SUSTAINABLE AGRICULTURAL PRODUCTIVITY GROWTH

AND

BRIDGING THE GAP FOR SMALL-FAMILY FARMS

Interagency Report to the Mexican G20 Presidency

With contributions by Bioversity, CGIAR Consortium, FAO, IFAD, IFPRI, IICA, OECD, UNCTAD, Coordination team of UN High Level Task Force on the Food Security Crisis, WFP, World Bank, and WTO.

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In 2011, G20 leaders committed to sustainably increase agricultural (production and) productivity (paragraph 43 of the Cannes Declaration). They "agree(d) to further invest in agriculture, in particular in the poorest countries, and bearing in mind the importance of smallholders, through responsible public and private investment," they "decide(d) to invest in research and development of agricultural productivity." Early in 2012 Mexico, as G20 President, invited international organisations to examine practical actions that could be undertaken to sustainably improve agricultural productivity growth, in particular on small family farms.

The preparation of this report, co-ordinated by the FAO and the OECD, responds to this request. It is a collaborative undertaking by Bioversity, CGIAR Consortium, FAO, IFAD, IFPRI, IICA, OECD, UNCTAD, Coordination team of UN High Level Task Force on the Food Security Crisis, WFP, World Bank, and WTO. We, the international organisations, are pleased to provide you with this joint report and look forward to continuing collaboration within the G20 framework to further elaborate and, as appropriate, implement the recommendations that it contains.

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Reccommendations

Terms and abbreviations

AIS	Agricultural Innovation System
DUS	Distinctness, Uniformity and Stability
FDI	Foreign Direct Investment
ICT	Information and Communication Technology
IPR	Intellectual Property Rights
ODA	Official Development Assistance
Public expenditures on agriculture	Transfers to agriculture from taxpayers through the government budget
Public investment in agriculture	Budgetary expenditures that lead to capital formation in the agricultural sector. Capital formation includes physical and human capital.
PPP	Public-Private Partnership
R&D	Research and Development
Support to agriculture	Gross transfers to agriculture from consumers and taxpayers arising from government policies that support agriculture. In addition to budgetary expenditures, support includes other estimated transfers that do not require actual monetary disbursement (e.g. credit concessions, but also market price support).
TFP	Total Factor Productivity; a measure of the efficiency with which all production factors are transformed into outputs
VCU	Value for Cultivation and Use
Yield	A measure of output per area of land (e.g. tonnes of wheat) per animal (e.g. litres of milk per cow).

Introduction

Global agriculture will face multiple challenges over the coming decades. It must produce more food to feed an increasingly affluent and growing world population that will demand a more diverse diet, contribute to overall development and poverty alleviation in many developing countries, confront increased competition for alternative uses of finite land and water resources, adapt to climate change, and contribute to preserving biodiversity and restoring fragile ecosystems. Climate change will bring higher average temperatures, changes in rainfall patterns, and more frequent extreme events, multiplying the threats to sustainable food security. Addressing these challenges requires co-ordinated responses from the public and private sectors and civil society that will need to be adapted to the specific circumstances of different types of farmers in countries at all levels of development.

Improving agricultural productivity, while conserving and enhancing natural resources, is an essential requirement for farmers to increase global food supplies on a sustainable basis. The role of smallholder farmers and their families in increasing agricultural productivity growth sustainably will be crucial.[1] Half a billion small family farms produce most of the food consumed in developing countries and farm over 80% of the land in Asia and Africa, but their productivity is generally lagging. The success of developing countries in increasing agricultural productivity will have global implications in strengthening the resilience of food markets, enhancing food security, improving wellbeing and promoting sustainability.

This report is submitted to the G20 Mexican Presidency by Bioversity, CGIAR Consortium, FAO, IFAD, IFPRI, IICA, OECD, UNCTAD, Coordination team of UN High Level Task Force on the Food Security Crisis, WFP, World Bank and WTO. It responds to Mexico's request for information and advice on practical actions that could be undertaken to sustainably improve agricultural productivity growth, in particular on small family farms.

The approach taken reflects the view of the collaborating international organisations that a successful strategy for sustainable agricultural productivity growth requires significant improvements in the investment climate in many countries, in agricultural innovation systems and farming practices, in the management of natural resources, and in specific policies and efforts to close the productivity gap of small family farms. This report first examines current trends in productivity and its main drivers — innovation, investment and policy. It then takes stock of actions underway, in particular those included in the 2011 G20 Ministerial Action Plan. The two following sections focus on four broad areas that require attention: providing an enabling environment conducive to investment and innovation in agriculture; investing in agricultural innovation, broadly defined; improving national and international research collaboration; and, closing the gap between actual and potential productivity levels of agriculture in developing countries.

1. There is no unique and unambiguous definition of a smallholder as explained in FAO (2012d).

The recommendations provided are broadly of two types: specific actions that can contribute in some way to improving productivity growth or sustainable resource use (whether building on existing initiatives or suggesting new activities) and more general proposals that may not be actionable as presented but that serve to highlight areas for priority attention. This report also invites G20 countries to engage in a medium- to long-term, analysis-based peer review of policies fostering sustainable productivity growth, which would identify specific constraints and opportunities, beginning with their own food and agriculture sectors. In addition to possible benefits to participating countries, a peer review process could contribute to the identification of best policies and best policy packages to achieve the widely held aim of sustainably improving productivity of the global food and agriculture system. While such an initiative is proposed to and for G20 countries, it could have much wider application to interested countries.

The sustainable productivity challenge

This section focuses on available evidence and outlines the main developments in agricultural productivity and sustainability, the evolution of Agricultural Innovation Systems (AIS), and the trends in policies, public expenditures and private investments in agriculture which affect agricultural productivity and sustainability.

Productivity and sustainability

The growing global demand for food, feed and biofuel is well established. It is estimated that the world population will be 9.1 billion persons by 2050, up from the current population of 7 billion. More importantly, income growth will increase the quantity and change the composition of agricultural commodity demand. The use of agricultural commodities in the production of biofuels will also continue to grow. Significant increases in production of all major crops, livestock and fisheries will thus be required. Estimates indicate that by 2050, agricultural production would need to grow globally by 70% over the same period, and more specifically by almost 100% in developing countries, to feed the growing population alone, excluding additional demand for crops as feedstock by the biofuel sector (FAO, 2009a).

Trends in agricultural productivity

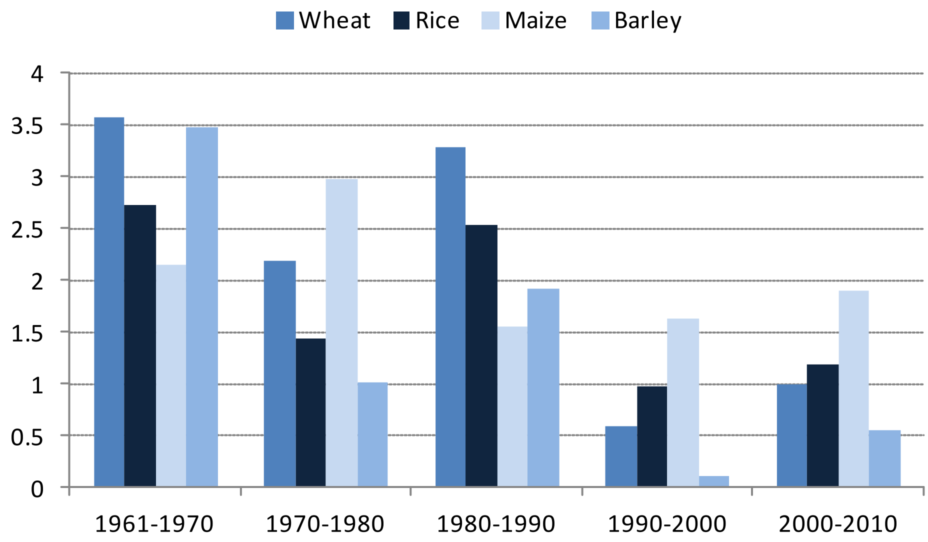
Throughout history, productivity in agriculture has shown high growth rates. Together with the expansion of the resource base, this has enabled food production to outpace population growth. For example, the Green Revolution resulted in an increase in food production from 800 million tonnes to more than 2.2 billion tonnes between 1961 and 2000 (FAO, 2011a).

Estimates of past and current productivity trends vary widely, and future productivity in the long run is difficult to project. The debate on whether global agricultural productivity has slowed down or not has been taken up again as the need for significant increases in food production is more widely recognised. Some recent estimates suggest that total factor productivity (TFP), the most comprehensive measure of productivity reflecting the efficiency to turn all inputs into outputs, grew at an average rate of around 2% per year since 2000 across major world regions (Fuglie, 2012). The picture is more complex when looking at individual countries or sub-regions. Some large countries like Brazil, China, Indonesia, Russia and Ukraine have achieved much higher TFP growth rates than the corresponding regional average. Sub-Saharan Africa is lagging, but some countries like Cameroon, Congo, Kenya, Mali, Benin and Sierra Leone have achieved above average TFP growth rates in the 2000s, mostly attributable to policy changes (Yu and Nin-Pratt, 2011).

Other studies, in particular those using partial factor productivity indicators such as land and labour productivity, give a more pessimistic global picture, in particular when China's performance is taken out of the calculation of the world average (Alston *et al.*, 2010). In Latin America, China and many developed countries, labour productivity increased faster than land productivity, as labour was shed out of the sector. This contrasts with Asia, where land productivity dominated, and Africa, where land expansion was a main driver. While productivity in some livestock sectors, in particular non-ruminants, is increasing fast, there are concerns about trends in crop productivity growth.[2]

The most popular indicator of land productivity is crop yield. The average global rates of growth in yield of most of the major cereals are declining. Since the 1980s, growth in wheat and rice yields fell from 2.5-3% to around 1%. Maize yields showed growth of slightly less than 2% over the last decade (Figure 1).

Figure 1. Compound annual growth rates in world crop yields (%)



Source: FAOSTAT.

Lower productivity and slow growth in some developing countries and in small family farms raise specific concerns. The gap between farmers' yields and technical potential yields[3] reflects the largely suboptimal use of inputs and insufficient adoption of most productive technology, often linked to lack of market integration. Yield gaps

2. Lower partial factor productivity does not necessarily lead to lower TFP. For example, lower land productivity (e.g. crop yields) can result from a more extensive use of land, with TFP change depending on the relationship between the decrease in fertiliser and pesticide use, and the change of output per hectare.

3. Technical potential yields are maximum yields with latest varieties, removing all constraints including moisture, at generally prevailing solar radiation, temperature and daylight, estimated from highly controlled on-station experiments or crop models calibrated with latest varieties, well-monitored crop trials (Evans and Fischer, 1999). Van Dijk *et al.* (2012) distinguish several measures of potential yields from closest to furthest to farmer yield: economic maximum farmer yield, technical maximum farmer yield, experimental maximum research station yield and modelled potential yield. They also find a large variability of yield gaps across sub-regions of Africa.

were estimated to range from 11% in East Asia to 76% in Sub-Saharan Africa in 2005 (FAO, 2011b). Globally, there are approximately 500 million small family farms, with over 280 million smallholders in India and China alone (IFPRI, 2007). Measures to reduce the productivity gap between actual levels and the technical potential could offer high returns in terms of food security, nutrition and rural income gains (World Bank, 2008). Studies show that high returns can also be achieved by reducing gender gaps in productivity on small family farms. According to FAO, closing gender productivity gaps associated with unequal access to resources and inputs could raise total agricultural output in developing countries by 2.5-4%, leading to a reduction of 12-17% in the number of undernourished globally (FAO, 2011a).

Trends in sustainability of agriculture

Efforts to increase food production will take place within an environment characterised by a scarcity of natural resources. In many regions, there is little room for expansion of arable land, with virtually no additional land available in South Asia, the Near East and North Africa. Where land is available, in sub-Saharan Africa and Latin America, more than 70% suffers from soil and terrain constraints (FAO, 2011a).[4] Unsustainable land use practices, such as overuse, poor land management and nutrient mining, result in global net losses of land productivity of an average 0.2% per year (Nelleman *et al.*, 2009). Land degradation makes the top soil vulnerable to water and wind erosion and reduces the productivity of inputs such as fertiliser and irrigation, which in turn leads to production and income losses.

At the global level, agriculture is the largest water user worldwide, representing about 70% of total withdrawal. In some countries, over 90% is withdrawn for agricultural purposes. Cities and industries are competing intensely with agriculture for the use of water and an increasing number of countries, or regions within countries, are reaching alarming levels of water stress and pollution. Global freshwater resources will be further strained in the future in many regions, with over 40% of the world's population projected to be living in river basins experiencing severe water stress by 2050 (OECD, 2012a).

Agriculture is also a major source of water pollution, from nutrients, pesticides, soils and other contaminants, leading to significant social, economic and environmental costs. It also damages the wider environment through the emission of greenhouse gasses. In some intensive farming systems, up to 50% of available inorganic and organic nutrient inputs are not always utilised by crops or pastures, leading to significant pollution from nutrient run-off (OECD, 2012b). The opposite is the case in large parts of the developing world, where crop farming leads to a net extraction of nutrients from the soil. In large parts of sub-Saharan Africa, soil productivity has been on a declining trend.

Biodiversity underpins agriculture and food security through the provision of genetic material needed for crop and livestock breeding. The past century has seen a great loss of biodiversity through habitat destruction, mainly due to deforestation (UN, 2001). Maintenance of biodiversity is crucial for sustainability and resilience of farming systems as it builds the capacity to absorb shocks and continue to function within a changing set of circumstances. The challenge is to maximise agriculture's positive contributions to biodiversity while minimising its negative impacts.

Global agriculture will need to adapt to climate change. There is growing evidence that climate change has had negative effects on agriculture and widespread agreement that agriculture, particularly in developing countries, will be for the most part

4. In Central Asia, there is potential for agricultural land expansion. Unfortunately our understanding about land use today is hindered by lack of good quality data (Fritz *et al.*, 2011).

negatively affected by climate change (IPCC, 2007; Lobell *et al.*, 2011; Nelson *et al.*, 2009, 2010; Wassmann *et al.*, 2010; Müller *et al.*, 2011). In the near term, climate variability and extreme weather shocks are projected to increase, affecting all regions with negative impacts on yield growth and food security, particularly in sub-Saharan Africa and South Asia in the period up to 2030 (Burney *et al.*, 2010; SREX, 2012). Agriculture (including deforestation) accounts for about one-third of greenhouse gas emissions; for this reason, it contributes significantly to climate change mitigation (IPCC, 2007). While crops can be adapted to changing environments, the need to reduce emissions will increasingly challenge conventional, resource-intensive agricultural systems (Royal Society, 2009). Productivity growth needs to increase to keep up with demand growth, but also to increase resilience of the sector to supply shocks, whether due to climate change or due to resource limits more generally.

Agricultural Innovation Systems

The productivity of farms can be improved through economies of scale and the adoption of more technically-efficient production systems. However, long-run productivity growth for the sector as a whole requires continuous technological progress, as well as social innovations and new business models. For agriculture to respond to future challenges, innovation will not only need to improve the efficiency with which inputs are turned into outputs, but also conserve scarce natural resources and reduce waste (OECD, 2011a).

Estimates of the rates of return to agricultural R&D suggest a very high social value of agricultural R&D. Annual internal rates of return of investments on agricultural R&D estimated in the literature range between 20% and 80% (Alston, 2010). In developing countries, the dollar-for-dollar impact of R&D investments on the value of agricultural production is generally within the range of 6% to 12% across countries (Fan *et al.*, 2008, Fan and Zhang, 2008, FAO, 2012a). Those countries which have heavily invested in R&D while simultaneously investing in extension have had the strongest productivity growth (Fuglie, 2012).

Driven by policy incentives, recent productivity improvements in developed countries have occurred with lower levels of variable input use, and thus more sustainably. Innovation systems have responded to the demand articulated by users, policy makers and international development partners and developed innovations that allow for more sustainable use of resources, such as no-till farming, insect-resistant crops, more efficient irrigation, water management systems, sensors for nutrient status in crops, remote sensing and Geographic Information Systems (GIS) to improve and monitor land use and SMS messaging for enhancing advisory services to farmers.

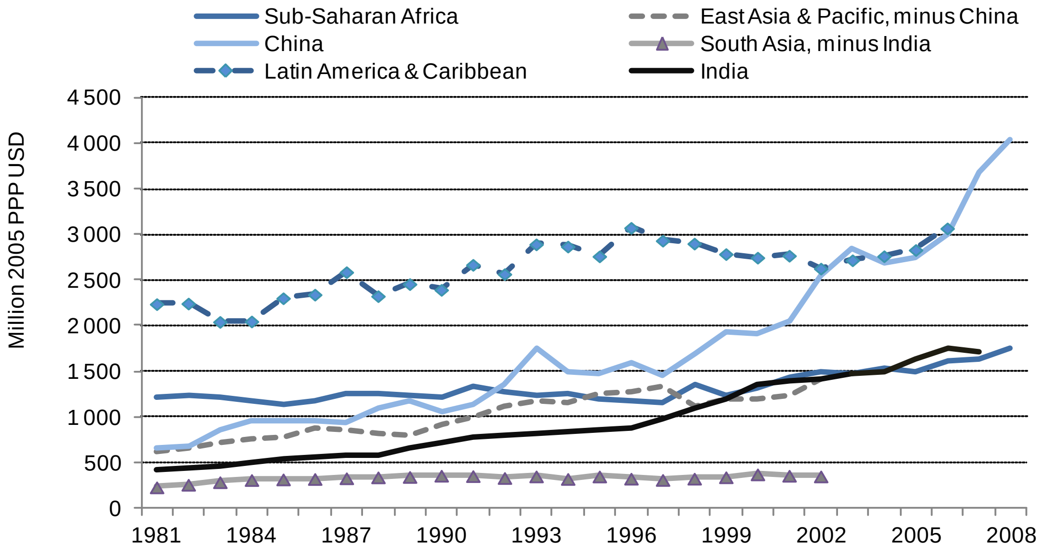
Trends in R&D funding

In all low- and middle-income country regions as a whole, public expenditure on agricultural R&D increased from the 1980s, but there are important variations across countries within regions (Figure 2). Several countries have well-managed and funded systems producing world-class research; others, some of which are highly dependent on agriculture, have experienced significant reductions in their R&D expenditure and capacity levels since the early 1990s. Overall, the average share of agriculture in total R&D expenditures is decreasing in both high-income and low- and middle-income countries.

Public R&D expenditure on agriculture accounts for above 1% of agricultural GDP in most OECD countries, and 4% in the United States. However, public expenditure on agricultural R&D in OECD countries grows slowly (e.g. by 0.2% per year in the United States and 0.5% in Japan in the 2000s) or even decreases. In some high-income countries, the slowing or negative growth rates of public R&D expenditure on agriculture in the last decade are raising concerns about the ability of the sector to maintain and increase productivity growth rates because agricultural research has to spread its efforts across an increasing number of topics (OECD, 2011b).

Public R&D expenditures on agriculture in low-and middle-income countries are generally lower as a percentage of agricultural GDP than in OECD countries, and there is wide diversity across countries. In East Asia and the Pacific, China accounted for about two-thirds of total public agricultural R&D spending in the low- and middle-income countries in 2002. Following a period of stagnation in the 1990s, China's agricultural research spending doubled during 2001-08 (Chen, Flaherty, and Zhang, 2012). In Sub-Saharan Africa, after a decade of stagnation in the 1990s, investment in agricultural research rose more than 20% between 2001 and 2008. However, most of this growth occurred in only a handful of countries (Beintema and Stads, 2011).

Figure 2. Trends in food and agricultural public research expenditures



Source: ASTI database.

While public expenditure is the main source of funding for agricultural R&D, private sector investment has increased but is generally focused on high value and market-oriented production systems. Greater protection of intellectual property, rapid progress in molecular biology, and the integration of global output and input markets have generated strong incentives for the private sector to invest in R&D. At the same time, the record of private research in natural resource management and in maintaining biodiversity is limited, with the exception of a few public-private partnership initiatives.

Investments by the private sector in the developing world remain small and agricultural research continues to be mostly funded by governments (Beintema and Stads, 2008). The evidence suggests that, on average, government allocations have accounted for 81% of funding since 2000, and only 7% of funding was derived through donor contributions. These latter contributions have been in the form of both loans and grants, and mostly attributed to countries in Sub-Saharan Africa and a few low-income countries in Asia and Latin America (Etcheverría and Beintema, 2009).

International R&D, in particular by CGIAR, has in many instances successfully led to the development of technologies well-suited to smallholder production systems. In the 1990s, more centres were added to the CGIAR and although total funding continued to grow, average spending levels per centre declined. Since 2000, overall funding to the 15 centres of the CGIAR has increased, but a larger portion of this funding is support for specific projects and programmes of research involving different centres and non-CGIAR research organisations (Beintema and Elliott, 2009).

Changes in Agricultural Innovation Systems

The predominant model for innovation has been mostly supply-driven: scientists in the public sector create new technologies which are then disseminated by extension officers to the farmers who are asked to adopt them. Many countries have reviewed their agricultural innovation systems (AIS) in recent years in response to concerns about lack of adoption of innovation and the need to increase performance to respond to emerging and pressing challenges. Indeed, sustainable production intensification requires a major shift from the supply-driven innovation model to knowledge-specific and often location-specific farming systems which conserve and enhance natural resources. Non-technological innovation such as marketing or organisational innovations also receive more attention today.

Unlike the experience of the Green Revolution which relied on improved and genetically uniform high-yield varieties complemented by high levels of inputs, increasing agricultural productivity in today's context will require gains among a large number of smallholders in very different agro-ecological regions. Traditional technologies and practices have proved their relevance to increasing productivity and ensuring environmental sustainability. Recognising the need to move away from supply-driven to demand-driven innovation, some countries have taken steps towards a more inclusive, interactive and participatory approach (UN, 2001).

Innovation is increasingly taking place in a network-based setting which fosters interaction and learning. AIS display a large diversity, reflecting different country contexts and different degrees of transition from the traditional top-down approach. While R&D remains an important component of agricultural innovation systems there is a growing recognition of the role of other actors: farmers, extension services, upstream and downstream industries, consumers, civil society, and information brokers. Working with farmers to validate and adapt technologies in an integrated way lies at the heart of AIS. The participation of more diverse actors along with institutional reforms have improved the responsiveness to AIS to specific needs, with resulting innovations better suited to resource-poor farmers (World Bank, 2012). However, most developing countries, particularly in Sub-Saharan Africa, face challenges in implementing an AIS approach due to weak resources and institutions (World Bank, 2005).

Upstream and downstream industries have increased their role in the diffusion of innovation to farmers and the private sector is increasingly involved in R&D activities with high potential market returns, such as biotechnology. Partnerships between public research and the private sector are being developed, including with local industries. Governments have encouraged public research institutions to engage in public-private partnerships with producer organisations and the agri-food industry.

Another notable trend in AIS is less government involvement in the delivery of extension services. This has permitted the emergence of other intermediaries, such as innovation brokers, who can articulate farmers' demand for research and help them access technology and knowledge, or who are associated with creating linkages in value chains (OECD, 2012c). However, public services still dominate extension in developing countries and they face widespread problems of limited funding, insufficient technology and knowledge, poorly trained staff, weak links with research, and limited farmer participation (World Bank, 2005).

