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Challenges for food system adaptation today and tomorrow

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ABSTRACT

Global environmental change presents both old and new challenges. A far more systematic application of existing science in the entire food chain is essential to meet future food needs. While this is daunting enough in itself, new questions present themselves through changing food habits and global environmental change. The immediate challenge is to adapt plant, animal and food systems to changing temperature, nutrient and water conditions. To develop sustainable food systems in the long term, the paper discusses a set of considerations such as food demand response, resource efficiency, GHG emission limits and provisions to reduce vulnerability. Finally, some factors are presented to reframe the nature of food systems: multifunctionality, globalisation, food and fuel prices, consumer behaviour and state support to food production.

1. Where we stand in understanding food systems today

Forty years ago, in 1968, when an exciting period of global social and technological progress was about to start, world population stood at about 3.5 billion, and the threats of massive famines similar to those in Biafra and Bengal seemed still immediate. In many countries, a new generation of students was aiming at combining, often unsuccessfully, personal freedom and social progress. They looked at the world in a rather simple and optimistic way. If they thought of climate at all, it was nuclear winter that concerned them, not the emission of greenhouse gases. The cold war divided the world in clear portions, and to that young and eager generation all developing countries were poor and without infrastructure and needed help. Many thought that capitalism, as symbolised by multinational companies, was inherently bad, and that true development could only come from a centralised socialist state. Many of them went on to study subjects that were considered of practical relevance to the world. Scientific progress in the fields of agronomy, nutrition and development appeared equally simple. The introduction of Green Revolution varieties of rice and wheat proved to be extremely promising. IR5 and IR8, which went on to conquer an enormous area, were actually among the earliest crosses made in the breeding program (Chandler, 1982). The biological basis for higher yields was obvious: adding nitrogen (and a few other nutrients) and water, creating shorter plants with a better harvest index to resist lodging, and intensifying pest control. This would be combined with shorter growing cycles and mechanisation for quick turn-around land preparation. All this would result in more efficient multiple cropping and a doubling of area and yields. Rice processing was to be improved in order to reduce losses and preserve nutritional quality, and stocks had to be better protected from pests. Equally simple, food processing was a matter of introducing the right types of mills and hand tools at village level. The recipe of the decade of the 1970s was to solve food availability by producing higher yields, more calories and more proteins.

Progress seemed so easy in those days, even if from the beginning the social costs soon became visible in the number of landless farmers thrown off their land and the morbidity and mortality resulting from the excessive use of pesticides and water pollution. Experimental yields quadrupled and slowly countries such as India that had always experienced food deficits became surplus producers.

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Agricultural and food science and politics have learnt many lessons since the naïve optimism of the 1970s. It soon became clear that the ecological effects, on and off site, of the heavy use of chemical inputs needed to be dealt with, that breeding techniques requires elaboration to select species for adaptation to multiple stress factors rather than just pest or abiotic stresses alone. In food processing, monitoring losses and quality and appropriate technology became the standard. Animal breeding could not be neglected while animal traction had only limited applicability. Regretfully, the Green Revolution, even with its social and ecological adjustments, appeared not applicable everywhere: for example roots and tubers were not amenable to this approach, and its application in Africa remained piece meal (IAC, 2004).

As a result, there have been considerable adjustments in the way we see the role of agricultural and food technology today: not as an external source of change, but as a fine tuning of ecological and technical processes in a given socio-economic and cultural setting. In nutrition science, the old idea that calories and proteins were the limiting factor followed by the emphasis on micronutrients, has evolved towards a better understanding of the physiological, psychological and economic potential of individual to react to food scarcity and food surplus (ACC/SCN, 1998). Agronomy itself became the science of agriculture, ecosystems and environment, to refer to the title of one of the many new scientific journals that sprung up in the 1980s and 1990s. The aim became to fertilize and irrigate the plant via its roots rather than the soil, and to close nutrient cycles in animal and horticultural production as much as possible and even create agricultural systems without soils. Similarly, the focus moved to manipulating tritrophic relations between plant, pest and predators through Integrated Pest Management, and to designing new resistance mechanisms to pests and diseases in animals and plants. Much of this work was facilitated by the rapidly growing understanding of the detailed genetic basis for plant and animal behaviour. Unfortunately, that very knowledge also caused public concern and misunderstanding that was addressed inadequately and often too late.

