EU Agricultural Markets *Briefs*

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# Global food security: challenges and options


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**Global food and nutrition security (FNS), the overarching theme of the EXPO Milan 2015, remains high on the policy agenda. Still there is a growing difficulty for scientists and policy makers to keep up with the expanding volume of information about the challenge of meeting human food and nutritional needs while preserving natural resources.**

**A 2-day event organised by the European Commission with the European Association of Agricultural Economists (EAAE) and the International Agricultural Trade Research Consortium (IATRC) at the margins of the EXPO Milan 2015, gathered high level speakers from academia, major international organisations and governments to provide a closer look at the various dimensions of food security. Recent food security scenario analysis set the scene and helped to identify the main drivers that will impact food security in coming decades, in particular the role of productivity, technological breakthroughs, different agricultural models, regional developments, policies and other factors also beyond market fundamentals.**

**This *Brief* recapitulates the main insights obtained from the various researches and viewpoints presented during the event.**

*EU Agricultural Markets Briefs are available on Europa:*
*http://ec.europa.eu/agriculture/markets-and-prices/market-briefs/index_en.htm*

*Agriculture and Rural Development*

## 1. Global outlook: setting scene

### *Prevalence and importance of FNS*

The recent USDA ERS International Food Security Assessment (IFSA, 2015) reports sharp declines (roughly 40 %) in **food-insecure people** in Asia and Latin America and the Caribbean (LAC) during the last 20 years. Success was driven by rising per capita grain output in both regions and rapid import growth in LAC. Although the trend is also downward, Sub-Saharan Africa (SSA) is lagging behind, despite the highest grain production growth of all the regions in the study. One of the main factors behind the results is the population growth, up 70 percent compared to 1995. Recent FAO numbers (Fan, 2015) confirm these trends, with world undernourishment prevalence declining from about 20% in the beginning of the 1990's to around 10% currently. For SSA, IFSA projects by 2025 an increase in food-insecure people of 100 million (compared to 250 million now), or 30% of the region's total population. This is primarily due to prospects for deteriorating food security in a few countries. Civil conflicts and high population growth are the contributing factors. Despite a projected increase of roughly 50 million in Asia (compared to the 200 million now), the share that is food insecure will remain below 10 percent. For LAC, the number of food insecure people is projected to decrease, with a little over 10 percent of the region's population food insecure in 2025.

Opposed to this is the upward trending prevalence of **overweight and obesity**, with overweight and obese children under five increasing considerably (de Onis et al., 2010 in Fan, 2015). The share is much higher in developed countries (around 14% by 2020) compared to developing countries (around 8% by 2020), but the trends are similar. Especially in SSA the share is projected to grow dramatically, from 4% in 1990 to an expected 12% in 2020. Micronutrient deficiency is another significant problem, which is alarmingly high in SSA and India (Muthayya et al., 2014 in Fan, 2015). All these issues impose large social and economic costs on the society. The global cost of malnutrition is estimated to be around $3.5 trillion annually, undernutrition and micronutrient deficiencies around $1.4 to $2.1 trillion annually and obesity $2 trillion in 2012 (FAO, 2013 and McKinsey, 2014 in Fan, 2015). As projected by Hoddinott et al. (2013 in Fan, 2015), economic returns to eliminating hunger and malnutrition can however be large (reducing stunting yields up to 50 fold return on investment depending on the region).

### *Factors driving future FNS*

According to von Braun (2013, in Van Meijl, 2015), at the **supply side** land (degradation), water (scarcity), productivity and technology, labour and farm structure and climate change are the main challenges towards 2050, while at the **demand side** these are population (growth), income (growth, urbanization), poverty and inequality, consumer behaviour, waste and bio-energy. For trade and markets the dominance of supermarkets, protection, the behaviour of financial markets and food stocks are main drivers.

OECD (2015) projects real agricultural **price** increases in the future to remain limited.

#### *Price volatility in an uncertain era*

After decades of decreases, real agricultural prices surged during and after the financial crisis, disrupting the functioning of markets and causing an inflation in malnourished and poor households, especially in developing countries heavily dependent on agricultural imports. Together with the price spike, price volatility increased. As discussed in previous briefs (Market *Brief* No 5), this was triggered by a combination of events, such as changes in demand growth, both for food and industrial use, the slowdown in yield growth and access to land, the co-movement of agricultural prices with energy and other commodity prices, the financialisation of agricultural markets, changes in stocks, adverse or beneficial weather events and the effects of agricultural trade restrictions.

Recent work from Baffes (2015) confirms that **price volatility** increased during the crisis across the entire commodity price spectrum. It increased first in metals (initially around 2003 and 2004, then sharply in 2006) followed by energy and agriculture, both around the time of the 2008 financial crisis. Volatility in equity markets also increased around the financial crisis. With the exception of crude oil, volatility during 2014 and 2015 seems to have returned to pre-boom levels. Last, directional comovement between commodity prices increased along with the price boom, but it has now returned to pre-boom levels. The question in what way **financialisation** has contributed to the price boom and volatility spike remains largely unanswered. A study by Grosche (2015) shows that determining the direct causal links between index trader long positions and futures prices, based on historical data, remains a challenge. The direction of the price effects (positive or negative) is not unambiguous and there is even evidence for reverse causality (i.e. future prices determine the index positions).

As the financial crisis has shown, risk plays a critical role in markets and policy. Less attention has however been given

to the **uncertainty associated with** current **measures of risk**. Implied volatilities from options and econometric model estimates are often used in policy making, but it remains unknown how accurate the volatility measures are. Both the example of the USA Congressional Budget Office scoring and of rating revenue insurance (Goodwin, 2015) show that errors may translate into big budget surprises and may lead to adverse selection. Policy distortions may be exacerbated by these issues. Greater focus on the uncertainty of our measures of risk is therefore needed.

To cope with price volatility, a whole series of price risk management strategies are applied in agriculture and along food supply chains (Meuwissen, 2015). As the FP7 Ulysses project shows, in the EU many types of contracts exist, but these are no longer based on price fixing. There is a general interest among farmers to cooperate more with other farmers and along the chain to reduce price risk. Producing for niche markets is also seen as a risk coping strategy as niche markets are perceived to be less volatile. In reality, margin management is considered more important than price risk management. Although these strategies reduce volatility, farmer' incomes remain unstable. From the policy perspective, Producer Organizations, Inter-Professional Organizations and contract standardization should be pursued further, while additional attention should be given to increased transparency of market price information along food chains, increased hands-on PRM experience (community of practice), further encouragement of cooperation among farmers and along the chain and the establishment of futures markets where such markets are missing.