Public institutional changes have generally aimed to increase co-ordination at the national level both within agricultural systems, and between agriculture and other sectors. Some countries have merged or strengthened the links between agricultural R&D and higher education institutions. Others have reformed their agricultural universities. Mechanisms and networks to set priorities for agricultural research have been strengthened and made more inclusive.[5]

Investments in agriculture

Investments in agriculture encompass both public and private spending on natural capital (such as land, water and biodiversity), physical capital (such as animals, machinery, irrigation systems, storage, processing and marketing facilities, roads, ports and other “hard” infrastructure on- or off-farm), human capital (such as health, education, training, and advisory services), and knowledge capital (such as research, technology development, and organisational and other innovations). These various types of investments play complementary roles in the production process and contribute to increase productivity. Investment needs will vary depending on the stage of economic and agricultural development.

Investment can be financed by both public and private sources, including domestic savings of households and private companies, government savings, external borrowing, and foreign investment. Public investments often focus on the provision of public goods, while private investments tend to focus on areas generating private returns. Private investors have been particularly involved in technology generation as IPRs have been strengthened. But these lines are becoming increasingly blurred and public-private partnerships are emerging where mutual benefits are anticipated

In terms of physical capital, increased mechanisation by investment in tractors and power-threshers spurred crop yield growth in many industrialised countries a few decades ago and continues to do so in developing countries. While this type of investment can be characterised as private investments **in** agriculture, investments **for** agriculture play an important enabling role. They have public good (or quasi-public good) characteristics and are consequently predominantly financed from public sources. Investment in infrastructure in rural areas, in particular transportation (ports and rural roads), soil and water conservation, irrigation systems, electrification and information and communication technologies, is an effective way to stimulate productivity growth (Shenggen Fan, 2008; Mogues and Benin, 2012). It allows smallholders to connect to markets and thereby provide higher incentives to increase productivity. Irrigation systems allow for increased land productivity, particularly in countries that depend on rain-fed agriculture and face water shortages. Often, infrastructure and road development are ranked among the top two sources of overall agricultural growth, second to R&D investments. Especially in Africa, irrigation and feeder roads are shown to have large output-increasing and poverty-reducing effects. The importance of transport infrastructure is demonstrated in Africa where, for certain landlocked countries, transport costs can be as high as 77% of the value of their exports. The establishment of development corridors linked to major ports can be an effective way to stimulate local economies (Foresight, 2011). Improving market facilities such as warehouses, storage facilities and market-information systems are important in creating an enabling environment and facilitating the integration of farmers into markets as well as providing incentives to increase investment and hence productivity.

5. For example the Forum for Agricultural Research in Africa (FARA) is an umbrella organisation bringing together and forming coalitions of major stakeholders in agricultural research and development in Africa.

Trends in private on-farm investment

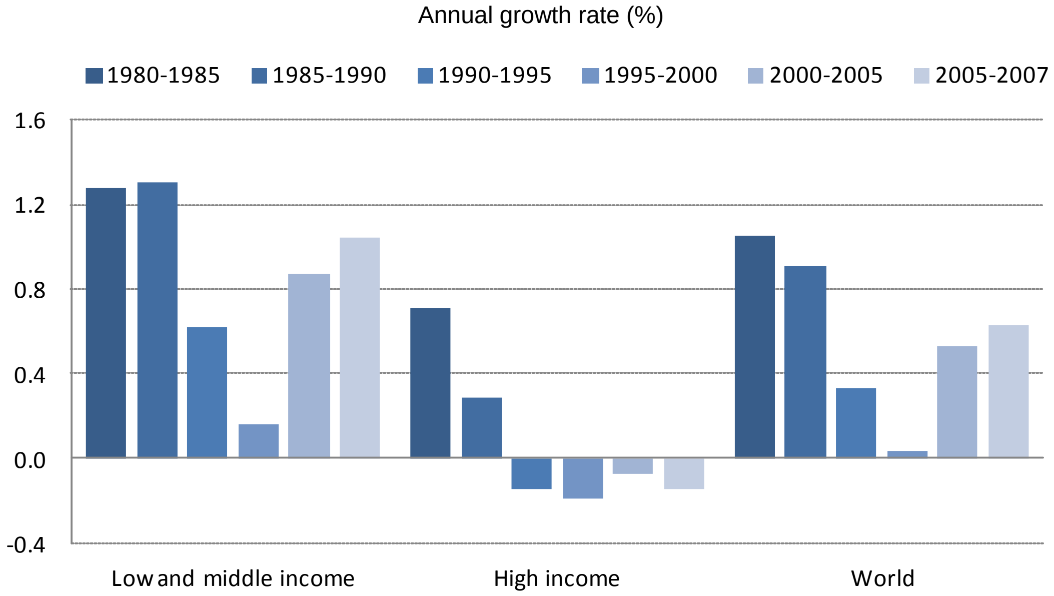
Expanding the capital base of agriculture is intrinsic to the process of increasing productivity, and generating higher and more stable returns to those whose livelihoods depend on this sector. In developing countries, smallholders provide the bulk of domestic private investment, notably on-farm. Better investment of their own labour and part of their income to improve land, acquire new equipment, expand livestock herds and farms, and invest in storage and the post-production chain will increase their efficiency to produce food and minimise losses.

Mechanisation and the use of animal traction to replace human labour have dramatic potential to increase productivity. Land improvements, such as land levelling, terracing and bunding for runoff and erosion control, can contribute significantly to the management of natural resources. In sum, other forms of investment, such as public investment or foreign direct investment, will have limited or no impact if they are not accompanied by increased on-farm investments.

Globally, on-farm investments, reflected by the volume of agricultural capital stock, have increased over time, with the increase concentrated in low- and middle-income countries. On-farm investments in high-income countries have remained relatively stable. However, the rate of growth of agricultural capital stock has been uneven over time, probably reflecting the impact of both market and policy incentives to farmers. Average annual growth in the global agricultural capital stock of about 1% during the 1980s was followed by significantly lower rates during the 1990s (Figure 3).

On-farm investment growth has recovered since 2000. This was partly due to the increasing trend in agricultural commodity prices, although these remain at a level significantly lower level than that which characterised the period 1980-1990.

Figure 3. Agricultural capital stock growth 1980-2007



Source: FAOSTAT.

Trends in foreign direct investment

Foreign direct investment (FDI) is often referred to as a major and growing source of finance for agricultural development. Higher agricultural prices and better incentives to invest in agriculture are likely to stimulate further international investment flows to this sector.

Flows of FDI to agriculture (agriculture, hunting, forestry and fisheries) as well as the food, beverages and tobacco sectors have increased significantly over the past decade. In many cases, this new momentum has translated into large-scale acquisitions of farmland in lower- and middle-income countries. Less attention has been paid to a wide range of collaborative arrangements between large-scale investors and local smallholders, such as various types of contract farming schemes, joint ventures, management contracts, and new supply chain relationships.

Data issues hamper the analysis of FDI, as the increasing flows are partly explained by wider country coverage of the statistics. Reporting in current USD also tends to overestimate the real increase. Nevertheless, in spite of the increase in recent years, current flows of FDI to agriculture remain limited in size. In 2008, out of total recorded flows of FDI of USD 1.2 trillion, flows to the food, beverages and tobacco sectors amounted to only USD 87 billion, less than 1% of the total. Flows to primary agriculture amounted to USD 5 billion, a far less significant sum (FAO, 2012a).

Policies and institutions

The incentives to innovate and adopt better technologies, as well as to invest in agriculture, depend on the overall policy environment, including macro-economic and sectoral policies and regulations. The policy set in developing countries has historically led to a clear bias against the agricultural sector. Diminished incentives for farmers to invest and expand production are significantly related to protection of non-agricultural sectors (Krueger, Schiff and Valdés, 1988). More recent estimations reveal that over the past four to five decades the nominal rate of protection afforded to non-agriculture steadily declined for developing countries as a whole, from 45% in the 1960s to less than 10% in the 1990s (Anderson, 2009). This trend has contributed more to a decline of net taxation of agriculture than specific agricultural support policies. Reforms in Asia, and especially in India and China, have significantly contributed to this outcome, while non-agricultural policies in many African countries still continue to lead to an anti-agriculture bias.

Policy-induced failures and the lack of enabling institutions constrain the productivity of small family farms. Of particular concern are poor policies and institutions that grant smallholders limited control over land and water resources on which their productive activities and livelihoods depend. An estimated 1 to 2 billion people globally live on and use commonly held land over which they have no legal title (IFAD, 2011a). Poorly defined property rights limit their access to credit and insurance markets, and prevent them from investing in improved environmental sustainability and natural resource management.

The impact of specific agricultural support policies on farm productivity depends on how and why it is delivered. Commodity-based support has the largest impact on production, but protecting farmers from competition does not encourage them to increase productivity. Market interventions often treat the symptoms of market failure and under-development rather than the cause. For example, food price stabilisation can provide a more stable investment climate but can also impose very high costs on consumers, thwart the development of private risk management, and can export instability onto world markets. It also thwarts the development of the private sector which is crucial for the long-term development of the food sector (OECD, 2012e).

Like price support, input subsidies also distort production. However, they can redress, at least temporarily, market failures such as the under-development of infrastructure, missing markets for credit and inputs, and a lack of knowledge of the benefits of using improved seeds, animal breeds and fertiliser. To this extent, they can help farmers acquire improved technology, and thus foster productivity, but over time they can also impede the development of private markets and do not tackle the problem of market failure directly.

More generally, if support is targeted to a specific input, it can encourage an input mix that will not necessarily be economically or environmentally sustainable. For example, irrigation subsidies can affect sustainable water use and may not encourage the adoption of water saving irrigation systems if appropriate regulations are not in place. Providing producers the tools they need for risk management is important for the adoption of innovation, but too much government support in risk management schemes may prevent the emergence of market solutions. As seen earlier, public expenditures on agricultural R&D have positive and large impacts on agricultural productivity, but public expenditures on extension and advisory services are also important and complementary as they promote the adoption of new production systems that enable productivity growth on a sustainable basis.

Trends in agricultural policies

Agriculture is a sector where government intervention is pervasive, but the objectives, instruments and resulting support vary by commodity, country and over time. High-income countries are providing relatively high support to their agricultural sector on average, although it has been declining since the 1990s. Low-income countries globally taxed their agricultural sector until the mid-1990s and support remains low on average. Exportable products receive less support in high-income countries than import-competing products, and are still taxed in developing countries. When decomposing the real rate of assistance to agriculture by income level, it is clear that countries are moving from taxing to subsidising their farmers as income levels grow (Anderson, 2009).

Support to agricultural producers in OECD countries has declined since the mid-1980s. In recent years, it has accounted for about 20% of gross farm receipts compared to 37% in the mid-1980s, with large differences across countries and commodities in terms of level and composition (OECD, 2011c). Policy reform has not only reduced support levels, but also the impact of support on commodity markets. The share of the most distorting support in OECD countries has decreased from 86% of total support to producers in the mid-1980s to 45% at the end of the 2000s.

The extent to which policy reform has affected productivity is not clear. Payments that are largely delinked from current production affect farm productivity. They favour extensification and help maintain less efficient farmers in business, but they also promote the adoption of environmentally-friendly production practices as farmers may use the extra income to invest in innovation.

In emerging economies and developing countries, support is concentrated on subsidies to variable inputs, such as fertilisers, and to farm, transport and marketing infrastructure. In emerging economies, support as a percentage of gross farm receipts is generally lower than the OECD average, but has increased since the mid-1990s and in 2010 it approached the OECD average of 18% in China (17%) and is above this average in Russia (21%). Nevertheless, these averages need to be interpreted with care, as some commodities in emerging economies are taxed while others are supported.

In developing countries, the share of agriculture in public expenditures declined in the 1980s and 1990s (Fan and Breisinger, 2011). Systematic international evidence on public expenditure in agriculture is not available, and it is generally not possible to ascertain to what extent the reported expenditure consists of subsidies, benefits and expenses on goods and services by governments, or can be considered as investment contributing to the formation of capital.

For developing countries as a whole, agricultural expenditure grew at 6% annually in the 2000s, outgrowing their population growth and agricultural GDP growth (IFPRI, 2011). However, only six African countries have achieved the target of 10% of total government expenditures allocated to the support of agriculture, as formulated in the 2003 Maputo declaration (Benin *et al.*, 2011). Little is known about the composition of those expenditures, the efficiency with which it is delivered, and the effects they have on productivity.

Plant-animal disease and food safety regulations that affect agriculture

Plant and animals diseases are a cost to producers, reduce productivity, and pose health risks to consumers. Food-borne diseases have an enormous impact on health and livelihoods, and are of great concern to consumers, producers and policy makers. As much as 70% of deaths among children under five are linked to biologically contaminated food and water in developing countries (Unnevehr and Hirschorn, 2000). Policy interventions are necessary to tackle such problems and governments have a number of options available to intervene. Some of these policies cam also have implications for international trade.

Policy heterogeneity in the area of Sanitary and Phytosanitary (SPS) measures reflects differences across countries in terms of their approaches to regulation, as well as different abilities to effectively implement measures that reduce plant and animal disease risks. While harmonisation across countries could facilitate trade and should be encouraged, policy heterogeneity will have to be recognised (OECD, 2009, 2010a).

Stringent private standards and import rules may be amongst the reasons why developing countries are not fully utilising market access preferences in high-income markets. Complying with food-related regulations and voluntary standards can have a high overall economic impact in low-income countries with a high share of agriculture in GDP and in exports. However, the costs associated with complying are significant. At the same time, food safety-related regulations and voluntary standards on export markets can provide a trigger to upgrade production methods in the home market of exporting countries.[6]

Import conditions for food products defined by public regulation and private standards continue to differ between countries despite all the efforts by international and regional organisations to foster international co-ordination. Participation from developing countries in standard setting bodies is currently limited.

6. The OECD Schemes for the Varietal Certification of Seed Moving in International Trade provide for the application of harmonized procedures and techniques that reduce technical barriers and facilitate international trade in high quality seed. The OECD Seed Schemes are open to OECD countries as well as all Member countries of the United Nations; currently, 58 countries actively participate in the Schemes. Over 200 species and more than 43 000 varieties are listed in the 2012 OECD List of Varieties. All varieties listed have met the OECD criteria including Value for Cultivation and Use (VCU) and Distinctness, Uniformity and Stability (DUS) (*www.oecd.org/tad/seed*).

Taking stock of actions underway

The recommendations in this report call upon the G20 governments to take action on increasing agricultural productivity in a sustainable manner in their own countries, but also to support non G20 developing countries in their efforts to address the challenges global agriculture faces.

Mindful of the need to avoid proliferation of new mechanisms and to build on the 2011 Action Plan on Food Price Volatility and Agriculture, the proposals made build on existing institutions, organisations and expertise. Box 1 summarises the status of ongoing initiatives that were launched by the G20 in 2011, and Box 2 provides more detail on the G20 Conference on Agricultural Research for Development, held in Montpellier, France in September of that year.

Box 1. 2011 G20 Action Plan on Food Price Volatility and agriculture

In June 2011 the meeting of G20 Agriculture ministers agreed to an Action Plan on Food Price Volatility and Agriculture, which was subsequently welcomed by Leaders during G20 summit in Cannes in November 2011. While several element of the action plan build on ongoing initiatives, some specific new activities were launched:

The **Agricultural Market Information System (AMIS) initiative** has three objectives: 1) to improve the information base and disseminate information in a transparent manner; 2) to develop the capacity to produce detailed commodity market data; and 3) to facilitate policy dialogue and co-ordination in the event of a serious development in commodity markets. The Agricultural Market Information System (AMIS) initiative is comprised of three components: 1) the AMIS Secretariat; 2) the Information Group (composed of experts in capitals); and 3) the Rapid Response Forum. The Secretariat is based at the FAO, with active involvement from other international organisations. The first meetings of both the Information Group and the Rapid Response Forum have taken place and considerable progress is reported in developing new systems to improve the quality and timeliness of market data for key food crops: wheat, maize, rice and soybeans. AMIS involves G20 countries and, at this stage, Egypt, Viet Nam, Thailand, the Philippines, Nigeria, Ukraine and Kazakhstan. The AMIS website was launched in December 2011 (*www.amis-outlook.org*).

The **Global Agricultural Geo-monitoring Initiative (GEOGLAM)** aims to strengthen the international community's capacity to produce and disseminate relevant, timely and accurate forecasts of agricultural production at national, regional and global scales, by enhancing national agricultural reporting systems; establishing an international network of agricultural monitoring and research organisations and practitioners; and creating a monitoring system of systems based on both satellite and in situ observations. It will, amongst other things, provide inputs into AMIS.

As a specific action to improve productivity through research and development the **International Research Initiative for Wheat Improvement (Wheat Initiative)** was launched in Paris on 15 September 2011. This initiative is mainly science driven and aims at better coordination of international research on wheat genetics, genomics and agronomy related to wheat, both bread and durum wheat.

The **Tropical Agriculture Platform (TAP)** focuses on enhancing capacity-building and knowledge sharing to improve agricultural production and productivity. It is aiming at fostering the generation, sharing and utilization of agricultural technologies and practices for smallholders in developing countries, mainly using existing mechanisms.

The **Platform for Agricultural Risk Management (PARM)** is an initiative to promote the integration of agricultural risk management into the agricultural policies of developing countries, by facilitating co-ordination among practitioners in this field. The Platform was initiated by the French development Agency (AFD) and is currently endorsed by IFAD (which is expected to host it), FAO, WFP, World Bank, some regional development banks, and some bilateral cooperation agencies.

G20 leaders agreed to remove food export restrictions or extraordinary taxes for food purchased for non-commercial humanitarian purposes by the World Food Program and agreed not to impose them in the future. Discussions on this issue continue in the WTO.

Source: agriculture.gouv.fr/IMG/pdf/2011-06-23_-_Action_Plan_-_VFinale.pdf.

Box 2. 2011 G20 Conference on Agricultural Research for Development

The G20 Conference on Agricultural Research for Development, held in Montpellier, France, on 12-13 September 2011, brought together the G20 Agricultural Research Systems and key international bodies, such as the Consultative Group for International Agricultural Research (CGIAR), the Food and Agriculture Organisation (FAO), the Global Forum for Agricultural Research (GFAR) and the World Bank, to promote scientific partnerships for Food Security.

The presidency summary recognised that:

- The **Global Conference on Agricultural Research for Development (GCARD)**, which first met in Montpellier in March 2010 at the initiative of GFAR and CGIAR, has a key role to play to develop greater international coherence of agricultural science policies and promote their implementation.
- The **CGIAR reform** resulted in a unique capacity in Agricultural Research for Development.
- Existing mechanisms, in particular **GCARD, CGIAR and GFAR** are essential to help identify and describe future challenges and opportunities, and shape priorities for Agricultural Research for Development.
- The principle of a **Global Agricultural Foresight Hub**, proposed by GFAR, was widely welcomed. It provides an opportunity for G20 countries to support the development of a neutral platform, linking international, regional and national levels and should be further elaborated.
- The International Research Initiative for Wheat Improvement (IRIWI), the Global Agriculture Geo-Monitoring Initiatives, CGIAR Research Programs such as the Global Rice Science Partnership (GRiSP) and the Coalition for African Rice Development (CARD), as well as triangular cooperation like PROSAVANNAH program, provide good examples of partnerships around the G20 Agricultural Research Systems that include stakeholders in developing countries and address their food security and sustainable development needs.
- Innovative public-private research partnerships at relevant scale are essential to stimulate access to the best knowledge, to achieve efficiency and effectiveness, and to deliver widespread and lasting impact of Agricultural Research for Development.
- The “**Agriculture Pull Mechanism**” Initiative provides an opportunity for market based mechanism.
- The **Tropical Agriculture Platform**, outlined by FAO, can contribute, in cooperation with interested G20 Agricultural Research Systems, among other initiatives, to identification of appropriate capacity development practices, the consolidation of best training practices and the promotion of modalities to support continuous learning and improve ownership by national stakeholders in developing countries.
- Agricultural Research for Development has to be mainstreamed into food security and development strategies and plans, at national, regional and international levels.

It also encouraged the interested G20 Countries to support, through national focal points, the preparation of a successful and inclusive GCARD in Uruguay in 2012, which aim to enhance the development impact of Agricultural Research Systems.

Source: www.agropolis.org/news/G20_Conference_AgricultureResearch_Development.php

In addition, this report recalls and reiterates the importance of continued support to a number of ongoing activities and generally accepted principles that contribute to improving agricultural productivity and sustainability. In that regard, G20 governments should:

- Recognise that increasing agricultural productivity growth in a sustainable manner requires long term commitment and significant changes in the mechanisms and institutions that support agricultural development.
- Commit to improve the consistency and stability of funding of national, regional and international Agricultural Innovation Systems.
- Ensure that policies and strategies in pursuit of short term food security minimise market distortions and do not compromise medium and long term sustainability.
- Support programmes that recognise the importance of the interface of the agriculture, nutrition, and health sectors by being better adapted and redesigned to maximise health and nutrition benefits and to reduce health risks.
- Commit to ensuring that the needs of women farmers are addressed in the infrastructure and energy agendas of the G20, and to explicitly consider the implications of G20-supported initiatives in these two areas for workload and wellbeing of rural women.

Recognising the potential for the creation of innovations that generate significant public global benefits, G20 governments:

- Continue to support the CGIAR systems ability to carry out R&D on smallholder productivity, including with continued specific attention to the needs of women farmers, in appropriate partnership with the national and regional research systems.
- Continue to support and strengthen special funding mechanisms, and in particular the Agriculture Pull Mechanism initiative to address the technology needs of smallholders.

Improving the policy environment for a more productive and sustainable agriculture

Supporting a long-term commitment to increased investment in agriculture development

A successful strategy for sustainable agricultural productivity growth requires significant improvements in macroeconomic, structural, and agricultural policies and institutions to provide the necessary incentives to farmers and the private sector to increase investments and build the necessary capital. G20 countries account for three-quarters of the global gross value of agricultural production. At the same time, most small family farms are situated in G20 countries, with over 280 million smallholders in India and China alone.

The required investments to achieve sustainable agricultural productivity growth encompass knowledge, human and physical capital, and both on-farm investments in agriculture and off-farm investments for agriculture. A challenge for policy makers in developing countries is to move beyond a plethora of interventions and policies towards a coherent policy framework which both facilitates and stimulates all actors, including smallholders and other private investors, to invest in and foster the accumulation of productive human and natural capital.

At the national and regional levels, this calls for comprehensive policy and investment strategies to increase agricultural productivity, improve the nutritional content of foods, mitigate food safety risks, promote sustainable use of resources, unleash innovation and new technologies, and enhance farm profitability. Climate change mitigation, water conservation, soil protection and biodiversity enhancement are also part of such strategies. Progress towards a more strategic approach to investment in agriculture, with clear long-term objectives and the harmonization of policy and public and private investment, would bring sustained benefits.

