based on its ability to design technical devices that enable yields to be maintained at sufficiently high levels (for Northern and emerging countries) and that also provide significant yield increases (for countries where yields are still low, such as in sub-Saharan Africa).

While the green revolution aimed at overcoming environmental conditions through inputs, allowing laboratory performance to be achieved in the field, the agroecology model is much more related to local soil, climatic and ecological conditions. This model, compared to the green revolution, thus leads to a diversification of products, and probably a greater variability of these products. This will be a marketing challenge given the stability requirements of processors, retailers and quality standards, which focus on a small number of primary products.

These two models that polarize the current debate should not obscure the existence of a wide range of proposals that can be attached to one model, to the other, or even to both. The IAASTD presents a set of models (organic, ecological, resilient farming...), that illustrate some trajectories of innovation that do not rely solely on biotechnology and breeding, but on innovation across the entire agricultural ecosystem. Among them, organic farming constitutes a real path of innovation based, like agroecology, on the improvement of the management of natural agroecological cycles and not only on the refusal to use synthetic inputs. This refusal leads to a controversy regarding the ability of organic farming to produce enough food to ensure global food security, which advocates are trying to reframe by highlighting the advantages in terms of local access to food. The agroforestry models presented by Dennis Garrity from the World Agroforestry Centre (Garrity et al., 2011) or the “Evergreen” model developed by MS Swaminathan (Swaminathan, 2004), father of the Indian green revolution, are also based on new ways to connect agronomy and ecology, to link conventional scientific techniques and alternative knowledge. In the
field, these alternative models can hybridize to various extents with the new green revolution. But in terms of innovation systems, they lead to a profound questioning of the current mode of research.

PROFOUND CHANGES IN ORGANIZATIONS AND PRACTICES OF AGRICULTURAL RESEARCH AND DEVELOPMENT

In its extreme, the pattern of laboratory research is to give new properties to living organisms (animal or plant) in vitro, to test them in vivo and then to disseminate them to farmers through agricultural advisory and development services, along with inputs enabling real conditions to be brought closer to laboratory ones. In this scheme, farmers are passive recipients of knowledge developed elsewhere (Dockès et al., 2011). Participatory research practices completely disrupt this pattern, incorporating not only the needs of farmers but farmers themselves at all stages of the research process, using their own empirical knowledge, both traditional and current, and involving:

- analysis of what needs to be improved (yields, the system as a whole, incomes, wellbeing...),
- combined mobilization of scientific knowledge (biology, ecology, chemistry, but also economics, sociology...), of intermediate concepts and knowledge produced in other situations of innovation, and of local knowledge to identify opportunities for improvement and possible solutions,
- combined experimentation within farms, and in interaction with laboratory work,
- validation and dissemination of innovations through farmer network organizations and other local social networks, in partnership with agricultural development services.

In this scheme, agricultural development services have a very large role to play since they must help farmers in expressing their needs, participate in experimentation and must also consider their interface role as a two-way interactive process between researchers and research users, who themselves become innovators. The knowledge of farmers is expressed, acknowledged and shared as much as that of the researchers, thus renewing the role of training systems themselves (Freibauer et al., 2011). This pattern of participatory research is indispensable for agroecological innovation trajectories aiming at the optimal management of agroecosystems in their specific conditions.

The ability to transfer innovations to a large number of different agro-ecosystems is at the heart of the green revolution model, which aims at adapting the ecosystem to improved varieties by benefiting from the contributions of external inputs (James et al., 2008). For agroecology, the diffusion capacity is not based on the transfer of research products themselves, but on the dissemination of knowledge within the research and development network. While economies of scale were a major driver for the operation and dissemination of green revolution innovation, the organization of participatory innovation is necessarily based on other conceptions of the knowledge economy, largely focused on the public nature of the knowledge produced.
In both processes, public and private research are interdependent, but take different forms and methods of organization (partnership between farmers and their organizations with public research, partnerships between private industrial research and public services of research and development). Private research has a place when innovation can be appropriated (intellectual property rights, including on mechanical, chemical, or biotechnological technology). Innovations at the scale of practices, farming systems, agricultural landscapes and their organization, that agroecology seeks to put back at the centre, have the nature of public good and thus reduces the incentives for private research (Pardey et al., 2010; Vanloqueren et al., 2009).