Scenario analysis by OECD (2015) shows that Food and Nutrition Security (FNS) profits most from a future **production and market model** based on sustainability principles, outperforming the scenario where globalisation is mainly focussed on economic growth. A production and market model that is based on national and regional self-sufficiency and limited international cooperation clearly underperforms compared to the latter two.

The past decades **trade liberalization** has opened up markets, fostering economic growth across the globe. The effect on food and nutrition security is however less clear. An appraisal (McCorriston et al., 2013[1] in Morrison, 2015) of 34 studies focusing on the question whether agricultural trade liberalisation has improved food security or not did not yield a consistent outcome (with 13 studies reporting an improvement, 10 a decline and 11 a more mixed outcome). A study from Olper et al. (2014 in van Meijl, 2015) on its turn shows heterogeneous but on average positive effects from trade liberalization on food security among 40 low and middle income countries.

For the EU, the new SCAR foresight exercise (Mathijs, 2015) complements the **challenges** of FNS, sustainable resource use, climate change, socio-economic conditions of farming and rural development, with the challenges of nutrition and dietary changes, market dynamics (integration with energy, new relations between industry and consumer) and concentration, big data and electronics revolution, the new energy landscape and the non-food use of biomass.

## 2. Regional perspectives on FNS challenges

We devoted a *Brief* (Market *Brief* No 7) to regional perspectives on food supply and demand evolutions. Here we further broaden the scope to FNS, based on the input from country experts. After identifying regional challenges, the policy options chosen are discussed. Finally we turn our attention to the broader impact on other regions.

### *China – balancing consumption and sustainable production*[2]

China's main challenge in the past was to meet the **rising demand** from a rapid growing population before 1980 (1.8% per year between 1950 and 1980, versus <1% between 1980 and 2010) and significant rise in per capita income after 1980 (2% per year between 1950 and 1980 versus 7% between 1980 and 2010). Until the late 2000s, China was a net food exporter, although in 2010 food self-sufficiency reduced to 97% (soybean is the main issue). The rural population under poverty has declined significantly over the past 3 decades. With only 8% of world cultivated land but 20% of world population, China was able to meet this rising demand by institutional change (land tenure) in the late 1970s, technology innovation since the mid 1980s, market reform since the early 1990s and substantial increase in investment in agriculture since the mid 1990s.

In recent years, previous challenges have intensified while new challenges have emerged. Increased food production has been realized largely **at the expense of environment** and sustainable development, with groundwater overexploitation, degrading soil fertility

[1] McCorriston S, Hemming DJ, Lamontagne-Godwin, JD, Parr, MJ, Osborn J, Roberts PD (2013) What is the evidence of the impact of agricultural trade liberalisation on food security in developing countries? A systematic review. London: EPPICentre, Social Science Research Unit, Institute of Education, University of London.

[2] Based on Huang, 2015.

and rising non-point pollution as consequences. One new challenge is the rising labour and land costs, making Chinese production less competitive and increasing the concern for food insecurity once again. Also challenging is the considerably smaller farmers' income compared to urban income, creating a flux of labour from rural areas.

To address the environmental challenges China recently invested heavily in water conservation (2011), drafted a plan to reduce fertilizer and pesticide use (2014) and set up a program to support the combination of grains and cash crops with forage crops and grass (2015). In 2015, the policy focus will also rest on improving production capacity. To boost agricultural income and competitiveness vis-à-vis industrial wages, agricultural subsidies (mostly decoupled) increased dramatically and price support is provided. A consequence of the latter is an enlarging price gap with world prices, increasing imports and storage. To deal with the challenges rising from increasing labour wage and low labour productivity of small-scale farms, farm land has been significantly consolidated through rental market since the late 2000s. For 2015 China plans to cap subsidies, and to pilot 20% of subsidies to relative large-scale farms for improving land quality and compensating for productive investments. A target price will be used to replace the minimal pricing and storage system. China also aims to eliminate rural poverty by 2020. While China is expected to increase its imports of many agricultural commodities, its role in global agricultural trade will highly depend on how the above mentioned policies will be implemented.

### *India – the main challenge still to come*[3]

India, with its 1.25 billion inhabitants today, is likely to surpass China by 2022. Urbanization will further increase from 380 million now to 600 million by 2030, putting pressure on land, water and energy supply. Expenditure on food remains high (avg 45%). Per capita income is expected to rise by 5 – 6 % per year while 65% of the population is currently below 35 years old.

Today India is a **net exporter** of agricultural commodities. Since the beginning of 2000, the agri-trade surplus has been growing rapidly. Similarly, grain stocks have surged, from 21 million tonnes in 2006 to 70 million tonnes in 2014. India's agri-GDP growth is positive (around 3% p.a.), although differences between states are widening. This was possible mainly due to more price incentives (relative price difference between agri and manufactured products improved substantially), more investments in agriculture and the National Food Security Mission scheme operated by the government to increase food grain availability.

One of India's emerging challenges is the shrinking farm size, for which the policy solution could be to liberalize the land lease markets. Another challenge is climate change and the associated production risks. From a policy perspective, more investments could be done in R&D for drought resistant varieties, irrigation water management and expansion of crop insurance. The rising input subsidies are another emerging challenge (as 80% of public expenditure on agriculture is subsidies with low returns). This could be tackled by rationalizing subsidies through cash transfers while raising investments in R&D, irrigation, rural roads etc. A major challenge is the economic access to food. With the high leakage in the Public Distribution System for grains, it might be better to move to cash transfers. Malnutrition also remains a challenge. Although numbers of underweight children and stunting are improving, better diets, sanitation and female education can contribute to a further reduction. The rather restrictive and cautious agricultural trade can also be liberalized more.

India's largely vegetarian culture remains an important trump for food security, as demonstrated by its protein intake per capita below world average. Further investments in infrastructure and processing will lead to large savings in wasted food (esp. perishables). While India can most probably feed itself up to 2030, it is projected that the main challenge will start after that.