G20 governments should support comprehensive national and regional agricultural development and investment strategies which are country-owned and -led, evidence-based, and inclusive of civil society and farmer organisations to prioritise, invest and foster the accumulation of productive, intellectual, human and natural capital, and facilitate private investment, both domestic and international, including that by smallholders. Such strategies should include monitoring and evaluation mechanisms to assess the transparency and effectiveness of investment programmes and strategies in terms of productivity, environmental sustainability, food and nutritional security and well-being.

G20 governments recognise that a productive and sustainable global food and agriculture system requires long-term commitment, in their own countries and elsewhere, as well as fundamental improvements in the mechanisms and the approaches to enable further development, particularly on small family farms.

Creating relevant data and information upon which to base policy decisions is often a significant limitation to effective policy-making. There is a growing need for information to guide policy concerning the environment, climate change, food security, biodiversity, investment in agriculture, water and land use, and agricultural research and innovation, as well as for information about processes of structural transformation in rural areas and in agriculture, including their social and gender dimensions. Improving the capacity of countries to collect economic, policy and environmental information to measure agricultural performance and the results of agricultural investment is central to formulate effective policies. The Global Strategy to Improve Agricultural and Rural Statistics provides a framework for national and international statistical systems, which enable them to produce and to apply the basic data and information needed to guide decision making in the twenty-first century (FAO-UN-World Bank, 2011). The Monitoring African Food and Agricultural Policies project (MAFAP), for example, is a pilot initiative to support decision-makers at national, regional and pan-African levels by developing a systematic method to monitor and analyse food and agricultural policies in African countries. Climate smart agriculture approaches seek to build evidence-based policy frameworks that integrate climate change adaptation and mitigation concerns into agricultural development strategies for food security and poverty reduction (FAO, 2010a). If successful, such initiatives should be expanded.[7]

Well functioning input and output markets are needed to ensure access to needed production inputs and to enable suppliers to reach consumers. Information on physical markets allows producers to make decisions about timely supply to markets, in response to seasonal and other demand trends. The G20 initiative of the Agricultural Market Information System (AMIS), for example, aims to enhance food market outlook information and build capacity in developing countries by strengthening collaboration and dialogue among countries. The OECD-FAO Agricultural Outlook assesses agricultural market prospects, presenting projections and related market analysis over a ten-year horizon. The FAO global perspectives publications provide assessments of the long-term

7. Another large scale data initiative is GEOSHARE. This recent research consortium gathers national and sub-national statistics from various researchers and public agencies worldwide to put together a consistent time series of spatially disaggregated global data on agriculture, natural resources, and environment. It develops an open source data portal to the global research and policy making community. It is an outgrowth of the UK Foresight project 'Global Food and Farming Futures" (*www.geoshareproject.org/*).

outlook for the world's food supplies, nutrition and agriculture, and highlight risks and uncertainties that may influence market outcomes, as well as the priority areas where investment and research should be directed (FAO, 2009b). These global initiatives are essential, but relevant sub-national level information is sometimes lacking.

Recommendation 1

Recognising the imperative to increase agricultural productivity sustainably, in particular on small farms in developing countries, and the long-term nature of the engagement required to meet future global demand for food and other agricultural products, G20 governments should:

1. Commit to invest in sustainable approaches to productivity growth in their domestic agriculture sectors, with particular attention to smallholder farmers, both women and men, according to their role in the overall domestic agricultural and food security systems, fostering structural transformation and sustainable agricultural growth.
2. Support the Global Strategy to Improve Agricultural and Rural Statistics and commit to collaboration with concerned international organisations (particularly OECD, FAO, IFAD, IFPRI and the World Bank) in measuring levels of public and private investment in agricultural productivity.
3. Introduce, as an on-going feature of G20 work, a process of analysis and peer review to identify best policy options to increase agricultural productivity growth sustainably, and more generally to promote coherence between food security, agricultural productivity and sustainability objectives

Improving trade policies

In their 2011 report to the G20, *Price Volatility in Food and Agricultural Markets: Policy Responses*, international organisations called upon G20 governments to demonstrate leadership in multilateral negotiations to strengthen international disciplines on all forms of import and export restrictions and subsidies as well as on domestic support schemes that distort production incentives or encourage investment in unsustainable agricultural production patterns and resource use.

They recognised that a trade environment where market access is substantially improved can foster productivity growth and contribute to building global food security. More specifically, substantially reducing trade and production distorting domestic support, improving market access opportunities, eliminating export subsidies, and strengthening the disciplines on export restrictions will improve the enabling environment for investment and productivity growth.

Expected profitability is an important driver behind innovation and the adoption of more productive techniques and practices. By impeding the transmission of price signals to producers and consumers, price-distorting policies misdirect efforts to increase productivity and maintain production in areas that do not yield the highest returns, both for the environment and in economic terms. It is increasingly important that food be able to move in a free and predictable manner from surplus to deficit areas, given the already strong pressures on the natural resource base in some regions and the expected impacts of climate change.

This should not prevent developing countries, in particular the most vulnerable ones, to maintain some flexibility in their policies to deal with exceptional circumstances that would threaten their agricultural sector. Developing countries may also take appropriate complementary measures that address specific constraints to improving supply capacity, including improving the ability of smallholders to turn potential opportunities into real economic gains for their families. The WTO-OECD Aid for Trade initiative, for example, aims to help develop trade-related skills and trade infrastructure in developing countries.

Reducing production losses due to pests, diseases and mishandling will both enhance productivity and contribute to reducing pressure on fragile resources. There is a need to ensure the implementation of viable, functioning, adequately funded and transparent sanitary and phytosanitary (SPS) systems, in particular to improve plant and animal health surveillance, control, inspection and approval procedures to reduce the risk of entry, establishment or spread of pests, diseases, and organisms that can affect human, animal or plant life or health.

The World Trade Organisation (WTO) SPS Agreement and SPS Committee should play a critical role in this regard. Capacity building in developing countries, in particular to implement international SPS standards, guidelines and recommendations, is another vital component of the strategy to be adopted. In this regard, the Standards and Trade Development Facility (STDF), a partnership including FAO, the World Organisation for Animal Health (OIE), the World Bank, the World Health Organisation (WHO), and the WTO, should be supported to strengthen collaboration, increase awareness, mobilise resources, and identify and disseminate good practice in SPS capacity building.

Recommendation 2

G20 governments should:

1. Demonstrate leadership in multilateral negotiations to strengthen international disciplines on all forms of import and export restrictions, as well as on domestic support schemes that distort production incentives. Specifically,
   - substantially improve market access, while maintaining appropriate safeguards for developing countries, especially the most vulnerable ones;
   - substantially reduce trade distorting domestic support and eliminate export subsidies;
   - improve transparency in trade policies and domestic support measures, including timely notification of measures;
   - support the WTO-OECD Aid for Trade initiative and other similar initiatives that aim to help developing countries, particularly least developed ones, develop trade-related skills and trade infrastructure; and,
   - commit to strengthen initiatives at all levels in favour of trade facilitation, that aim to reduce border restrictions to trade, and demonstrate leadership in multilateral negotiations in this field.

2 Promote greater adherence to the science-based sanitary and phytosanitary measures developed by the FAO/WHO Codex Alimentarius Commission, the FAO International Plant Protection Convention, and the World Organisation for Animal Health, in full conformity with the WTO Agreement on the Application of Sanitary and Phytosanitary Measures.

3. Support sanitary and phytosanitary capacity building, including through the Standards and Trade Development Facility (STDF) to strengthen collaboration with developing countries and assist in building their capacity and the capacity of their farming communities to implement international sanitary and phytosanitary (SPS) standards, guidelines and recommendations.

Strengthening development cooperation

Official development assistance (ODA) to agriculture has received new international attention following the food price spikes of 2007/08. In 2010, net ODA flows from members of the OECD Development Assistance Committee (DAC) reached USD 128.7 billion, representing an increase of 6.5% over 2009. This is the highest real ODA level ever, surpassing even the volume provided in 2005 which was boosted by exceptional debt relief. However, the share of ODA going to agriculture fell to 6%.

As the economic crisis deepens, aid budgets may be affected. The evidence suggests that economic crises have important consequences on aid, not only decreasing aid budgets but also changing the evolution as donors tend to slow down, and sometimes reverse, the pre-crisis paths of aid budget expansion (Rapsomanikis, 2009). Preliminary findings based on DAC members' returns to the forward spending survey suggest slower aid growth ahead. Global country programme aid is planned to grow at a real rate of 2% per year from 2011 to 2013, compared to 8% per year on average over the period 2008-10 (OECD, 2012e).

Donors should reaffirm their commitments to ODA, and where appropriate prioritise agriculture development to help the world's poorest improve their economic prospects. These efforts should align with national agricultural development plans and priorities. The Paris Declaration on Aid Effectiveness in 2005 and the 4th High Level Forum for Effective Development Cooperation in Busan in 2011 were significant steps to enhancing donor co-ordination and responsiveness to country strategies and priorities.

The Global Agriculture and Food Security Program (GAFSP), launched in April 2010, provides an additional important avenue for public investment. As of February 2012, the GAFSP has pledged and committed USD 1.1 billion from a number of donors. To date, investment programmes are assisted by the World Bank, the African Development Bank, the Inter-American Development Bank, the International Fund for Agricultural Development (IFAD), and the FAO. Currently, GAFSP has approximately USD 180 million to allocate to the highest ranked proposals. However, there is no guarantee that all deserving proposals will be funded given the limited availability of funds.

Facilitating private sector investment in agriculture

Farmers are the main source of private investment in primary agriculture. However, foreign investment can also have a significant role in agricultural capital stock accumulation in some countries. Many developing countries are making significant efforts to attract and facilitate foreign investment into their agriculture sectors. Foreign direct investment (FDI) is seen as a potentially important contributor to filling the investment gap and providing developmental benefits through technology transfer, employment creation, and infrastructure development. However, the acquisition of rights to land, water and other natural resources by foreign investors has been controversial.

Mechanisms that promote responsible investment in agriculture, including building international consensus on Principles for Responsible Agricultural Investment (PRAI) are important in shaping FDI in agriculture to achieve higher productivity and ensure benefits are shared by all stakeholders, which in turn contribute to global food security and poverty reduction. FAO, IFAD, UNCTAD and the World Bank are assessing the developmental aspects of agricultural foreign investments in developing countries and pilot-testing the RAI principles with investors and host country governments. The 2011 Action Plan reaffirmed the G20 Leaders' commitment at the 2010 Seoul Summit to uphold the Principles of Responsible Agricultural Investment (PRAI) to ensure sustained investment in agriculture. The Committee on World Food Security will soon begin a comprehensive consultation on these Principles. The OECD Policy Framework for Investment in Agriculture (PFIA) has helped Burkina Faso, Indonesia and Tanzania evaluate, design and implement in a coherent manner different measures aimed at enhancing agricultural investment. At the 37th session of the Committee for World Food Security (CFS), the proposal to integrate smallholder sensitivity into the criteria for responsible investments in agriculture was also put forth.[8]

8. *www.fao.org/economic/est/investments/en/*

The OECD Guidelines for Multinational Enterprises develop standards for responsible business conduct that are applicable to the agricultural supply chains. New initiatives are emerging to harness large private investors, both international and domestic, to contribute to boosting agricultural growth in developing countries. Innovative mechanisms bring together public and private sector stakeholders to define middle-range investment plans with a growth "corridor" or a value chain focus, such as the recent Grow Africa Partnership initiative, the New Vision for Agriculture of the World Economic Forum, and the Southern Agricultural Growth Corridor of Tanzania (SAGCOT).

Public-private partnerships (PPP) are at the core of these initiatives and include, but are not limited to, joint ventures between foreign investors and local producers or their associations. In addition, supermarkets in developing countries are leading processors and exporters to transform the marketing channels into which smallholders sell. Business models include contract farming or out-grower schemes under which smallholders can be offered inputs, credit, technical advice, and a guaranteed market at a fixed price, albeit at the cost of some freedom of choice over crops. Mixed models are also possible with investments in a large-scale core enterprise at the centre, with out-growers under contract to supplement core production (Hallam, 2012).

Care must be taken, however, in the selection and formulation of business models that are capable of meeting the needs of both host countries and investors. There is scant evidence on the impact of PPPs involving foreign investors and agro-industry/supermarket organised value chains on the participation of smallholders in market integration. While some positive experiences emerged recently, the literature suggests that agricultural value chains routinely shed participants or collapse completely, while the degree to which participating smallholders benefit remains uncertain, especially in cases where new business arrangements leave smallholders exposed to risks (Barrett *et al*., 2010).

International guidance must go beyond setting principles that agricultural investments should comply with in order to avoid negative impacts. It must also move towards practical advice that would help ensure benefits are shared equitably between investors and host countries and, in particular for their local populations. Generating solid evidence on inclusive business models and scaling up effective partnerships between agribusiness, governments and smallholders can harness private capital and capacity towards the achievement of broad-based national priorities in terms of food security, productivity growth and sustainable agriculture.

Recommendation 3

Recognising the importance of defining framework conditions that would attract increased investment, whilst ensuring appropriate sharing of benefits between the host country citizens and investors, G20 governments should:

1. Support country-level implementation of the Voluntary Guidelines on Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security, recognizing the importance of fair and efficient institutions for natural resource tenure and management.
2. Support the Committee on World Food Security process on the Principles for responsible Agricultural Investments (PRAI) and on-going work to field test and operationalise the PRAI, and advocate their implementation by investors, governments, international organisations and civil society.
3. Support a series of international consultations with the relevant international organisations, the B20 and farmers' organisations to assess the potential of various public-private partnership models to increase foreign direct investment in developing country agriculture and, promote and scale-up appropriate partnership models in developing countries' agriculture, noting in particular the plans of the B20 New Vision for Agriculture, the Grow Africa Partnership, and the FAO Committee on World Food Security.

Improving agricultural innovation systems and adoption of innovations for sustainable productivity growth

Improving Agricultural Innovation Systems (AIS) to generate innovative solutions

Agricultural Innovation Systems (AIS) worldwide are in transition in an effort to better reflect users demand and generate innovative solutions more effectively. International, regional and national R&D and extension services continue to be at the heart of effective AIS to improve productivity and sustainability, but innovation is increasingly taking place in interactive and dynamic processes involving a diversity of public and private actors, including farmers. This reinforces the need for comprehensive agricultural development and investment strategies, policy co-ordination and collective action.[9]

Reform of AIS does not necessarily mean more direct government involvement and more public funding, but may mean a different organisational set-up of the innovation system and a better policy, business and regulatory environment which will attract financial and human resources, and provide incentives for knowledge exchanges, partnerships and innovative business developments to take place (Bernet *et al*., 2006; Hall *et al*., 2007; World Bank, 2006a and 2012).

Improving co-ordination and institutional design

In most countries, innovation policy and governance structures are still very much in flux, and the large majority of developing countries still lack an innovation policy. Overarching co-ordination is only possible with strong and high-level political support (OECD, 2010b). Adequate information and analytical capacity is required to assess performance and identify future needs. However, there is a lack of mutually agreed methods and indicators to track the efficiency and effectiveness of expenditures in innovation systems, and in AIS in particular.

Various methods are being developed, such as benchmarking combined with multi-stakeholder policy dialogues and diagnostic foresighting tools. Collaborative efforts that involve governments, international organisations and other actors are needed to develop a common framework and methods for assessment, and to help build country level mechanisms for improved policy co-ordination, assessment, prioritisation, and monitoring and evaluation of AIS investments.

Agricultural innovation needs effective co-ordination to allow the often fragmented stakeholders with different assets, knowledge, and experience to participate in the innovation process. There is a need to strengthen linkages with agricultural development and investment strategies in developing countries so that innovation and technology needs are clearly identified and thus effectively prioritised. Successful co-ordination requires leadership on behalf of the government, capacity-building to strengthen organisational capabilities and an environment that enables self-organisation and emergence of broker organisations (World Bank, 2012). Wider policy coherence, across innovation, competition, trade, education and rural policies, is also needed.

9. Collective action is understood here to be an action by multiple actors (individuals and organisations) to identify opportunities for innovation, assess the challenges involved, and access and use the social, human, and capital resources required to innovate, learn, and share information, as well as to implement the activities.

Improving the cross-country supply of innovations

In the traditional agricultural innovation system, technologies were developed and extended by the public sector. Today, growth of sustainable agricultural productivity will require the active participation of farmers and other stakeholders in innovation systems. The private sector also plays an increasingly important role, but will typically orient its innovations towards high value and market-oriented production systems. Public goods, such as improved natural resource management and maintenance of biodiversity, will typically fall outside the scope of purely private innovations.

Governments in developed and developing countries, together with international organisations, need to assure predictable and consistent financial support to basic research and innovation in areas that are not taken up by the private sector. They also need to collaborate and pursue positive synergies, and avoid duplication of efforts to improve the overall efficiency in the use of financial resources.

Enhancing the cross-border technology transfer potential of the international R&D architecture is pivotal to increasing productivity growth and addressing issues that are transnational, such as transboundary diseases, climate change, water scarcity, and price volatility in global markets, or that require investment beyond one country. The Global Research Alliance on Greenhouse Gases, for example, is a low/no cost approach to cross-country collaboration on research that help to address climate change challenges.[10] Opportunities provided by advances in biotechnology require concentrated investments in infrastructure, advanced computing, and human capacity that call for regional or central hubs (e.g. the BecA-Hub[11]) that offer economies of scale. It is not efficient for every country to have its own basic agricultural research system, and resources in those cases could be better focussed on adapting solutions developed elsewhere.

Many agricultural technology breakthroughs, especially the improved wheat and rice germplasm that shaped the Green Revolution, emerged from research that was encouraged by the international community and governments with the CGIAR making significant contributions through basic research that had substantial international spillover effects that also benefitted smallholders.

Over the years, CGIAR's activities have broadened considerably towards an expanded development mandate, as well as to addressing country-specific activities in response to donor support. As such, its role as a provider of productivity-enhancing public research and a source of international R&D spillovers has weakened (Pardey and Pingali, 2010; Pardey, Alston and James, 2008). This reality, among others, impelled the CGIAR to examine and revise in 2008 its approach to agricultural R&D. As a result, funding to the system has been increased, research agendas are now more results-oriented (new CGIAR Research Programmes) and increasingly complemented by broader partnerships for uptake of research results.

The CGIAR system continues to hold immense promise to respond effectively and efficiently to the challenge of improving small family farm productivity, with specific attention to the needs of women farmers. It is uniquely well placed to undertake scientific research and development, in partnership with national and regional research systems, encompassing a wide range of diverse needs and circumstances.

Improving the linkages between international R&D providers and developing countries and making them effective in sharing knowledge, identifying and prioritizing needs and transferring technology is challenging. Good co-ordination with

10. *www.globalresearchalliance.org*.

11. Biosciences Eastern and Central Africa: BecA website, *hub.africabiosciences.org/*.

international, regional and sub-regional research networks is important for countries to develop their own national research system.[12] Increases in the effectiveness of R&D international spillovers can also be achieved by mechanisms such as the G20 Tropical Agricultural Platform initiative and regional research collaboration.[13]

Such initiatives provide important regional and sub-regional focus, facilitate the transfer of innovations, technologies and practices and strengthen linkages with agricultural development and investment strategies in developing countries. The growing capacity of large national agricultural systems in Brazil, China, India, and South Africa, for example, holds huge potential for increased South-South co-operation, while a strategy for small countries with limited resources, in particular, could be to rely more on technology adaptation/adoption and regional and international partnerships.

The G20 can spearhead global coordination and collaboration on agricultural R&D and innovation, as in the Conference on Agricultural Research for Development, held in Montpellier on 12-13 September 2011, which brought together the G20 Agricultural Research Systems and key international bodies. More regular meetings of agriculture scientists will be crucial to establish global research and development priorities and actions for sustainable agricultural productivity growth. Such meetings may take place within the activities of existing mechanisms and platforms, such as the G20 Tropical Agricultural Platform, the Global Conference on Agricultural Research for Development (GCARD), CGIAR Research Programmes (CRP) planning mechanisms, and the Global Research Alliance (GRA) on Agricultural Greenhouse Gases.[14]

Better connecting research to demand

To improve the contribution of the R&D system to long-term challenges and shorter-term market demands, governments and research agencies could embrace a dual strategy that involves upgrading the R&D infrastructure ("innovation hardware") and investing in the institutional infrastructure ("innovation software").

Governments need to improve the institutional infrastructure for innovations by implementing policies that enable national and international partnerships, leverage skills and resources, diversify funding, and result in improved products and practices that meet the needs of the entire agri-food system. In all cases, new competencies related to communication, ICT, intellectual property rights, participatory planning, facilitation of partnerships-teamwork would help (Horton in World Bank, 2012).

A key strategy to improve the demand articulation for innovations is to link to "bridging organisations" within the context of agricultural development and investment strategies. Extension services, farm or trade associations, NGOs or extension-research-farmer councils can facilitate small family farm inclusion effectively. However, research partnerships could develop further if they moved from participatory research

12. For example the Forum for Agricultural Research in Africa (FARA), the Inter-American Institute for Cooperation on Agriculture (IICA), Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), Conference of African and French leaders of agricultural research institutes (CORAF), the Asia-Pacific Association of Agricultural Research Institutions (APAARI), and the Forum for the Americas on Agricultural Research and Technology Development (FORAGRO).

13. Such as the regional agricultural research in Africa, the West Africa Agriculture Productivity Program and the East African Agricultural Productivity Programme.

14. The OECD Co-operative Research Programme (CRP) on Biological Resources in Agriculture, which aims to strengthen the scientific knowledge that informs policy decisions on sustainable use of natural resources in agriculture, food, forests and fisheries, could also provide such a platform. See for example the proceedings of the Conference on Challenges for Agricultural Research it organised in Prague on 6-8 April 2009 (*www.oecd.org/agriculture/crp*)

and use of competitive research grants toward wider alliances and R&D consortia, such as the Papa Andina network in Latin America that brings farmers, researchers, and processing industry together to address technology and market challenges. In more market-oriented contexts, the strategic focus for institutional partnerships in the research system is expected to shift towards more resource leveraging and research linkages to producer organisations, agricultural input or processing industries, and supermarkets. This takes place usually within the framework of public-private partnerships (PPPs) and in the form of consortia (Annex A). The key challenge is to maintain a balance between strategic research that focuses on small family farm productivity and market-oriented research. Specific funding strategies are required to ensure that research continues to contribute to the reduction of rural poverty.

Improving private sector engagement at national level

Private sector investment in agriculture R&D has been rising for the increasingly high value and marketed oriented production systems in emerging economies. The key to opening the potential of private R&D for smallholders will lie in creating a viable market for R&D outputs and innovation-related services.

Governments can employ instruments to direct private investments to areas of significant public interest and areas where the private sector alone would generally under-invest in areas which are usually of importance for smallholders. Public policies, well-designed financial incentives and significant efforts in capacity-building are needed for effective public private partnerships with respect to advanced science and technology, complex regulatory systems, Intellectual Property Rights (IPR) protection, sophisticated markets and market infrastructure, and international trade considerations. Governments of developing countries will have to establish new institutions and policies that facilitate private investment in technology, technology transfer, services and innovation based on international good practice, either directly through foreign direct investment or indirectly through alliances and partnerships (Annex A presents successful experiences with consortia and PPPs).