In terms of social and economic development science, it was discovered quite soon that farmers are unable to use new technology if they have no secure land titles, and no access to reliable financial services and credit, or to marketing and inputs. Progress halts if there is no articulated demand for farmers' products. This, more so than climatic vagaries, is what nearly always limits productivity.

In all, since the 1960s, world population has doubled while the available calories per head increased by 25% (FAO, 2004). Worldwide, households now spend less income on their daily food than ever before, in the order of 10–15% in the OECD countries, as compared to over 40% at the middle of the last century (OECD, 2004). Even if many developing countries still spend much higher but declining percentages, the diversity, quality and safety of food have improved nearly universally and stand at a historic high. Even if a decreasing number of people acknowledge it today, the application of agricultural and food system science has been one of the great success stories of mankind, and it has been such a success story because of the collective capacity of humankind to adjust to the lessons learnt.

2. The "business as we know it now" challenges

Yet there is no reason for complacency and no room for naïve optimism about technological progress in the future. The need to produce more food for a growing and increasingly urbanised world population, involving at least a doubling of cereal yields and a 75% increase in meat production by 2030 (World Bank, 2008) is as urgent as ever. We know now that the human impact on the planet leaves no ecosystem untouched and that the effects of food systems are all pervasive (MEA, 2005). Globalisation and the end of the Cold War have created vast opportunities in areas that were thus far isolated and poor. Young people are moving out of the agricultural and food sector at an ever increasing speed, and universities do not attract the brightest students any more for these subjects. In fact, the entire generation of practical agricultural and food engineers who started to study in the late 1960s and early 1970s, is phasing out rapidly. They leave a void, as they are likely to be replaced by modellers, IT nerds and bio-engineering specialists who have little practical experience in breeding, soils or food packaging for example. In the area of nutrition, we now know that food habits are not fixed and change very rapidly within as short a period as one generation. Even modest affluence means a massive shift towards higher intakes of animal proteins, fats and sugars. For the first time in human history the number of overweight people vastly exceeds the number of hungry people (Popkin, 2006).

Compounding these transitions, global climate and environmental change imply a new set of challenges, even if many of these can be related to the earlier ones of dealing with the vagaries of weather. What is new is the speed at which change occurs, the global linkages and the number of people affected. It is too early to say whether the aggregate result on the food system of climate change is negative or positive, but it seems likely that it will lead to more fluctuations in production in response to weather variability and possibly increased probabilities of extreme weather events. Global land use effects in terms of area needed for future agricultural needs are predicted to be very limited, but locally area expansion may be expected due to unfavourable weather conditions. Climate change is likely to influence plant and animal growth through changes in CO_2 levels, day and night temperatures, precipitation, lengths and dates of onset of growing seasons, rainfall variability, wind speed, and pest and disease build up; and also through changes in sea level, in groundwater tables and salt intrusions. Insect-borne diseases may become an important problem. In the main regions affected in the relatively short term by reduced precipitation, i.e. Africa, Australia, the Mediterranean and the Middle East, yields are projected to decline due to water and heat stress. Roughly speaking, in the northern hemisphere, agro-ecological zones will tend to move towards the north and yields may actually increase. As such the shift of production systems should not pose major difficulties since their speed, even if counted in years, ought to be slow enough to adjust cropping patterns. Countries with very low population densities or very mature economies will have the smallest adjustment problems.

The immediate challenge now is to optimise plant and animal types and cropping and animal systems to changing nutrient, CO_2, water and temperature conditions. The aim is to create agro-ecosystems that are climate resilient, flexible and adapted to new pest and disease pressures. In marginal areas, tree crop and pasture optimization will provide interesting alternatives. Specific localised challenges lie in adapting agro-ecosystems to changing hydrological conditions such as high water tables, flooding and salt intrusion, and, conversely, to persistent drought and low soil organic matter levels. In food processing, the use of alternative energy sources such as solar and biomass as decentralised options will need to be explored. Nutritionally further improvements in food safety and quality are needed, such as improved slaughter house practices, cooling and transportation.