### *Brazil – tackling income disparity*[4]

While Brazil is a major food producer and exporter, lack of food access has been diagnosed as an issue of **income deficiency** (not food supply). Income increase and income transfers have been the two major angles of the food security system. Nutritional quality was not considered. Important innovations in family farming however took place.

Food security policies in Brazil are based on three main pillars. The first one is the stimulus to food production, with general rural credit policies and PRONAF, a credit program to small food producers at

[3] Based on Gulati, 2015.

[4] Based on Bento, 2015.

preferential interest rates. The second are the food supply policies, with CONAB as main program. This program contributes to the regularity of food supply and guarantee of income to rural producers by facilitating product flows from isolated regions to markets (local or exports), or to regions with product shortages. It is operated basically through financial instruments, like sales options. The 3rd and most important pillar is the Bolsa Familia program, which is a conditional income transfer program targeted to the poorest. Total expenses within this program amount to 0.5% of Brazilian GDP. All these programs have contributed to the further reduction of poverty in Brazil from above 30% in 2003 to below 14% in 2013.

Important challenges for the FNS in Brazil however remain. Its FNS system is complex and expensive. There are for example no "rules of exit" for the conditional transfer programs. At the same time GDP growth is sluggish (0.1% in 2014 and -2% expected in 2015) and food prices are rising faster than general inflation. The quality of the educational system also remains low. The extent to which the Brazilian federal government will be able to fund its social policy in the coming years is the most important issue for food security in Brazil.

### *Australia – depending on export*[5]

Australia's agriculture is largely dependent on export (65% of the production value), mainly towards high value markets in neighbouring Asian countries. Its main challenge is the long term increasing cost-price squeeze in agriculture. Focus for Australia should rest upon investing in agricultural R&D to improve agricultural productivity; technical and policy development assistance to food deficient nations to improve their agricultural productivity; encouraging open global markets so that food can get to where it is needed in less distorted markets; and promoting economic development and improved governance that result in higher incomes and improved income distribution in the poorest countries. To boost the competitiveness of its farming sector, the Australian government has developed a white paper[6] which delivers $4 billion across five key priority areas: a fairer go for farm businesses; building the infrastructure of the 21st century; strengthening their approach to drought and risk management; farming smarter; and accessing premium markets.

[5] Based on Morris, 2015.

[6] http://agwhitepaper.agriculture.gov.au/

### *Africa – the world's main challenge*[7]

Africa is characterized by rapid urbanisation (with 3.5% per year fastest in the world) and by an expanding middle class (34% of Africa's population in 2010, expected to be 42% in 2060). Also GDP (around 5% per year) and human population (from 0.9 billion in 2005/07 to an expected 2.2 billion in 2050) are growing fast.

Africa faces a number of challenges with respect to food **availability**. The use of traditional production methods results into low productivity. The lack of purchasing power for smallholder farmers hampers the acquisition and use of modern technology. Both public and private investments in agriculture remain low. Policies are largely inconsistent and institutions weak. Trade amongst African countries is also low, especially compared to extra-Africa trade. It is regularly troubled by political instability and regional/ethnic conflicts. Disasters, both natural and manmade, occur frequently. It is also prone to land degradation and issues of climate change.

Food **access** also remains problematic. Low incomes are compounded by high unemployment rates particularly among the youth and young adults in all African countries. Markets are weak for staple food and export crops/commodities. Important bottlenecks in regulations relating to intra-country and cross-border trade remain. The instability in markets results in food-price spikes. Infrastructure, particularly roads and railways, are only poorly developed.

Major challenges remain for food **utilization** as well. Illiteracy and poverty constrain many African households from getting nutritionally balanced diet. The low use of technology hampers to address food quality and food safety issues within the countries and at the borders, while policy fails in addressing problems of dumping of low quality food commodities in many African countries.

Africa's response to the above mentioned FNS challenges is the **Comprehensive Africa Agriculture Development Program** (CAADP). Launched at AU Summit in Maputo in 2003, it provides a common policy framework for agricultural development in Africa. African Heads of State committed to spend 10% of national budgets in agriculture annually and make efforts to raise agricultural production by at least 6% a year. Ultimate

[7] Based on Asuming-Brempong, 2015.

aims are to reduce poverty, hunger and malnutrition through an agricultural-led strategy that transforms subsistence agriculture into a sustainable farming business. The Maputo 2003 Declaration was reinforced during Malabo 2014. This initiative shifted the focus back onto African agriculture through the mobilisation of high level political support and financial resources, but the increase in public spending and investment in agriculture remained below expectations. Neither Africa nor SSA currently meet the 10% target. Overall, there is only modest progress in productivity and growth, with significant cross country variation. Poverty rates are overall declining but in absolute number there is an increase of people living in poverty across the continent. Only Egypt, Ghana and Mauritania are on track to meet MDG1 targets (halving poverty and hunger).

### *EU – balancing sustainable growth*[8]

Overall EU challenges regarding food availability mainly relate to realizing **sustainable production** growth faced with limited and deteriorating natural resources as well as the need to address climate change. Concerning access, constraining elements are the outlook for sustained higher food prices and negative income effects of the economic crisis (secular stagnation, high unemployment, growing inequality). The utilization challenges relate to sustainable food consumption in the wake of changing dietary patterns with concerns regarding **food waste** and **malnutrition** (obesity and overweight). Stability on its turn is challenged by increased likelihood of market disturbances with a wide array of factors: economic, policy, climate, plant/animal health, etc.

The EU agro-food sector faces uncertainties surrounding the long-term trend of agricultural prices, higher production costs (deterioration in its terms of trade), increased likelihood of (extreme) price volatility, concerns about price transmission (uneven and asymmetric transmission, declining value added) places additional pressure on farm profitability, declining rate of productivity growth, intensification of production in some areas, land abandonment or under-management of land in others and rural unemployment in the wake of the economic crisis.