With the growing diversity of partners and institutional arrangements, the demand for more innovative funding mechanisms is growing. The appropriate financing instrument (e.g. a grant or subsidy, a guarantee, or a loan) depends on the type of public good to be produced and the role of the public sector. Reforming innovation institutions and mechanisms may require a re-definition of the relationship between public and private researchers and their “clients”.

New applications for other funding mechanisms, such as tax incentives, venture capital, and advance market mechanisms, are beginning to emerge. Over two-thirds of OECD members and many developing countries have tax incentives for R&D. Available evidence on the effectiveness of R&D tax credits is mixed, but they can be an effective mechanism to overcome market failures resulting in underinvestment in private R&D (Hall and van Reenen, 2000).

The use of venture capital has been limited in developing countries, but small- and medium-sized agricultural enterprises require risk capital to capture opportunities presented by agricultural innovation. Although traditional venture capital may not always be appropriate for many developing countries, innovative financing models can be explored.[15] [16] The African Agriculture Fund, Actis Africa Agribusiness Fund, African

15. An angel investor provides backing to very early-stage businesses or business concepts. For example, a business may have little more than a business concept and perhaps a plan for growing the business.

Agricultural Capital, African Agribusiness Investment Fund are examples of new venture funds targeting African agriculture.

Agricultural pull-mechanisms reward successful innovations *ex post*, as compared to push mechanisms which fund potential innovations *ex ante*. Models for pull mechanisms include: 1) standard prizes that reward achievements in a technology development contest; 2) proportional prize structures that reward innovations in proportion to their impact; and 3) advance market commitments (Annex A).

The Agricultural Pull Mechanism Initiative (AGPM), to be launched in 2012 by the G20, convenes experts across a variety of fields and collaborates with a diverse set of stakeholders, including governments, private companies, non-governmental organisations, and civil society organisations. It has developed a short list of potential pilot concepts and has formulated the architecture for the underlying pull mechanisms to overcome some of the constraints for the creation of an innovation that will generate wider social benefits.

Such pull programmes are financially attractive because no resources are spent until the desired product is developed and approved by regulators. They can be structured so that total expenditure depends on adoption rates creating strong incentives for researchers to select appropriate projects and focus on developing products that farmers will want to use. Pull-mechanisms ought to focus on a specific market failure and development solution, embedded in agricultural innovation systems in terms of regulatory environment.

Strengthening public and private extension and advisory services

Extension and advisory services are critical for facilitating smallholder access to technology and knowledge. They increasingly play a brokering role to support multi-stakeholder innovation processes. In many cases, extension is the only AIS institution that actively facilitates adoption among smallholders (Christoplos, 2010; Klerkx *et al.*, 2009). Countries that have invested in extension simultaneously with investment in R&D have had the strongest TFP growth (Fuglie, 2012).

Yet, many governments over the years have reduced their investment in extension and advisory services, leaving these with insufficient staff and operational resources (World Bank, 2005; Christoplos, 2010). The private sector, along with ICT-and other group-based approaches, has increasingly taken up this space with specific objectives for the development of their value chains. However, many extension tasks still have a public goods nature that requires public investment, such as co-ordination and technical backstopping of diverse service providers, the regulation and quality control of service providers and often the overall extension system, service provision to small-holders and disadvantaged areas, and monitoring and evaluation of services (World Bank, 2012).

To enhance national extension systems, one recommended strategy is to establish and strengthen a demand-driven, pluralistic and decentralised advisory service that mixes both public and private services. Common characteristics of such services include the development of extension programmes based on client demand, both from men and women, the organisation of rural producers to build social capital and develop

16. Venture capital is a form of private equity that is provided for both early-stage and more mature companies with substantial market potential. Returns on venture capital investment stem from a trade sale (sale to, or merger with, another company) or an initial public offering in which the company becomes authorized to sell its stock to the general public on a stock exchange. Venture capital funds will not only provide money but will mentor their investee firms.

economies of scale, and the provision of the technical background and certification for service providers.

Extension services also need to be geared to the development of integrated extension and advisory services that combine market-oriented services with other services, such as group organisation, access to technology and knowledge, and links to finance (Swanson and Rajalahti, 2010; World Bank, 2012), along with empowerment of producers, women and men alike. Investment in new capacities (market-oriented services, group-based approaches, use of ICT), and new tools and actors is often needed in countries with a weak system and a large small-holder base. Among new tools, ICTs are increasingly used to circulate market, price, and weather information and to offer specific kinds of extension advice. ICTs targeting small-holders, however, require both public and private investment (World Bank, 2011). Successful implementation requires more knowledge of good practices in extension, which can be provided by coordinated efforts of different actors, such as the Global Forum for Rural Advisory Services (GFRAS).

Making agricultural education and training more attractive and relevant

Sustainable productivity growth in agriculture represents a knowledge intensive undertaking, the success of which hinges on the development of the capabilities of the actors primarily involved. Fostering the education and development of the ability of farmers to innovate, to solve new problems as they emerge in a volatile environment, and to engage with other stakeholders — from researchers and policy makers to retail buyers — is at the heart of agriculture development.

In many countries, agricultural education and training has been neglected. Low levels of general education in the farming population of developing countries can also be an obstacle to adaptation.

A broader approach to, and a new emphasis on, agricultural education and training is required for two reasons. First, there is a need to provide farmers and rural small and medium enterprises (SME) with the skills, understanding and innovative capacity that they require to practice sustainable agricultural intensification and market-oriented activities. Strengthening individual capabilities and human capital are important for all aspects of farm and business management. Sustainable agricultural intensification must be recognised and presented as modern and profitable, so that the aspirations of rural youth — young men and women — can converge around this. Second, there is a need to train a new generation of agricultural specialists, scientists and service providers who can work with smallholders in new ways to develop the skills needed to make sustainable agricultural intensification work (IFAD, 2011a).

Agricultural universities, faculties of agriculture, vocational and technical colleges, and farmer training centres all play a role in creating human capital needed to modernise the sector. The emphasis on the innovation system as a dynamic, highly interactive market place for ideas poses challenges to the education system, in particular to match the supply of education and training with labour market demands (World Bank, 2007). Building a productive and financially sustainable educational system needs sustained political support for investments in Agricultural Education and Training (AET) to develop a system of core institutions.

Aside from technical knowledge (e.g. production, processing, agribusiness, biotechnology), graduates require professional skills such as leadership, communication, facilitation, and organisational capabilities that are crucial for performing in an AIS. Important reforms include reforming curricula and teaching methods to better match modern labour market needs and building capacity, and stakeholder partnerships for technical education and training. Such reforms have wide implications for inter-ministerial co-operation (e.g. Ministries of Agriculture, Education and Labour), financing, and stakeholder involvement (World Bank, 2012) (Annex A).

Reccomendation 4

Mindful of the benefits of multilateral cooperation in Agricultural Innovation Systems (encompassing education, science and extension), G20 governments should:

1. Continue to support existing and on-going initiatives that contribute to improving agricultural productivity sustainably, including the Tropical Agriculture Platform, the Wheat Initiative, the Global Forum for Agricultural Research, the Global Research Alliance on Agricultural Greenhouse Gases and the Global Alliance on Food Security Research.
2. Facilitate exchange of experience and policy dialogue on AIS at high level, initially in at least two ways:
   - supporting on an on-going basis, an annual meeting of "chief scientists" in G20 countries; and
   - inviting existing mechanisms and platforms, such as the G20 Tropical Agricultural Platform, the Global Conference on Agricultural Research for Development (GCARD), CGIAR Research Programmes (CRP) planning mechanisms, and the Global Research Alliance (GRA) on Agricultural Greenhouse Gases, to consider ways in which to further facilitate international collaboration and information exchange on sustainable agricultural innovation and growth, including identifying ways to better integrate research on transnational/transboundary issues into agricultural production research, and ways to effectively leverage existing research funding.
3. Strengthen efforts at the national, regional and global levels to identify, assess, prioritise, monitor and evaluate investments in Agricultural Innovation Systems and identify the necessary resources to support the Agricultural Science and Technology Indicators (ASTI) initiative[1] to a) collect and maintain a comprehensive database on expenditures on agricultural innovation; b) develop tools and methods to assess the performance and impact of innovation systems.

1. See Annex B.

Improving the system of intellectual property rights (IPR), where there is need

Protection of intellectual property rights (IPRs) is an important factor influencing the performance of agricultural innovation systems. Through adequate IPR protection, rights-holders can exclude competitors from use of an innovation for a limited period of time or, in the case of open innovation approaches, promote access and sharing. The WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS, which entered into force in 1995) established near-global minimum standards of protection for the main types of intellectual property.[17]

Of particular importance for agricultural productivity, TRIPS provides that patents shall be available – with a few exceptions – in all fields of technology for inventions that are new, non-obvious and useful. One exception concerns plant varieties, which may be excluded and protected via a *sui generis* system such as the one provided under the convention of the International Union for the Protection of New Varieties of Plants (UPOV), or by any combination of those two options. In addition, in some cases, national law and regional or international accords afford IPR protection beyond the TRIPS minimum standards (e.g. availability of protection for new plant cultivars via patents and plant variety protection laws).

17. The TRIPS Agreement covers patents, including plant variety protection, copyright and related rights, trademarks, undisclosed information (including trade secrets), geographical indications, industrial designs and topographies of integrated circuits.

The strengthening of IPR protection in recent decades has also been associated with an increase in private sector investment in agriculture-related research and development and a surge in innovation leading to improved plant varieties, agricultural chemicals, and production technologies (e.g. OECD, 2011b; Wright and Shih, 2010; Kolady *et al.*, 2010). In part due to the incentives provided via IPR, many of these innovations have moved rapidly into commercial use. In some cases, the strengthened IPR regime has led to new collaboration via pooling of intellectual property, as was the case with development of a nutritionally enhanced strain of rice known as golden rice (OECD, 2011d). A World Bank report (2006b) draws lessons on the design of regimes to support plant breeding in developing countries, based on an empirical analysis of existing regimes.

At the same time, concerns have emerged with respect to some aspects of the present approaches to IPR protection in agriculture, particularly with respect to patents and breeder's rights. Fragmented ownership of intellectual property with respect to research inputs (technologies and materials such as genes), may hamper the innovation process or result in industry concentration to consolidate ownership of intellectual property (Blakeney, 2011). The threat of litigation may hamper scientific freedom to operate or may lead to liability for farmers using protected innovations such as biotech crops (Wright and Shih, 2010; McGloughlin, 2012).

There are a variety of options available that may improve the system of IPR protection to provide further incentives for private investment in innovation, without compromising the sharing of knowledge and further innovation. Some of these issues can be addressed by use of best practices in regulation and innovation policy frameworks such as with respect to collaborative approaches, public-private partnerships, or licensing of genetic inventions (e.g. OECD, 2011d and 2006). The administration of the patent system is also important in terms of delivery of quality patents that provide an appropriate degree of protection (Dons, 2012).[18]

IPR protection remains uneven across some developing countries, both in terms of compliance with TRIPS (e.g. Perera, 2011) and in terms of the ability to capitalise on economic opportunities associated with the IPR system.[19] Improved compliance and awareness building may lead to improved performance of incentives for innovation and diffusion of innovation in developing countries. There may be further potential for the international community in providing technical assistance for improvement of IPR systems in developing countries as well as for complementary measures such as *Aid For Trade* that may improve the business environment for private sector engagement including with respect to agriculture (OECD-WTO, 2011).

A major problem in agriculture in many developing countries, particularly relevant in the case of small-scale farms, is a growing conflict and imbalance between the traditional farmer seed systems and the commercial seed sector. Seed laws in many developing countries have been reviewed and changed during the last decade, in particular to support the emergence of the private sector. In many countries, the law applies to all seeds and planting materials, including traditional varieties, but implementation rules are available for only a few major crops. Despite the growing awareness of the value of the farmers' sector, very few countries have explicit exemptions for farmers' traditional seed systems, which make marketing of farmers'

18. This means that the patents awarded should be clearly defined with a scope in line with the nature of the invention and not overly broad.

19. The African Agricultural Technology Foundation (AATF) facilitates and promotes PPPs for the access and delivery of appropriate proprietary agricultural technologies for use by resource-poor smallholder farmers in Sub-Saharan Africa. *www.aatf-africa.org/* (*www.iphandbook.org/handbook/ch17/p18/*).

seeds technically illegal. The concept of farmers' rights, adopted in the International Treaty on Plant Genetic Resources for Food and Agriculture (PGRFA) (FAO, 2009c), prescribes involvement of farmers in the development of policy and gives farmers the right to save, use, exchange and sell farm-saved seed. This may require some countries to revise their seed laws or regulations taking into account national needs and priorities, while also respecting international obligations concerning IPR protection, including with respect to the TRIPS Agreement.

Improving management of sanitary and phytosanitary systems

Regulatory systems exert an overarching influence on the ability of agricultural trade to develop. For example, where Sanitary and Phytosanitary (SPS) provisions and certification systems are inadequate, agricultural trade may be constrained which in turn may diminish incentives for productivity increases and demand for innovation. Regulatory issues of particular importance for agricultural innovation include IPR, health and food safety regulations, and bio-safety regulations. Poor choices in regulatory policy settings or inappropriate application of tools may delay scientific advancements, prevent technology transfer and impose crippling transaction costs on organisations.

In developing an appropriate SPS regulatory environment, including implementation provisions, experience has shown that science-based approaches are most effective and least market distorting. A variety of innovative approaches can help reduce the regulatory cost burden for governments. These include use of public-private partnerships based on "best practices" in the way the SPS regulatory framework is managed, including the interface between private voluntary standards and compulsory compliance regulation. In general, the achievement of regulatory objectives mainly relies on adequate national practices supported by on-going harmonization towards best international practices, with the contribution, if necessary, of well-targeted capacity building in developing countries, including through mechanisms like the Standards and Trade Development Facility (STDF).

Ensuring biodiversity and sustainability

A key element to ensure sustainability in production is the proper use of agricultural biodiversity both in its conventional use in breeding, as well as and in its direct use by farmers and communities for livelihoods and other multiple benefits. Agricultural biodiversity has been and continues to be a foundational source of traits for crop and livestock improvement through breeding and biotechnology. Important collections of plant genetic resources exist in gene banks around world – including those of the CGIAR Centres and national and regional institutions.

A major bottleneck for the effective use of the diversity existing in these collections for crop improvement and productivity growth is the lack of easy access to information on the characteristics of materials to potential users. In this regard, the development of a global information system that provides users with direct access to information on the wealth of material conserved *ex situ* may well be the single most important contribution that could be made to improving the efficiency of crop improvement.

The first version of a global accession-level information gateway on genetic resources (GENESYS) was released in May 2011 and supported by the International Treaty on PGRFA, the Global Crop Diversity Trust and the CGIAR. GENESYS already provides access to information about more than 2.3 million accessions from CGIAR gene banks, the EURISCO web catalogue of European gene bank accessions, and the Germplasm Resources Information Network (GRIN) of the United States Department of Agriculture. The expansion and promotion of this tool and a commitment from the G20

Countries to provide their data to this information gateway would represent a tremendous boost to crop improvement and global agricultural productivity growth.

Investments in capacity strengthening and establishing frameworks and platforms for data sharing to enable scientists worldwide to access and fully exploit new genomic information and associated germplasm can result in a significant reduction in the time it takes to breed better producing animals and plants. There are many existing collaborations designed to share genomic information, such as US/NSF's iPlant, EU's Elixir and others, which can be leveraged to develop a network which will facilitate searches for desired traits and linking these to the correct germplasm. A listing of some existing networks which can be leveraged is provided in Annex C.

Recommendation 5

G20 governments should:

1. Commit to support developing countries to establish and enforce appropriate IPR systems consistent with international obligations, in particular the Agreement on Trade-Related Aspects of Intellectual Property Rights and the International Treaty on Plant Genetic Resources for Food and Agriculture, including application of the provisions of the latter treaty with respect to farmers' rights, with a view to promoting productivity and private investment in line with each country's strategy for food security.
2. Support the development and promotion of a global information system on plant and animal genetic resources conserved *in situ* as well as in genebanks as a tool to boost plant breeding and to sustainably increase agricultural productivity both worldwide and at small-scale farmer levels. They also commit to make the information relating to genetic resources conserved in their national genebanks available through a common portal, such as "Genesys", which is hosted by the CGIAR and to support the linking of this portal with information systems containing genomic data.

Annex D provides an overview of the contribution of agricultural biodiversity to stable and sustainable agricultural production, system resilience and ecosystem services, which are currently undervalued, and could be better exploited to ensure the resilience and sustainability of agricultural systems.

Addressing the water challenge in agriculture

To meet the projected global growth in demand for agricultural commodities over the next fifty years will have significant implications for surface water and groundwater resources, as well as the quality of rivers, lakes, aquifers and marine waters. Expanding agricultural production will heighten competition for water resources with other users and increase the risks of water pollution damaging human health and the environment.

Most of the increased competition for water, and pressure on water quality, will occur in those developing countries where population growth, economic and agricultural growth will be most rapid. As a consequence the need to improve the future performance of agricultural water management will be critical to help reduce pressure on water resources and the quality of water.

Annex E outlines the water challenge in agriculture and discusses how to improve water use in agriculture and water quality. The Annex concludes that the policy responses countries might consider as part of an economy-wide water policy reform programme, are to:

1. *Create incentives* to signal to farmers and other water users the value of water and the cost of water pollution caused by agriculture. This can also include, for example, instituting water brokerage pilots in watersheds and river basins to

increase efficient water use, recovering operation and maintenance costs for water supplied to irrigators; and reforming water pricing policy.

2. *Invest in water infrastructure* to address water resource and quality concerns, including fostering more efficient farming practices and farming systems, such as aggressive crop breeding for (biotic) water stress tolerance, which can yield significantly larger water conservation benefits than direct interventions in irrigation systems. Also, in regions of greatest water stress expand water storage capacity.

3. *Enable innovation* to promote improved water management in agriculture. To enable, disseminate and speed-up innovation over the long-term requires changing the behaviour of governments, farmers, water managers, the agro-food chain and other stakeholders by:

   - *engaging* these stakeholders to address water management issues, especially at the water catchment or sub-catchment level;
   - *enabling* change by educating, training and raising awareness of farmers through farm advisory services and building the capacity of other stakeholders in a water catchment in the realisation of policy goals; and,
   - *establishing* information and knowledge systems to provide technical and socio-economic information about the likely impact (science), costs (financial) and farmer reactions (social) to a given policy change to address water management in agriculture.

4. *Strengthen institutions and governance* to support efforts enhancing food and water security. This involves the establishment of secure water use rights for smallholder farmers, which should be the highest priority for water policy and institutional reform, given its inherent potential to increase the efficiency of water use and equity for the allocation of water resources for different users.

5. *Build resilience*, to address long-term concerns with food and water security, including developing and implementing agricultural adaptation and mitigation options, most of which are related to water.

Recommendation 6

Recognising the importance to improve the efficiency of water use in agriculture and to safeguard the quality of water, as an integral part of sustainable productivity growth, G20 governments should:

1. Support countries in considering a range of policy responses to address the increasing importance of improved agricultural water management to sustainable productivity growth in both rainfed and irrigated agriculture. This includes policies that create incentives for farmers and other water users to better incorporate the value of water and the cost of pollution into their decisions and it includes strategic investments in water storage and supply infrastructure with the involvement of water user associations, including farmers, in private–public partnerships.
2. Promote innovations in water research, information and knowledge systems, and outreach to farmers and other stakeholders at the water catchment level.
3. Seek to improve the institutional effectiveness of water governance in agriculture, and build resilience to address the increasing risks to water security associated with climate change.
4. Continue dialogue based on the recommendations concerning food security and water made by Ministers in their Declaration at the World Water Forum, Marseille, France, 13 March 2012.

Closing the gap for the smallholders and their families

Considerable potential exists to improve small family farm productivity with existing technology and practices. To be profitable, however, sustainable intensification requires dynamic and efficient input and output markets. It also requires that smallholders, both women and men, have access to such markets and to the information needed to be able to participate effectively in them.

Policies to directly stimulate the adoption of specific technologies

There is no single "technical package" to underpin the quest for agricultural productivity growth and environmental sustainability gains. An extensive spectrum of options is available to instigate the transformation of agriculture, together with continuing innovations.

Input subsidies

The use of fertiliser in Africa averages only eight kilograms per hectare, that is, only 10% of the world's average. Addressing Africa's fertiliser crisis is therefore urgent. Over the last ten years, African countries have implemented large-scale, multi-year input subsidies.[20] These programmes have multiple objectives: to increase production and enhance food security by loosening the constraints posed by price volatility, cash constraints and lack of knowledge and strengthening the demand for inputs by smallholders. They aim to consolidate input marketing systems, which suffer from lack of economies of scale (Annex F). They are considered "market-smart" as they target smallholders exclusively through vouchers and grants, and attempt to promote private sector solutions for the provision and distribution of inputs (Dorward, 2009; Dorward *et al.*, 2008).

Available evidence, albeit very limited, suggests that subsidies in many countries have contributed to agricultural productivity gains, although their success cannot be totally separated from exogenous factors such as favourable weather and depends strongly on implementation performance (Druilhe *et al.*, 2012). The associated costs are also very high, crowding out alternative forms of public investment. If "market-smart" subsidies are used to boost small family farm productivity sustainably, their cost-efficiency must be improved.

It is important that such programmes be temporary and only target farmers who are not aware of the benefits of fertiliser and improved seeds, or who have no means to finance input purchases or access to credit. Interventions that do not affect the cost of specific inputs, but rather enhance farmers' liquidity, such as loan guarantees and credit for input purchases, or facilitate access to inputs under value chain arrangements, can provide efficient alternatives (Rapsomanikis, 2009). In the longer term, one-time "starter packs" which combine input provision and extension can effectively foster the adoption and diffusion of technology.

International organisations should support countries to strengthen monitoring and evaluation systems of "market-smart" input subsidy programmes, improve small family farm targeting and graduation mechanisms, and implement specific training to enhance farmers' knowledge of precision approaches to ensure sustainable input applications.

20. Amongst recent interventions, one can distinguish between targeted and rationed subsidies implemented in East and Southern Africa (Kenya, Malawi, Rwanda, Tanzania, Zambia), and universal schemes (untargeted, pan-national for specific crops) adopted in West African countries (Burkina, Senegal, Mali, Nigeria, Ghana).

More attention could usefully be focused on improving the functioning of input markets generally, and fertiliser markets in particular. Given the fertiliser raw material resources available in Africa, the African Union Member States in the Abuja Declaration on Fertilizer for the African Green Revolution in 2006 undertook to promote national/regional fertiliser production and intra-regional fertiliser trade to capture a bigger market and take advantage of economies of scale through measures such as tax incentives and infrastructure development. There is a need to identify the tools to facilitate the increase in competition in the fertiliser industry, including through the promotion of new investments in fertiliser plants in prioritised geographical locations, specifically in Sub-Saharan Africa which is by far the smallest producer and consumer in the world.

