



Wilton Park



Conference report

Global agriculture, food and land use

How to create resilient agricultural systems in a world of increasing resource scarcity and climate change

Monday 15 – Wednesday 17 April 2013 | WP1229

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Introduction

Building the resilience of agricultural systems in a world faced with the converging crises of increasing population, global economic instability, resource depletion and fluctuating climate should be the goal for ensuring the security of the future of food production. However what does agricultural resilience look like at the local, national and international levels?

Drivers of change for agricultural systems

1. World population has exceeded 7 billion and is on track to surpass 9 billion people by 2050 according to United Nations (UN) population estimates. As a consequence, there will be increasing numbers of mouths to feed nutritionally well to prevent malnutrition.
2. There are also changing trends in the type of food products demanded by consumers with increasing demand for meat and dairy products in the rapidly developing nations of Asia. These products require high inputs of grain for livestock feed, grain which are also suitable for human consumption.
3. An increased global population and their changing diets has led to an increased demand for resources, including fossil fuels, fertilisers and water, all essential inputs for sustaining and increasing agricultural yields. Compounded by increasing demand for these resources is the declining global availability of many. Reserves of crude oil and natural gas may be depleting overall, which calls for alternative sources of fossil fuels as an energy source used in agricultural systems, and also as a chemical feedstock.
4. Increasing demand for food crops means that global food production will need to increase by around 70 per cent (from 32 million tonnes to 44 million tonnes) by 2050¹. If this increase is to be met a 38 per cent increase in the annual rate of increase of cereal production is needed.
5. FAO anticipate that 90 per cent of increases in food production will come from intensification of agricultural production, including higher crop yields and more crop rotations.
6. Yield growth, however, has been linear since the 1960s; 30% of this gain due to improved genetics. However, even if linear trends are maintained this may not be adequate to meet projected demands requiring exponential growth in yield.
7. In recent years the global economic shocks have jeopardised the attainment of the two long-term goals for agriculture: achieving food security and adapting to climate change. Global economic instability and short-sighted policy-making are also stressing agricultural systems, distorting markets and making agricultural producers vulnerable to

price shocks.

8. In July 2008, crude oil reached a record price of \$147 per barrel. The impact of this price increase was felt by agricultural commodities. Whilst crude oil prices have fallen since, they demonstrate a general increasing trend. Those most at risk are in developing countries, who rely on agriculture for basic subsistence living.
9. There has been a historical trend for declining food prices for consumers in real terms throughout the 1980s and 1990s. However, international food prices began rising in 2002 in an apparent reversal of this long-term trend.² Drought or other weather related challenges, fossil fuel costs and biofuels production have all contributed to pushing prices upwards. While international food prices have come down slightly from their 2011 peak, they still remain well above historical averages and cereal prices increased again in mid-2012.
10. The 2010 Foresight Report highlighted the challenges for long term sustainability of food systems, including balancing future demand and supply instability and ensuring adequate stability in food prices, which will protect the most vulnerable from volatility.³

Climate change and extreme weather events stress an already vulnerable agricultural system

11. Increasing population pressures and increasing demand for natural resources is putting global agricultural systems at threat. This threat is compounded by climate change and the incidence of extreme weather events, including drought, flooding and temperature fluctuations.
12. In 2011, global fossil fuel CO₂ emissions increased a further 1.0 Gt to 31.6 Gt, according to the International Energy Agency (IEA). In order to stabilise global temperature increases at 2-4°C by 2050, 50 per cent less emissions are needed than are currently being achieved.⁴
13. Climate change could negatively affect the production potentials of agricultural resources in many areas. Increasing incidence of drought and desertification reduces the area of productive agricultural land. Climate change has encouraged the prevalence of new crop diseases and pests for which farmers are not prepared. Water sources have been influenced by climate both in terms of incidences of flooding and drought. These issues are often experienced in the same region, in the same year. The climate focus is shifting from a basic increase in global temperature, to increasingly erratic and extreme global weather events. It is as yet unclear whether these are short-term anomalies or demonstrating long-term climate patterns.
14. Global inequities are expected to grow under climate change. Climate change is a 'risk multiplier' as it presents additional threats to already vulnerable rural populations. Increasing disparities between the global rich and poor are narrowing, but increasing volatility in weather patterns are impacting on farmers' ability to resist change. Rural areas need to be able to adapt to the volatility of climate change and recognise that extreme weather events could potentially be the status quo of the future.
15. Resource scarcity also contributes to increasing social and geopolitical tensions. Competing demand for resources are triggers for social problems at both a community and global level and resource competition can contribute to incidences of famine, mass migration and conflict.
16. Thus ensuring a resilient global agricultural system, able to feed a growing population is a significant challenge to all those involved in the chain of producing food and contributing to food and nutrition security.