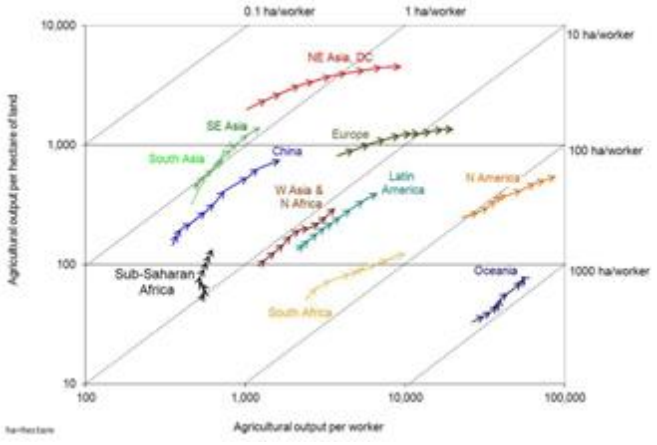
The recent **Common Agricultural Policy** (CAP) reform tries to address market failures, especially those linked to economic and environmental sustainability, policy failures in areas linked to the fairer distribution and 'green' targeting of support and '**jointness**' in delivery of private and public goods. As the CAP is constrained by a budget ceiling in nominal terms, its share in the Multi-annual Financial Framework budget is decreasing.

Main **remaining policy priorities** for EU food security relate to competitiveness, knowledge based agriculture, jobs and growth, food chain, generational renewal. To meet the challenges a multidisciplinary approach is required, with climate and environment policies to ensure sustainability, economic and regional policies to foster jobs and growth, social policies to provide a safety net for vulnerable households, health and education policies to improve food utilisation (nutrition and waste) and trade and development policies to address the external dimension of food insecurity. Policy coherence will therefore be a major requisite.

## 3. Towards solutions: can productivity increase provide the answer?

Although population growth has seriously outpaced crop land expansion, the global agricultural price index shows a long term downward trend since 1900 (Pfaffenzeller, 2011 in Fuglie, 2015). This has been possible due to productivity increase. As shown in Graph 1, countries follow alternative technology pathways to agricultural development.

***Graph 1 Agricultural land and labor productivity, 5-year averages, 1961-1965 to 2006-2010***




*Source:* Fuglie, 2015 updated from Hayami and Ruttan.

Output growth has been realized through area growth, input intensification and Total Factor Productivity (TFP) growth[9]. In Industrialized Countries input

[8] Based on Haniotis, 2015.

[9] TFP compares total outputs relative to the total inputs used in production of the output. It reveals the joint effect of many factors

intensification is contracting since the 1980s, while the agricultural area is also contracting since the 1990s. Agricultural growth is realized through increases in TFP while resources leave the sector. In Developing Countries input intensification and land expansion are still increasing, but TFP is becoming the dominant source of growth as well. SSA, the Russian Federation and some Latin American countries are however lagging behind. Fuglie (2012 in Fuglie, 2015) confirms the strong link in developing countries between national research capacity, the national capacity in extension and schooling and annual TFP growth.

Recent work from Pardey et al. (2015)[10] shows that both **public and private spending in agricultural R&D** are trending upwards, with public spending still exceeding private spending but the latter is increasing more rapidly. While spending in high income countries follows a linear trend, middle income countries follow an exponential growth curve, rapidly accelerating since 2000 and now exceeding spending by high-income countries. The majority of this growth comes from increases in private expenditure. China is now a major player, both in terms of public and private R&D spending. The total EU and USA expenditures on agricultural R&D are about equal, but the share of public spending is considerably higher in the EU. The top 20 countries in public agricultural R&D spending account for more than four fifths of global spending, while the bottom 100 countries seriously lag behind, pointing to a large spatial concentration in the conduct of food and agricultural R&D worldwide.

Productivity gains have a great **potential to lower poverty**. According to simulations by Ivanic and Martin (2015), a global productivity gain of 1% of GDP lowers global poverty by 0.5–1.5 percentage points depending on the sector (agriculture, industry, services). Improvements in agricultural productivity generally benefit the poor more than gains in other sectors, partly because so many of the poor work in agriculture, or supply the unskilled labour that is so intensively used in developing country agriculture. If an innovation is adopted only in a single, small, open economy, most of the gains to the poor arise from higher incomes of small farmers. If an innovation is adopted more broadly—or if it occurs in a closed economy—it tends to reduce the real price of food. In this situation, more of the gains to the poor come from reductions in the cost of food, which are especially important for the poor, who tend to spend a large share of their incomes on food. Small, poor farmers tend to be net gainers, even when food prices fall, because of these reductions in the cost of their food. Agricultural productivity is most effective in reducing poverty when widely adopted rather than only locally.

Stresses on production and productivity vary by region. The region around the Mediterranean Sea, and especially North Africa and the Middle East, will be most severely hit by decreases in annual precipitation in the coming decades. In dry areas, **efficient water use** poses one of the main challenges to increase agricultural productivity (Solh, 2015). Dry areas are prone to physical water scarcity, rapid natural resource degradation and desertification, groundwater depletion, drought, salinity, climate change and poverty. Challenges remain at the basin level (competition among uses, conflicts between countries, equity issues), at the national level (food security or produce for hard currency, socio-political considerations), at farm level (maximizing economic return but also nutrition in subsistence farming) and even at the field level (maximizing biological versus economic output). Innovative agricultural practices and technologies to enhance water productivity include deficit irrigation, supplemental irrigation, water harvesting for fruit trees & forage production, sustainable intensification of production systems, raised-bed production, greywater reuse, hydroponics/Soilless Culture for high-value crops and breeding for drought tolerance. Improving uptake however requires increasing investment in upscaling and prioritisation of the water scarcity issue at the political level.

One of the main challenges to increase productivity remains **access and uptake of new technologies by smallholders**, especially in developing countries, where productivity gains can still be substantial. Innovative extension approaches (Wubeneh, 2015) to monitor soil fertility, improve agronomic practices and access to inputs, such as seeds and fertilizers, and credits prove to be able to boost productivity and economic viability in SSA.

Technology development and uptake should be embedded in the **right policy environment**. Brazil for example has propelled the development of the sugar cane sector with a specific set of policies, amongst which its biofuel policy (Nastari, 2015). More

including new technologies, efficiency gains, economies of scale, managerial skill, and changes in the organization of production.
[10] Presentation not yet available

than 41.5% (in gasoline eq.) of the domestic transport fuel demand is met by ethanol, allowing for a substitution of 2.41 billion barrels of gasoline since 1975, enabling savings of USD 381.3 billion (including the cost of foregone debt). The sugarcane industry is fully deregulated since 1999. For a total investment of US$ 2.7 billion, total value creation in the sugarcane industry is estimated between USD 400-500 billion in the last 40 years. Sugar cane productivity has tripled, while industrial efficiency has also increased substantially. Room for progress is still expected a.o. from biotech and improved agronomic practices.

