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# Agricultural technology for development

## Report of the Secretary-General

*Summary*

Agriculture in a broad sense, comprising crops, livestock, fisheries and forest products, presents both a major challenge and a potential solution in terms of sustainable development. Land degradation and soil health, scarcity of and competition for land and water resources, loss and waste of food, the environmental impacts of agrochemicals, biodiversity loss, climate change and natural disasters all affect the ability of producers to ensure food security in a way that is environmentally, economically and socially sustainable. The present report examines trends in technologies that have the potential to overcome those challenges and enable producers to transition to more sustainable agricultural systems.

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# I. Overview

1. The present report has been prepared in response to General Assembly resolution 68/209, entitled "Agricultural technology for development", in which the Assembly requested the Secretary-General to submit, at its seventieth session, a report on the implementation of that resolution.

2. With the upcoming adoption of the outcome document "Transforming our world: the 2030 Agenda for Sustainable Development" of the United Nations summit for the adoption of the post-2015 development agenda, there is an urgent need to transition from negotiation to action, and from vision to implementation.

3. We have the solutions to transform our food systems. However, implementing those solutions requires increased political will. In developed countries, where large surpluses of food are produced with subsidy support and the externalization of social and environmental costs, and where food waste is rampant, sustainably producing what is needed while minimizing waste should be the priority. In developing countries, where production is insufficient, there is a need for incentives to expand production sustainably by focusing on the local production of diverse, culturally appropriate and nutritious food. This, in turn, would generate local wealth, reduce rural-to-urban migration, improve the nutritional status of the population and create an enabling environment for equitable and sustainable development. In addition, the unfair competition created by subsidized commodities from developed countries must be avoided.

4. The necessary shift in agriculture and the food system will require a major overhaul of international research institutions. Research and development must evolve to address a more complex set of challenges. It is insufficient to invest in climate-smart agriculture alone. Only a comprehensive, holistic and dynamic approach to the food system will bring about the results needed to achieve sustainable development.

5. To enable that shift, thorough assessments at the national, regional and global levels are needed, as suggested in the International Assessment of Agricultural Knowledge, Science and Technology for Development synthesis report.[1] Integrated assessments will enhance policymakers' capacity to develop, implement, and follow up and review progress on policies and strategies to achieve the Sustainable Development Goals. The Committee on World Food Security has been given a mandate under paragraph 115 of the outcome document of the United Nations Conference on Sustainable Development, entitled "The Future We Want", to develop guidelines for such national assessments of sustainable food production and food security, and will take up discussions on that subject in October 2015, in relation to the proposed workstream on implementing the post-2015 development agenda.

6. The present report examines the current status and trends of agricultural technologies and provides suggestions for transitioning to sustainable agricultural systems.

[1] Beverly D. McIntyre, ed., *Agriculture at a Crossroads*, International Assessment of Agricultural Knowledge, Science and Technology for Development (Washington, D.C., Island Press, 2009).

# II. Challenges to sustainable production

## A. Land degradation and soil health

7. Healthy soils are the basis of food security and nutrition. According to the Food and Agriculture Organization of the United Nations (FAO), approximately 95 per cent of our food is directly or indirectly produced on soils.[2] However, due to erosion, salinization, compaction, acidification and chemical pollution, 33 per cent of world soils are moderately to highly degraded.[3] Unsustainable farming practices, including conventional agriculture, monoculture and deep tillage, greatly accelerate rates of erosion and soil loss in both developed and developing countries.[4]

8. There is an increasing awareness of agriculture's dual role as a source of food security and as a source of environmental services. As soil is the basic resource for land use, it is central to sustainable land management. Rapid advances in scientific understanding of soil processes in areas such as global carbon and climate models[4] are crucial, as soil carbon is directly correlated with soil quality and can also contribute to carbon emissions.[5] According to the Intergovernmental Panel on Climate Change, carbon sequestration will account for 90 per cent of global agricultural mitigation potential by 2030. However, progress in adopting technological advances to improve sequestration is slow, especially in the developing world.[5]

## B. Competition for land

9. A new FAO report notes that, in recent years, "many Governments have … set limits on transfer of land, revised processes for assessing project proposals, and engaged local communities and individuals in participatory land use planning".[6] However, least developed countries, which have much to gain from investment in sustainable land management, often have inconsistent laws and policies as well as limited institutional capacity.[6]

10. Given the increasing demand for land-derived products and services, low leasing fees and diminishing land supply, large-scale land investments or speculation on them are expected to yield high returns.[6] Pressures on productive land are further increased by urban growth. In Africa, urbanization is expected to

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[2] FAO, "Healthy soils are the basis for healthy food production", accessed on 25 August 2015. Available from www.fao.org/3/a-i4405e.pdf.

[3] FAO, "Soil is a non-renewable resource", accessed on 25 August 2015. Available from www.fao.org/3/a-i4373e.pdf.

[4] Ronald Amundson and others, "Soil and human security in the 21st century", *Science*, vol. 348, No. 6235 (8 May 2015). Available from www.sciencemag.org/content/348/6235/1261071.figures-only.

[5] World Bank. "Carbon sequestration in agricultural soils", report No. 67395-GLB. Available from https://openknowledge.worldbank.org/bitstream/handle/10986/11868/673950REVISED000CarbonSeq0Web0final.pdf?sequence=1.