Resilient agricultural systems – what is resilience?

17. Agricultural production systems should achieve the following:

- Provide adequate food and nutritional requirements
 - Provide sufficient income for farmers to sustain a comfortable standard of living
 - Protect ecosystems both now and for future generations, including coping with changing weather patterns.
18. Resilient agricultural systems concern the interactions of people and nature. Rural communities, which depend on agriculture for basic food provision and rural incomes, are especially vulnerable. Rural livelihoods, better health and nutrition and overall national development can be improved through more resilient agriculture systems.
 19. There are many aspects to agricultural resilience, as the meaning and measurement of resilience is contested. The European Commission's (EC) concept of resilience is defined as the ability of an individual, a household, a community, or a region to withstand, to adapt, and to quickly recover from stresses and shocks⁵. This concept of resilience in the agricultural context applies to all levels; from the individual farmer, to the rural community and to the national level.
 20. Resilience can be thought of as both an incremental process, when linked to building adaptive capacity, and an overall outcome, when rural communities have taken ownership of their own developmental pathways. Whilst rural communities are dependent on ecosystems for agriculture and rural economic activities, these ecosystems are often not resilient themselves and are subject to degradation and at risk from extreme weather events. Ecosystem vulnerabilities include fragile water systems, soil degradation, and loss of species biodiversity.
 21. The future may involve changing ways of thinking about agriculture, from one of relative stability, to one that is resistant to fluctuations in weather patterns and input prices. Resilience occurs over different time scales. Being resilient in the short-term does not ensure there is resilience in the long run. Over-exploiting natural resources, such as soils, can achieve immediate returns for farmers, at the expense of degrading soil nutrients and structure if careful management is not carried out.

Improving soils and water – the basic requirements for crop growth

Soils

22. Globally, agricultural soils need to be conserved from the threat of degradation, including erosion, salinity and pollution. Soil erosion is a major issue in many regions, which may be imperceptible to the farmer on the short-term, but long-term consequences are severe.
23. Crop growth is limited by the soil nutrients and the availability of water. The primary soil macronutrients are nitrogen (N), phosphorus (P), potassium (K), and these are needed in the greatest quantities in the soil to ensure efficient plant growth. These nutrients are most likely to be in short supply in agricultural soils. The lack of any one of these essential nutrients can result in a severe limitation of crop yield. Secondary macronutrients are also needed in smaller quantities.
24. The presence of Soil Organic Matter (SOM) is crucial for fertile soil as it provides essential plant nutrients, beneficially influences soil structure, buffers soil pH, and improves water holding capacity and aeration. Although the short-term benefits of maintaining SOM levels are often unseen by farmers, SOM contributes to sustainable long-term productivity of agricultural land.
25. The integration of biochar into agricultural soils is being investigated as one method of carbon sequestration, alongside its potential to increase soil fertility. Biochar is produced from heating waste biomass to produce a solid charcoal material. Biochar presents a long-term method of storing carbon in a stable way. Its integration into soil can also provide a slow-release porous material for conservation of water and soil nutrients.

26. Minimum tillage practices can lead to an improvement in upper soil structure. There are also associated environmental benefits from reducing tillage intensity, such as reduced soil erosion rates, reduced run-off and reduced emissions release from soils. However, with reduced field cultivations, weed growth can be a problem unless herbicide applications or occasional ploughing is carried out.