## 4. How to realize productivity increase in an environmentally constrained world?

### *Green Revolutions: implications for food security and the environment*

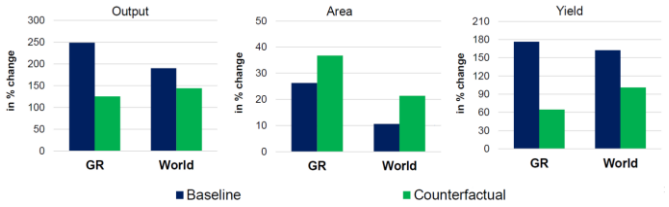
In the light of FNS, the last Green Revolution received considerable criticism, given its presumed negative environmental effects and skewed distribution of benefits (Stamoulis, 2015[11]). To face the new FNS challenges, the next Green Revolution has to be quite different in nature. The Gene Revolution will most likely be a key aspect of the new Green Revolution.

According to Stamoulis (2015), **challenges for the next Green Revolution** are the public perception of scientific agriculture as the problem rather than the solution; much more complicated goals (not only yield but also environmental and social aspects); international research systems in disarray and very few developing countries having the national agricultural research systems with the capacity to carry out high-tech research; no good mechanisms for public research systems to set objectives/priorities; public research funding being now very short term and depending on measurable impacts in a short time frame.

Hertel (2015) shows that the historical Green Revolution acted land (see Graph 2) and greenhouse gas emission sparing, while contributing to improved global food security (by improving world dietary intake by more than 300 kcal/day/capita).

The **future rate of technology change** (TFP growth) will have a critical effect on future crop prices, with slower growth rates contributing to food price rises. Climate change on its turn will likely hamper continued productivity growth.

***Graph 2 Effect of green revolution on output, area and yield between 1961 and 2006***




*Note:* The counterfactual indicates no Green Revolution. GR indicates areas where GR took place.
*Source:* Hertel, Ramankutty and Baldos, 2014.

Baldos and Hertel (2015) show that the impact of climate change on malnutrition depends critically on $CO_2$-fertilization stimulating plant growth. They also show the impact of R&D investment paths to achieve full adaptation to climate change in 2050. This technology driven climate adaptation provides environmental co-benefits, by reducing greenhouse gas emissions (GGE) from cropland conversion, and it provides nutritional co-benefits by reducing malnutrition, although required outlays are highly uncertain.

### *Biodiversity will play a critical role[12]*

Agricultural biodiversity is seen as an important part of the solution to what we produce, how and where we produce it. More biodiversity helps to provide diverse nutrient content and dietary diversity through many available species and varieties within a species. It increases the multifunctionality of production and allows farmers to limit the spread of pests & diseases. It provides more crop options for climate adaptation and the variability to adapt to different soil conditions.

Diet diversity reduces diet-related diseases and deficiencies. More diversified production systems achieve multiple functions, such as providing calories while reducing GGE and pollution, increasing soil and water quality, fuelwood and pest regulation. Both in marginal areas, areas with high seasonality and areas facing new climate challenges agricultural biodiversity offers options. However, to take full advantage of the possibilities offered by functional biodiversity, new business models will need to emerge, with more co-creation between consumers, producers and researchers.

[11] Stamoulis (2015). Introductory speech to session on the Next Green Revolution, Global Food Security Challenges conference, Milan.

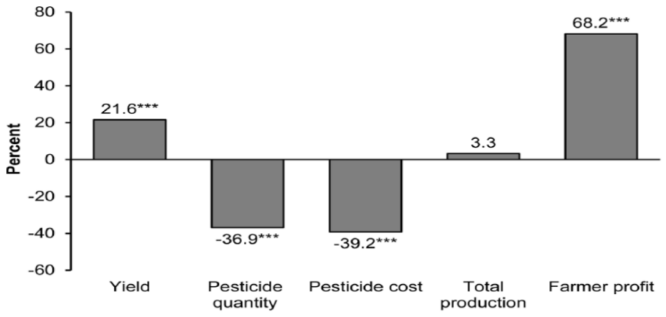
[12] Based on Tutwiler, 2015.

### *Is plant genetic engineering the solution?*[13]

Genetically modified (GM) crops have contributed to important yield increases in soybean, maize, rapeseed and cotton. Apparently, as the example of sweet potato (Kyndt et al., 2015) shows, natural genetic modification of plants by soil bacteria already took place thousands of years ago. Between 1996 and 2014 the global area of GM-crops has increased from 0 to 180 million hectares, with the developing world surpassing the industrialized since 2011. About 82% of global soybean area is transgenic, while the same are 68% for cotton, 30% for maize and 25% for rapeseed.

Klümper and Qaim (2014) show the positive impact of GM adaption on key agricultural variables (Graph 3).

***Graph 3 Impact of GM adoption on key agricultural variables***




*Source:* Klümper and Qaim, 2014.

While yields and farmer profits increase, pesticide use and costs decrease. Some other studies (Brookes et al., 2010, Trigo and Cap, 2006) report that mainly farmers (and not the seed and herbicide suppliers) profited from the GM crop adoption.

Climate change is expected to have a significant impact on production. Rainfall will affect yields, the temperature the growth cycle, solar radiation the biomass accumulation, $CO_2$-concentration the photosynthesis-, water and N-efficiency and extreme events will increase the variation. GM breeding could contribute to make crops more tolerant to drought, salt and temperature extremes. Current agricultural biotech applications in the pipeline are pest resistance beyond Bt, improved agronomic performance, increased food and feed quality, medical applications such as vaccines, environmental applications such as removing soil pollutants or even detecting landmines, adaptation to environmental stresses and resource use efficiency increase.

[13] Based on Ortiz, 2015.