Policies to reduce costs or provide incentives to smallholders to adopt improved inputs should be coherent with national objectives on agricultural sustainability. In some countries, overuse of Green Revolution technologies led to the depletion of water tables (UN, 2001). Complementary measures to enhance farmers' ability to use inputs in efficient and sustainable ways, such as building the knowledge about precision approaches in the use of mineral fertiliser and water, are also necessary to ensure that natural resources are not over- or misused. Also critical is to identify and remove policy-based incentives that encourage the wasteful use of water and fertilizers. In rain-fed areas, climate change threatens millions of small family farms and policies should ensure the proper economic valuation of natural resources to encourage their sustainable use (FAO, 2012b; IAASRD, 2008; IFAD, 2011c).

Sustainable production intensification and climate smart agriculture

Some tried and tested technologies and practices have proved their relevance to increasing productivity and promoting environmental sustainability, according to local conditions and needs. The best option for sustainable production intensification depends on specific agro-ecological and market conditions, but generally they involve increasing ecosystem services in agricultural production systems (to increase the resilience and efficiency of agricultural production systems as well as improve agriculture's contribution to environmental "goods") and increasing the efficiency of input use (to reduce agriculture's contribution to environmental "bads"). Sustainable Land management practices, such as reduced tillage, maintenance of a protective organic soil cover, crop rotation to enhance nutrient levels and manage pests, and integrated nutrient and water management techniques, are associated with both environmental and productivity benefits (FAO, 2011b, 2001c). Sustainable production intensification requires the use of well adapted and high performing varieties to meet productivity, nutrition and agro-climatic challenges. Increased efficiency of organic and inorganic fertiliser, water use and pest and disease control are needed to increase returns to agriculture while reducing negative environmental externalities when achieving needed productivity gains.

Climate smart agriculture (CSA) is an approach to managing multiple objectives in agricultural growth and development strategies under the specific constraints of climate change. The approach involves identification of policies, strategies, technologies and financing to support sustainable increases in agricultural productivity and incomes, incorporating necessary adaptation by building resilience and adaptive capacity in agricultural systems, while reducing and removing and greenhouse gases to contribute to climate change mitigation. CSA is based on a principle of site specificity, recognizing that the priorities and practices will vary from place to place. CSA incorporates sustainable intensification approaches, emphasizing the importance of efficiency to increase returns and reduce emissions per unit output, and building ecosystem services to foster resilience as well as sequestration. Aligning international climate policy and financing approaches under the UNFCCC process with the priorities of developing countries to achieve CSA is a fundamental component of the approach, just as building innovative financing mechanisms to link climate adaptation and mitigation financing with agricultural development and food security funds is a major component of CSA. Leveraging private investments through the establishment of appropriate public-sector incentives and funds is part of this innovative approach, as is the establishment of financing to support the long-term transitions often required to achieve CSA objectives.

Achieving sustainable production growth and climate smart agriculture will require shifts in policies to support transition to sustainable and climate smart production systems. One key barrier is secure rights over key production resources such as land and water. The Voluntary Guidelines on the Governance of Tenure of Land, Fisheries and Forests in the context of National Food Security provide guidance on how to improve access to support sustainable development. Another key issue is the time it takes to achieve net economic benefits after the switch to new practices, and the need to support livelihoods over this transitional phase. Major investments in human capital are required to achieve the needed improvements in management. Linking environmental sources of finance, such as for climate change adaptation and mitigation, to agricultural development finance is a potential means to overcome this barrier that is being promoted under climate smart agriculture approaches (FAO, 2010b). Translating these approaches at the national level into large scale co-ordinated programmes of action will require significant institutional support. Consideration must be given to the different incentives for adoption that may be faced by men and women when their access to services and control over vital assets are unequal. In practical terms, mechanisms should be developed to assess the productivity, resilience and environmental impacts of production systems. Key issues include risk management, and collective action in managing natural resources.

Successful adoption of sustainable productivity intensification practices will depend on the capacity of farmers to make optimal choices, which in turn depends on the availability of information, technical support to smallholders through extension services and appropriate incentives. At the local level, farmer organisations are vital in facilitating the uptake of sustainable production intensification practices, scaling up pilot studies, empowering disadvantaged social groups, and using farmers' experiences, local and traditional knowledge.

Country experiences are diverse (IFAD, 2011c). In some cases, these approaches have spread easily due to the existence of favourable agro-ecological and market conditions, without need for direct policy support. In other countries, their scaling up has required a favourable policy environment. In yet other instances, political commitment to both productivity growth and a sustainable intensification agenda has been critical. In Zambia, adoption of conservation agriculture was successful, being an explicit part of the current national agricultural policy (IFAD, 2011c). In China, the promotion of "ecological agriculture" has also been clearly promoted through a package of policy measures under the 11th Five Year Plan, while Indonesia has a national programme for the promotion of integrated pest management. In 2012 FAO initiated a project to support the development of climate smart agriculture policies, strategies and investments with three partner countries: Malawi, Zambia and Viet Nam.

Recommendation 7

Recognising the need to address the short-term imperatives of ensuring food security while increasing the resilience and sustainability of food systems for the longer term and taking into account the need to minimise potential market distorting effects, G20 governments should:

1. Commit to reviewing policies that may generate perverse incentives for sustainability and encourage unsustainable use of natural resources, undertake the integration of natural resource management into agricultural policy making to redress them, and work towards ensuring that environmental sustainability gains are achieved.
2. Support developing countries in designing and implementing policies based on a comprehensive analysis of the relationships between food security, food production and natural resource use.
3. Support developing countries to strengthen monitoring and evaluation systems of "market-smart" smallholder targeted input subsidy programmes, improve small family farm targeting methods and graduation mechanisms, and implement specific training to enhance farmers' knowledge of precision approaches to ensure sustainable input applications on a gender equal basis.
4. Support interested international and regional organisations to conduct analysis and studies and recommend options to strengthen competition in the fertiliser industry, and improve access to fertilisers at competitive prices, specifically in Sub-Saharan Africa (Annex F).

Risk management

Risk considerations are important factors that influence farmers' decisions to adopt new practices or technologies. Smallholders are rarely well equipped to manage risks in an environment that is increasingly characterised by fragile ecosystems, persisting poor integration into output, input, and finance markets, and often with a high prevalence of diseases, such as HIV or malaria, or conflict.

Risk aversion hinders the adoption of technologies and practices, in spite of their long term benefits for the individual farmer and for overall sustainable productivity growth. Small family farms may choose lower return crop and livestock production options over more technology- and input-intensive options. Or they may opt for productivity enhancing over sustainability enhancing practices. The threat of shocks, either general, such as droughts, or farm-specific, such as a crop failure, increases their financial risks and makes smallholders reluctant to access credit markets due to the consequences of an inability to repay.

Reducing the risk for farmers to adopt more sustainable and productive practices is complex. Appropriate public investments in infrastructure, storage, services, and better governance of natural resources and of agricultural markets, including contracts and institutional arrangements in value chains, are both critical to limiting the risk environment for smallholders, as well as for other private sector actors.

On-farm risk management strategies include diversification of production and maintenance of on-farm genetic diversity. These strategies allow agricultural systems to maintain production in the face of changes to climate and markets, and develop the capacity to absorb shocks and continue to function within a changing set of circumstances.

As recognised in the G20 Agricultural Ministers' Action Plan of June 2011, financial instruments are important to mitigate and manage agricultural risks. Farmers with adequate access to credit and saving services, and with insurance coverage are better able to invest in productive assets (Cai *et al.*, 2009). However, traditional agricultural insurance and credit services are unsustainable throughout the developing world, mainly as a result of the high transaction costs of reaching farmers who operate on a small scale.

The development of market-based approaches to financial inclusion for smallholders has been central to recent efforts. Credit is essential to build up the necessary capital. In particular, longer term loans are needed for investment in productive and natural capital, such as storage and soil fertility. Initiatives for the development of innovative micro-insurance schemes and of weather index insurance products have gained attention, particularly – in the case of weather index insurance – as a tool to manage systemic risks.

Pilot initiatives undertaken with support from a number of donors, alongside private and public sector partners, indicate that weather index insurance products indexed to weather station data, area and yield, or satellite rainfall estimations, have the potential to overcome high transaction costs associated with traditional multi-peril crop insurance (IFAD and WFP, 2010).

Although index insurance is in the early stages of development, numerous pilot studies have been completed and several practitioners and donors have begun to shift their attention to the challenge of scaling up successful approaches. The work of the WFP-IFAD Weather Risk Management Facility is an example of a systematic approach to taking stock of success factors for weather index insurance programmes, defining the complementary roles of public and private sector actors, and identifying the preconditions for scaling up successful models.

Challenges to the diffusion of index insurance include its limited affordability and appeal for poor farmers, and the constraints faced by the private sector to develop index insurance products outside the context of partnerships with the public sector. In order to design quality index insurance contracts, it is important to improve the quality of data to which such risk management instruments are indexed. In this regard, reaching many farmers with instruments to manage weather risks requires more and better weather stations emitting higher-quality weather data. Current technological developments on the use of ICTs and satellite imagery are gradually making the collection of meteorological information easier, which may significantly help developing countries.

For scaling up purposes, there remains a need to broaden efforts to improve data collection systems and to strengthen national meteorological services and their weather observing networks. More importantly, there is a need for historical meteorological data to be made available and easily accessible to insurers and re-insurers to facilitate the design of weather risk management instruments and improve the estimation of risk premia.

Relevant initiatives were supported by the G20 as part of the 2011 Action Plan on Food Price Volatility and Agriculture. In particular, efforts to provide smallholders with innovative and effective market-based risk management options should be scaled up. Public-private partnerships, specifically with international organisations and the cellular telecommunications corporations, promote the establishment of networks of stations in developing countries for the making of meteorological observations. Initiatives such as the “Weather Info for All” (WIFA) in which the World Bank and the World Meteorological Organization work together with mobile telephony operators aim at hosting weather equipment at mobile network sites to strengthen weather networks and systems.

Recommendation 8

G20 governments should:

1. Support the efforts of relevant International Organizations and existing risk management initiatives, such as the Platform for Agricultural Risk Management, the Global Index Insurance Facility, the Weather Risk Management Facility, the R4 Rural Resilience Initiative and the Weather Info for All, to provide smallholders with innovative and effective market-based risk management options, including weather index insurance.
2. Strengthen their own efforts towards exchanging weather information, including the recovery of historical meteorological information to facilitate the development of weather index insurance and re-insurance markets (Annex G).

Promoting market integration and increasing competitiveness

The adoption of technologies and practices to increase productivity sustainably must be profitable. Neither the widespread adoption of productivity enhancing technologies, nor the provision of services required to facilitate their adoption are likely to occur unless greater attention is given to removing the constraints facing small family farms (FAO, 2012c). This requires the development of markets and agricultural value chains so that farmers can participate competitively, obtain fair prices for their products, and invest on-farm.

Smallholders, in particular women, face significant constraints to access markets. Their choice is dependent on both their ability to participate in output and input markets and on the functioning of those markets. Policies to facilitate market integration should take into account the modern nature of value chains, and differences in the capacity of men and women smallholders to meet market demand for nutritional quality and food safety standards. Efforts are needed to support the ability of poor producers to participate in new market opportunities, and to ensure that nutritious and safe foods are available, accessible, and affordable to poor consumers.

Farmers are not a homogeneous group. They differ in terms of the extent to which they participate in markets and the importance that different markets (for agricultural products, inputs, labour, services) have for them. Even within the same household, women and men farmers may participate in different kinds of markets and their production decisions may reflect a different balance between income generation and household food security and nutritional concerns.

Governments have multiple roles to play in supporting the development of agricultural markets and value chains in which smallholders can find profitable, yet low-risk, market opportunities. Governments need to invest, develop enabling policies and regulations to promote the expansion and transformation of agricultural markets and specific value chains, and support the capacity of poor rural people, in particular women, to engage in these more profitably (IFAD, 2011c).

Land access and tenure security influence the extent to which farmers are prepared or able to invest in improvements in production and sustainable land management, adopt new technologies and promising innovations, or access finance for on-farm investment and working capital. Since the full benefits of certain sustainable practices accrue over several years, secure tenure that provides the incentive for farmers to invest is vital.

Land tenure systems that allow renting in and out easily can contribute to bridging the productivity gap. The evidence indicates that secure tenure can double investment and significantly increase land values, while well developed rental markets can result in increased productivity by around 60% (Deininger and Jin, 2007; Feder, 2002).

The restructuring of downstream segments of the food value chain presents new risks of marginalisation for smallholders, and new opportunities for some to raise their income and productivity. This is particularly true in domestic markets in developing countries which are becoming more segmented and differentiated, offering different entry points for smallholders with diverse potential in terms of quality of production and market engagement.

Progress has also been made in recent years in innovative financing to agriculture through public-private or donor-facilitated mechanisms, such as equity financing, refinancing, guarantee funds to allow development of new financial products, and fiscal incentives to financial institutions providing inclusive services in rural areas. Value-chain financing is an innovative terrain with promising opportunities for smallholders and offers the potential to link access to finance to productivity growth. Including agriculture in a broader financial agenda is increasingly recognised.[21]

New market opportunities are often linked to establishing collaborative arrangements between smallholders and larger private sector enterprises – retailers, processors, but also providers of inputs and technical assistance. A variety of business arrangements – including contract farming, out-grower schemes, and others – can provide incentives for smallholders to engage in more productive activities. However, ensuring that this occurs often requires the public sector to play both enabling and active supportive roles, in particular in ensuring that the business arrangements that link smallholders to the modern value chains provide incentives to more sustainable practices.

With a supporting enabling environment, smallholders will be better placed to adopt productivity enhancing technology. However, the greater challenge is to improve the functioning of both upstream and downstream agricultural markets so that they can serve smallholders on an equal footing with larger actors, with manageable risks, and on terms that make it worthwhile and feasible for them to shift to more productive and sustainable practices. The ability of smallholders to organise is often the key enabling factor for them to engage profitably and at reduced risk in new markets as organisations can facilitate economies of scale in access to inputs and services, information, capital, marketing and negotiations with other actors.

About a third of food produced for human consumption is wasted or lost globally, and over 40% of the losses in developing countries occur at the post-harvest and processing levels (FAO, 2011d). Efforts to develop new technologies to reduce post-harvest losses have been comparatively much lower than those to boost production. Improved post-harvest systems, however, require more than improved technologies and need to cover a large segment of value chains, including preservation, conservation, safety and quality control or enhancement, processing, packaging, storage, distribution, and marketing. There is a need for a comprehensive approach that links R&D to technology dissemination, advisory services, infrastructural development, capacity building, and institutional innovation in all segments of agricultural value chains where losses may occur (IFAD, 2011b).[22]

21. This issue is thoroughly dealt with in a report to the G20 by the Global Partnership for Financial Inclusion and the International Finance Corporation, namely CPFI and IFC (2011).

22. Among the several existing initiatives to address post-harvest losses at the international level we may cite the FAO-hosted Information Network on Post-Harvest Operations, which promotes sharing of data and best practices in post-harvest activities, supporting post-harvest management and related capacity building at the country level, and the Post-Harvest Action, Global Post-Harvest Forum, which contributes towards a post-harvest R&D agenda developed on a multi-stakeholder basis (IFAD, 2011b).

Investments in human capital

Human capital development, including health, nutrition, education, and skills development, is essential to increase farmers' productivity in agriculture, as well as their ability to seize decent non-farm employment opportunities.

In many developing countries, access and quality of education in rural areas need to be urgently improved. Rural-urban gaps remain wide in education enrolment and attainment rates, basic education is frequently biased against agriculture and, in general, fails to teach young people about agriculture in the context of sustainable development or to appreciate how it is linked to the communities' development aspirations. Gender disparities in access to education, particularly above the primary level, also remain a major problem in many countries.

In order to effectively invest in human capital, governments must integrate long-term solutions with immediate food security measures that empower farmers to invest. Well designed social protection safety nets programmes and interventions can play a critical role, in enabling the transition to sustainable intensification, especially if they are well integrated with policies aimed at promoting transformational changes and at enhancing agricultural productivity. Labour-based, "productive" safety nets such as public works or "food-for-assets" programmes can empower poor farmers to increase their productive potential, enhance local infrastructure such as irrigation systems, and contribute to ecosystem restoration and local resilience.

Cash transfer programmes have become an important tool for social protection and poverty reduction strategies in low- and middle-income countries around the world. Their focus is on food security, health, nutritional and educational status, particularly of children, but comparatively little attention is paid to boosting the productive activities of beneficiary households.

There is good reason to believe, however, that cash transfer programmes can influence the productive capacity of beneficiary households, in particular by helping households with limited access to financial services for investment and risk mitigation. The provision of regular and predictable cash transfers to poor households in the context of missing or malfunctioning markets has generated economic and productive impacts at the household and local levels. For example, the Mexican PROGRESA programme has led to increased land use, livestock ownership, crop production and agricultural expenditures, and a greater likelihood of operating a microenterprise (Todd *et al.*, 2009; Gertler *et al.*, 2012). The Malawi social protection programme has led to increased on-farm investment and production (Covarrubias *et al.*, 2012; Boone *et al.*, 2012).

Recommendation 9

G20 governments promote human capital development and agricultural productivity growth for smallholders, women and men alike, and with particular attention to youth. They should:

1. Support the continued provision of targeted, well-designed and gender-sensitive social safety-net programmes that meet the immediate food and nutrition needs of smallholders and their households, and that also help reduce risks and costs associated with the adoption of more productive and sustainable practices and technologies.

Unless policies to promote innovation and investment have an explicit gender focus, women will continue to be disadvantaged with respect to accessing technologies, markets and services. As a result of their multiple responsibilities, women face major labour constraints. Investing in labour-saving and productivity enhancing technologies and infrastructure to free women's time for more productive activities is pivotal.

Increasing women's access to land, livestock, education, financial services, extension, technology and rural employment would boost their productivity and generate gains in terms of agricultural production, food security, economic growth and social welfare. Closing the gender gap in agriculture would generate significant gains. If women had the same access to productive resources as men, they could increase yields on their farms by 20–30%. This could raise total agricultural output in developing countries by 2.5–4% (FAO, 2010b).

The Women's Empowerment in Agriculture Index (WEAI) measures the empowerment, agency, and inclusion of women in the agriculture sector in an effort to identify ways to overcome those obstacles and constraints. The Index is a significant innovation in its field and aims to increase understanding of the connections between women's empowerment, food security, and agricultural growth (IFPRI, 2012).

Many labour saving technologies exist and can be made available to large numbers of poor rural women. Infrastructure investments can greatly contribute when designed specifically with gender roles and the needs of rural women in mind. Priority areas for technology and infrastructure investment include access to water and water management (both for farming and for household consumption), access to energy (cooking fuel and on and off-grid electricity in particular), and access to tools and implements well suited to women's physical requirements and cultural preferences (Carr and Hartl, 2010; World Bank, FAO and IFAD, 2008).

Recommendation 10

G20 governments should:

1. Recommend the explicit integration of agricultural education and of the sustainable agriculture intensification agenda into the international organisations' initiative to support national skills development strategies, as developed under the G20 Development Working Group in 2011, and widen the range of involved organisations to explore possibilities to enhance South-South and triangular co-operation in the gender-sensitive reform of agricultural education systems.
2. Recognise the equal importance of the roles of women and men farmers in promoting sustainable agricultural productivity growth, the critical need to bridge gender productivity gaps in agriculture, and the need for measures to improve gender equality, in particular concerning access to land, water, education, services, technology and decent rural employment. In particular, they should promote tools such as the Women's Empowerment in Agriculture Index to assess the impact of policies and investment on women

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Annex A.

Additional Information on AIS

Box A.1. Features of Papa Andina's partnership programmes

This programme is an example of a regional institutional mechanism for research-innovation in small-holder-agrarian contexts.

Papa Andina is a regional partnership that involves the International Potato Center (CIP) and national agricultural research organisations in Bolivia, Ecuador, and Peru. Since its inception in 1998, Papa Andina has shifted its focus from implementing a regional research agenda to developing a regional learning agenda and strengthening national capacities for innovation.

Organisational interface. Papa Andina's participatory market chain approach (PMCA) features facilitated, face-to-face meetings that involve diverse market chain actors, researchers, and other agricultural service providers in exploring options for market chain innovation. The facilitating R&D organisation then conducts or arranges for R&D on specific innovations. A project team based at CIP has continued to serve as a broker and facilitate interactions between researchers, market actors, and decision makers at various policy levels (in theory this task should eventually pass to the market actors). Full-time facilitators and innovation brokers reduce some of the transaction costs and co-ordination issues related to partnerships and networks. Financial sustainability beyond donor funding remains controversial and problematic for Papa Andina, both in CIP and in national research organisations.

Outcomes. PMCA and stakeholder platforms have achieved higher prices for native products, increased farmers' revenues, developed more stable markets for producers of native potatoes (partly through successful branding and marketing), and increased farmer's self-esteem. In Bolivia, new potato products sold to supermarkets enable farmers to receive 30–40% higher prices than they received in traditional markets. The innovation network in Ecuador (Plataforma) enabled farmers to raise yields by 33%, improve input–output ratios by 20%, and increase gross margins per hectare four-fold.[1]

New products and markets. Other key outcomes include the creation of a new brand of high-quality fresh potatoes for the wholesale market, a new native potato chip product and brand, and the first brand of high-quality native potatoes to be marketed in Peruvian supermarkets. Technological innovations improved pest and disease management and the selection of harvested produce. A national platform, CAPAC-Peru,[2] was established to promote the marketing of quality potato products and innovation, in which local actors are gradually taking more responsibility as their capacity and trust increases. CAPAC helped organise small-scale farmers to supply potatoes meeting the more demanding market requirements. When a multinational entered the market, Papa Andina began to work on corporate social responsibility to balance corporate interests with the interests of community suppliers and the environment. Other indirect results include the popularisation of native potatoes in Peru's urban cuisine and the establishment of Peru's annual National Potato Day, which caused the United Nations to declare 2008 the International Year of the Potato.

Key lessons

- Approaches such as PMCA require substantial time and resources for capacity development if they are to strengthen linkages between researchers, economic actors, and policy makers.
- Traditional evaluation approaches based on objectives and logical frameworks do not work for innovation processes and innovation brokers' performance. The processes and tasks involved are too complex and results often take some time to be apparent.
- A pro-poor focus is vital to market chain approaches and innovation networks, which run the risk of benefiting those who are better able to take advantage of new market opportunities and innovations. In Peru, native potato varieties have evolved from "poor peoples' food" to a source of national pride, and the main beneficiaries have been the smallholders from the high Andes who preserved and grew them over thousands of years.

1. Impact statistics from Cavatassi *et al*. (2009).
2. CAPC = Cadenas Productivas Agrícolas de Calidad en el Perú (Quality Agricultural Productivity Chains in Peru).
Source: Devaux *et al.* (2009, 2010); Horton *et al*. (2010).

Box A.2. Design of the Australian national agricultural innovation system

Two events have significantly shaped the present Australian national agricultural innovation system.

The first was the introduction of the rural research and development corporation (RDC) model in 1989 under the Primary Industries and Energy Research and Development Act 1989 (PIERD Act), to invest in and facilitate R&D in the agriculture, fisheries and forestry industries (the original model also included an energy RDC). The Australian rural sector comprises a diverse range of industries, mostly owned and operated by a myriad of small family businesses. The market failure in the provision of socially optimal levels of RD&E is likely to be more severe in the rural sector than in many other sectors of the economy, as individual small businesses have a very low capacity to conduct significant RD&E. It is also difficult for rural businesses to capture benefits from the application of property rights to the technology and knowledge generated from investment in R&D in the sector.