The overriding question then is: what constitutes a sustainable food system in the light of these new challenges? There are two ways to look at this question: the ''business as we know it now'' view, which should not be confounded with a business as usual scenario, and the pro-active, long-term innovative view. Business as we know it now implies that we apply what we know at this point in time, anticipating the challenges of a growing population and their increasing needs for safe and balanced diets, making use of the best of existing technologies and taking into account the changes that result from climate change and shifting agro-ecological zones. From such a perspective it becomes possible derive a simple set of considerations to define sustainable food systems.

3. Considerations for sustainable food systems

Firstly, *a sustainable food system is productive and responsive to changing demands*. As all of the demographic increase is expected to take place in the developing world, where the potential of food production growth may not be as easily achieved as in the developed world, this implies massive investments in promoting modern technology and infrastructure. We may expect the majority of calories to come from the rather limited range of plant and animal species currently in use, although some varietal diversification may be expected (especially in horticulture). Rice consumption worldwide is expected to decline in favour of wheat (IFPRI, 2007). Temperate vegetables will slowly replace tropical vegetables in the lower latitudes while the inverse also happens, tropical fruits being increasing consumed in the temperate zones (Fresco and Baudoin, 2002). The greatest challenge will be the steeply growing demand for animal proteins, including eggs, dairy and fish, from urban populations. This will cause massive transfers of feed from other areas (and hence transfers of soil nutrients such as N and P), as well as major risks for veterinary public health (such as avian flu). Nevertheless, all of this involves well-established production increasing technology on well-known species. One may call it an improved, greener version of the Green Revolution (Conway, 1997).

Secondly, *a sustainable food system is resource efficient*. Resources such as land, labour, energy, agrochemicals will become scarcer and hence more expensive or must be limited to reduce the environmental impact. Little unused land of adequate quality is available worldwide and the unintended side effects of past intensification must lead to new modes of ecologically sound efficient production on existing land areas. Even more than in the past, natural resource use intensification is the only way out. Hence the development of production systems that aims for optimising resource efficiency close to its biological optimum and to maximise output per unit of labour. This trend may be modified somewhat by an increasing interest in local products and biological or organic agriculture at least among urban professionals, but worldwide this will remain marginal. Optimising resource use efficiency implies not necessarily aiming for maximum output, since for most resources below maximum input leads to the best possible resource use. This has been demonstrated for many inputs, mostly notably for water and nitrogen (Garabet et al., 1998). In the short term, however, the use of many inputs will increase as will leaks to the ecosystem, particularly of nitrogen and biocides. Many techniques exist, however, to reduce losses to the environment, and to capture nutrients such as phosphate through the reuse of water. Their introduction and application are a function of how quickly market failures are addressed. Efficiency will often mean adapted forms of irrigation such as deficit irrigation and vastly expanding irrigation in Africa where only 4% of the agricultural land area is currently irrigated as compared to 39% in South Asia and 29% in East Asia. In terms of pesticides, advances in pest and disease management in greenhouses present an interesting model of resource use efficiency. Not only because of IPM, but also because the combination of short-day length and high temperatures in winter reflect the conditions of temperate agricultural systems under global warming (Kiritani, 2006).

Thirdly, *a sustainable food system puts explicit limits on emissions of GHG and imposes strict energy efficiencies along the entire food chain*. It aims to close, to the extent possible, energy, nutrient and water cycles, in order to reduce disturbance of global biogeochemical cycles. It explicitly factors in total energy costs. Ultimately, food products from sustainable food systems will probably carry labels to quantify their resource use and emissions.

Fourthly, *a sustainable food system is responsive to changes in the opportunity costs of labour, and allows for mechanisation*. This is perhaps counter intuitive, as agricultural employment seems a short-term way out of poverty. But, in the long term, economic growth leads to further urbanisation resulting in a rapidly decreasing labour force in rural areas, since young and physically able people will tend to leave. Even those who stay and manage to find a living in farming and food production, are unlikely to accept the hardship that comes with manual labour. This will force mechanisation, in a locally adapted form, and labour productivity rises. Only in this way will farming remain attractive and profitable to young entrepreneurs.