### *Non-technical challenges to productivity increase in Africa*[14]

Africa's low productivity results from a mix of challenges and solutions will depend on both technological and non-technological interventions. Examples of possible technological interventions relate to improved varieties, better agronomic practices, better post-harvest management, mechanization and soil nutrients management. Non-technological interventions should focus on enabling policies, efficient and adequate markets, good infrastructure, sufficient government support, strong agricultural finance systems, adequate funding, capable institutions (seed, etc) and working extension services.

## 5. Which agricultural model(s) can jointly provide the desired private and public goods?

As already highlighted before (par. 2), agricultural production is increasingly resource constrained. A National Geographic special series on Feeding our hungry planet[15] highlights these pressures as well. More than 38% of ice free land is used for agricultural production, so agriculture is one of our biggest accomplishments. Only 55% of world's crop calories are used to feed people directly, 36% is used to feed livestock and 9% for biofuels and industry. 25% of world food calories are lost or wasted. Towards 2050, population will increase by 35%, needing crop production to double as prosperity is driving demand for more meat. Agriculture emits more greenhouse gases than all types of transport combined and clearing of farmland accelerates loss of biodiversity. Proposed solutions are to grow more on the farms we already have, to use resources more efficiently, to change our diets and to reduce waste. The question remains which type of food system is able to meet these challenges.

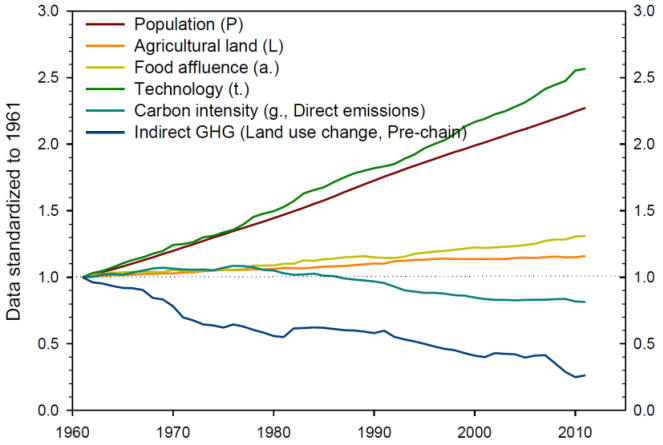
The pressure of climate change adds to the challenge of reducing the number of 800 million chronically undernourished, especially given the large share of agriculture in total emissions. Since the 1990's, direct GGE per unit food have declined (i.e. lower carbon

[14] Based on Kyetere, 2015.

[15] http://video.nationalgeographic.com/video/food-by-the-numbers/141014-world-food-day-ngfood?source=relatedvideo

intensity of agricultural production) at a slow pace (0.75% per year). Under different future scenarios (SSPs), chronic undernourishment is likely to increase with increasing $CO_2$-emissions.

***Graph 4 Global food system dynamics over 1961-2011***




*Source:* Soussana *et al.*, 2015.

### *Paradigm shifts in agricultural models*[16]

Since the 1960s, the standard agricultural production paradigm was **specialisation**, with simplified systems, increased inputs, increased volumes and reduced commodity costs as main trademarks.

Since the 1980s the focus has shifted towards the **sustainable intensification** paradigm, characterized by eco-efficiency (maximization of plant and animal products per unit of inputs or natural resources), substitution between scarce inputs and reduced emissions per unit product. This paradigm is also associated with the idea of land sparing. Eco-efficiency would allow environmentally sustainable intensification of agricultural production and land sparing for nature conservation while producing large volumes suitable for industries and exports. In the context of modernized and simplified systems, eco-efficiency can be further developed through genome based plant and animal breeding, advanced phenotyping, precision agriculture and livestock farming, 'Big data' combining soil, weather, micro-climate, remote sensing, markets, etc… with decision support models. From a socio-economic perspective it represents capital intensive systems, with low on-farm labour. Nevertheless, resilience of specialized systems is at risk by increased sensitivity to pests and diseases, and to climatic hazards, reduced biodiversity and ecosystem services (apart from production) and increased GGE per unit land (not necessarily per unit product).

The alternative paradigm of **agro-ecology** recently gained popularity. It focuses on balanced ecosystem services through system diversification, heterogeneity in space and time and exploiting ecological infrastructures better. Main characteristics are reduced external input use, increased resilience to pest and diseases, increased on-farm labour, increased biodiversity and ecosystem services and reduced GGE per unit land (not necessarily per unit product). Agro-ecology is also associated with the land sharing paradigm. Agro-ecology could develop through participatory research supported by advanced knowledge of ecological processes in agriculture and by dedicated technologies (e.g. bio-control, soil biota indicators, etc.) at field and landscape scales. However, it requires capacity building, dedicated tools and extra-monitoring time, reorganization of up- and downstream industries.

Recently, a new term emerged, **Climate Smart Agriculture** (CSA). It has been defined as agriculture that sustainably increases productivity and resilience (adaptation), reduces greenhouse gases (mitigation), and enhances food security and development. It in fact combines the virtues of the two paradigms mentioned earlier in the light of climate change. The concept also applies to the challenges of sustainable food systems and landscapes. Metrics of CSA and how risks are layered in different systems still remains unclear.

### *The nutritional dimension has been neglected*

The above addresses the supply side. While past improvements in our agricultural production (green revolution) have dramatically increased yields and food availability, striking the right nutritional balance has not been the focus of attention. Nutrition studies yield valuable insights on the importance of nutrition (Headey, 2015). Early childhood malnutrition has long-lasting impacts on cognitive and learning outcomes, adult wages, etc. The low availability of micronutrients is a major contributor to impaired physical and cognitive development. The low absorption of micronutrients due to disease is a major contributor to stunting and cognitive development. Inequities mean that adequate national and household supply does not equal adequate individual supply. Countries can rapidly transition from undernutrition to obesity, even at fairly early stages of development.

[16] Based on Soussana, 2015.

While undernutrition can be sticky, overnutrition can be irreversible.

As already exemplified, the returns to healthier food systems are likely enormous, and action now can prevent a large stream of expected future costs. IFPRI (Headey, 2015) comes with following policy implications: focus more attention on nutrition, especially once basic national food security is achieved; view food policies as one component of a broader nutrition strategy, with sanitation, water, health, education and behaviour change communication, safety nets, and other sectors; within the food sector, focus on increasing availability of nutrient-rich foods via production, trade, safety nets; and, do-no-harm: ensure food policies have no harmful health effects: e.g. farming practices; obesity and other chronical diseases. Some of the proposed implementation strategies to be tested are incentives for producing healthy foods in agriculture; a major overhaul of R&D and extension systems; the removal of supply chain bottlenecks for nutritious perishables in infrastructure and trade; subsidizing healthy food, while taxing unhealthy food; teaching nutrition in schools, especially targeting future mothers and provide income support for the poor by means of food, cash or vouchers.