Water

27. Scarce water supplies have a direct impact on agricultural productivity and are already strained through increasing demand, incidence of drought and pollution. The Food and Agriculture Organization's (FAO) projections indicate that global demand for water for agriculture will increase by 11 per cent from a 2006 baseline to 2050. By 2050, it is estimated that more than half of the world's population will face severe water constraints⁶. At the same time as many countries are experiencing water shortages, others can be suffering from an overabundance of water through flooding. Some can suffer from both flood and drought in the same year.
28. Water access is a highly politicised issue with water systems sometimes difficult to allocate fairly, particularly where water sources cross national borders. There is a need for mechanisms to share water equitably through legislation of watershed distribution.
29. A United Nations General Assembly resolution declared 2013 to be the UN International Year of Water Cooperation⁷. This resolution focuses on cooperation in the use of fresh water resources. Mapping and understanding water resources can assist countries in developing a science-based, long-term strategy of allocating and managing fresh water equitably and sustainably.
30. Where water is scarce there is a question of whether it is due purely to lack of water or to poor management. Access largely comes down to issues of power and information, not just quantity. Information on the availability of water resources, including underground aquifers is still inadequate in many areas, for instance the Sahel region, which is chronically short of water, making management of the resources difficult.
31. Globally, 20-30 per cent of food is produced on irrigated land on which higher crop yields can be achieved. However, this may be an unsustainable use of water resources, and the capacity for irrigation is scarce in many areas, for instance sub-Saharan Africa. The question of whether irrigation is publicly or privately paid for is also important. Soil salinity is the greatest problem associated with irrigation, around 11 per cent of irrigated land being affected by salinity.
32. Water shortages could potentially be mitigated through the development of efficient desalination technology. Desalination technologies are a method of producing fresh water suitable for human consumption or irrigation by removing salt from seawater. However, desalination processes can rely on large amounts of fossil-fuels. Costs could be reduced though implementing technologies such as nanotube solar-powered partial desalination, whereby solar thermal energy can be used to significantly reduce production costs.
33. The availability and sustainability of freshwater in many regions needs to be achieved through science-based comprehensive assessments of national water resources. However, projects need to address both macro- and micro-scale issues. This includes enabling equitable sharing of water, not just across national boundaries, but by ensuring local-level provision to rural communities.

Hydroponic systems

34. Hydroponic systems can permit a more efficient use of water and plant nutrients than conventional cropping systems. Hydroponics allows water to be fully recirculated through a lagoon and the water can be adjusted for nutrient content. Hydroponic substrate materials, including zeolite (a silica-based material), can store and release nutrients and water as required by the plants. Such systems can be used for crop production through periods of drought, using stored rainwater from previous high-rainfall seasons.

35. In Goa, India hydroponic systems are being trialled to produce fodder for dairy cows to produce milk for use by tourist hotels. With Goa facing monsoons followed by no rain this option of growing of white maize hydroponically close to its consumption is an innovative way to ensure continuous local supply. It could be replicated for other crops such as legumes. Costs will need to be measured; using artificial lighting for instance. Questions related to potential scale-up of such a system is also important.
36. In other examples hydroponics systems are being developed using stored rain-water and a base 'soil' of waste materials, for example a 9 month tomato crop in the UK. The nutrient content needs to be adjusted regularly for instance additional use of K and N, and supplementary lighting particularly in winter. Critical to its success is the knowledge and management of plant nutrition.
37. Hydroponics is also being used to grow food on the top of buildings, for example in the Bronx in New York, and urban indoor farming in Tokyo. There is the potential for completely 'sealed' systems in the future using hydroponics. Whether this is will be a hi-tech niche production or more urban/peri-urban is questioned.

Ensuing equitable distribution of water resources: the Brazilian example

38. Brazil has 12-15 per cent of the world's fresh water sources. However, access to this water is not distributed uniformly throughout the country, which dictates the structure of its agricultural systems. The northern arid regions average just 300mm of rainfall a year, compared with around 3,000mm in the Amazon basin, which captures around 80 per cent of the total rainfall.
39. The Brazilian government has encouraged major collaboration between public and private sectors in building irrigation infrastructure, with 69 per cent of Brazil's water now used for irrigation. The majority of this irrigated area is dedicated to rice production. Rice yields can be increased by 70 per cent though irrigation, rather than production in traditional rice paddies. Irrigation has reduced water demand from 4m³ per kg rice to just 1m³. Currently 5 million ha of rice is irrigated, with a plan to expand to 30 million ha.
40. Whilst private irrigation predominates in the South, Southeast, and Western regions, in the semi-arid Northeast water access is very limited. Often there is not enough for people to drink let alone to support agricultural production.