[6] Jesper Karlsson, "Challenges and opportunities of foreign investment in developing country agriculture for sustainable development", FAO Commodity and Trade Policy Research Working Paper No. 48 (Rome, FAO 2014). Available from www.fao.org/3/a-i4074e.pdf.

not only increase the conversion of arable land into urban and industrial areas, but simultaneously fuel demand for arable land due to increased urban food demand.[7]

## C. Loss and waste of food

11. It has been estimated that 30 per cent of cereals; 40 to 50 per cent of root crops, fruits and vegetables; 20 per cent of oilseeds, meat and dairy products; and 35 per cent of fish are lost or wasted annually. This translates to approximately $1 trillion per year. At the global level, one third of the volume of food produced for human consumption (one quarter of calories) is lost or wasted. Food loss and waste threaten food security by reducing the availability of food, access to food and its nutritional content and have an unsustainable impact on natural resources. Food loss and waste also contribute significantly to climate change. Cereals, meat and vegetables account for more than 60 per cent of the carbon footprint from food waste in every region.[8]

## D. Environmental impact of agricultural chemicals

12. The use of insecticides such as neonicotinoids has increasingly been questioned over the years, and recent studies highlight their subtle but lethal impact on ecosystems and ecosystem services. Where neonicotinoids are used, between 11 and 24 per cent of pollen and 17 to 65 per cent of nectar are contaminated with these insecticides. The health and survival of bees are being threatened by contaminated pollen from monoculture crops, which weakens their immune systems and causes them to contract more viral diseases.[9]

13. In addition, herbicide and pesticide resistance has increased over the past few years. In the United States, as at 2012, glyphosate resistance had expanded to affect 25 million hectares. Many studies[10] indicate that the resistance of weeds to glyphosate is due to the widespread adoption of genetically engineered herbicide-tolerant crops. Some plants have become resistant to more than five herbicides.[11]

14. The possible negative effects of the use of herbicides include biodiversity loss and a decline in soil quality.[11] Herbicide residue in surface water negatively affects regional biodiversity. Pesticides and herbicides also have an impact on the quality of aquatic environments, contributing to a decline in fish stocks. Studies indicate that more than 50 per cent of the 11,300 insecticide concentrations tested in surface

[7] T. S. Jayne and others, "Land pressures, the evolution of farming systems, and development strategies in Africa: a synthesis", *Food Policy*, vol. 48 (October 2014).

[8] FAO, "Food losses and waste in the context of sustainable food systems: a report by the High-level Panel of Experts". Available from www.fao.org/3/a-i3901e.pdf.

[9] Francisco Sanchez-Bayo, "The trouble with neonicotinoids", *Science*, vol. 346, No. 6211 (14 November 2014).

[10] Jorge Fernandez-Cornejo and others, *Pesticide Use in U. S. Agriculture: 21 Selected Crops, 1960-2008*, United States Department of Agriculture, Economic Research Service, Economic Information Bulletin No. (EIB-124) (May 2014). Available from www.ers.usda.gov/publications/eib-economic-information-bulletin/eib124.aspx.

[11] "A growing problem", *Nature*, vol. 510, Issue 7504 (11 June 2014). Available from www.nature.com/news/a-growing-problem-1.15382.

waters or sediments exceeded safe levels.[12] In the Netherlands, for example, the decline of farmland bird populations has been associated with the use of pesticides.[13]

15. New research has helped to quantify the negative impact of biodiversity loss on food security and nutrition. For example, an estimated 100,000 species of insects, as well as birds and mammals, are responsible for pollinating two thirds of our food plants, representing 35 per cent of the world's crop production. With a mere 40 crops providing 95 per cent of humankind's food energy needs, and a subset of five cereal crops providing 60 per cent of the global energy intake, ecosystem services and biodiversity are crucial to achieving food security for all.[14] However, biodiversity continues to decline, thereby reducing the ability to provide essential life-sustaining services at the individual and community scales.[15]

## E. Water use and management

16. According to the High-level Panel of Experts of the Committee on World Food Security, under the Organization for Economic Cooperation and Development's business-as-usual scenario, by 2050, multiple challenges related to water use and management will emerge. First, there will be a 55 per cent increase in global water demand. Second, 40 per cent of the global population living in river basins will experience water stress. Third, there will be a 130 per cent increase in domestic water use. As a result, there will be limited ability to increase irrigation.[16]

17. While groundwater represents an important source of water, including 40 per cent of irrigation water, much groundwater is not renewable, and slowly replenishing reservoirs can quickly become depleted.[16] Rain-fed agriculture continues to contribute significantly to food production globally, and reducing yield gaps without irrigation is a key challenge. In addition to crop management, livestock water availability needs to be improved, as drinking water constraints for livestock often limit the use of pastures and rangelands, and making water available could increase the sustainable use of available biomass.[16]

## F. Climate change

18. In 2010, greenhouse gas emissions from agriculture accounted for 10 per cent of total anthropogenic emissions, almost as much as forest and land use combined, which amounted to (11 per cent). In addition, agricultural emissions have increased

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[12] Sebastian Stehle and Ralf Schulz, "Agricultural insecticides threaten surface waters at the global scale", *Proceedings of the National Academy of Sciences of the United States of America*, vol. 112, No. 18 (13 March 2015). Available from www.pnas.org/content/112/18/5750.full.

[13] Caspar A. Hallmann and others, "Declines in insectivorous birds are associated with high neonicotinoid concentrations", *Nature* (9 July 2014). Available from www.nature.com/nature/journal/vaop/ncurrent/full/nature13531.html.

[14] "Biodiversity for food security and nutrition", *The World We Want*, No. 5 (July 2013).

[15] WHO and secretariat of the Convention on Biological Diversity, *Connecting global priorities: biodiversity and human health* (WHO Press, Geneva, Switzerland, 2015). Available from www.cbd.int/health/SOK-biodiversity-en.pdf.

[16] FAO, "Water for food security and nutrition: a report by the High-level Panel of Experts". Available from www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/HLPE_Reports/HLPE-Report-9_EN.pdf.

by approximately 1 per cent over the past two decades. Between 2001 and 2011, the three main emission sources from agriculture were enteric fermentation (40 per cent) followed by manure left on pasture (16 per cent) and synthetic fertilizers (13 per cent). Emissions from agriculture are likely to increase by 18 per cent by 2030 and 30 per cent by 2050[17] unless the above suggested transition to sustainable agriculture becomes a reality.