Under the RDC model, the government collects statutory levies on rural industry production, and the levies are paid to research and development corporations which conduct RD&E to benefit the industry collectively. The levy rate is set by a vote of producers in each industry. The Australian Government contributes funding to match the producer levy contributions up to a limit of 0.5% of the gross value of production by the industry. The contributions provided by government act as an incentive for private investment, but also recognise the spillover benefits to the wider community in the form of research which contributes to environmental stewardship and more sustainable use of natural resources. Industry is closely involved in RDC priority setting for scientific, technological or economic R&D which extends from basic and strategic research to applied research and development. The RDCs are accountable both to producers and to the Australian Government.

The second major influence on the present Australian system was a decision in 2005 by the primary industries ministers of Australia’s national, state and territory governments to endorse the concept of “National R with Regional D&E”. The concept recognises that basic and strategic research (R) can be provided from a distance, with regional adaptive development (D) and local extension (E) required to improving the uptake of innovation by industry. The governments, RDCs and public research providers (including universities) subsequently agreed to develop the National Primary Industries Research, Development and Extension (RD&E) Framework in an effort to encourage greater collaboration, reduce duplication, and improve the investment of RD&E resources nationally. Under the framework, 14 primary industry sector strategies for national co-operation in RD&E are in various stages of development or implementation, and eight cross-sectoral strategies promote cooperation in relation to animal biosecurity, animal welfare, biofuels and bioenergy, climate change and variability, food and nutrition, plant biosecurity, soils and water use in agriculture.

Source: ABARE.

Box A.3. Chile technology consortia

Chile is considered a pioneer in using consortia to align public research with national innovation policies, and the government issued its first tender for a Technology Business Consortium in 2004. Chile's consortia are expected to strengthen links between research communities and local and global business communities, thereby improving scientific skills and techniques, competitiveness and opening new business opportunities.

A consortium is defined as a technology company in which one or more companies agree to carry out joint projects with universities, institutes, and/or technology centres to develop new technologies that can improve and add value to production processes and products. The theoretical justification for this type of instrument is to discover solutions for market failures limiting innovation by an enterprise and encourage partnership strategies to incorporate knowledge externalities, co-ordinate the use of complementarities, and share the risk of investment in technology innovation.

Public agencies fund and manage the consortium programme. The maximum contribution of the public sector to a single consortium is USD 6 million, and each consortium can operate for up to five years. The maximum yearly public contribution to a consortium's total budget is 25% for research activities, with an additional contribution of 10% for human capital development and 15% for research infrastructure. This funding is matched by co-financing of 50% from non-public consortium members.

Most of the consortia studied have focused on improving the competitiveness of productive sectors rather than on improving capacity to pursue innovative activities. Their main contributions are improved access to technological and other kinds of knowledge (such as marketing, international market regulations and requirements, and staff with specific kinds of expertise) and joint technology development by researchers with companies.

Given their short duration and the applied research they generally conduct, applications for IP protection are still very low. For the same reason, the companies in the consortia have not yet achieved major technological breakthroughs. Consortia are a good option when industry is strongly committed to the process and the partners possess the technological capabilities to develop the kinds of products they seek. When these conditions are not met, a strictly corporate model such as the one used in Chile may not work. Special programmes may be needed, for example, if consortia are intended to include small-scale producers.

Source: Álvarez *et al*. (2010); World Bank (2012).

Box A.4. India's evolving agricultural innovation system

The National Agricultural Innovation Project (NAIP), launched in 2006, addresses R&D and innovation challenges by changing the way in which scientists, farmers, and agricultural entrepreneurs interact in the national AIS. NAIP incorporates lessons from the three earlier projects (representing almost 25 years of experience), including the need to develop public-private partnerships, integrate technology development and transfer mechanisms, and finance research through competitive research grants.

The project sought to strengthen the role of the Indian Council for Agricultural Research (ICAR) in catalysing and managing change in the National Agricultural Research System and to promote the development of three kinds of multistakeholder, multidisciplinary consortia of public and private organisations, universities, NGOs, and others: (1) market-oriented, collaborative research alliances with a focus on selected agricultural value chains; (2) livelihood research alliances with a focus on strategies to sustain secure rural livelihoods in about 110 disadvantaged districts; and (3) basic and strategic research alliances with a focus on well-defined areas of frontier science with potential applications for problems in Indian agriculture. The trade-off between market-driven innovation and innovation for lagging areas has been addressed by creating dedicated funding streams to support different types of innovation clusters.

Promising consortia and research alliances were funded by NAIP through a competitive process. In each case, consortium members were jointly responsible for the governance, design, and implementation of their research programmes; maintaining satisfactory fiduciary and safeguard arrangements; applying the resulting innovations; and disseminating new knowledge through conferences, innovation marketplaces, networks, and communications strategies. A Helpdesk was established to support the new and more challenging partnerships that the consortia represented. It provided guidance for preparing concept notes and full research proposals, assisted in matching consortium partners, and helped to overcome initial problems in managing the consortia.

The outcomes of NAIP are numerous and diverse: the approach received an overwhelming amount of interest and resulted in funding 188 consortia; NAIP was able introduce greater pluralism into agricultural research, with almost 40% of consortium institutes coming from outside the ICAR–state agricultural university system, PPPs were promoted on a large scale for the first time; the consortium approach has promoted pluralism, synergy, teamwork, partnership, value addition, learning, and better, more relevant research, and the anticipated greater impact is associated with the approach. Lastly, the institutions have been strengthened as a result of formal training and, even more important, through development of new partnerships, as illustrated by the continuous interaction between public, private, and NGO sectors and the willingness of ICAR institutes to work outside their system. ICAR has started to mainstream the consortium approach and competitive selection process throughout its institutes.

Source: World Bank (2006, 2012).

Box A.5. Promoting PPPs for agricultural technology transfer in China

The China Agriculture Technology Transfer Project responded to strategic concerns about China's agriculture by piloting innovative models to transfer and use agricultural technology. It aimed at enabling poor farmers to adopt new, value-adding technologies and generate additional income by producing for high-value markets. Public investments in agriculture were leveraged with complementary private investments from agribusiness. Aside from developing new models to transfer technology, the project fostered better public–private partnerships in agriculture.

The project PPP approach addresses public good nature investments, placing emphasis on environmental technology, social services, and small-holder productivity along with innovativeness of the technology, economic and financial viability, and additionality of the investment (the grant will not drive out other funding), particularly strong company, and compliance with strategic policy directions. The PPP models promote commercially attractive technologies and new institutional arrangements:

Competitive matching grants provide partial funding to develop and test successful tripartite investment models in which researcher-investor-farmer partnerships focus on increasing farm income.

Grants support researcher-company interactions to develop profitable public good technologies for sale.

Funding helps farmer organisations develop strong grant proposals.

The project also finances technology transfer to farmers lacking capital, information, or the decision-making power to adopt technologies on their own. Through *block grants*, the project supports public programmes to help the private sector commercialise innovative technologies. Public funds are also used to develop public good technologies—technologies that do not appeal to the private sector on purely commercial grounds.

Results: More than 200 sub-projects have been selected for implementation. Poor farmers are adopting new, value-adding technologies and generating additional income by producing for high-value markets. Public investments in agriculture are leveraged with complementary private investments from agribusiness. The project was also able to change the mentality of actors, have an impact on PPP policy and program; institutionalised project selection and management procedures; built capacity, and identified innovative models.

Source: Adapted from World Bank (2005, 2010).

Box A.6. Examples of technology transfer offices and incubators

Technology transfer offices (TTO) are special units affiliated with a research organisation or university with a mandate to identify and protect as well as facilitate the use and commercialisation of research results. These offices can expand the recognition of the research organisation's work (thereby strengthening public perceptions of its value), move technologies to end-users (seed companies, farmers) on an exclusive or nonexclusive basis, and generate revenues to fund continuous research. Technology transfer offices can provide special expertise on IP protection and/or legal agreements and contribute to formal transfers of technology from public organisations or universities or from the private sector to commercial or international partners.

Inova, a technology transfer office established by the State University of Campinas Unicamp in Brazil in 2003, helped create productive linkages between the university's own R&D and industry. By 2007, Inova had become the most frequent patentor and licensor in Brazil. The greatest contributor to the patent and licensing portfolio is the Chemistry Institute (48%); the corresponding figure for agribusiness and food is 16%. Factors in Inova's success include: it is driven by market demand; the technology transfer team comes from private institutions and has business skills (not researchers); and the government provides many incentives to companies, such as tax benefits and sponsorship/subsidy of the salary of a scientist hired by a company.

Incubators nurture young firms, helping them to survive and grow during the start-up period when they are most vulnerable. Incubators provide hands-on management assistance, access to financing, and business and technical support services; they frequently also provide shared office space and access to equipment. Although they work with a broad spectrum of business development models, the vast majority of business incubators fall into two general categories: *technology* (focusing on commercialising new technology and transferring technology) or *mixed use* (serving a wide range of clients).

The Agri-Business Incubator@ICRISAT at Hyderabad, India offers technology consulting, business development, and training services, as well as office space, laboratories, and agricultural land for startups to test new technologies and services. ICRISAT has established several partnerships and has been able to commercialise several technologies for both small and commercial farmers. Developing countries require also broader, less intensive, and more diverse incubator services to develop entrepreneurial, innovative cultures and business environments. In Mozambique, the Technoserve Incubator leverages entire agribusiness sectors, and provides diverse services to different target groups.

Sources: World Bank (2012); Di Giorgio (2007) and Campbell (2007).

Box A.7. US Model for Technology Transfer: Agricultural Technology Innovation Partnership program (ATIP)

The US Department of Agriculture (USDA) established the ATIP to further enhance likelihood that USDA intramural research outcomes would be adopted by US private sector businesses for commercialisation. Although replete with scientific expertise, the intramural research components of USDA do not have the resources nor the authority to provide business partners of USDA (licensees) with marketing, manufacturing, and fiscal resources (complementary assets) needed by them for their businesses to be successful. As a result, ATIP was established to strategically form geographic partnerships with well-established economic development entities that excel in providing the complementary assets that USDA cannot.

Ten organisations across the United States each have a Partnership Intermediary Agreement with USDA to formalise their membership in ATIP. This network represents a novel approach to enhance and accelerate commercialisation of USDA research outcomes. The ten members of ATIP established a Foundation to provide both a unifying entity for the members external to USDA, as well as flexibility to engage other organisations that have a vested interest in seeing USDA research outcomes adopted by the private sector to create goods and services for public benefit.

ATIP and USDA have held a number of regional events, called “Rural Agriculture and Business Innovation Forums.” The goal of these forums is to provide to rural farmers and agribusinesses innovations and technology-based solutions to their regional agricultural problems. The forum approach entailed several steps: 1) Regional listening sessions comprised of businessman, farmers, economic development, regulatory and extension personnel are held to identify broad lists of regional issues; 2) Second session is then held for an in-depth discussion of the list of region issues in order to identify priority areas for which they may be an existing technology based solution; 3) The Forum is convened as a roundtable discussion to address the three topic areas with farmers, agri-business professionals, USDA researchers, university and, extension service personnel, rural development personnel, and funding and regulatory agency personnel.

Source: US Department of Agriculture.

Box A.8. Models for pull mechanisms

Standard prizes reward achievements in a technology development contest. It can be designed as a winner-takes-all prize or so as to reward runners-up as well.

Proportional prize structures reward innovations in proportion to their impact. Such mechanisms could offer a fixed per-unit reward that depends on the total benefits achieved, so that the total award is flexible. For instance, a fixed payment per hectare planted in a new seed variety, where the total reward paid out would depend on adoption provides incentives to fund research aimed at improving the variety and adapting it to local conditions.

Advance market commitments (AMCs) offer a public-sector subsidy payment for goods and services that the AMC‘s intended beneficiaries want to buy. This increases the market size and makes returns more certain for producers. In exchange, the industry commits to providing the product at a sustainable long-term price for an agreed period after public support ends.

Box A.9. Positive education reform examples

Reforming India's State Agricultural Universities was a major effort to modernise university administration and management; update the curriculum; make related changes in pedagogy, learning materials, and infrastructure; set new standards for higher agricultural education; and improves human resource management in state line departments.

In 1997, the Netherlands initiated a major investment in the knowledge infrastructure for agriculture that led Wageningen University to change its focus, structure, programmes, and staffing and co-operate with a wider research, social science, and stakeholder network.

The private, autonomous EARTH University in Costa Rica was established to educate young people to deal with the region's numerous problems in rural areas. It blends academic work with practical experience and collaboration in agrarian communities and agribusiness; building capacity and stakeholder partnerships for technical education and training.

In five Egyptian universities, a curriculum change enabled course content to respond to the needs of potential employers and has proven to be a good entry point for wider institutional change. Vocational agricultural education programmes in 25 secondary schools in Egypt were transformed to introduce students to practical training and to skills such as problem solving, critical thinking, and decision making.

Source: World Bank (2012).

References to Annex A

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Annex B.

Measuring Investments and Capacities in Agricultural Research: The ASTI Initiative

The Agricultural Science and Technology Indicators (ASTI) initiative is one of the few sources of information on agricultural R&D statistics for low- and middle-income countries. Facilitated by the International Food Policy Research Institute (IFPRI), ASTI has been compiling, analysing, and publicizing primary data on institutional developments, investments, and capacity trends in agricultural R&D in low- and middle-income countries since 2001, building on prior projects undertaken by IFPRI and the former International Service for National Agricultural Research (ISNAR).

ASTI has published sets of country briefs and country notes, datasets, regional synthesis reports, and other analytical reports that have been widely and frequently cited in national and international agricultural research policy documents. ASTI outputs provide both data trends — the progress of human and financial capacity in agricultural research over time — and data comparisons — the performance of a country or a region relative to another. The initiative has produced a large amount of original and ongoing survey work focusing on developing countries, but it also maintains access to relevant data for developed countries for comparative purposes. ASTI is also a comprehensive source of qualitative information on the history of national agricultural R&D systems, institutional changes, and constraints that agencies and researchers face in undertaking agricultural R&D. Data collection, analysis, and dissemination are conducted through a network of national, regional, and international agricultural R&D agencies. ASTI data and associated reports are made freely available at the ASTI website (*www.asti.cgiar.org*).

ASTI has been funded on a project basis, and as a result, data collection activities have been rather *ad hoc* and focused mainly on updating out-of-date datasets. Since 2008, ASTI has received two subsequent grants from the Bill and Melinda Gates Foundation for its data collection and analytical activities in Sub-Saharan Africa and South Asia. This has allowed ASTI to initiate a transformation of its program to a more sustainable and institutionalised monitoring system with frequent updates, and to enhance the use of ASTI datasets and outputs for analytical purposes. ASTI is currently seeking funding to replicate this institutionalized and decentralised data collection and analysis system in Sub-Saharan Africa to other parts of the world. ASTI is also developing plans to expand its indicators to include performance measurements.

Annex C.

Networks to Share Genomic Information

This annex provides a listing of some existing networks which can be leveraged to share genomic information:

- **Ensembl Plants** (European Molecular Biology Laboratory-European Bioinformatics Institute, Cambridge, United Kingdom): 14 plant species. *plants.ensembl.org/index.html*. Collaborating with ARS.

- **InterPro** (European Molecular Biology Laboratory-European Bioinformatics Institute, Cambridge, United Kingdom): InterPro is an integrated database of predictive protein "signatures" used for the classification and automatic annotation of proteins and genomes.

- **UniProt Knowledgebase (UniProtKB)**: UniProt is the central hub for the collection of functional information on proteins. UniProt is a collaboration between the European Bioinformatics Institute (EBI), the SIB Swiss Institute of Bioinformatics and the Protein Information Resource (PIR).

- **Gene Ontology Consortium** (with support from NIH-NHGRI) is an international consortium.

- **GMOD (Generic Model Organism Database)** is an international consortium.

- **Oryzabase** (National Institutes of Genetics, Japan): Integrated rice science database.

- **The Generation Challenge Programme (GCP)** of CGIAR and its partners: Partners and products in GCP are:

  – **The Integrated Breeding Platform** (**IBP**) is a web-based, one-stop shop for information site providing tools for a configurable Breeding Management System (based on concept of the International Crop Information System, ICIS); a Field Trial Management System including an Integrated Breeding Fieldbook; and tools for a Decision Support System including a Molecular Breeding Design Tool, a Cross Prediction Tool and a tool for marker-assisted recurrent selection (MARS).

  – **MoU with iPlant for the IBP**: The **Generation Challenge Programme (GCP)** and **iPlant Collaborative** signed a joint Memorandum of Understanding (MoU) on 17 January 2011, in San Diego, California, United States. Under the terms of this MoU, iPlant will collaborate with GCP in developing GCP's **Integrated Breeding Platform (IBP),** including hosting a team of GCP software engineers. *www.iplantcollaborative.org/learn/news/2011/01/18/iplant-collaborates-cgiar-integrated-breeding-platform-ibp-powerful-new*

  – **The Crop Trait ontology and Trait dictionaries** (*www.cropontology.org/*): A collaborative effort of the Crop Lead Centres for developing the controlled vocabularies necessary for integrating phenotypic and genetic, genomic data through annotations. Collaboration with the Plant Ontology Consortium, SOybase (USDA), SolGenomic Network (SGN), Gramene and Trait ontology, RCN-Phenotype ontology, GARNet (UK) and initiation of collaboration with NCBI.

– CGIAR Centres: AfricaRice, Bioversity, CIMMYT (Centro Internacional de Mejoramiento de Maíz y Trigo), CIAT, CIP, IITA, International Rice Research Institute (IRRI), ICARDA, International Crops Research Institute for the Semi-Arid Tropids (ICRISAT).

– List of GCP partners in developing countries, newly developed countries, developed countries, public and privates institution can be found at: *www.generationcp.org/gcp_partners* and the list of principal investigators: *www.generationcp.org/gcp_principal_investigators*.

– **Agropolis,** Agronomic Research Platform in Montpellier, France is a Collaborator of GCP since the beginning and is collaborating on the Challenge initiatives for Rice and Sorghum.

– The **John Innes Centre** (Norwich, United Kingdom) is one of eight institutes that receive strategic funding from the BBSRC for plant science and microbiology, and is collaborator of GCP since the beginning.

– The **Scottish Crop Research Institute** (SCRI, Scotland, United Kingdom) is one of the Scottish Government's main research providers in environmental, crop and food science and will have a major role in the Scottish knowledge economy. It changed its name for The James Hutton Institute and is collaborator of GCP since the beginning.

– Monsanto, Dupont/Pioneer Hi-Bred, Syngenta, Limagrain, Noble Foundation, major universities in Canada, South Korea, Japan, United Kingdom, etc., are all GCP collaborators.

– **iPlant** (National Science Foundation, USD 50 million award, currently in year 3 of five-year award to University of Arizona and the Texas Advanced Computing Center) is a research community based (including ARS scientists), educators, and students working to enrich all plant sciences through the development of cyberinfrastructure-the physical computing resources, collaborative environment, virtual machine resources, and interoperable analysis software and data services – that are essential components of modern biology. It is a GCP collaborator.

– **Sol Genomics Network** (Boyce Thompson Institute, Ithaca, NY and ARS scientists) contains genomic, genetic, phenotypic and taxonomic information for Solanaceae (tomato, potato, eggplant, pepper and petunia) Rubiaceae (coffee), and more. It collaborates with GCP for the ontology.

– **Plant Ontology Consortium** and the **Reference Plant Trait Ontology**, Oregon State University, provide an international controlled vocabulary for annotating Genomic and Phenotypic, Breeders' data enabling integration for supporting data mining and discovery, comparison, etc. They collaborate with GCP.

– **Knowledgebase** (DOE, Office of Biological and Environment Research, first year of new program) is a community-driven cyberinfrastructure for sharing and integrating data and analytical tools to accelerate predictive biology.

- **Phytozome** (DOE): 25 plant species many in collaboration with ARS scientists.
- **i5K** (5 000 arthropod genomes): ARS and university scientists will sequence, assemble and annotate the genomes of 5 000 insects and other arthropods in the next five years. The i5K project is hosted at the Arthropod Genomics Consortium site (arthropodgenomes.org/wiki/i5K).
- **1000 Fungal Genomes Project:** DOE-Joint Genome Institute (JGI) Community Sequencing Project initiated by ARS and university scientists to inform all areas of fungal biology.
- **Maize NAM** (ARS, China MOST, other).
- **African Orphan Crops** (AOC) consortium *www.worldwildlife.org/what/globalmarkets/agriculture/orphancrops.html*

Annex D.

The Contribution of Agricultural Biodiversity to Stable and Sustainable Agricultural Production, System Resilience and Ecosystem Services

The loss of biodiversity in agriculture

FAO (2011) states that, in many places around the world, achievements in agricultural production in the last decades are the results of management practices that have led to the loss of biodiversity and have degraded the land and water systems upon which the production depends. Gliessman (2007) states that the loss of genetic diversity in agriculture has occurred mainly because of conventional agriculture's emphasis on short-term productivity gains.

There is broad consensus that global rates of agricultural biodiversity loss are increasing (Jarvis *et al.*, 2007). The first report of the State of the World's Plant Genetic resources for Food and Agriculture (FAO, 1998a) already described as "substantial" the loss in diversity of plant genetic resources for food and agriculture, including the disappearance of species, plant varieties, and gene complexes.

The world food base is depending on a decreasing number of species and varieties. In fact, despite the existence of some 50 000 edible plants in the world, rice, maize and wheat provide 60% of the world's food energy intake and only a few hundred plants contribute significantly to food supplies (FAO, 2010). Six varieties of corn account for more than 70% of the world's corn crop, and 99% of the turkeys raised in the United States belong to a single breed (FAO, 1998a).

Instances of crop genetic erosion in major and minor crops were reported by several countries to the Second Report on the State of the World Plant Genetic Resources (FAO, 2010). The following two examples are only a glimpse at what seems now to be more a rule than an exception in all regions of the world: peasant farmers on the island of Chiloe, Chile, cultivated 800 to 1 000 varieties of potato when only about 270 varieties are now found; in Mali, 60% of local varieties of sorghum have disappeared in one region over the last 20 years (FAO, 2010). The loss of traditional culture, including the loss of traditional farming culture and changes in traditional food habits were also mentioned (FAO, 2010).

Domesticated animals are also threatened by genetic erosion: FAO (1998b) estimates that as many as two domesticated animal breeds are being lost each week worldwide while 20% of animal breeds (mammalian and avian species together) are at risk and 9% are extinct (FAO, 2007).

The contribution of agrobiodiversity to stable and sustainable agricultural production, system resilience and ecosystem services

The Millennium Ecosystem Assessment (2005) summarises the contribution of biodiversity in terms of its role in provisioning, regulating, supporting and providing cultural ecosystem services (Table D.1).