Fertilisers

41. On average crops use 50 per cent more nutrients from the soil than are replaced each year, thus there is real concern about the 'mining' of soils. Productivity can decline sharply unless some form of organic matter or fertilisers are used and nutrients added back to the soil.
42. Global demand for nitrogen fertiliser is rising. Fertilisers comprise 25 per cent of agricultural costs in industrialised agricultural systems. Fertiliser use is inelastic in response to price as it has a significant role in sustaining crop yields. Depleting fossil fuel used for their manufacture, such as natural gas, will mean that alternative sources are required in the longer term. These sources need to be economically viable to sustain the increasing global demand for nitrogen fertilisers, especially in China and India.
43. Globally, the US, China and India collectively consume more fertilisers than the rest of the world combined. One-third of ammonium fertilisers are manufactured and used in China. In areas of Western and Eastern Europe, fertiliser use has decreased slightly, due to price increases and drives for nitrogen reduction in environmental policy.
44. Whilst fertiliser use has increased steadily globally, the efficiency of its use has fallen due to over-application, especially in China and India. Excessive use of nitrogen fertilisers is harmful to local ecosystems, for instance excessive nutrients entering water systems, and its production contributes to global GHG emissions. This contributes to reducing agricultural resilience in the long-term, in pursuit of short-term gains. Fertiliser use should also be more efficient to increase agriculture's resilience to

the impact of fertiliser price volatility.

45. In many areas of sub-Saharan Africa and North Africa nitrogen fertiliser use is very limited. One contributing factor to Africa's food shortages is soil nutrient depletion due to continuous cultivation without nutrient replacement. The 2006 Africa fertiliser summit saw 12 resolutions adopted⁸. These include calls for a uniquely African Green Revolution, which will require an increase in the use of fertiliser. Some hybrid varieties of crops are dependent on nitrogen fertilisers for their high yields.
46. In addition to being an agricultural commodity fertiliser is also a political tool, and can be used by politicians in some countries to leverage votes through control of access. Fertiliser policy is one example where agricultural policy could be better planned and greater information provided to farmers.

Improving agricultural efficiency through better management of inputs and reducing waste

47. Simply increasing inputs should not be the primary solution in order to increase agricultural yields. Better management of inputs is required to reduce wastage, improving agricultural efficiency, and thus resilience.
48. With fluctuating cost of inputs farmers are at the mercy of the markets. However they can control their inputs. Purchasing external inputs is a high-risk strategy in global markets. Farmers should be aiming to wean themselves off external inputs as much as possible, some argue, increasing their resilience by improving self-sufficiency. There are growing examples of greater self-sufficiency within one farming system to manage inputs better.

Overuse of fertilisers - lessons from China

49. China has seen agricultural production expand rapidly to keep pace with its rising population and increasing demand for livestock products. There has been a meteoric rise in peri-urban vegetable production under poly-tunnels systems. These systems are highly productive in terms of crop yields, but are also highly polluting due to over-intensification. Since the 1940s, the Chinese government has subsidised the use of nitrogen fertilisers, making them affordable to farmers. This policy remains in place and has led to farmers over-applying cheap fertiliser.
50. Although farmers are educated in their role and application rates, they continue to be over-applied as a yield 'safeguard', due to their low price and from a lack of environmental regulation. Simple technology such as in-field nitrate testing would be a solution to help farmers' confidence in the amount of fertiliser which is required.

The use of precision farming and minimum tillage

51. Precision farming technologies can significantly improve agricultural efficiency. Whilst precision farming rarely achieves higher yields, it does reduce the cost of production by intelligently targeting inputs, and thus reduces the inputs themselves. One of the benefits of precision agriculture is to minimize the volume of herbicides required by using site-specific weed management. Technology such as automatic computer vision methods for detecting disease-affected leaves, can reduce pesticide applications up to 99.9%.
52. Precision farming techniques and minimum tillage practices can also mean reduced fuel consumption on mechanised field cultivations.

How can science and technology improve resilience?

High-tech approaches for building agricultural resilience: the use of crop-breeding and genetics

53. Researchers rely on genetics as the raw material for improving the quality and output of food production. However, gene diversity is being reduced at an alarming rate, as a consequence of biodiversity losses. There is potential for new plant species providing solutions to crop yields and diversity of food crop species. There is much scope for

neglected varieties of crops, including traditional crops, suited to climates of a particular region.