19. Agriculture is also greatly affected by climate change. Negative impacts on crop yields, mainly for wheat and maize, are more common than positive ones, which occur mostly in high-latitude regions.[18] They include new challenges from pests as well as water and heat stress.

## G. Regional policy environments

20. Innovative systems to support family farmers and women farmers must move beyond a singular focus on increasing yields and addressing a complex set of objectives, including preserving natural resources and raising rural incomes.[19] Increased public investment is needed in research, development and extension services, along with market-based investment linked to private sector development.

21. It is important to emphasize that vast regional differences exist, with lower percentages of family farmers and women farmers in Latin America than in Asia and Africa. Therefore, innovations need to take into account their agroecological and socioeconomic conditions, and government policy objectives for the sector. Long-term funding for agriculture in developing countries is imperative to address the challenges of low investment levels and high volatility in funding. In addition, volatility in research and development expenditure is almost twice as high in low-income countries as it is in high-income countries.[20] Sub-Saharan Africa, where there is great dependency on donors,[19] also has the highest volatility. This has resulted in investment levels that are still well below the levels required to sustain agricultural research and development needs.

22. According to the Tropical Agriculture Platform, diverse regional challenges must be addressed to develop effective national agricultural innovation systems. In Africa, the challenges include limited access to resources, environmental challenges and lack of market access for value-added products. In Central America, proposed innovations are not adopted because they are found unsuitable for local conditions. In Asia, the lack of policies supporting capacity development is the most serious constraint.[20]

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[17] Francesco Nicola Tubiello and others, “The contribution of agriculture, forestry and other land use activities to global warming, 1990-2012”, *Global Change Biology*, vol. 21, Issue 7 (July 2015).

[18] Intergovernmental Panel on Climate Change*, Climate Change 2014: Synthesis Report* (Geneva, 2015). Available from www.ipcc.ch/report/ar5/syr/.

[19] FAO, “The state of food and agriculture: innovation in family farming”. Available from www.fao.org/3/a-i404e.pdf.

[20] Nienke M. Beintema and others, *ASTI Global Assessment of Agricultural R&D Spending: Developing Countries Accelerate Investment* (Washington, D.C., International Food Policy Research Institute, 2012).

# III. Trends in agricultural technologies in developing countries

## A. Trends in agricultural technologies

23. In order to address the challenges to sustainable food systems, a range of agricultural technology options exist. One study on the subject evaluated 11 agricultural technologies with at least some proven potential for yield improvement and wide geographic application: no-till, integrated soil fertility management, precision agriculture, organic agriculture, nitrogen-use efficiency, water harvesting, drip irrigation, sprinkler irrigation, the use of improved drought-tolerant varieties, the use of improved heat-tolerant varieties and crop protection.[21] According to the International Food Policy Research Institute, these select technologies and practices may increase yields of maize, rice and wheat through sustainable intensification.[22]

24. According to climate change models and the International Model for Policy Analysis of Agricultural Commodities and Trade, the most promising technologies for improving yields are the use of heat tolerant varieties in North America and South Asia; the use of drought tolerant varieties in Latin America and the Caribbean, the Middle East and North Africa, and sub-Saharan Africa; and crop protection in Eastern Europe, South Asia and sub-Saharan Africa. In addition, the adoption of irrigation technologies is expected to amplify and complement the adoption of these technologies.[22]

25. The International Food Policy Research Institute concludes that addressing the issues of both climate change and food security will require increased investments in research on crop productivity, irrigation technologies, and resource management and conservation.[22]

26. In contrast to the Institute's sustainable intensification focus, the United Nations Conference on Trade and Development (UNCTAD) builds upon the report of the International Assessment of Agricultural Knowledge, Science and Technology for Development by calling for a paradigm shift from the Green Revolution's focus on yield maximization to an "ecological intensification"[23] approach. Such an approach involves increasing agricultural outputs (food, fibre, agrofuels and environmental services) while reducing the use of and need for external inputs (agrochemicals, fuels and plastic), capitalizing on ecological processes that support and regulate primary productivity in agroecosystems.[24]

27. Recommendations by UNCTAD include agricultural technologies that can contribute to the establishment of mosaics of sustainable, regenerative production systems that also considerably improve the productivity of small-scale farmers. The keys to an agricultural transformation include increasing soil carbon content and

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[21] Mark W. Rosegrant and others, *Food Security in a World of Natural Resource Scarcity* (Washington, D.C., International Food Policy Research Institute, 2014).

[22] FAO, "Climate-smart agriculture sourcebook", 2013. Available from www.fao.org/3/a-i3325e.pdf.

[23] UNCTAD, *Trade and Environment Review 2013: wake up before it is too late*, document UNCTAD/DITC/TED/2012/3, 2013.

[24] Pablo Tittonell and Ken E. Giller, "When yield gaps are poverty traps: the paradigm of ecological intensification in African smallholder agriculture", *Field Crops Research*, vol. 143 (1 March 2013).

better integration between crop and livestock production and increased incorporation of trees, (agroforestry) and wild vegetation; the reduction of direct and indirect (i.e. through the feed chain) greenhouse-gas emissions of livestock production; the reduction of indirect greenhouse gas emissions, which occur as a result of changes in land-use, through sustainable peatland, forest and grassland management; the optimization of organic and inorganic fertilizer use, including through closed nutrient cycles in agriculture; the reduction of waste throughout the food chain; changes in dietary patterns towards climate-friendly food consumption; and reform of the international trade regime for food and agricultural products.[23]

28. The United Nations Environment Programme's green economy models have shown that investing 0.16 per cent of global gross domestic product (GDP) in sustainable agriculture per year ($198 billion between 2011 and 2050) would provide strong returns compared to the baseline scenario of conventional and traditional agriculture. Investment divided equally across environmentally sound practices, such as no- or low-till; preventing pre-harvest loss; preventing post-harvest loss; and research and development in soil science, climate adaptation and improvements in energy and water-use efficiency, lead to improved soil quality, increased agricultural yields and reduced land and water requirements in addition to increasing GDP growth and employment, improving nutrition and reducing energy consumption and carbon dioxide emissions.