Fifth, *a sustainable food system ranges from producer to consumer, from farm to fork*. Although, the term food system or food chain is now common, it is used too loosely and often does not include post-harvest, processing, marketing and storage, where up to 40% of the losses may occur. It is only through the optimisation of each component of the food chain that food security can be achieved. A noted exception is Ericksen (2008) who takes a similar holistic approach.

Sixth, *a sustainable food system includes provisions to reduce vulnerability*. This must combine physical structures such as (regional or local) stocks and economic incentives, e.g. crop and animal insurance. Vulnerability reduction implies not only risk prevention, but also provisions for disaster management such as safe areas for cattle, seeds and local food stocks in the case of flooding.

To conclude: in the "business as we know it now" scenario of future food system development, although there are economic uncertainties, scientific knowledge is not the limiting factor. Existing agricultural and food processing technology when duly adapted to changing conditions will most probably allow the world to deal with most of the medium term adaptation needs. The best safeguard against vulnerability is after all high productivity in systems that reduce environmental impacts to a minimum.

4. Rethinking food systems

There is, however, yet a wider set of challenges resulting from global environmental change (rather than climate change alone), increasing globalisation and future technological, economic and behavioural shifts. Potentially, these factors may break the trend and provide different answers than the ones that emerge from the "business as we know it now" scenario.

Dealing with global environmental change in food systems involves also new energy solutions, further applications of information technology, new insights in medical and pharmaceutical sciences and changing consumer demands for tailor made individual foods. In 2030 or beyond food systems may look quite different from what we know now. As an illustration one may think of:

- The return of semi-urban agriculture, at least as intensive vegetable or poultry production concentrated on the roofs of industrial or office buildings with excess heat stored in aquifers or used as additional heating.
- Aquaculture not in sea or surface water, but in land-based closed basins with new feed sources such as mud worms.
- The systematic recycling of plant nutrients from urban waste.
- Meeting future protein needs from new species lower down the food chain such as algae.
- Meat substitutes from soy or lupins.

More generally an examination of some of the current and new ideas about food systems, may help to shift our thinking.

4.1. *Multifunctional food systems*

Food production, in all its diversity, will remain the single most important form of human land use, and in the centuries to come, the vast majority of our calories will continue to be produced on land. Many species produce more than one product that is useful to man: dual purpose sheep are bred for meat and milk, maize in Africa is used for grain, feed and roof thatching (as well as to raise SOM). Historically, increasing specialisation has often favoured one type of use over others resulting in food systems that focus on single products. Multifunctionality or non-food use of food systems may grow, in two different ways. On the one hand, carbohydrates, proteins, lipids in food (or feed) may become products along with other by-products. Biomass such as stems and leaves (cellulose for biofuels), or secondary metabolites ('pharming') in particular pharmaceuticals and nutriceuticals (insulin from cow milk, etc.) may become equally important to primary food products. This may also lead to systems where food processing is powered by biomass by-products from the same plant or animal source. Hence, food systems become multifunctional.

On the other hand, there is growing economic recognition for the social and ecological services of agriculture, such as maintaining rural livelihoods, protecting watersheds and managing open landscapes. This has already led to agricultural systems where, say, maintaining landscape diversity is as important as production (for example in Tuscany, Italy where olive production has become the by-product of landscape management). This could be called multifunctionality of land use.

While overall multifunctionality may increase, it is too early to say if the overall trend might be towards specialisation in high potential areas and multiple purpose production in other areas. Multifunctionality also corresponds to a cradle-to-cradle type of approach that has been developed in industry: every type of waste or emission is an input into a new system, so no waste exists and all by-products are taken up in secondary processes (McDonough and Braungart, 2002). This could be coupled with an advanced glasshouse model, coupling energy, water and CO_2 captured from industrial plants, and using aquifers for storing heat and cooling in summer.