54. Maintaining diversity is therefore essential for developing the capacity to respond to future challenges, through hybrid crop technologies. Hybrid varieties of crops offer farmers significant benefits in terms of yield improvement, agronomic performance and consistency of quality. This is due to the 'hybrid vigour' derived from a combination of two carefully selected parent lines. Crop quality is a particular area that needs to be addressed, particularly in increasing the nutrient content of crops.
55. Key limitations for hybrid crop breeding are a lack of resources, including a shortage of future plant breeding researchers. There is a lack of free communication due to intellectual property rights and industry confidentiality. Benefits of using plant genetic resources should be shared through information-exchange and funding is needed to help mobilise programmes to help small farmers in developing countries.
56. Genetic modification (GM) is another source of new crop varieties, but this technology is not always necessary, as there remains much scope for non-GM varieties. However, GM permits novel variation beyond what is naturally available. 'Golden Rice' is an example of where beta carotene had to be added.⁹ Regulatory demands impose high costs on GM crops, preventing them from reaching the farmer. The regulatory complexity and high costs prevent the widespread delivery of new GM varieties, although cotton, soybean, maize are currently dominated by GM varieties.
57. The future of crop breeding technologies should aim for yield stability, where crop yields can be maintained in sub-optimal conditions. This means developing varieties that can withstand rapid changes in environment, including drought, flooding and salinity. There has also been neglect of root traits, an area for potential research.
58. Plant genetic resources for food are a common concern for all countries. No country is self-sufficient in plant genetic resources and all countries depend, to some degree, on plant genetics that originated elsewhere. The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA)¹⁰ promotes the conservation and sustainable use of these genetic resources. This system applies to over 64 major crops and forages. The fair sharing of benefits arising from the use of genetic resources is essential for food security.
59. High-tech solutions may not be the main source of future change in many countries. Tailored, low-tech solutions can also make incremental changes to improving livelihoods and resilience of the rural poor particularly in developing countries.

Low-tech approaches for building agricultural resilience: the example of fertiliser briquettes in Bangladesh

60. The International Fertiliser Development Center (IFDC)¹¹ has been working on developing Fertiliser Deep Placement (FDP) as a low-tech response for increasing crop yields and improving rural incomes, whilst reducing the amount of fertiliser required.
61. FDP is a field-tested technology that increases crop yields, reduces fertiliser use and decreases environmental impacts of nitrogen-based fertiliser application. FDP involves the targeted application of nitrogen fertiliser, whereby commercially available urea fertiliser is compacted into briquette form. This is a more efficient means of plant nutrient application than the conventional method of applying fertiliser by surface broadcasting.
62. Bangladesh is the world's fourth largest producer of rice. Rice farmers¹² have begun to utilise this technology, placing briquettes below the soil surface in the irrigated rice paddy. These can be placed either by hand or using a mechanical applicator. The briquette releases nitrogen slowly, providing the nutrient requirement over the growing season. The consistent weight of briquettes means that farmers can provide a relatively constant amount of nutrients. This technology is currently used by over 1,000 farmers in Bangladesh. It is an example of community-level technology, which provides returns

to briquette manufacturers in the community, supporting local rural economic development.

63. There is scope to produce briquettes with other fertiliser nutrient mixes, depending on the individual nutrient requirements of the plants and soils in a local region. Micronutrient deficiencies are also recognised as serious yields constraints.
64. This benefits the environment, as the deep-placement of the nitrogen means that the majority remains in the form of ammonium, and less is lost through leaching or as nitrous oxide gases, a powerful GHG. There is only 4 per cent nitrogen loss in briquette form, compared to around 35 per cent loss when fertiliser is applied through broadcasting. There is also improved plant absorption of the nitrogen. Results have demonstrated a 15 per cent yield increase with 35 per cent less nitrogen applied. This saw farmers' incomes grow by over \$200 per hectare in 2012.
65. Whilst FDP is more labour-intensive than broadcasting methods FDP needs to be placed only once, compared to broadcasting which is carried out 2-3 times in a season. Increased labour costs are offset by reduced fertiliser requirements and increased rice yields. The use of mechanical applicators can reduce the labour requirement and the IDFC are carrying out research into this technology.
66. Presently over 2.5 million Bangladeshi farmers use FDP and its use is being targeted at an additional 1 million farmers across Bangladesh. Whilst used most widely on rice, FDP is suitable for vegetable and other cereal crops, including sorghum, maize and wheat. The potential for FDP expansion is significant, and suitable for use on many types of crop in a variety of poor agricultural regions of the world.

Transferring low-tech solutions to Africa

67. Rice production is increasing in other regions, including sub-Saharan Africa, where production has risen by 31 per cent in the past 10 years. Rice has become the second most important cereal crop in sub-Saharan Africa, with the majority grown in West Africa. Despite rice production increasing by 6 per cent each year, Africa remains a net importer of rice, as domestic supplies cannot keep pace with demand increases.
68. FDP is an example of a successful low-tech approach to increasing yields, which can be transferred and implemented in other developing countries.
69. African smallholder farmers are increasingly forced to cultivate marginal land with infertile soils as population pressures are increasing. Fertiliser prices are much higher in Africa than the rest of the world, and yields are consequently well below their potential. Food production has not matched population growth in many African countries. The FDP African initiative, working alongside hybrid rice varieties and improved water management practices, has demonstrated positive results in Burkina Faso, Niger and Nigeria.