29. Given the current low yields in developing countries, the introduction of sustainable agricultural practices, including organic farming, in developing countries can significantly increase yields, although reliable long-term studies are still lacking. One study identified an average of 80 per cent higher yields for organic agriculture in developing countries, but it has been criticized for double-counting and not controlling for inorganic inputs.[25] Subsequent meta-studies used more restricted samples, which effectively excluded wheat, maize and rice from their calculations of lower estimates. Comparing high-input conventional agriculture to organic agriculture, one such study contended that the claim that organic agriculture can increase yields in smallholder agriculture in developing countries could not be ruled out.[26] A review of sustainable intensification emphasized the necessity for a radical rethinking of food production to achieve major reductions in environmental impact,[27] because in some locations and contexts, yield reductions would be necessary to ensure sustainability and strengthen the ecosystem.

30. The Swiss office of the Research Institute of Organic Agriculture is conducting ongoing long-term system comparison trials in India (cotton); Kenya (maize, potato and beans); and Bolivia (cacao). Initial results on yield and profitability from India show higher gross margins in organic as compared to conventional agriculture after conversion.[28] That impact was confirmed in a meta-analysis of 55 crops across five continents, which showed that organic

[25] Catherine Badgley and others, "Organic agriculture and the global food supply", *Renewable Agriculture and Food Systems*, vol. 22, No. 2 (June 2007).

[26] Verena Seufert, Navin Ramankutty and Jonathan A. Foley, "Comparing the yields of organic and conventional agriculture", *Nature*, vol. 485, Issue 7397 (10 May 2012).

[27] T. Garnett and others, "Sustainable intensification in agriculture: premises and policies", *Science*, vol. 341, No. 6141 (5 July 2013).

[28] Dionys Forster and others, "Yield and economic performance of organic and conventional cotton-based farming systems — results from a field trial in India", *PLoS ONE*, vol. 8, No. 12 (4 December 2014).

agriculture is 22 to 35 per cent more profitable than conventional agriculture when price premiums are applied.[29]

31. While certified organic agriculture continues to display significant annual growth, now occupying 1 per cent of global cropland, its direct contribution to nutrition is limited by the export focus in developing countries, with some exceptions, including China. There is a movement to go beyond certified organic agriculture, e.g., through the participatory guarantee system of the International Federation of Organic Agriculture Movements, which is aimed at more domestic and regional production by reducing certification costs by 70 to 90 per cent.

32. Addressing nutrition insecurity will require moving beyond a few global staples and diversifying production and farmers' strategies for increasing their resilience to climate change. Since the most recent report of the Secretary-General on agricultural technology for development (A/68/308), agroecology has gained significant momentum as a set of practices that address those challenges. At the first International Symposium on Agroecology for Food Security and Nutrition, the Director-General of FAO stated that agroecology offered win-win solutions that could increase productivity, improve resilience and make more efficient use of natural resources.[30] Using a knowledge-intensive approach, an agroecological system minimizes dependence on energy-intensive (external) inputs, enhances the recycling of biomass and optimizes nutrient availability; has minimal negative effects on the environment and releases insignificant amounts of toxic or damaging substances into the atmosphere, soil, surface water or groundwater; minimizes the production of greenhouse gases and works to mitigate climate change, including by increasing the ability of managed systems to store fixed carbon; works to value and conserve the biological and genetic diversity of plants and animals, both in the wild and in domesticated landscapes; contributes to the eradication of hunger and the achievement of food security in culturally appropriate ways; and strives to guarantee every human being the right to adequate food.

33. The following sections outline specific agricultural technologies and practices that are aimed at not only addressing current challenges, but also achieving long-term food security and social and economic development.

## B. Addressing food security

34. A recent study contends that smallholder farmers in Africa are unable to benefit from the current yield gains offered by plant genetic improvement, as continued cropping without sufficient inputs of nutrients and organic matter leads to localized but extensive soil degradation and renders many soils in non-responsive.[24]

35. Improving soil health means going beyond singular applications of inorganic fertilizer. At a minimum, integrated soil fertility management involves the use of locally available resources, the combined application of organic resources and fertilizer, and more efficient use of both inputs. Where soil nutrients have been

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[29] David W. Crowder and John P. Reganold, "Financial competitiveness of organic agriculture on a global scale", *Proceedings of the National Academy of Sciences of the United States of America*, vol. 112, No. 24 (1 May 2015).

[30] FAO, *Final Report for the International Symposium on Agroecology for Food Security and Nutrition* (Rome, 2015).

mined, more elaborate interventions are needed, such as subsoil tillage or the application of large quantities of high quality manure or lime. The availability of organic fertilizer can be enhanced by intercropping nitrogen-fixing legumes, such as pigeon peas or cowpeas, and nitrogen-fixing trees, such as Faidherbia albida. A metastudy of conservation agriculture found that although no-till reduces yields, the reductions can be mitigated through the use of residue retention and crop rotation. The study therefore recommended that the promotion of conservation agriculture in South Asia or sub-Saharan Africa be limited to areas where both residue retention and crop rotation are already employed.[31] Historically, the adoption of no-till agriculture has been slow in capital-constrained developing countries, where additional herbicide input and access to no-till seeder equipment is more difficult.