Table D.1. Biodiversity benefits to agriculture through ecosystem services

(Adapted from Millennium Ecosystem Assessment, 2005)

Provisioning	Regulating	Supporting	Cultural
Food and nutrients	Pest regulation	Soil formation	Sacred groves as food and water sources
Fuel	Erosion control	Soil protection	Agricultural lifestyle varieties
Animal feed	Climate regulation	Nutrient cycling	Genetic material reservoirs
Medicines	Natural hazard regulation (droughts, floods and fire)	Water cycling	Pollinator sanctuaries
Fibres and cloth	Pollination		
Materials for industry			
Genetic material for improved varieties and yields			
Pest resistance			

Frison *et al.* (2011) summarise evidences that agricultural biodiversity contributes to sustainable production and that it has potential to make an even greater contribution. In his report to the UN Secretary General, De Schutter (2010) noted that agroecological approaches to food security involve the maintenance or introduction of agricultural biodiversity (diversity of crops, livestock, agroforestry species, fish, pollinators, insects, soil biota and other components that occur in and around production systems) to achieve the desired results in system sustainability and productivity.

Agricultural biodiversity, through dietary diversity, can contribute to nutritional health gains and in moderating problems related to micronutrient deficiencies (Johns and Eyzaguirre, 2006). Dietary diversity is a vital part of diet quality. There is evidence of the beneficial effects of dietary diversity (as opposed to specific dietary components) on disease, morbidity and mortality (see references in Frison *et al.*, 2006 and 2011). Thus, a wide range of local plants and 'minor' crops and varieties are key contributors to accessing essential micronutrients and health promoting factors for nutrition security. Research has demonstrated a strong association between dietary diversity and diet quality and nutritional status of children (Arimond and Ruel, 2004; Kennedy *et al.*, 2007; Rah *et al.*, 2010; Sawadogo *et al.*, 2006).

Agricultural biodiversity can contribute to system sustainability and resilience: the deployment of biodiversity in agriculture contributes to a more diverse production base which can lead to more sustainable and resilient systems. One of the many descriptions of the concept of resilience includes: (i) the capacity to absorb shocks and still maintain function; (ii) the degree to which a system is capable of self-organisation; and (iii) the degree to which a system can build and increase its capacity for learning and adaptation (Folke *et al.* 2002; Carpenter and Brock, 2008). Resilience is a vital ecosystem property, allowing agricultural systems to maintain production in the face of changes to climates, markets and other factors. It builds the capacity to absorb shocks and continue to function within a changing set of circumstances. Examples of the contributions of different components of agricultural biodiversity are given below.

The contribution of increased diversity of crops and increased crop production, particularly through genetic diversity, to improve resistance to biotic and abiotic stress, and to improve ecosystem regulating and supporting services are reported in Ostergard *et al.* (2009), Hajjar *et al.* (2008) and Gurr *et al.* (2003).

The role of diversity of soil biota and the maintenance of all components of soil food web and of diversity within different levels for supporting agricultural systems is described by Beed *et al.* (2011), Gliessman (2007) and Mäder *et al.* (2002).

The value of diversity in livestock production through improved provision of nutrients, overall productivity, system resilience, and income is explored in Morton (2007), and the importance of diversity in aquaculture to improve ecosystem function, nutrition and income in many different farming systems is described in Halwart (1998) and Pullin and White (2011).

The introduction of trees into agricultural environments to improve ecosystem function and to provide marketable products and realize the full potential of agroforestry systems is explored in Garrity *et al.* (2010).

The value of pollination services and the relation between pollinator diversity versus density is reported in Gallai *et al.* (2009) and Dag *et al.* (2006).

Agricultural biodiversity has various dimensions or scales (gene level, species or population level, interspecific or ecosystem level, and landscape level) and can be divided into structural, compositional and functional components (PAR/FAO, 2011). Those various scales and components support ecosystem services upon which agriculture is based. The hierarchy concept explained by Noss (1990) suggests that biodiversity be monitored at multiple levels of organisation, and at multiple spatial and temporal scales. No single level of organisation (e.g. gene, population, community) is fundamental, and different levels of resolution are appropriate for different questions. He states that big questions require answers from several scales.

In fact, Jarvis (2007) states that our understanding of the relationship between biodiversity and ecosystem functions is incomplete but the following points can be stated with a high degree of certainty:

- Genetic diversity within population is important for continued adaptation to changing conditions and farmers' need through evolution and, ultimately, for the continued provision of ecosystem goods and services;
- Species composition may be more important than absolute number of species;
- Diversity within and between habitats and at the landscape level is also important in multiple ways.

In conclusion, the multiple roles of agricultural biodiversity are currently undervalued and should be better exploited to ensure the resilience and sustainability of agricultural systems, to maximise its role in providing multiple ecosystem services and in contributing to the supply of the diverse diets needed for healthy lives.

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Annex E.

Towards Improving Water and Food Security: The Policy Challenge

Background

In paragraph 49 of the Cannes Declaration, G20 leaders "welcomed the production of a report by the international organisations on how water scarcity and related issues could be addressed in the appropriate fora". Taking into account the importance that the G20 leaders attach to the water and food security link, this Draft Text provides an Annex to the G20 report "Improving global sustainable agricultural productivity growth and bridging the gap for small family farms".

The scope of linkages between water and agriculture

To meet the projected global growth in demand for agricultural commodities over the next fifty years – food, feed, fibre and feedstock for bioenergy – will have significant implications for water systems.[1] Expanding agricultural production will heighten competition for water resources with other users and increase the risks of water pollution damaging human health and the environment. Most of the increased competition will occur in those developing countries, where both population, economic and agricultural growth will be most rapid. As a consequence the need to improve the future performance of agricultural management will be critical to help reduce pressure on water systems.

Delivering the required improvements in agricultural water management will be a challenge because of the complex linkages between agriculture (rain-fed and irrigated) and water systems:

- *Water resources*: Agriculture accounts for the major share of water withdrawals for consumptive use for most countries, about 70% globally.
- *Water pollution*: In industrialised countries, agriculture is often a major source of non-point water pollution as a result of intensification of production (e.g. intensive use of farm chemicals and increased livestock manure waste) and because other point sources of water pollution, such as from industry and sewage treatment, have been contained. In most developing countries, agriculture's contribution to water pollution is less important, mainly because of the greater significance of pollution from urban and industrial sources, and has yet to be addressed (Jawahar and Ringler, 2009). However, in many developing countries the future expansion of agriculture is projected to lead to growing pressure on water systems, as illustrated by the growth in excess nitrogen (Figure E.2).

1. The term "water system" covers the consumptive uses of water (e.g. agriculture, energy, industry, domestic) from mainly surface water and groundwater sources and non-consumptive water uses, largely supporting ecosystems and meeting social needs (e.g. bathing, aesthetic and spiritual values), but also for hydropower and navigation.

- *Water and energy links*: These include the direct links through the use of energy to pump water through irrigation canals and extract surface water and groundwater; and indirect links such as through the production of agricultural feedstocks to supply bioenergy with consequences for water resources and quality, and also the competition for water stored in a reservoir used for both irrigation and to generate hydropower.
- *Droughts and floods*: The impacts of droughts and floods have significant human life and food security costs. Agriculture can both exacerbate floods and droughts, such as through land clearing for agricultural use, and also contribute to ameliorating the harmful consequences of floods on the rest of the economy by providing water retention services and slowing flood water flows that may harm urban populations and infrastructure.
- *Ecosystems*: With agriculture a major user of land and water, the sector can have important consequences (positive and negative) on ecosystems, such as wetlands and coastal zones.
- *Climate change*: Agricultural and some water systems contribute to climate change but are also vulnerable to the adverse impacts from climate change and climate variability, with significant regional variation within and across countries. Much of the adverse burden is placed on developing countries, especially in some sub-tropical and lower mid-latitude regions (Nelson *et al*., 2010; OECD, 2010a).

Global outlook for water to 2050 and implications for agriculture

The OECD (2012a) *Environmental Outlook to 2050* indicates that the global prospects for water are more alarming than projected by the previous OECD (2008) *Environmental Outlook to 2030*. Urgent action is needed to avoid significant costs for society, including increased food insecurity. The OECD (2012a) *Environmental Outlook to 2050* provides a 'business as usual' baseline which can help improve understanding of the challenges and the trade-offs that need to be made.

Freshwater resources availability to 2050 will be further strained

Freshwater availability will be further strained in many regions, with over 40% of the world's population projected to be living in river basins experiencing severe water stress. Overall water demand is projected to increase by 55% between 2000 and 2050, due to growing demand from manufacturing, energy generation, domestic use and to ensure environmental water needs. In the face of these competing demands, there may be little scope for increasing water for irrigation (Figure E.1).

The combined effects of these pressures could mean water shortages that would hinder the growth of many economic activities. Environmental flows will be contested, putting ecosystems at risks. Groundwater depletion and pollution from many sectors (e.g. agriculture, industry) may become the greatest threat to agriculture and urban water supplies in several regions in the coming decades.

Under business-as-usual water productivity and medium GDP growth, over 50% of the global population, 45% of global GDP, and almost 50% of global grain production will be at risk due to water stress by 2050 (Ringler *et al.* 2011). For China and India and many other rapidly growing developing countries, water stress will increasingly affect growth negatively – with globally 3.9 billion people living in water stressed basins by 2050 up from 1.6 billion in 2000 (OECD, 2012a). Low-income countries will be particularly subject to water stress, with 39% of low-income countries experiencing much more severe shifts towards water stress than wealthier/more industrialised countries. Moreover, risk to economic growth and food security as a result of water scarcity is not only a reality in developing countries. Many key industrialised areas and countries will have to increasingly cope with water scarcity and its effects on growth (OECD, 2012a).

Water pollution is projected to worsen in most regions

The quality of surface and groundwater water outside the OECD area is expected to deteriorate in the coming decades, for example, from excess nutrient flows from agriculture (both inorganic fertilisers and livestock manure) and poor wastewater treatment (Figure E.2). In addition, as agricultural production expands, this will exert further pressure on water systems, from pesticides, soil sediments and other agricultural pollutants (e.g. veterinary products). The consequences will be increased eutrophication, biodiversity loss and human health concerns. For example, the number of lakes at risk of harmful algal blooms will increase by 20% in the first half of this century, while groundwater pollution is a growing problem.

Addressing the water and food security challenge

The outlook for water systems indicates that policy makers need to address the twin challenges of increasing agricultural production while reducing stress on both the quantity and quality of water systems. It will be important that farmers receive the right policy and market signals to improve water use productivity, advance agricultural management practices to lower water pollution, and enhance the benefits that some farming practices can bring to water systems.

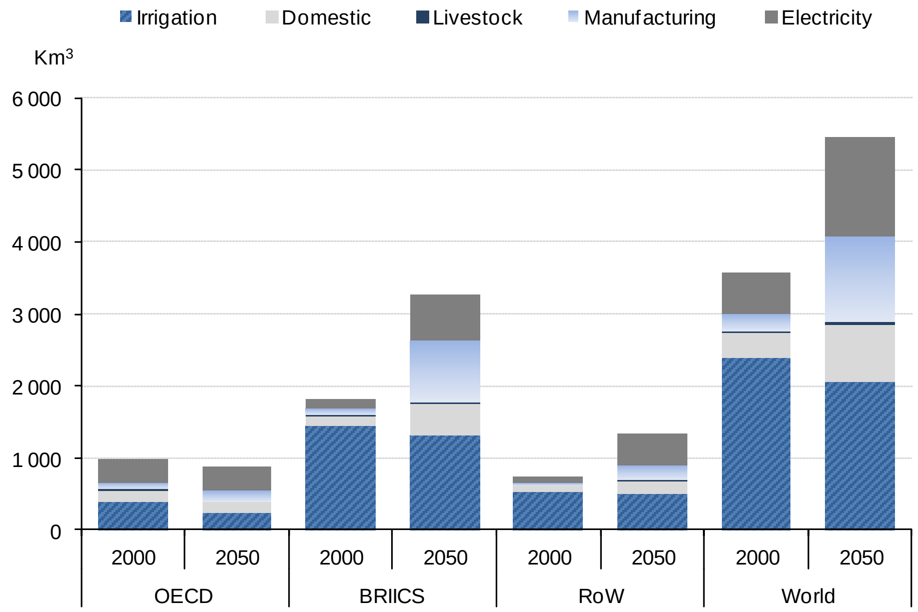
Agricultural water management and incentive policy reform will be key to enhance the efficiency of existing water use. This must be supported by infrastructure investment to build, modernise and upgrade existing irrigation and water delivery systems in most developing countries and some OECD countries (OECD, 2010a; Rosegrant *et al.*, 2009).

In terms of water quality, monitoring and enforcing water quality standards will be important, with recent innovations in monitoring technologies that could help an otherwise highly costly and complex task. In addition, encouraging farm practices that are beneficial in reducing agricultural pollution need to be encouraged that are targeted and tailored to specific local conditions, such as creating riparian buffers, removing land from production near watercourses, and using conservation tillage to conserve soil moisture and reduce soil sediment flows into water courses are important policies.

The overall economic, social, and environmental costs resulting from the impact of agriculture on water systems, both over extraction of water resources and pollution, exceed billions of dollars annually, according to recent estimates for OECD countries (OECD, 2012b). No global estimate of these costs exists, but based on the OECD experience they are likely to be extremely high. At the same time, the rapid increases in food production and decline in real prices of food could not have been achieved without irrigated agriculture. Irrigation’s importance has increased further as a result of climate variability and climate change (Rosegrant *et al.*, 2009).

Policies used to address water resource stress and water pollution linked to agriculture, are costing OECD governments billions of dollars annually, such as maintaining irrigation infrastructure and providing support to farmers to adopt practices to combat pollution (OECD, 2012b and 2010a). Extrapolating to non-OECD countries the cost of such policies could be substantial. This cost, however, must be counter-balanced with the rapid growth in food production and poverty reduction achieved as a result of public investment in irrigation. But policies such as energy subsidies to reduce water pumping costs for irrigators, has led to unsustainable use of groundwater resources in some cases.

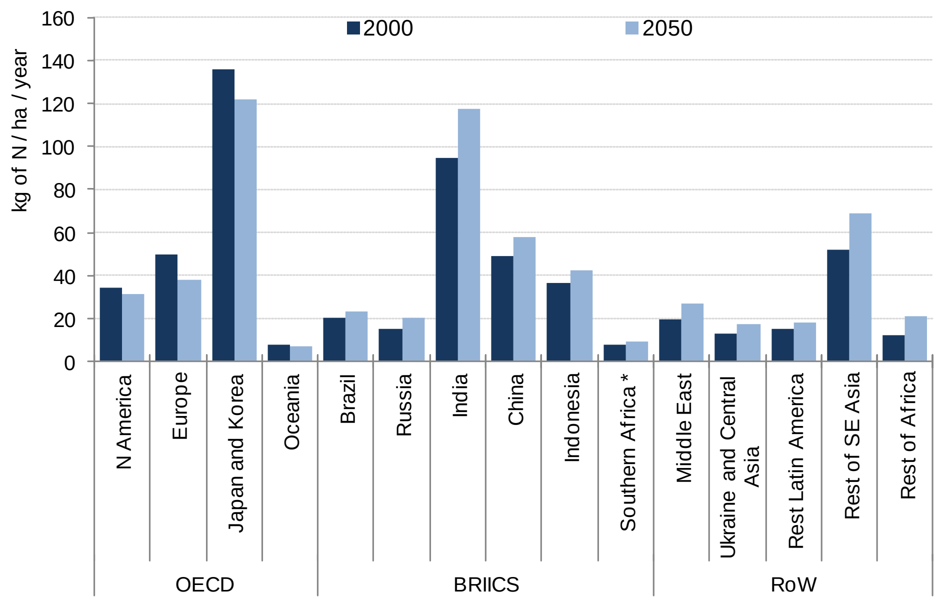
Figure E.1. Global water demand: Baseline scenario, 2000 and 2050



Note: This figure does not consider rain-fed agriculture. BRIICS includes: Brazil, Russia, India, Indonesia, China and South Africa. ROW – Rest of the World.

Source: OECD (2012a) *Environmental Outlook to 2050,* Paris, France, output from IMAGE suite of models.

Figure E.2. Nitrogen surpluses per hectare from agriculture: Baseline, 2000 and 2050



Note: * In the IMAGE model the Southern Africa region includes ten other countries in this geographical area including the *Republic* of South Africa, when dealing with land use, biodiversity, water and health. For energy-related modelling the region has been split into the Republic of South Africa and "Rest of Southern Africa".

Source: OECD (2012a), *Environmental Outlook to 2050,* Paris, France, output from IMAGE suite of *models*.

Policy responses in addressing the water challenge in agriculture

The policy responses countries might consider to address the water challenge in agriculture (both rain-fed and irrigated farming), as part of an economy-wide water policy reform programme, can be summarised under five broad areas of action:

- *Create incentives*, to signal to farmers (and other water users) the value of water and the cost of pollution.
- *Invest in water infrastructure*, to foster more efficient farming practices and systems.
- *Enable innovation*, to promote improved water management in agriculture.
- *Strengthen institutions and governance*, to support efforts enhancing food and water security.
- *Build resilience*, to address long-term concerns with food and water security.

Create incentives *to signal to farmers, and other water users, the value of water and the cost of pollution*

Water resources

Water has a value which is seldom transmitted through markets. Many countries provide support to the development of irrigation infrastructure; water service fees are generally below cost; and some governments even supply free or subsidized energy for pumping ground and surface water. Such policies can undermine the sustainable use of water resources, especially in regions where water is scarce.

An important consideration in policy makers tool kit to stimulate higher water efficiency gains in all sectors, is introducing market (or market-style) incentives into water-use decision-making. Market-based incentives can range from water charges to formal or informal trading of water (use rights), the latter which can be observed in some water stressed developing countries that rely on irrigation for food production. A key prerequisite to introducing these water policy reforms, especially for developing countries, is improving water services and the reliability of water supplies to farmers. This can provide a pathway to introducing water charges, as can increasing the accountability of water service providers to their clients (the farmers), hence, providing a signal to farmers of the scarcity value of water.

Some OECD and some developing countries (e.g. China) are now beginning to embrace water policy reforms that move toward raising water charges for farmers and related policy reforms, to reflect the costs of supply and the scarcity value of water. But increasing water cost recovery rates through water charges also requires a comprehensive approach that fully recognises the equity issues that arise from distributing the benefits of water policy reforms and the importance of ensuring reliable and high quality access to water for all parts of the population. Developing virtual water trade is also another option to address water scarcity that has been advocated by some observers (Box E.1). Projections show an increase in cereal trade from water-abundant to water-deficit areas from 23% in 1995 to 38% by 2025 (Rosegrant *et al.*, 2010).

The experience in OECD countries, and some developing countries, reveals that where water charges to farmers have been raised as part of broader water policy reforms to develop water markets (e.g. Australia, Chile), the improvement in lowering the quantity of water applied per hectare irrigated has been substantial (OECD, 2010a; Rosegrant and Gazmuri Schleyer, 1995). Evidence also indicates that raising water charges to farmers, at least to cover the operation and maintenance costs of supplying water to irrigators in some OECD countries, has not led to an overall reduction in agricultural output or incomes (OECD, 2010a).

Water quality

Policies that raise producer prices or subsidise the use of inorganic fertilisers and pesticides encourage farmers to over-use the subsidised fertiliser, leading to unbalanced applications and increasing water pollution. OECD research has shown that where countries have lowered overall agricultural support and shifted to forms of support decoupled from production and input use, this has helped to lower water pollution pressure from agriculture activities than would otherwise have been the case in the absence of these reforms (OECD, 2012b).

Box E.1. Virtual water trade and water footprints: Sound concepts to guide policy makers?

Virtual water: The term "virtual water" began appearing in the water resources literature in the mid-1990s to describe the water used to produce crops traded in international markets. During the time since its inception, the concept has been very helpful in gaining the attention of public officials and policy makers responsible for encouraging wise use of limited water resources.

However, the fundamental shortcoming of the virtual water concept as a valid policy prescriptive tool is the lack of an underlying conceptual framework. Some researchers have incorrectly described virtual water as analogous to, or consistent with the economic theory of comparative advantage. The virtual water concept is applied most often when discussing or comparing water-short and water-abundant countries. By focusing on the water resource endowment alone, virtual water represents an application of absolute advantage, rather than comparative advantage. For this reason, policy prescriptions that arise from virtual water discussions will not maximise the net benefits of engaging in international trade. Comparative advantage is the pertinent economic concept, and virtual water considers only absolute advantage.

A number of authors have begun describing the important role of non-water factors such as population densities, historical production trends, national food security goals, poverty reduction targets, and the availability of complementary inputs when determining whether to transfer water from one region to another, or to achieve desired outcomes alternatively by transporting or trading agricultural commodities.

Water footprints: The notion of water footprints describes the volume of water required to support production and consumption in selected regions or countries. It is used to assess whether a region or country is consuming resources in a sustainable or unsustainable fashion from a global perspective. However, estimated water footprints are somewhat one-dimensional, as they depict the use of only one resource. In addition, water footprints do not describe the implications of water use. Instead they consider only the amounts of water used in production and consumption activities.

Hence, ecological water footprint analysis is not sufficient for determining optimal policy alternatives, as it does not account for the opportunity (scarcity) costs of water resources and the ways in which water is combined with other inputs in production and consumption. Water footprints enable one to compare estimated water use per person or in aggregate across countries, but they are inadequate for evaluating the incremental costs, benefits, or environmental impacts of water use.

Farmers, traders, and public officials must consider many economic and social issues when determining optimal strategies. Virtual water and water footprint concepts will be helpful in policy discussions in many settings, in combination with other environmental, economic, and social indicators. But they will not be sufficient for determining the optimal outcomes of those discussions and establishing economically efficient and environmentally effective policy alternatives.

Source: Adapted from Wichelns (2010).

Taking a more holistic view of agricultural pollution policy design can help to avoid adverse environmental effects and encourage co-benefits. For example, the development of riparian buffers, which can limit pollutant farm runoff, can also provide other benefits in terms of wildlife habitats and carbon sequestration by establishing green cover (OECD, 2012b).

As well as reforming agricultural support policies, there is increasing interest in using innovative policy tools and market approaches to lower agricultural water pollution. These tools and approaches, albeit not widely used to date, mainly include: water quality trading (Shortle, 2012); voluntary arrangements, supported by private payments, such as between private water supply utilities working with farmers to ensure improved water quality so as to reduce water treatment costs; information based instruments, like organic standards; and capacity building, such as setting environmental standards by agro-food companies, backed by farm advisory services, to encourage best management practices to protect water quality and meet other environmental goals (OECD, 2012b).

***Invest in water infrastructure** to foster more efficient farming practices and systems*

Investors in water infrastructure encounter a high level of diversity in hydrological conditions and farming systems operating in a greatly varying set of political, cultural legal and institutional contexts across the world. Management of water systems in agriculture includes a spectrum of options ranging from purely rain-fed (the majority of systems) to entirely irrigated systems.

Creating incentives to improve agricultural water productivity through removing perverse incentives will not necessarily be sufficient to meet water demands in agriculture, especially in developing countries. Hence, water supply capacity for irrigated agriculture needs to be expanded in some countries, particularly in Sub-Saharan Africa where only 4% of cultivated area is currently irrigated (Svendsen *et al.* 2009). Moreover, water storage capacity needs to be selectively expanded; water recycling and reuse developed; and the poor state of irrigation infrastructure, which is impeding improvements in water productivity in agriculture in many countries, needs to be enhanced.