Land: the fundamental agricultural asset

70. Land is a fixed asset, yet the security of land rights is an issue for many farmers which impacts on their long-term management of the land and thus the resilience of agricultural systems. Land tenure or ownership rights are of central importance for devising appropriate interventions in agriculture, food security and rural development.
71. For tenant farmers rising land prices are translating into higher rents, thus incurring higher business costs for the farmers. Insecure and short-term tenancy agreements mean that farmers may not have the confidence to invest in technologies to improve their efficiency, or the necessary incentives to maintain soils for example, as the payback may be over a longer timescale than their period of tenancy. Some may abuse the soil to optimise their returns during their tenancy period without investing in replacing nutrients and organic matter. Thus insecurity of tenure can seriously jeopardise the resilience of the soils and agricultural systems, both in the developed and developing countries.

72. Greater security of land tenure can give farmers the confidence they need to get returns on investment during their period of occupancy and maintain the ecosystems they are working with. There therefore needs to be a shift in farmer and landowner attitudes towards tenure. Those farmers who do not have the land resources they can rely on are most vulnerable.
73. Agriculture also faces competition for land use with real estate development. Effective planning and legislation is needed to secure agriculture's value in society. This involves an approach that factors in the value of food and the value of landscape in land pricing; otherwise agricultural land cannot compete with housing development. Increasing urbanisation is taking away potential productive land from agriculture, just at the time when agriculture needs to be expanding its production. Once urban land development takes place it is not easily reversible to agricultural land.

People: a key agricultural resource

74. Building agricultural resilience does not just come down to the biophysical aspects of agriculture's productive capacity; food production is ultimately dependent on farmers and their decision-making. There needs to be a people-based approach to improving agricultural production and systems, an aspect often neglected. Improvements are as much about changing the behaviour and perception of farmers as a simple first-step in increasing production.
75. Farmers are not just responsible for food production, they are also responsible for managing the biodiversity of ecosystems surrounding their land, and also preserving the cultural landscape of the surrounding region. These ecosystems services are not always fairly enumerated or reflected in prices farmers receive for agricultural products. Historically food prices are actually very low. A 'fair' price for farmers is required.
76. Whilst agricultural production becomes less resilient on weakened ecosystems, the resilience of the individual farmers themselves is at risk if they are malnourished, stressed, or suffering from disease. Education is vital for increasing farmers' sense of self-efficacy and building mental resilience, allowing them to independently find innovative solutions to business threats. Healthcare provision is also essential for building rural resilience, otherwise farmers may not have the physical capacity to work their land effectively and provide food for their families.

Growing inequality: empowering women in African agriculture

77. There has been a recent trend in many African developing nations for men to leave rural regions in order to find work in urban centres. This leaves the women behind to farm in these communities. For example in Tanzania about 67 per cent of farmers in are women, yet they own less than 1 per cent of the land, have access to less than 1 per cent of agricultural extension services, despite being the primary farm decision-makers.
78. Women have unequal access to water sources, since men have priority access to the nearest sources of water. Women farm poorer land, further downstream, and receive insufficient water supply. Agricultural support packages mainly fall into the hands of men, who use them for improving the production of export crops such as cotton, rather than for the production of staple food crops.
79. Agricultural policies in Africa need to support the role of women role in agriculture. Women farmers need to feel empowered and informed and be given a voice for their needs. The use of mass media is a contemporary way of communicating information to help farmers improve their methods. Television programmes, such as "Maisha Plus"¹³, a popular Tanzanian reality TV show, are an opportunity to promote women's voices in Tanzania. It helps women access the same kind of support and rights already available to male farmers.
80. WASH for Life (Water, Sanitation & Hygiene), a joint initiative between the United States Agency for International Development (USAID) and the Women Farmers

Advancement Network (WOFAN), is another such initiative to support women farmers which aims to increase access to water supply and sanitation services for the people of Bauchi State, Nigeria¹⁴ by working with the key decision-makers in rural communities – the women. Empowering women involves giving them control of their own technologies. Embedding maintenance and repair in rural communities increases community resilience by not being reliant on external providers. Women can be trained to repair and maintain boreholes rather than relying on getting someone from outside the community to do the repairs.