36. In terms of biodiversity loss, a meta-analysis found that when compared to conventional farming, organic agriculture has a significant positive effect on species' richness.[32] The study focused on data from developed countries, highlighting the potential to address the challenges posed by input-intensive mono-cropping, and illustrating the need to move beyond using yield as the sole criterion when undertaking long-term systems comparisons in developing countries. In a recent meta-analysis of more than 1,000 observations, multi-cropping and crop rotation have been found to not only benefit the ecosystem, but also successfully reduce the yield gap between organic and conventional agriculture from 19.2 per cent to 9 and 8 per cent respectively.[33] Another study, in Malawi found that integrating community nutrition education activities into a legume diversification project not only increased yields but also significantly improved the weight of children under the age of 2 for years after the intervention.[34]

37. Sustainable crop intensification has shown promise in terms of contributing to food security. It is a knowledge-intensive approach and combines the early establishment of healthy plants with reductions in crop density, thereby increasing soil fertility with organic matter, and the systematic application of water to support plant-root and soil-microbial growth. With yield increases above 70 per cent for rice and wheat in India and 70 per cent for teff in Ethiopia, this agroecological technology has attracted the attention of policymakers and is now applied to numerous other crops, including finger millet, sugarcane, legumes and vegetables.[35]

38. Integrated pest and weed management can particularly benefit marginalized populations and women (see box below).

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[31] Cameron M. Pittelkow and others, "Productivity limits and potentials of the principles of conservation agriculture", *Nature*, vol. 517, Issue 7534 (15 January 2015).

[32] Sean L. Tuck and others, "Land-use intensity and the effects of organic farming on biodiversity: a hierarchical meta-analysis", *Journal of Applied Ecology*, vol. 51, Issue 3 (June 2014).

[33] Lauren C. Ponisio and others, "Diversification practices reduce organic to conventional yield gap", *Proceedings of the Royal Society B* (10 December 2014).

[34] Rachel Bezner Kerr and others, "Farmer-led climate change adaptation strategies to improve food security, nutrition and soil health: policy recommendations," paper presented at a climate change adaptation policy workshop, 4 March 2014.

[35] Binju Abraham and others, "The system of crop intensification: reports from the field on improving agricultural production, food security, and resilience to climate change for multiple crops", *Agriculture & Food Security*, vol. 3, No. 1 (25 February 2014).

**Push-Pull — a knowledge-intensive solution**

The Push-Pull technology, developed by the International Centre of Insect Physiology and Ecology, based in Nairobi, efficiently controls pests and improves soil fertility. Push-Pull provides agroecological solutions to some of the most common challenges facing smallholder farmers in sub-Saharan Africa: stem borers, Striga and low soil fertility affecting cereal production. It is based on research by the International Centre and Rothamsted Research on behaviour-affecting chemicals produced by plants and insects.

The technology consists of intercropping maize with a repellent plant, such asdesmodium, and planting an attracting plant, such as napier grass, as a border crop. Stem borer moths are attracted by the volatile compounds of the napier grass and, after the eggs hatch, the larvae get trapped by a sticky substance produced by the grass. Napier grass is also a valuable carbohydrate-rich livestock fodder. Desmodium, on the other hand, is a perennial cover crop that repels the moth through its volatile compounds, suppresses Striga, fixes nitrogen, conserves soil moisture, enhances arthropod abundance and diversity, and increases organic matter in the soil.

While providing a pest management solution, Push-Pull makes cereal cropping systems resilient to climate change. The latest version of this technology includes drought-tolerant desmodium, brachiaria as a trap crop and sorghum. Furthermore, it promotes the integration of livestock husbandry, increasing household nutrition via milk products, and diversifies income sources, allowing smallholders entry into the cash economy. As it employs local plant varieties, it integrates well with the traditional mixed cropping system of sub-Saharan Africa.

With respect to its impact, Push-Pull has to date been adopted by nearly 100,000 smallholders in East Africa and has successfully and sustainably doubled and even tripled maize yields.

39. Without private funding, it is difficult to achieve widespread adoption of knowledge-intensive agroecological technologies owing to poor public extension and advisory services. Farmer field schools help to scale up technologies and reach marginalized populations by addressing both technical complexities and the local contexts required for knowledge-intensive practices to be understood and adopted. In a West African regional programme, introducing integrated pest management to 30,000 farmers from a field school resulted in a median pesticide use reduction of 75 per cent, yield increases of 23 per cent and net margins of 41 per cent. In addition, building the capacity of farmers to become trainers can enhance the reach of a successful pilot project.[36]

40. Preharvest losses have a significant impact on food security in rural communities. Therefore, new technologies are needed to reduce food loss and waste. The FAO Global Initiative on Food Loss and Waste Reduction helps develop regional programmes and supports their national implementation, including through

[36] FAO, *Investing in Food Security* (2009). Available from http://www.fao.org/fileadmin/templates/ag_portal/docs/i1230e00.pdf.

projects for piloting and implementing food loss reduction strategies. The main areas of action identified along the food chain include improved production planning, aligned with markets; the promotion of resource-efficient production and processing practices; improved preservation and packing technologies; improved transportation and logistics management; enhanced awareness of purchasing and consumption habits; and ensuring that all chain actors, including women and small producers, receive a fair share of the benefits. Smallholders will need access to new and innovative technologies even when capital constraints exist. A recent meta-analysis in six African countries found that the majority of innovations address storage pests in a smallholder environment, with only a minority dealing with handling, transportation and processing.[37] In addition to the need to conduct studies beyond the area of storage, country-level case studies and community-based solutions are essential and should include working with producer organizations to implement a warehouse ticketing system. Furthermore, local innovations such as evaporative cool storage systems that require no energy input and can address one of the main causes of food loss in rural settings in developing countries must be supported with public funding.