The additional investment required to expand and upgrade agricultural water supply systems will present a considerable challenge for public and private finance (OECD, 2011a; 2011b); especially in developing countries. Investment is also required to reduce the impact of drought and flood disasters impacting agriculture.

Transparent and predictable investment policies, relying on good institutional government capacity and regulatory measures at both the national and sub-national levels, are crucial to foster private investment in water infrastructure for agriculture. The key factors that might be able to encourage private investment in irrigated agriculture, include (OECD, 2010a):

- defining titles to water rights that promote market transfers of water;
- developing regulatory measures that require the upkeep and maintenance of infrastructure, as well as minimum flows for environmental needs;
- increasing the cost recovery rates of water supplied to farmers so there is a flow of financial resources to support water delivery infrastructure maintenance and renewal;
- shifting from an investment strategy for water infrastructure in agriculture of ‘build and neglect’ to one centred on ‘build and maintain’, looking toward facilitating private – public partnerships to raise finance for infrastructure

development. Water user associations, including farmers, can play a key in fostering private – public partnerships.

Property rights and institutions, which are capable of coping with the rapidly increasing demand for land and water resources, are critical for investment in agricultural water management and for the successful adoption of efficient, equitable and sustainable resource use (Binswanger-Mkhize *et al.*, 2011).

In establishing new capital investment projects, especially augmenting water storage capacity, will require examination of the economic, environmental and social costs and benefits of such projects. Consideration of improvements in incomes for small family farms and the urban poor should be a key element in the cost/benefit analysis of projects.

Enable innovation *to promote improved water management in agriculture*

Enabling innovation will be crucial in meeting the challenge of raising water productivity and improving water management in agriculture. Taking a long term vision and strategy to enable innovation in agriculture and water policy reforms over the next 20-30 years is also important. There are often trade-offs between investing in short-term projects with an immediate effect and undertaking actions that can have a larger and longer-term impact, for example, investing in research, farmer education, and establishing data monitoring systems to improve decision making (OECD, 2010b).

To enable, disseminate and speed-up innovation over the long-term requires changing the behaviour of governments, farmers, water managers, the agro-food chain and other stakeholders by (OECD, 2010a; 2010b and 2012b):

- *Engaging* these stakeholders to address water management issues, especially at the water catchment or sub-catchment level;
- *Enabling* change by educating, training and raising awareness of farmers through farm advisory services and building the capacity of other stakeholders in a water catchment in the realisation of policy goals;
- *Establishing* information and knowledge systems to provide technical and socio-economic information about the likely impact (science), costs (financial) and farmer reactions (social) to a given policy change to address water management in agriculture.

Strengthen institutions and governance *to underpin efforts to raise water productivity*

There are frequently many organisations involved in managing, allocating and regulating water resources at different levels of government. Rationalisation of these institutional structures could improve transparency and accountability (OECD, 2011c; 2012c).

Associated with this institutional complexity is an intricate set of legal rules concerning water property rights in some countries, but where institutional structures are less developed water property are often ill-defined and non-statutory rights often do exist. As pressure builds-up to reallocate water between different users and to meet environmental demands there is a need for water property rights to become more flexible, where these rights exist, and for supporting institutions to be more robust to ensure an economically efficient and environmentally effective allocation of water.

There are a number of drivers that are likely to improve the institutional effectiveness of water governance in agriculture, including the (OECD, 2010b):

- extent of commitment from key groups in a water catchment;

- level of stakeholders understanding and representation in water policy decision making, notably at the water catchment level;
- importance of timing by governance structures, especially reducing the time from inception to effect of a water project;
- definition of a clear message by institutions as to the goals of water projects; and the
- development of social capital in building co-operation among stakeholders.

***Build resilience** to address long-term concerns with food and water security*

Most countries are reporting the growing incidence, severity and costs of flood and drought events on agriculture, heightening concerns for food and water security. In response countries are beginning to develop mitigation and adaptation strategies, including for example, developing new crop varieties or change farm practices where climate change alters temperatures and precipitation; and adapting management practices that can contribute to slowing water transport across farmland and reducing flood damage in urban areas (Morris *et al.*, 2010).

These approaches are more likely to be effective if they are embedded in longer term strategies closely linked with overall agricultural policy reform, risk management policy and market approaches.

Climate change will also require greater attention in agriculture to water saving practices, both in terms of on-farm distribution systems and also the larger infrastructure systems delivering water to farms. In Sub-Saharan Africa, a key response to climate change will be irrigation development that needs to be aligned with changing levels, seasonality and variability of runoff and water availability (see, for example, Zhu and Ringler, 2012). Better understanding of the importance of extending risk management approaches in agriculture to existing climate variability, can also help build a more solid foundation for addressing climate change in the future (OECD, 2010a).

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- ***Key Links***: *www.oecd.org/agriculture/water* *www.oecd.org/tad/env/indicators*

Annex F.

Impact of an Increase in Competition in the Fertiliser Industry

It is well established that low adoption of improved land management practices is one of the main factors behind lagging agricultural productivity in many developing countries. Although an increase in fertiliser use is not the only solution to this problem, countries that have increased their agricultural productivity have also considerably increased their use of fertiliser. Several regional and local policies have been promoted in the past years to stimulate sustainable fertiliser use with mixed results, but not much has been said about the high and increasing dependence of developing regions on imported fertiliser, which is a highly concentrated industry at the global level. As shown in Table F.1, a small number of countries control most of the production capacity for the main nitrogen, phosphate, and potash fertilisers. The top five countries control more than half of the world's production capacity for all major fertiliser products. Similarly, except for China, the industry shows a high level of concentration among firms within each main producing country. In most cases, the top four firms control more than half of each country's production capacity.

Table F.1. Concentration of World Fertiliser Production Capacity, 2008/09

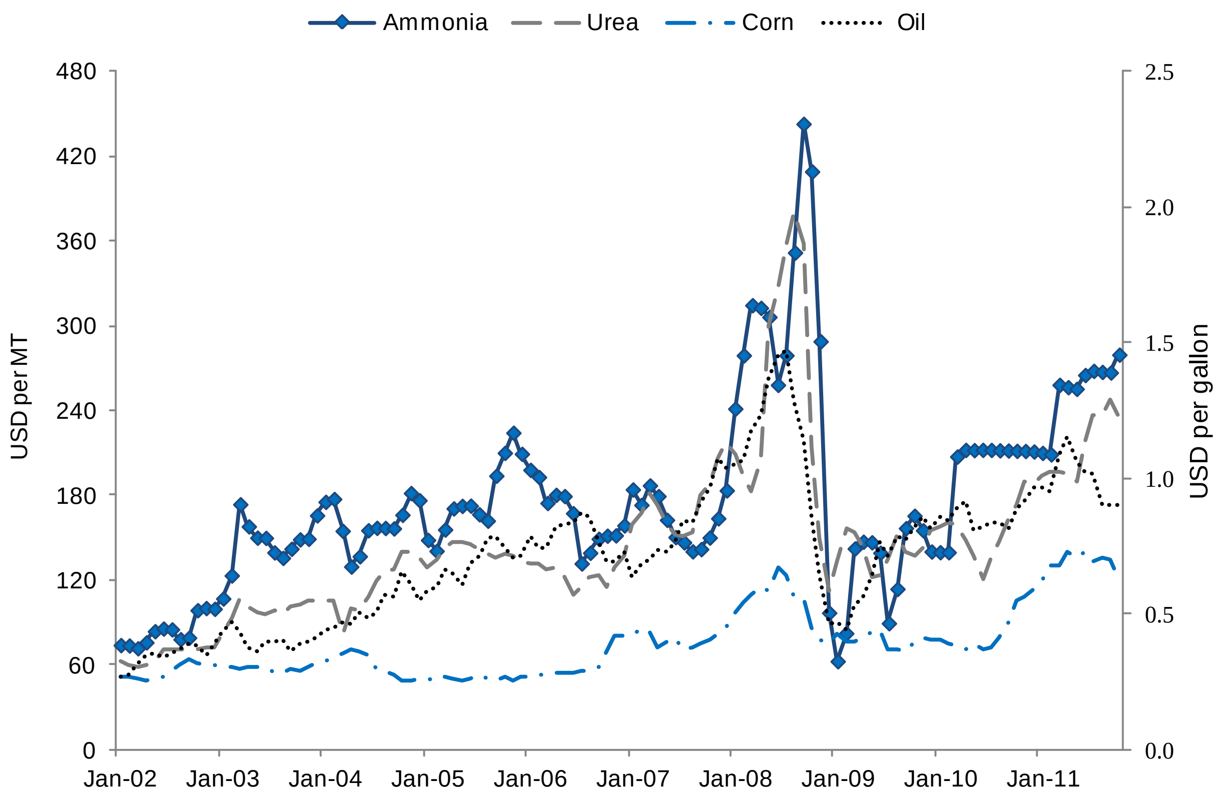
Fertiliser	Top-5 countries	Top-5 Capacity	Top-5 Share
	(% of World in parenthesis)	(000 MT)	(% of World)
Ammonia	China (22.8), India (8.9), Russia (8.5), United States (6.5), and Indonesia (3.9)	84 183	50.6
Urea	China (33.1), India (13.1), Indonesia (5.4) Russia (4.2), and United States (4.1)	95 802	59.9
DAP/MAP	China (23.3), United States (21.2), India (11.4), Russia (6), and Morocco (4)	22 896	65.9
Phosphoric acid	United States (20.9), China (19.3), Morocco (9.6), Russia (6.2), and India (5.3)	28 274	61.3
Potash	Canada (37.6), Russia (13.2), Belarus (9.9), Germany (8.2), and China (7.7)	39 687	76.7
NPK	China (29.3), India (8.2), Russia (6), France (4), and Turkey (3).	47 186	50.4

Note: Based on capacity of operative plants in 2008/09. MT: Metric tonnes.

Source: IFDC *Worldwide Fertilizer Capacity Listing by Plant*. Elaborated by Hernandez and Torero (2011).

The high levels of concentration in the fertiliser industry mainly result both from high requirements of raw materials, which are not available worldwide, and from potential economies of scale in production, which result in cost efficiencies. However, high concentration in an industry may also result in market power exertion and tacit collusion among firms, which may allow a few companies to take full advantage, for example, of international price spikes in energy and grain markets to the detriment of farmers' wealth. On this matter, Figure F.1 shows that during the food crisis of 2008, where oil and agricultural prices drastically increased, ammonia and urea prices exhibited even higher price spikes. By mid-2008, when the crisis was felt most, ammonia and urea prices were 2-3 times larger than in mid-2007; oil and corn prices, in turn, were 1.5-1.9 times larger. The market power effects could be outweighing the cost-efficiency effects in this highly concentrated industry.

Figure F.1. Real monthly ammonia, urea, corn and crude oil prices, 2002-2011



Note: Prices deflated by CPI, 1982-84=100. The prices correspond to Ammonia US Gulf barge, Urea US Gulf prill import, No. 2 yellow corn FOB US Gulf, and Oklahoma crude oil FOB spot price.

Source: Green Markets, Energy Information Administration, and FAOSTAT.

Hernandez and Torero (2011) have formally analyzed the relationship between fertiliser (urea) prices and market concentration using annual data from a panel of 38 countries. One of the variables used to measure concentration is the top-4 concentration ratio (CR4), which is the sum of the market shares of the four largest firms operating in the market. The shares are measured both in terms of production capacity and number of plants. The analysis accounts for the relative importance of fertiliser imports on use in each country. The estimation results indicate a positive correlation between prices and market concentration. In particular, a 10% decrease in the top-4 concentration ratio using production capacity to measure market share leads, on average, to an 8.2% decrease in fertiliser prices, while a 10% decrease in the top-4 concentration ratio using number of plants, leads to an 11.6% decrease in prices. In the case of the HHI, a 10% decrease in the index leads to a 5.6% decrease in prices using production capacity and to a 9.2% decrease using number of plants, although the former change is not statistically significant at conventional levels (Table F.2).

Table F.2. Impact of increased competition on prices through a 10% decrease in the concentration

Top-4 Concentration measure	Decrease in concentration	Decrease in prices
Based on production capacity	10%	8.2%
Based on number of plants	10%	11.6%

Source: Hernandez and Torero (2011).

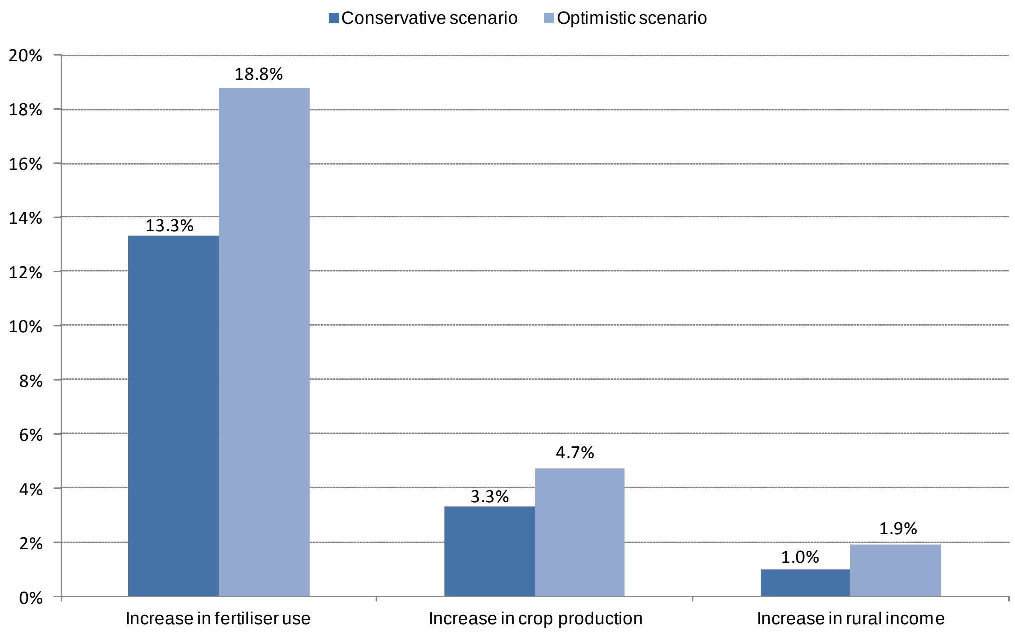
From the previous analysis, an 8.2% decrease in prices could be considered as a conservative scenario while an 11.6% decrease could be regarded as an optimistic scenario. Gruhn, Goletti and Roy (1995), in turn, report an average elasticity of fertiliser demand with respect to prices of around -1.62 based on a study conducted by David and Otsuka (1994) in some Asian countries. Similarly, Bumb, Johnson and Fuentes (2011) assume that the elasticity of crop production with respect to fertiliser use is 0.25. With these elasticities, an estimated impact of the change in prices on both fertiliser intake and crop production can be derived, as shown in Table F.3. A 10% increase in competition in the fertiliser industry will increase fertiliser intake by 13-19% and crop production by 3-5% (Figure E.2). Considering that the share of crop sales to rural income is roughly between 30-40% in developing regions like Africa and South Asia, rural income will increase by 1-2%.

Table F.3. Impact of increased competition on fertiliser intake and crop production

	Conservative	Optimistic
Decrease in fertiliser prices	8.2%	11.6%
Elasticity of fertiliser demand to prices	-1.62	-1.62
Increase in fertiliser use	13.3%	18.8%
Elasticity of crop production to fertiliser use	0.25	0.25
Increase in crop production	3.3%	4.7%

Source: Gruhn, Goletti and Roy (1995) and Bumb *et al*. (2011).

Figure F.2. Impact on fertiliser intake, crop production and rural income of a 10% decrease in concentration



Source: Hernandez and Torero (2011), Gruhn *et al.* (1995) and Bumb *et al.* (2011).

Cost-benefit analysis

To put this in context, as shown in Hernandez and Torero (2011), a cost-benefit analysis of such a policy can be assessed using some countries in South Asia and Africa as examples (India and Bangladesh in South Asia and Senegal, Ghana, Kenya and Tanzania in Africa). In particular, to decrease the top-4 concentration ratio in South Asia and Africa by 10% it will be necessary to build a fertiliser (nitrogen) plant in each region with a corresponding annual production capacity of 1.2 million metric tonnes (MT) and 0.7 million MT. These numbers are equivalent to 10% of the annual production capacity reported by the top-4 firms in each region according to IFDC Worldwide Fertilizer Capacity Listing by Plant. The new plant will absorb the share-reduction of the top-4 firms in each market and will not be large enough to be among the top four producers in each region. The following cost and income assumptions are made.

Cost assumptions

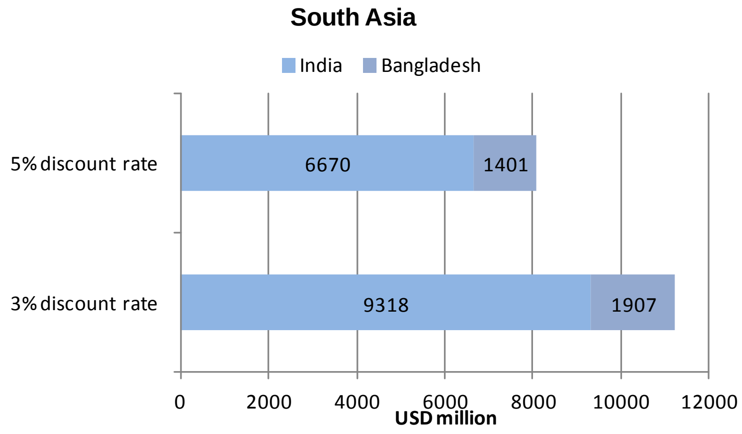
- The cost of building the 1.2 million MT plant in South Asia would roughly equal around USD 1.2 billion and the cost of building the 0.7 million MT plant in Africa would roughly equal USD 700 million, using as a reference the estimated cost of the nitrogen plant which is currently under construction in the Delta and Lagos States in Nigeria (USD 2.5 billion for two 1.3 million MT plants).
- The investment cost of the plants, which can be built in any of the countries in each region, are prorated based on the relative amount of fertiliser (nitrogen) consumed by each country according to IFA open-access database and FAOSTAT Online database. For example, India accounts for 93% of the total fertiliser used between India and Bangladesh, so India will cover 93% of the building costs of the plant in South Asia.
- The cost per MT of nitrogen production is USD 130 for a plant size over 1 000 MT of capacity per day (over 330 000 MT per year) according to the Production Cost Survey by the Fertilizer Institute.

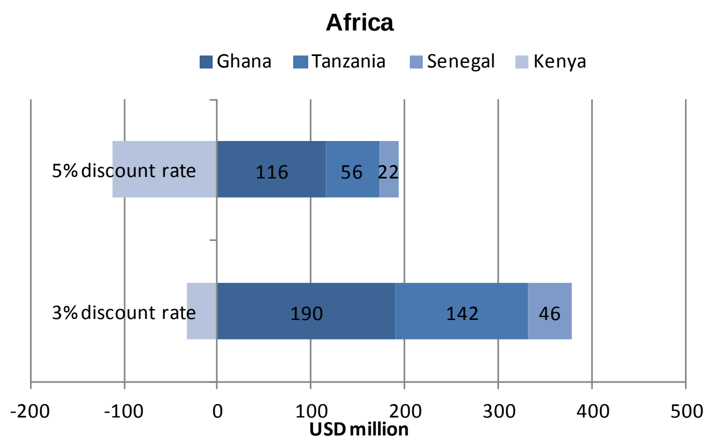
Income assumptions

- Only 20% of the rural population in each country will experience an effective increase in their income of 1%. This conservative scenario accounts for the fact that some farmers may already be using the optimal amount of fertiliser while the increase in fertiliser use for several others may still not reach a certain level which results in a higher income.
- The estimated per capita rural income in each country is based on their most recent household survey available (2009/10 National Sample Survey in India; 2005 Household Income and Expenditure Survey in Bangladesh; 2001 Household Survey-ESAM II in Senegal; 2005/06 Living Standards Survey in Ghana; 2005/06 Integrated Household Budget Survey in Kenya; and 2007 Household Budget Survey in Tanzania).

The total net present value of such a policy over a time horizon of 2012-2050 (39 years) will be equal to USD 11.2 billion in the two countries in South Asia and to USD 345 million in the four countries in Africa using an annual discount rate of 3%, and to USD 8.1 billion and USD 80 million, respectively, using an annual discount rate of 5% (Figure F.3). By country, only Kenya will experience a negative net present value.

Figure F.3. Net present value of simulated policy in South Asia and Africa





Note: Time horizon assumed is 2012-2050.
Source: Hernandez and Torero (2011).

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Annex G.

Recommendation to Improve Access to Weather Information

Core objective

The key objective of this recommendation is to facilitate through public-private partnerships, in co-operation with cellular telecommunications corporations and multilateral banks, the establishment of a network of meteorological observation stations. The impact will be twofold.

1. There will be a significant increase in the number of weather stations given the significant presence of cellular phone towers.

2. The availability of information via cellular phone towers will increase the availability of information via SMS in real — or near to real — time to agencies in charge of collecting such information and to farmers.

The problem this initiative proposes to resolve

Access to more and better quality weather information will allow farmers to optimise their decisions (especially small farmers who currently do not have access to this information). Insurance and re-insurance companies will also have better and more frequent weather information available to them to develop their insurance schemes.

Proposed pilot

This initiative can be implemented in developing countries by promoting initiatives similar to **"Weather Info for All"** in which public-private partnerships which include leading providers of cellular telecommunications host weather equipment at mobile network sites to strengthen weather networks and systems.

Specific Pilot implementation: The key initial action will be the implementation of a pilot project for Mesoamerica. It will include the following phases.

Phase 1: Testing different technological alternatives

Phase 1 will test different technological alternatives in three countries to identify which is the most cost-effective standard Automatic Weather Station. It will then evaluate which is the most cost-effective platform to transmit the weather information obtained to the National Meteorological Services and from there directly to potential users in the agricultural sector. Transmission of information will in all cases use cellular technology.

Phase 2: Feasibility study

Based on the results of Phase 1, a feasibility study will be implemented to assess the cost-benefit ratio of the intervention. This feasibility study will assess the results of a pilot phase in three countries.

Phase 3: Implementation of pilot in three countries of Mesoamerica

The development of the weather stations and the information to farmers will be implemented in three selected countries. An impact evaluation will be implemented to assess the cost-effectiveness of the intervention.

Phase 4: Implementation of the intervention in other Mesoamerica countries

Based on the results of Phase 3, efforts will be made with different cellular companies to introduce the pilot project to additional countries in Mesoamerica, and possibly to countries in other regions.

Key partners

The objective will be to have the support of the following actors.

1. America Movil, company of Carlos Slim, for the pilot and potential intervention in Mesoamerica.

2. The Inter American Development Bank has confirmed its support to work in partnership with America Movil. The IADB, through its General Manager for Mesamerica, has agreed to support this initiative in collaboration with America Movil.

3. Other cellular companies in the region.

4. International Food Policy Research Institute will support the design of the pilot project and the cost-effectiveness analysis of the intervention.

5. World Meteorological Organization (WMO) – Official United Nations authoritative voice on weather, climate and water.

6. Other interested international organisations.