Infrastructure: bridging the gaps in communication and transportation

81. The gap between researchers and farmers still needs to be bridged, and communication facilitated between the two communities. Farmers need to be empowered so that their needs for innovation can be heard by researchers and who can respond, rather than a 'top-down' approach to research and innovation. It is also essential that methods of feedback are established to measure the impact of such transfer of knowledge to the farmers on the ground.
82. There is scope for the revival of extension services, and the use of 'model farms'. Farmers can follow by example of how new technologies can work in real-world scenarios. Farmer-to-farmer knowledge transfer is often the most effective.
83. Whilst there needs to be more investment in technology, research projects also need to be assessed on whether they achieve the desired goals. Assessing the reasons for success and failure can allow such methods to be improved for future technology transfer.
84. Developing physical infrastructure of rural areas is also critical, such as the construction of rural roads to connect small farmers to markets. This will benefit all in local communities by facilitating trade and access to information and technologies. Farmers need to have access to markets and suitable infrastructure to build resilience. If farmers have no way of getting their produce to market, or no storage facilities to preserve their harvest, there is little point in increasing production.
85. The crops grown also need to be appropriate for the local circumstances; there has to be demand for a particular food crop by local consumers or markets.
86. Also, the decentralisation of services through community-based animal health practitioners, for example, means that long after the extension services have left the knowledge is retained in the communities.

Building greater resilience in Africa

87. The 'Green Revolution' of the 1960s was a period of rapid uptake of high-yielding crop varieties, fertilisers and pesticides that significantly increased agricultural production in developing nations. However, this revolution bypassed Africa due to serious organisational weaknesses. Agricultural innovation in the 21st Century should not bypass Africa again.
88. Smallholders and subsistence farmers are most vulnerable to climate stresses in arid regions. In Kenya for example poor soils, erratic seasonal rainfall and a population weakened by HIV or inadequate nutrition affect the ability of smallholders to build resilient agricultural systems. Whilst there are suitable technologies and crop varieties which could be of assistance to farmers in this region, they lack access to technology and drought-tolerant varieties of traditional crops. Thus the promotion and uptake of traditional crops which are tolerant to regional climate and provide adequate nutrition is needed. Cowpeas, for instance are a traditional crop which provides a good source of vitamins and minerals from the leaves, and a good source of protein from the bean.
89. Small farms are often dismissed as being inherently unproductive compared to large farms, which benefit from economies of scale. However, scale is a relative term in

agriculture; it depends very much on the location. Smallholder farming will continue to remain significant for the majority of the developing world. Whilst it is likely there will be a transition towards larger, more consolidated farms in the future, the short-term future will see smallholder and subsistence farms prevail. Resilience needs to be extended to these small farms, on which so many rely for food or income.

90. Food aid is often vital to rebuilding resilience and assisting regions in recovering after disasters such as drought. The EU's Global Alliance for Resilience Initiative (AGIR) is a long term strategy for building resilience in the Sahel region of Africa. AGIR initiatives are a 'twin-track' approach whereby humanitarian and development assistance is coupled with short-term relief to help vulnerable people recover in the immediate aftershock of a disaster¹⁵.

Building resilient global systems: framing national and international policies

91. Agricultural resilience needs to be embedded in policy at all levels. Good national and international policy formation should enhance the autonomy of farmers and self-sufficiency of farm systems.
92. Recent efforts to secure international agreements on policies which affect agriculture have failed in recent years, for instance the recent Doha Development Round failed to come up with an agreement¹⁶. However, more is needed to reduce the barriers to trade in agricultural goods and trade costs, especially for developing nations. An open and transparent international trading system would go some way to responding to the requirements of agricultural resilience. However, while many poorer countries have liberalised and removed subsidies (sometimes with disastrous consequences) the US and the EU have not. Developed countries are able to maintain high import duties and quotas in certain products, blocking imports from developing countries
93. There is also no major global commitment to reduce carbon emissions further. It is likely that greater use of international regulations rather than global agreements will bring about change in future¹⁷.
94. Any regulations however must ensure that problems are not 'exported' from developed nations to other regions or vice versa. The European Union (EU) has a rigorous environmental protection, yet there is no trade system that seeks the same standards for outside supplies. For example UK livestock welfare regulations have led to increased costs and therefore food prices, whereas other countries can produce at cheaper prices due to lower welfare and environmental standards.
95. 'One size doesn't fit all' in terms of policy, as there is much variation across countries worldwide. In the case of the EU, agricultural policy applies across all 27 EU member states, even though there are significant differences in terms of agricultural systems, production methods and climates across the EU.
96. Policy needs to encourage a move away from broad-based support to more targeted measures to address market failures. There are calls to end the system of agricultural support that distort markets, including coupled payments and export refunds.
97. Agricultural policies needs to be pro-rural, which involves providing the supporting infrastructure to markets and processing of produce, and should incentivise farmers rather than penalise them.
98. Policy mechanisms need to be in place to ensure farmers are paid for their management of ecosystems and natural landscapes, which wider communities put value on. Farming's value to society goes beyond food, to include a wide range of ecosystem services.
99. To ensure greater resilience long-term policies are needed with long timescales for policy plans. Good governance also needs to be implemented at all levels, from individual farmers' rights to global trade networks.