4.2. *Globalisation*

The overall development of food systems depends on many economic scenarios that are hard to predict. They may range from full globalisation with entirely open economies to regionalisation and even increased national protectionism. It is generally understood that further globalisation will lead to more specialisation with the production of many food products moving to countries with low labour costs and optimal climate conditions. Any further globalisation of input and output markets as well as further concentration of corporate food systems are fundamentally changing opportunities for all those involved in food systems, and small farmers in particular. While small farmers and retailers still dominate in the developing world, horizontal (between similar companies) and vertical integration (along the supply, production and processing chain) are increasing dramatically. Globalisation also implies labour migration, some of it regional and seasonal, some of it more permanent. The conditions of employment should be subject to review by national and international bodies such as ILO, and are part and parcel of sustainable food systems. The dominance of a relatively small number of companies on the input supply side (seeds, chemicals) and on the demand side (food processing, retailing) presents both risks, such as increased dependency and market volatility, as well as opportunities for new developments, as these branch out to non-food uses.

The overall question is to what extent market forces will promote food system sustainability as consumer awareness increases and technology develops a sounder ecological basis. Or to put it differently, if market failure occurs, how national and international regulation is able to redress the negative social and environmental effects of food production and distribution. The thinking about the mechanisms to address market failures such as the marginalisation of small producers or the veterinary public health risks of intensive poultry production is still in its infancy. This ought to be a matter of national and international concern.

4.3. *Food prices (or the food versus fuel dilemma)*

One of the major issues is to understand the factors that influence food prices and their effects, in the long or short term, on the adaptive capacity of food systems. Many have expressed the fear that high food prices would lead to massive hunger and even threaten world peace (for example WFP, 2008). Food riots occurring in politically unstable countries are not a sign that the world is on the brink of starvation, now or in the future. Firstly, food is not oil, it is a renewable resource that cannot be exhausted, as food production renews itself with every growing season through photosynthesis. With the possible exception, in the long term, of phosphate (that is retrievable from waste and irrigation water), the inputs for food production (solar radiation, water, N, and K) are not globally deficient, even if there may be local shortages (in particular water). Food is grown by a billion or more small farmers who do not act like a cartel. Hunger is a matter of purchasing power, or entitlements, not of absolute shortages (Drèze and Sen, 1990).

But food is like oil in the sense that as a set of commodities it is up for speculation. On futures markets, a dry summer in the main producer countries drives up the prices. The current price increases must be seen against the historical low of food prices around 2000 and the long-term downward trend (Braks, 2007). Structural and conjectural factors explain the rise today. The extremely rapid growth in demand in countries like China, India, Brazil, Central Europe for food grains, feed, beer and animal and fish products has surpassed the growth in production. Food production is relatively inelastic and cannot adjust immediately to higher prices, which has led to declining stocks. The increasing energy prices have also affected agriculture through land preparation, transportation and processing costs. Another structural factor lies in the suboptimal weather conditions in Australia, Southern Europe and North America. The US and EU fallow regulation that has taken up to 10% of the agricultural land out of production and the quota for products like milk have created artificial shortages. Finally, large amounts of liquidity floating in the international market as a result of the financial crisis in the US and the overall nervousness have further contributed to price volatility. This has caused several countries, including China and Argentina, to take measures to restrict exports, causing further price effects.

In contrast to public perception, modern biofuels do not (yet) have a major *direct* effect on global prices to date. However, in several countries their share is increasing rapidly as a result of government policy and subsidies, in particular in the US. There are also cases where food crops are directly driven from the land by biofuel crops, but such substitution does occur more logically with feed crops. The global area under biofuels area is still very small (about 1% of total agricultural areas) and so its global price effects, independent from the conjectural and structural factors above, is expected to be limited. It is to be noted prices of all major grains are increasing, also of wheat which is not a biofuel crop. As a further indication that biofuels only play a minor role in the current rise of food prices, is the declining price of sugar, an important ingredient for ethanol which had its peak in 2006. Nevertheless, at a local scale competition may occur and have major effects, leading to high prices and land clearings, such as in the Amazon where deforestation is on the rise again.

In all, we may expect food prices to remain volatile and high for several years, even if the market will eventually restore itself—that is, if farmers get a fair chance to react to world market prices without governments restricting access. In themselves, high prices also present a chance to food systems, as long as guarantees are in place to promote sustainable production and access to food by the poor. National policies must be put in place to avoid market distortions and, in particular, the effects of biofuels should be carefully monitored (Fresco, 2007).