## C. Addressing social and economic development

41. Providing access to markets is key for social and economic development. By moving beyond certified organic agriculture for export markets, the introduction of participatory guarantee systems will allow access to regional markets for marginalized farming populations, who can then produce for a growing middle-class consumer base. A 2015 study found that median organic premiums for organic crops were 32 per cent, but the median breakeven premiums needed to match conventional farmers' were merely 5 per cent.[29] Since organic farmers in low-input environments tend to obtain significantly higher yields, these lower price incentives are realistic even when the time for conversion to organic practices is taken into account. Public investments in traditional markets and farmers' understanding of market forces, and producer organizations are critical for other crops as well. A successful example can be found in the case of indigenous highly nutritious vegetables, or "orphan crops", that have long been ignored but are making a revival in African markets due to strong consumer demand, benefiting not only the female farmers who grow them but also household nutrition.[38]

42. The farm household economy can be improved, especially for women, by increasing access to water and by providing technologies to reduce fuelwood consumption, and small-scale equipment for food processing or field operations. At the collective level, investments are necessary for sustainable landscape management and to improve access to financial services. The mere availability of credit, however, is not enough. Financial services must be structured to induce farmers to make innovations in their operations. Since adopting such innovations often yields benefits over the longer term, it is essential to not only support farmers with access to sustainable financing services, but also strengthen their land tenure security.

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[37] Hippolyte Affognon and others, "Unpacking postharvest losses in sub-Saharan Africa: a meta-analysis", *World Development*, vol. 66 (February 2015).

[38] Rachel Cernansky, "The rise of Africa's super vegetables", *Nature*, vol. 9, Issue 7555 (9 June 2015).

43. The importance of secure tenure is recognized in the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security, which were endorsed by the Committee on World Food Security at its thirty-eighth (special) session, in 2012, and in the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication, which were endorsed by the FAO Committee on Fisheries at its thirty-first session, in 2014.

44. Additional investments in public goods, such as roads and electricity, and improved access to information and communications technology are also important. In China, every dollar invested in communication resulted in an increase in rural GDP by nearly $7 and agricultural GDP by $1.91.[39] Providing access to innovative information and communications technology for agronomic information can result in significant dividends.

## D. Addressing climate change

45. Shifts in agricultural production systems can successfully reduce or halt carbon dioxide emissions, in addition to sequestering carbon. According to the Rodale Institute, findings from farming system and pasture trials show that more than 100 per cent of current annual carbon dioxide emissions can be sequestered by shifting to organic sustainable management practices.[40] Sequestration is enhanced by permanent ground covers, perennial crops and no- to low-tillage; fossil fuel use can be reduced by decreasing the use of synthetic fertilizers and pesticides. Improved resource efficiency in livestock can both improve food security and reduce the intensity of greenhouse gas emissions.

46. A variety of proven knowledge-intensive adaptations to climate change with low technological requirements have been identified, including improved planting dates, integrated pest management, intercropping and crop rotation, nitrogen-fixation, agroforestry, composting, perennial crops, cover crops, green manure, zero- or reduced-tillage, and microdrip irrigation.[41] At the structural level, social capital, governance and safety nets are important.

47. While breeding plant varieties for drought- or heat-tolerance shows promise, the challenge that remains is to create varieties that not only outperform others in stress conditions but also remain competitive under limited stress. Thus far, conventional breeding efforts, including under the Drought Tolerant Maize for Africa project, have outperformed efforts involving genetically engineered varieties,[42] thereby re-emphasizing the need for genetic diversity in adaptation to climate change. However, the potential to provide improved yields or strengthen

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[39] FAO, "Investing in smallholder agriculture for food security: a report by the High-level Panel of Experts on Food Security and Nutrition". Available from www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/HLPE_Reports/HLPE-Report-6_Investing_in_smallholder_agriculture.pdf.

[40] Rodale Institute, "Regenerative organic agriculture and climate change: a down-to-earth solution to global warming" (Kutztown, Pennsylvania, 2014). Available from http://rodaleinstitute.org/assets/WhitePaper.pdf.

[41] Benjamin E. Graeub, Samuel Ledermann and Hans R. Herren, "Knowledge and technological requirements to adapt to climate change", in *Global Environmental Change*, Bill Freedman, ed. (Springer Netherlands, 2014).

[42] Natasha Gilbert, "Cross-bred crops get fit faster", *Nature*, vol. 513, Issue 7518 (16 September 2014).

climate resilience continues to depend on healthy soils that are rich in nutrients and water-storing organic matter.

48. A 2014 study found eco-intensification — in that case, the inclusion of nitrogen-fixing trees — a viable option for yield increases, because it improved water infiltration rates and the soil's water-holding capacity under conditions potentially caused by climate change, as long as such conditions did not exceed critical water and temperature thresholds.[43] Agroecology offers practices that strengthen the resilience of farmers and their rural communities via the diversification of agroecosystems in the form of polycultures, agroforestry systems and mixed crop-livestock systems, accompanied by organic soil management, water conservation and harvesting, and a general enhancement of agrobiodiversity. Field observations in Central America after Hurricane Mitch showed that plots under agroecological management had 20 to 40 per cent more topsoil, greater soil moisture and less erosion, and experienced lower economic losses than their conventional neighbours.[44]

49. To improve food security and build climate resilience, it will be important to move beyond the field level and address the landscape level as well. Resilient landscape management, illustrated by World Food Programme (WFP) case studies in Ecuador, Ethiopia and Kenya, has been successful at the community level. The practices implemented included environmental rehabilitation and ecological restoration through area closures, moisture harvesting and biomass enhancements or rainwater harvesting by means of trapezoidal bunds, water pans or rock catchments.[45] A range of successful technologies, including their costs and benefits, have been compiled in the World Overview of Conservation Approaches and Technologies database and published as field guides.[46]

## IV. Role of agriculture technologies in the post-2015 development agenda

50. The post-2015 development agenda, entitled "Transforming our world: the 2030 Agenda for Sustainable Development", which is to be adopted by heads of State and Government in September 2015, includes the Sustainable Development Goals and their targets for ending hunger, achieving food security and nutrition, and shifting to sustainable agriculture and food systems. Goal 2, "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" and its targets set out detailed objectives.