Biofuels and biofuels policy

100. Demand for biofuels has meant that conversion of food crops to biofuel has globally diverted significant stocks of grain from a food source to a fuel source. Biofuels sit between two of the most heavily subsidised global markets – agriculture and energy. Biofuels policy remains controversial and, it is argued, has exacerbated agricultural price spikes by making demand more inelastic. Careful policy planning is essential to avoid unintended consequences.

101. Biofuel production in Africa is an example where biofuels have weakened the system, rather than contributed to agricultural resilience. External biofuel investors have been given the best quality agricultural land for biofuel production, in order to attract further investors. This land has been taken out of community food production; Jatropha tree production in Kenya for example resulted in a shortage of staple food crops.

Conclusion

102. Creating resilient agricultural systems is vital to feed a global population in excess of 9 billion by 2050 in a nutritionally sufficient way. Extreme weather conditions however are likely to be the norm and weaken existing agricultural systems.

103. Intensification is likely to be a common future for agriculture but this does not have to be done at the expense of ensuring long-term sustainability of production and maintaining the health of soils and careful husbandry of vital inputs such as water.

104. Global agricultural production systems will remain diverse and this diversity of approach will ensure greater resilience. Resilient systems will therefore not look the same in different regions and circumstances; tailoring resilience to suit the local conditions will mean localised approaches work best.

105. Good practice in one area however, can be beneficial for others even when conditions are very different and it is vital that good practices are learnt and shared. Greater cross-fertilisation of farming successes, technologies and policies will lead to building resilience regionally and globally. Improvements are also as much about changing the behaviour and perception of farmers as a simple first-step in increasing production and ensuring greater long-term resilience.

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- ⁴ IEA (2010) 'Transport, Energy and CO2': Moving towards sustainability'
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- ⁷ United Nations General Assembly declared 2013 as the United Nations International Year of Water Cooperation
http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/65/154
- ⁸ African Fertilizer Summit 2006 http://www.ifdc.org/About/Alliances/Africa_Fertilizer_Summit
- ⁹ See Wilton Park report from conference WP1189 Global food security; the role of science and technology
(<https://www.wiltonpark.org.uk/conference/wp1189/>)
- ¹⁰ International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) <http://www.planttreaty.org/>
- ¹¹ The International Fertilizer Development Center (IFDC) is a public international organisation which addresses issues such as food security, the alleviation of global hunger and poverty, environmental protection and the promotion of self-sufficiency. This is achieved by the transfer of crop nutrient technology and agribusiness expertise in a culturally relevant and environmentally sound manner.
- ¹² Rice is the staple crop for over 3 billion people, cultivated in over 100 countries. Its production provides employment for over 1 billion people in South and Southeast Asia. However, the majority of rice farmers live in poverty.
- ¹³ Maisha Plus <http://www.maishaplus.tv/about.html>
- ¹⁴ USAID <http://nigeria.usaid.gov/access-water-sanitation-and-hygiene-wash>
- ¹⁵ AGIR's objective is to promote greater resilience by a synergy between the emergency response and long-term development strategies.
- ¹⁶ The Doha Round of world trade negotiations was launched in Doha, Qatar, in 2001. This round of trade negotiations aims to further liberalisation of world trade, whilst facilitating the integration of developing countries. It aims to achieve cuts in trade-distorting agriculture subsidies, reduce tariffs and offer duty-free access to the exports of the world's poorest countries. Negotiations stalled, however, without any conclusions on a trade resolution.
- ¹⁷ UN FCCC (2012) 'Report of the Conference of the Parties on its eighteenth session, held in Doha from 26 November to 8 December 2012'
<http://unfccc.int/resource/docs/2012/cop18/eng/08.pdf>