4.4. *Transparency of food production and distribution*

The sustainable production and provision of healthy foods will not come about automatically as a result of policy declarations on food health and safety. Consumer behaviour needs to change, and consumers need to be guided by transparent systems that guarantee the quality and conditions of production of food. This is not only a luxury for western countries but one which most developing countries need as well, if only because they will be increasingly exporting food, but also to protect domestic consumers from unsafe food. At the same time, concern about the use of genetically modified products has hardly decreased. Hence, there is an urgent need for transparency and adequate information. The need for information has led to a bewildering array of partial and parallel labels of unequal nature: fair trade, energy and biological or ecological labels cover each a selection from a wide variety of poorly defined criteria, from transportation to child labour to endangered species and use of pesticides. There is no internationally agreed label on GHG emissions or food miles or carbon footprints related to food. The entire production chain needs to be documented, including processing and distribution, and especially suppliers from developing countries. Independent international bodies for the certification of production processes and monitoring are a requirement. This applies not only to food but also to products potentially competing with food such as biofuels. Food labelling and certification are extremely complicated and politically charged matters, not least because of issues of WTO compliance. It is expected that the lifecycle GHG reduction component is expected to be WTO compliant, while other environmental and social dimensions of labelling and certification may be challenged.

In view of the adaptation of food systems to climate and global change, there is a vast number of national and international bodies and agreements that deal with quality definition, control and information, ranging widely from the Codex alimentarius, the OIE, the Code of Conduct on Pesticides to ILO labour standards and various food industry standards. They need review to assess their coherence with what is needed to promote the transformation to more sustainable and climate resilient food systems.

4.5. *Meat and mitigation: consumer behaviour*

Information is a necessary but not sufficient condition to foster shifts in consumer behaviour towards sustainable food systems. The case in point is, of course, meat consumption with its well documented environmental – deforestation, methane emissions from cattle – and public health effects (FAO, 2007). In the short-term meat consumption will continue to increase. Yet there are signs in the OECD countries of consumers systematically reducing their meat intake. Companies are currently reviving the earlier technologies of meat substitution through textured vegetable proteins, for example from lupins. Considerations of food safety as well as the increasing awareness of the role of food in human health will also steer the research and adaptation agenda.

More in general, consumer demand for more sustainable or ecological products (which are not necessarily identical), is still mostly limited today to the urban upper middle classes, but this will strengthen considerably in the coming decade. There is another dimension: markets for biological or ecological products are gradually developing, at least among the middle class. Awareness of food miles and a search for traditional diets has led to a return to local or regional production and supply patterns. While these are not aimed at the majority of the rural poor, this may promote some form of peri-urban niche markets that could help small farmers in a new way.

4.6. *Politics and state support for agriculture*

In the end, food security is the responsibility of the state. This does not mean that food security necessarily requires state intervention. The state has a role in providing the conditions for sustainable food systems, through a combination of fiscal, legal and policy measures. There is probably a strong positive relationship between food security, food safety and democracy. The state sets the conditions for the market to operate – e.g., through standards for food composition and labour conditions – and supervises the results. Markets operate within this framework, and only where markets fail, the state must intervene. This is the case, for example, when disaster strikes, or, more commonly, where farmers in disadvantaged areas cannot compete on a level playing field with others and need to be compensated for the marginality of their lands, as the EU does with its mountain areas. In nearly all countries, direct support to farm income or production per hectare is phasing out. What will remain is support for special areas or ecological services of agriculture such as watershed or biodiversity protection. The sensitive question is if such state support distorts the level playing field for farmers. Harmonisation of environmental regulations and ecosystem services that can be rewarded will be a priority in future negotiations, for example in the review of the European CAP.

4.7. *Food systems and development*

Vulnerability of food systems is not limited to developing countries, but it is most pervasive among the poor who have no resource buffers (land, savings or food stocks) or funds to escape food system failure. We need to transcend the simplistic term 'developing countries' and to classify countries more precisely in terms of their food systems, their technological levels, the proportion of the labour force in agriculture and other relevant variables. The countries most at risk are those where poor farmers are unable to compete on the world market for reasons of quality, production volume or price, but where the agricultural sector constitutes the major and often only export sector and hence few other employment opportunities exist. Although, this may still be contentious under WTO rules, there is a case here for temporary state support to allow agriculture to grow and diversify. In areas with poor market development and weak or failing governments it will be most difficult to reform food systems. This is a global concern since nearly the entire growth in production needs to take place in the so-called developing countries which also have the lowest average yield levels and face many of the most serious threats to the environment. Moreover, the urban and industrial sprawl of mega-cities, nearly all of which are located in developing countries will displace many farmers. By the middle of this century as many as two-thirds of the world population may live in urban areas.