The controversy between the different models of agricultural techniques might seem overly polarized when perhaps we need to allow these different models to coexist. However, it is rooted in profound changes to practices and the organization of research systems, innovation, development and training, all of which require consideration on the ways to control the transition from one model to operate with another.

**TRANSITIONS THROUGHOUT THE FOOD SYSTEM AND IN INNOVATION SYSTEMS: THE NECESSARY STRATEGIC CHOICES**

The current controversy is not just about emerging farming practices, that could be technically combined in an optimal way with practices from the new green revolution. These models are in fact distinct innovation trajectories and the transition from one to another involves inextricable and profound changes in upstream (agricultural advisory services, farm supply) and downstream (collection, processing, marketing) sectors, and also changes to the organization and functioning of innovation systems, and public policy support for these changes. The strategic choices discussed for the CGIAR reform process will therefore have a wider impact than purely on the 15 research centres involved.

To drive through a transition, the approach of leaving all options open it is not sufficient: such a non-strategic choice ignores the balance of power, the rigidity of structures and institutional resistance. A common representation of transitions in innovation systems is that a dominant regime (a configuration of stakeholders, institutions, with privileged access to resources and funding...) is being challenged by emerging models (Geels et al., 2007). During transition, dominant and emerging models co-evolve through a process of confrontations, until one of these new models becomes dominant again.

The modernization project of the green revolution has proved dominant in agricultural practices, in the research for new technologies, in public policies and private organizations that have been implemented to ensure the effective performance of the project, the structuration of the agri-food sector (elongation of processing lines, concentration of processors...), consumption habits, etc.

For many years this dominance has been challenged, but without it being possible
to say that the transition has begun. In the worldwide debate on agricultural research, the agroecological innovation model has become a serious candidate for succession in recent years.

What policies to support innovation are required to drive such transitions? Apart from the need to ensure that niches exist for the emergence of new models, isn’t it also important to make choices in support of a particular model to allow a sufficiently rapid transition given the pressing issues of resource scarcity and global change? Or to offer an undifferentiated specific public support to all emerging models, but according to which criteria? Do we have the luxury of time to allow spontaneous change in research and innovation systems to run their course? With no simple answers to these questions, political choices must be made between the contrasting visions of the relationship between the current environmental and social emergencies and the different models of innovation. They make divergent predictions on the speed of transitions in the systems of innovation, and on the proximity in time of environmental, social and economic crises.

Specifically, controlling these transitions entails the enablement of organizational changes in the innovation system, and changes in the distribution of financial, human and symbolic resources. The Global Conference on Agricultural Research for Development (GCARD) in 2010 was a step in the right direction for this “quiet revolution”. The first conference of its type, which is to be held every two years, the 2010 GCARD seemed to focus on the capacity of national research systems and farmers in Southern countries (who are the beneficiaries of these research efforts, gathered within the GFAR) to become involved in the upstream determination of priorities of the CGIAR. The outcome of the transition process remains very uncertain however. In Beijing in October 2011, the CGIAR structures held a “Science Forum” to reaffirm their position at the head of, or alongside, GFAR, each claiming the capability to produce the strategic prospective reflections necessary to achieve the required shifts. Moreover, while the GCARD seems to have gathered all public and private initiatives for national and international agricultural research into GFAR and CGIAR, the future influence of foundations such as the Gates Foundation, which currently mainly funds the CGIAR pragmatically aiming above all for “impact”, remains unclear. The same applies to national research systems in emerging countries, whose international ambitions are still not well-defined, and also to the expected emergence of national or regional research systems in the least developed countries, which are especially needed for the agro-ecological trajectory of innovation.

This system of the global governance of research is still under construction, in parallel with the reform of the FAO’s Committee on World Food Security and its high level panel of experts, or the FAO’s Treaty on plant genetic resources for food and agriculture and the Cartagena or Nagoya Protocols of the Convention on biological
diversity. However, the same actors circulate between these arenas, disseminating the controversies on the new modalities of the relationship between science and society, be it through the questioning of technology choices, the role of experts or the participatory functioning of innovation systems.

Far from being restricted to the corridors of power where research policies are made, the transformation of this international governance regime for agricultural research for development therefore currently constitutes one of the conflict arenas in which the strategic options for innovation are discussed, which in turn will outline the future trajectories of the world’s agricultural and food systems.

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TOWARDS AGRICULTURAL CHANGE?

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