## 6. Policy implications[17]

### *Main challenges for FNS*

According to OECD, for the **world overall** main challenges are contributing to the reduction of poverty, improving general income and agriculture productivity growth. To enable this, increased investments in innovation and more efficient and open markets are necessary. Production should take place where production is economically and environmentally best. This is opposed to the closing of borders and markets we see now. Overall, the good prices and farming conditions offer an opportunity in developed countries.

As ICTSD states, poverty, obesity and micronutrient deficiency are the main challenges for **developing countries**. Regarding access, the main challenge is to ensure that poor consumers but also producers can access food, as well as increasing agricultural labour. Availability can be achieved by raising farm productivity, which should also tackle poverty. Regarding stability, in the short term price volatility is the main issue, while in the longer run environmental sustainability and climate change will be major challenges. The utilisation challenge and especially the lack of nutrient intake can be met by improving the coherence between agricultural and health policy. A crosscutting issue for developing countries remains the reduction of trade distortions.

One currently prevailing narrative on global food security is that we do not need to be worried as solutions rest in eating less meat, wasting less food and a more equitable food distribution. However, this ignores that the increase in demand of food will take place in the developing countries, and production increases are necessary there; otherwise these countries would come to rely excessively on trade to meet their food security needs.

### *Prevailing policy shortcomings*

Policies look really different now compared to the past. Since completion of the Uruguay Round, agricultural domestic support has shifted from coupled to decoupled subsidies. Even though some authors question the degree of trade distortion of blue and green box support, in so far as amber box support is concerned, two of the WTO members with the largest AMS levels during the 1980s—the EU and Japan—have made substantial reforms to reduce their amber box support. By contrast, the US has seemed to move backwards with its abandoning of direct payments with the 2014 farm bill and its heavy reliance on price- and revenue-based amber box support. Price support policies popular in industrialized countries in the 1980s are now applied in emerging economies, such as India and China, creating tensions in the Doha negotiations. Lastly, crop insurance has become increasingly popular in the world, particularly in the US and China. While touted as green box programs, most insurance programs have been notified to the WTO as amber box policies. The main issue on the table is whether the rules under annex 2 (Green Box) should be revised to accommodate insurance programs. Critics challenge whether crop insurance belongs in the green box and there have already been WTO disputes (for example, US-Upland Cotton) where such subsidies have been challenged.

The emerging spread of **regional trade agreements** is also creating concern, as large countries are setting the standard for the poor. These regional agreements set the WTO aside. The question remains whether this is a necessary step to come to new agreements or

[17] This section draws heavily on the Conference's final panel debate. See Conference Proceedings for more information.

whether this means the end of progress towards a global trade agreement. Within the Doha Development Agenda, industrialized countries try to protect many of the commodities where they would lose against developing countries, making progress within Doha questionable[18]. The latter is an argument in support of multinational public institutions.

After the Lisbon treaty **policy coherence** in development issues became a legal obligation in the EU. All structural policies need to take this into account. In the EU CAP, a lot has been done to remove distortions, but some authors think further progress can be made[19]. Not only in agriculture, but also in fisheries steps are taken. The Common Fisheries Policy defines the managing of fish stocks. For the fish rights of EU external fishing vessels, many concerns of developing countries are considered, but enforcement will be important.

The Renewable Energy Directive (RED) and the EU mandate of **biofuels** have an impact on food availability. By reducing the mandate the EU shows its commitment of reducing the use of agricultural resources for non-food use. The indirect land use changes (ILUC) have an impact on land and food availability, but the size of this impact remains unclear. The surge of biofuels has pushed prices upward. The question remains whether high or low food prices are beneficial for FNS[20]. NGOs at least turned their argument around.

On the issue of **waste** reduction and the need for specific policies, opinions are divided. While some argue that the current high prices already provide sufficient incentive to reduce waste, others are in favour of more stringent policies. Wrongly devised policies however could contribute to waste creation due to avoidance behaviour. What is clear is that better data are necessary to allow for a more informed debate. Linked to this is the issue of **fair prices** and internalisation of external costs, especially related to environmental issues. Currently it is difficult to enforce the internalisation of global environmental issues (climate, biodiversity etc.). Domestic policies to reduce emissions might be offset by demand driven production displacement to other regions. With increasing productivity levels, resource use might also increase (rebound effect), which can create additional environmental burdens. The emerging complacency at the supply side (especially in the industrialized countries) is misplaced as production should be increased in the developing countries.

**Healthy food systems rarely emerge organically** (Headey, 2015). One reason is the many bottlenecks of value chains for perishable vegetal and animal products in poor countries. Another issue, the fact that people naturally do not perceive micronutrient deprivations, but strongly perceive macronutrient deprivations, instigates that policies mainly focus on calorie deprivation. A strong preference for unhealthy foods is also embedded in our human nature. Processed food, becoming more popular, contains lots of information asymmetries. Finally, due to economies of scale in production, producers of unhealthy foods have strong lobbying power. There is also a large variation across countries. This can be related to cultural differences in preferences, the prevalence of certain agricultural and trade systems as well as the maintained pricing policies.

### *Policy focus in the future*

To reduce food and nutrition insecurity further, IFPRI (Fan, 2015) argues for a rethinking of the global food system, with increased focus on quality (nutrition) and safety, diversification instead of specialization, food losses and waste reduction and gender issues. Sustainable intensification of production should include the **focus on nutrition**. To achieve this, following pathways are put forward: investing in agricultural R&D to produce more nutrition with less; leveraging smallholder agriculture for nutrition-sensitive value chains; empowering women in linking agriculture to nutrition; supporting policies and institutions for better nutrition; and ensuring safety in food systems. As IFPRI, JRC (Foresight 2030 in Mathijs, 2015) also advocates **policy coherence** and coordination to work towards a **food systems approach**. They stress the important challenge of feeding cities and recognize the crucial role of demand side dynamics (responsible consumer behaviour) to shape future food systems. OECD advocates the use of robust policies, able to remain effective in different market constellations rather than optimal policies for one type of scenario. Focus should not only rest on agricultural policies and policy coherence is a must.