In development circles the dominant approach is often based on ''small is beautiful'', i.e. marginal improvements with simple technology and on an emphasis on disadvantaged areas. However, important these are from a humanitarian point of few they will not provide the staple basis for long-term food security. Unfortunately, few systems are potentially as environmentally destructive as unfertilised annual cropping on slopes in the humid tropics (Webster and Wilson, 1973). Promoting productivity from marginal lands is doomed to fail unless it is sustained through considerable economic support.

Rural poverty is expected to remain more prevalent than urban poverty during the next decades so the challenge will be to create employment within and outside the food system while increasing productivity. It is impossible to look at rural areas in isolation today without concentrating on rural–urban linkages. In many cases employment will be found more easily in food processing than in primary production, but this requires investments which are currently not available. This may change now that the major donors of development funds, such as the EU and the World Bank, appear to be reversing the trend of neglect of the agricultural and food sector (World Bank, 2008). In this context, it should be noted that sustainable food systems in the broad sense used here are notably absent from Millennium Development Goals (with the exception of hunger and poverty) and poorly reflected in Agenda21. This requires further discussion on the implementation of the MDGs at various upcoming occasions (2010 UN General Assembly, Johannesburg +10, etc.).

5. Last but not least: Food System Policy

Global environmental change presents old and new problems to food systems, requiring a fine tuning of well tested existing solutions and innovative ideas. This implies the incorporation of the most advanced science, particularly in genetics where rapid advances can be expected in understanding plant or animal response to combined biotic and abiotic stresses. Work in food systems should now rigorously move beyond an agronomy-based approach and involve food processing, transportation and distribution. This includes energy and an analysis based on resource cycles rather than production alone. The driving force in the world is consumer demand, not farmer supply. In particular, developing sustainable animal protein production chains will be the greatest challenge. No progress will be made without the private sector: each farmer is a business man or woman in his own right, and there are many examples of successful cooperation among farmers and between farmers and larger corporations. The current high food prices, the increasing awareness of climate and deforestation issues and the concern about unhealthy diets provide fertile ground for new awareness among urban decision makers and consumers. To what extent global warming beyond 2 °C will stretch the limits of existing food systems and hence requires a drastic overhaul of agricultural and food policies remains to be seen. Much depends on the speed of such a temperature increase and the potential of science to apply new insight to changing crop, animal and food chain characteristics. Governments are well advised to take a pro-active strategy and invest more rather than less in food system research.

One issue remains: the concept of food system itself is poorly reflected in institutional terms. Notwithstanding occasional overlaps, the fields of agriculture, food processing, nutrition, marketing and consumption are still miles apart. The responsibility for these different fields lies in the hands of many different bodies, both nationally and internationally. There is a great need for an integrated approach, linking national and international food system strategies. We should be concerned about the manifold separate processes dealing with aspects of food systems and global changes. What we now require is a transparent and pro-active strategy for food systems, focusing on production and processing, access and utilisation, and involving agronomy as well as nutrition, economics and social science. Such a strategy should go well beyond the partial attempts in various OECD countries to aim at improving diets, or the NEPAD agricultural production strategy. It should be nationally and regionally based but internationally inspired, fully recognising the intricate linkages between food systems in the world: the fact that each of our meals is composed of ingredients from many different countries, produced under a variety of ecological and economic conditions.

Soon we will live in a world where never before in human history the responsibility for the food of so many has been borne by such a small minority of farmers and food processors and retailers. A minority that is barely recognised by an increasingly dominant urban population, and often blamed for many of the ills of environmental damage and globalisation. In bringing about such a policy, based on new thinking, we need the concerted efforts of all, science, government, the UN and other international and non-governmental organisations. Food needs to become an issue of concern to all and needs to be put back on the political agenda as well as on the educational curriculum. Because, in the end, food is what links humankind, now and in the future.

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