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[43] Christian Folberth and others, "Effects of ecological and conventional agricultural intensification practices on maize yields in sub-Saharan Africa under potential climate change", *Environmental Research Letters*, vol. 9, No. 4 (April 2014).

[44] Eric Holt-Giménez, "Measuring farmers' agroecological resistance after Hurricane Mitch in Nicaragua: a case study in participatory, sustainable land management impact monitoring", *Agriculture, Ecosystems and Environment*, vol. 93 (2002).

[45] Louise E. Buck and Ian D. Bailey, *Managing for Resilience: Framing an Integrated Landscape Approach for Overcoming Chronic and Acute Food Insecurity* (Washington, D.C., EcoAgriculture Partners, 2014). Available from http://ecoagriculture.org/documents/files/doc_699.pdf.

[46] Hanspeter Liniger and others, *Sustainable Land Management in Practice: Guidelines and Best Practices for Sub-Saharan Africa* (TerrAfrica, World Overview of Conservation Approaches and Technologies and FAO, 2011).

51. Targets that speak to the same challenges can also be found in goal 3 on health, goal 5 on gender, goal 6 on water, goal 7 on energy, goal 8 on economic growth, goal 11 on sustainable cities, goal 12 on sustainable consumption and production, goal 13 on climate change, goal 14 on oceans, goal 15 on ecosystems and biodiversity and goal 17 on the means of implementation.

52. Agriculture technology will have an important role to play in successfully implementing the targets of the post-2015 development agenda related to food security, nutrition and sustainable agriculture. These include the targets under goal 2 and interlinked targets in other goal areas, such as targets 3.9 on reducing deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination, 6.4 on increasing water-use efficiency and reducing water scarcity, 12.3 on halving global food loss and waste, 14.b on providing access for small-scale artisanal fisheries to marine resources and markets and 15.3 on restoring degraded land and soil and striving for a land-degradation neutral world.

53. Agroecology and organic and regenerative agriculture can make a substantial contribution towards meeting targets 2.3, 2.4, 3.9 and 15.3. Those practices also have the potential to address targets 2.1, 2.2 and 6.4. Investing in efficient storage solutions for smallholders contributes towards meeting targets 2.1, 2.3, 2.4 and 12.3. Sustainable agricultural technologies, such as biological pest and weed management or sustainable crop intensification, have the potential to contribute to the achievement of targets 2.1, 2.2, 2.3, 2.4, 3.9, 6.4 and 15.3. Resilient and sustainable landscape management can contribute to achieving targets 6.4 and 15.3, with long-term contributions to achieving targets 2.1 through 2.4, while agroforestry can specifically contribute to achieving target 2.2 on reducing malnutrition. Investing in improved systems for monitoring the effectiveness of agricultural technologies will further support the achievement of these targets. No- or low-till agriculture that avoids herbicide use has the possibility to contribute to achieving targets 2.1, 2.3 and 2.4.

54. Agroecology offers the needed range of solutions to deliver on all elements of the Zero Hunger Challenge. In addition, it has all the elements necessary to make agriculture and food systems more sustainable and resilient and therefore contribute to a transition to sustainable agriculture and help countries achieve food and nutrition security while protecting and enhancing the natural resources upon which agriculture is based. The 2014 FAO International Symposium on Agroecology for Food Security and Nutrition was an important step in fostering exchange and galvanizing momentum for a transformation towards regenerative, ecological, sustainable agriculture and food systems. The International Symposium is now being followed by regional symposiums in Latin America, Africa and Asia in 2015.

55. There are several initiatives aimed at promoting agroecological practices and solutions at the regional and national level. For example, the Ecological Organic Agriculture Initiative for Africa, launched by the African Union in 2011, seeks to mainstream ecological organic agriculture into national agriculture systems by 2025. An initiative launched by the Ministry of Agriculture of France in 2015 on soils for food security and climate seeks to increase soil fertility by 4 per cent per year through carbon sequestration in agricultural soil, thus mitigating greenhouse gas emissions. Several countries and areas, including Brazil, France, Paraguay and Haryana State in India, already integrate agroecology and sustainable agriculture in their respective national and subnational strategies and action plans. These regional

and national initiatives are complemented by numerous agroecological programmes at the local level in all regions of the world.

56. The dissemination of sustainable agriculture technologies must be supported by increased investments in international cooperation, rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks to enhance agricultural productive capacity in developing countries, in particular in least developed countries. Technologies that draw on public domain knowledge, including traditional knowledge of indigenous peoples and other farming and pastoralist communities, are extremely useful.

57. The Rome-based agencies, namely FAO, the International Fund for Agricultural Development (IFAD) and WFP, estimate that eradicating hunger by 2030 will require an estimated additional $267 billion per year for investments in rural and urban areas and in social protection. Possible areas for additional investment include agricultural research and development, professional education and extension services, and sustainable agricultural practices that will lead to soil and water conservation, improved irrigation systems, higher water efficiency, biodiversity preservation and genetic improvements in agriculture, fisheries and forestry. In rural areas, the Rome-based agencies propose investments in transport infrastructure, electricity and communications, and access to credit and financial literacy. Mechanization may also be required to increase agricultural productivity, as may investments in agroprocessing operations to reduce food loss and waste. In addition, the provision of services to secure tenure rights is also essential.[47]

58. Public investments play a key role in agriculture, because the needed services are public goods, the scale of investment can be considerable, the services constitute natural monopolies (as in the case of irrigation systems), and returns may only materialize in a time frame that private investors find unattractive.[47] Public investments should also target information dissemination and communication. The Addis Ababa Action Agenda of the Third International Conference on Financing for Development calls for an increase in public investments in these crucial areas (see General Assembly resolution 69/313).