[18] See also Laborde and Martin (2013). Agricultural trade: what matters in the Doha Round? IFPRI Discussion paper 01251. Available at http://dx.doi.org/10.2139/ssrn.2235660

[19] As Alan Matthews shows by the example of Uganda. If the EU would remove direct payments, Uganda would be better off, but if the EU removes trade barriers, they are worse off as they now have duty free access.

[20] This largely depends on the degree of import dependence and the structure of poverty (predominantly rural or urban) of the concerned country.

Priority rests with removing policy-induced obstacles to adjustment.

As ICST advocates, the centre of attention should be on **public goods**. Especially in the most deprived regions it is dangerous to be complacent. Environmental governance and social safety are hence a necessity. The idea of Josling[21] for a global food stamp scheme could be revisited. FAO on its turn talks about transfers to cover the poverty gap. A first step is to take the trade distortions of direct income support into account. Another step could be to make a distinction in legal terms between payments which are meant for public goods and payments for income support.

The urgency now rests upon the **supply side**, as we are moving from a demand constrained past to a supply constrained future. The EU, for example, uses income transfers, but the focus should rest upon investments. According to OECD, trade and investment openness should be part of the national policy suite. To identify the potential of **R&D and investments**, country specific reviews are a necessity. Australia for example is not excelling in crosscutting research and also lacks international cooperation. Brazil on its turn has a very good agricultural R&D system, but faces other types of challenges. Additional investment in physical infrastructure is for example necessary to get products to the markets. The Dutch on their turn place perhaps too much attention exclusively on their public-private partnerships. IFPRI also indicated the importance of sustained investments in research and development and pointed that research among many OECD countries, including the United States, is declining when adjusted for inflation. The United States will likely spend over $5 billion on its new price-and revenue-based "shallow loss" programs this year—over twice as much as it spends on R&D. By contrast, R&D spending is increasing in countries like Brazil, India and China.

How to stimulate **public research** remains an open question. Von Braun (2015, in van Meijl, 2015) argues for more attention in research and policy action on the basic causes of food insecurity, relating to lack of financial, human, physical, social and natural capital, driven by the social, economic and political context. An important recommendation from the 4th SCAR exercise (Mathijs, 2015) relates to the relation between food production and the emerging bio-economy. The main bio-economy principles (food first, sustainable yields, cascading, circularity and diversity) should be reflected in the research and innovation agenda.

***The role of research in global FNS – an EU perspective***[22]

The Steering Committee of the EU Scientific Programme for Expo 2015, a joint initiative of the European Commission and European Parliament launched on March, 21st, 2014, is preparing a discussion paper on the role of research in global food and nutrition security, in order to give recommendations for the Future European Research Strategy. Main drivers and constraints they identified are the land constraint, the decreasing yield growth, climate change, rising demand and pressure on resources.

***Graph 5 Research needs to address global food and nutrition security***


The main outcomes are first that we need research and innovation in many areas (Graph 5). Moreover, we need to do things differently. It is important to follow a 'systems'-thinking and interdisciplinary approach to connect the various environmental, social and economic aspects of FNS. To this end, we need to align and coordinate better, both nationally and internationally. The Steering Committee promotes the use of a virtuous spiral from horizon scanning to set the agenda over research into use, to societal change.

For agriculture, a **multilateral agreement** within WTO seems a necessity. There remains a huge

[21] A food stamp scheme provides food-purchasing assistance to low and no-income people. The Supplemental Nutrition Assistance Program in the US is the biggest example. See also Josling, T (2011), "Global Food Stamps: An Idea Worth Considering?". ICTSD Programme on Agricultural Trade and Sustainable Development, International Centre for Trade and Sustainable Development, Geneva, Switzerland.

[22] Based on Fischler (2015). Speech at Global Food Security Conference, August 2015, Milan.

amount of policy space[23] for countries in the area of border measures and domestic support. IFPRI expressed concern that **regional trade agreements** would allow developed countries such as the US to reap much of the market access gains without having to make concessions in the other pillars—export competition and domestic support. While regional trade agreements could allow for a soft road to multilateral agreements, they could just as easily foster a splintering of trade interests and frustrate efforts to achieve completion of the Doha Round. One option worthwhile considering might be to focus within WTO on trade in value added. Given the complex interaction between trade and food security, and, with openness to trade expected to increase further, Morrison (2015) advises to separate short term reactions from longer term strategies and to acknowledge that there is no single most appropriate policy instrument, as trade policy objectives address different food security dimensions, and differ across countries and time. He advocates focusing on policy processes instead of policies to agree on common objectives.

[23] See also Brink, L. (2015). Policy Space in Agriculture under the WTO Rules on Domestic Support. IATRC Working paper #15-01, http://ageconsearch.umn.edu/bitstream/207090/2/WP15-01%20Brink.pdf.

## 7. Conclusion

### *Important challenges remain, new are upcoming*

Population and income growth will put further pressure on our already constraint resource base. While availability of nutritious food remains an obstacle in some regions, the challenge of climate change will likely exacerbate the issue. Limitations in access to food mainly relate to persisting income disparities, while the food utilization challenge is linked to both under- and overnourishment. Stability largely depends on the resistance of the supply base to shocks, of which climate change is the most prominent.

### *Options for the future*

To tackle the issue of FNS, a food systems approach, with coherence across many domains, is advocated. At the demand side, the issues of nutrition and health are becoming increasingly central to the discussions. At the supply side, agricultural production has the challenging task to simultaneously provide private and public goods. A next Green Revolution has the potential to further increase productivity in the light of climate change while limiting additional stress on our resource base. Which production practices to stimulate remains an issue of debate. Different agricultural models based on different principles are emerging. While many of the solutions could be region-specific, the global interplay demands coordinated approaches, amongst others in the trade policy arena. Increased linkages between public, private research and practice are another prerequisite.

## 8. Additional information

The program and all presentations to which we refer can be found on the following website:

http://ec.europa.eu/agriculture/expo-milano-2015/cap-events/global-food-security-challenges_en.htm

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