59. Enabling environments are of particular importance in the areas of food security, nutrition and sustainable agriculture. Sustainable development targets 2.b on correcting and preventing trade restrictions and distortions in world agricultural markets and 2.c on ensuring the proper functioning of food commodity markets, and provisions contained in paragraphs 83 and 108 of the Addis Ababa Action Agenda outline different measures to address structural deficits in the international trade and finance regimes. Technologies such as the Agricultural Market Information System must play an important role in bridging the information gap in agricultural commodities markets.

60. The summit on the post-2015 sustainable development agenda, to be held in September 2015, will launch a technology facilitation mechanism that will support the implementation of the Sustainable Development Goals. The multi-stakeholder forum on science, technology and innovation for the Sustainable Development Goals will provide a venue for facilitating interaction, matchmaking and the

[47] FAO, IFAD and WFP, *Achieving Zero Hunger: the critical role of investments in social protection and agriculture* (FAO, Rome, 2015). Available from http://www.fao.org/3/a-i4777e.pdf.

establishment of networks among relevant stakeholders and multi-stakeholder partnerships in order to identify and examine technology needs and gaps, including in scientific cooperation, innovation and capacity-building.

# V. The way forward

61. Given that the green revolution model has reached its limits and the world faces a situation where, globally, nearly twice the calories necessary to feed the global population are produced but nutritious food is not always available where it is most needed and an inordinate number of calories are lost or wasted, new approaches are needed to address food, nutrition and climate challenges.

62. The problems created by the overuse of pesticides, such as neonicotinoids and glyphosate, and the increasing resistance of weeds to herbicides point towards the urgent need to use available alternatives and stimulate the development of new approaches to plant and animal health. They should deal with the causes rather than symptoms of the problems and provide long-lasting ecological solutions. Alternatives include shifting away from monocultures towards increasing farm-level diversity and agroecological practices, as increased production diversity is linked to both better human health via nutrition security, and biotic (pest control) and abiotic (climate) resilience.

63. It is of critical importance to introduce agricultural practices that move beyond yield gains to build up organic matter in the soil. This will contribute significantly to mitigating climate change while also reducing soil erosion and increasing soil fertility and soil health.

64. As identified by the report of the International Assessment of Agricultural Knowledge, Science and Technology for Development, agroecology and organic and regenerative practices provide increased resilience through crop, animal and system diversification, crop rotation, permanent plant cover and significant underground carbon storage.

65. Supporting smallholders and family farmers, especially women and youth, will entail not only improving their access to knowledge-intensive technologies and productive resources, but also increasing their labour productivity with appropriate mechanization for small-scale farming, thereby making farming less onerous and more attractive to women and youth.

66. Empowering women will pay large dividends, as they are responsible for 85 to 90 per cent of the time spent on household food preparation.[48]

67. Investments in pre- and post-harvest loss reduction should take precedence over increases in production.

68. Building the capacity of family farmers, fisherfolk, fish farmers, forest dwellers and rural producers, especially women, is needed to enable them to access resources, technology and services and to participate effectively in decision-making processes and policy dialogues. This can include strengthening participatory

[48] Brian Lipinski and others, "Reducing food loss and waste", working paper, instalment 2 of "Creating a sustainable food future" (Washington, D.C., World Resources Institute, 2013). Available from www.wri.org/sites/default/files/reducing_food_loss_and_waste.pdf.

research, providing more practical farmer training with an emphasis on women and youth and educating for jobs beyond production, including farm and value chain management. Investments are needed in research and development and farmer education institutions to remedy low productivity in agriculture in developing countries and build capacity for agroecology and regenerative agriculture. To be successful, research, education and extension services need to respect local constraints.

69. Research and development focusing on systemic approaches and sustainable agriculture and food systems require public support and therefore increased public investment and conducive policy environments, including provisions that allow all producers to access innovations in agricultural technology.

70. In addition to increased public investments in agricultural research, there is a need to increase the role of the private sector by providing incentives when the appropriation of rewards is more difficult in the short and medium term. Similarly, providing sustainable financing mechanisms for investing in technologies would support early adopters. Given the knowledge-intensive nature of some key technologies, extension services must be strengthened, including through community extension service providers and innovative new approaches to using information and communications technology.

71. Although a smart mix of financing is needed from various sources, it is important to keep in mind that private financing cannot be substituted for but should only complement public funding for food security, nutrition and sustainable agriculture. Gender-balanced investment aimed at closing the gender gap in agriculture should be encouraged.

72. Policymakers and stakeholders around the globe must ensure that agricultural technologies can realize their full potential in implementing the post-2015 development agenda, as well as the new climate change agenda that will be defined during the twenty-first session of the Conference of the Parties to the United Nations Framework Convention on Climate Change, to be held in Paris. Country-initiated, multi-stakeholder assessments can help to prioritize the allocation of public funds for public services, such as agricultural research, extension services, rural infrastructure, technology development and innovation. At the global level, the Committee on World Food Security, as the foremost inclusive international and intergovernmental platform on food security and nutrition, will play a key role in implementing sustainable development goal 2 and targets within other goals linked to food security, nutrition and sustainable agriculture.

73. Sound institutions, in particular in rural areas, are key to providing a framework and incentives for participatory research. Institutions can also establish transparent and inclusive legal frameworks on land tenure, land use and property rights, which are necessary for equitably applying agricultural technologies.

74. Although costly, monitoring systems are essential to assess technologies' impact on food security. The savings generated from avoiding additional expenditure and ultimately shifting away from ineffective agricultural technologies and policies, however, can offset monitoring costs.[21] Investments in better data collection and information systems will be key to monitoring progress regarding the implementation of the post-2015 development agenda.