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Towards Efficiency & Resilience in Agriculture for Food Security in a Changing Climate

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Abstract
Agriculture has to address three intertwined challenges, produce enough food, adapt to climate change and contribute to mitigate climate change. In order to ensure food and nutrition security and to meet an increasing demand, production has to increase, particularly in developing countries. Climate change, both increased variability and slow onset changes, will impact food systems, especially where they are already most vulnerable. Agriculture is also called upon to contribute to mitigate climate change. Considering the necessary increase of production, it can do so by reducing emissions per kg of output and by enhancing carbon sinks. These three challenges require radical changes of food systems towards more efficiency in the use of resources and more resilience to shocks. These two aims of increased efficiency and resilience shall be considered at every scale, from farm to global levels, taking into account environmental, economic and social dimensions. They can be declined in technical aspects for agricultural systems and food chains. Comprehensive policies are required to increase systemic resilience and efficiency at every level. They call for increased coordination between international food and nutrition and climate change fora.

Introduction

Agriculture will be and is already the first "marker" of climate change. Since the beginning of the climate negotiation, the fear that climate change might disrupt the food system was present. This is why, already in Rio 1992, the ultimate goal of the Convention on Climate Change calls for a stabilization of GHG in such a time frame "to ensure that food production is not threatened". We now know that food production will be, is, threatened. It is a global concern, for exporting countries, but especially for countries that need to import food, that are dependent on importations, because food will be less accessible and more expensive.

Agriculture has now to face three intertwined challenges: first, it has to produce enough food, secund, it has to adapt to climate change ("manage the unavoidable"), third, it can contribute to "avoid the unmanageable", and take part in the global, cross sectoral efforts to mitigate Climate Change, without compromising food production. Meeting these 3 challenges all together requires radical changes of food systems worldwide, towards more resilience and more efficiency.

A: Three intertwined challenges

1) Ensuring food security

The world is globally producing enough food but there are still 925 million people estimated to be undernourished in 2010, representing almost 16 percent of the population of developing countries (FAO 2010a), and 2 billion malnourished people, lacking essential micronutrients. The paradox is that 60% of the malnourished actually are food producers, smallholders and pastoralists, with 20% in cities and 20% landless rural people. For the poor producers, food is not only a basic need, it is also the only and fragile support to their livelihood. What is true at the household level is also true at the macroeconomic level: there are 32 countries in food crisis needing international emergency action, 20 of them in Africa. In most of these countries, paradoxically agriculture is an important, if not the major, part of economy.

The objective is to ensure food and nutrition security, worldwide. It is not only availability of calories and sufficient global production which has to be ensured. We need also to have enough food accessible to everyone, everywhere, physically and economically. It is also utilization: the need to have the right food in quality and diversity. And to ensure the stability of these three components (availability, access, utilization).

The world population will increase by a third from now to 2050. This 2 billion increase will be in developing countries. And in the same time there will be much more people living in cities (70%, against 50% now). Urbanization and income rise in developing countries are driving an increase in the consumption of animal products (FAO, 2009a). Considering these trends, FAO estimates that, business as usual, production will have to increase by 70% to 2050 to satisfy the expected food and feed demand (Bruisma, 2009). Demand for biofuels is another important factor. It is very dependent on national policies and it is expected to grow. According to the OECD/FAO projections, because of increasing mandates and consumption incentives, it is expected to double between 2005 and 2019 (OECD-FAO 2010).

2) Impacts of CC on agriculture

Climate change is suspected of having already significantly impacted agriculture (Lobell et al, 2011) and is expected to further impact directly and indirectly food production. Increase of mean temperature, changes in rain patterns, increased variability both in temperature and rain patterns, changes in water availability, frequency and intensity of “extreme events”, sea level rise & salinisation, perturbations in ecosystems, will have profound impacts on agriculture, forestry and fisheries. Their extent will depend not only on the intensity of the changes but also on their combination, which are more uncertain, and on local conditions. Anticipating appropriately the impacts of climate change on agriculture requires data, tools and models at the spatial scale of actual production areas. Since the last IPCC report in 2007 some studies attempt to do so and provide projections at such a scale, which enables to have a more concrete vision of projected changes.

A prospective study in Morocco (WorldBank 2009b) points to gradually increasing aridity because of reduced rainfall and higher temperatures, with negative effects on agricultural yields, especially from 2030 onwards. Rain fed crops are expected to be particularly affected. If irrigation water continues to be available in sufficient quantities, irrigated crop yields might continue to increase in spite of climate change. But it will be dependent on the availability of irrigation water. In this study, if agricultural yields will remain more or less stable up to 2030, they are predicted to drop rather quickly beyond this date, more markedly in the case of IPCC scenario A2 than in that of scenario B2.

A prospective study in Brazil (EMBRAPA 2008) shows dramatic changes in the potentials for the various crops analysed and of their potential geographic repartition. Globally, the increase of evapotranspiration induces an increase of the areas at high climatic risk for 7 of the 9 crops analysed (cotton, rice, coffee, beans, sunflower, millet, soya bean) and a decrease for cassava and sugar cane. It will also induce important displacements of crops’ areas, especially for coffee and cassava. In traditional production areas, coffee would be affected by lack of water or high temperatures. In the States of Sao Paulo and Minais Gerais it would not be cultivated anymore in areas where it is now cultivated. On the contrary, with the reduction of risk of frost, there could be an increase of the production area in Parana, Santa Catarina and Rio Grande do Sul. As a result, the global area at low climatic risk for coffee would be reduced by 9,5 % in 2020, 17 % in 2050 and 33 % in 2070. On the contrary, favorable areas for sugar cane will considerably increase.

Impacts of climate change will thus have major effects on agricultural production: a decrease of production in certain areas, an increased variability of production, and up to necessitating important changes in the geography of productions.

Local impacts will bring global imbalances, with, broadly speaking, climate change leading, everything else being equal, to an increase, in both crop and livestock productivity in mid to high latitudes (IPCC, 2007) and a decrease in the tropical and subtropical areas. Among the most impacted countries, figure economically vulnerable countries already food insecure and some important exporting countries. This will induce profound changes in trade, with impact on prices and on the situation of net food importing countries. Therefore climate change is expected to increase the gap between developed and developing countries through more severe impacts in already vulnerable developing regions, exacerbated by the relatively lower technical and economical capacity to respond to new threats. Smallholders and pastoralists will suffer complex, localized impacts (IPCC 2007).

According to IFPRI (Nelson et al. 2010), it will cause an increase of between 8,5% and 10,3% in the number of malnourished children in all developing countries, relative to perfect mitigation.

There will also be probably important effects on malnutrition. To date, studies mostly focused on cereals. There is a need to better capture all the nutritional consequences of the effect of Climate change on all foods, vegetables, wild foods… which have a very important role for balanced diets and which are at risk..

In terms of impacts, it is necessary to distinguish between increased variability and slow on setting changes. The potential impacts of increased variability are often less emphasized. For various reasons: first of all because they are less well known (but they will be felt before), then because they sit between the much emphasized category of "extreme events", (but what exactly is an "extreme event" ?), and the much more "easier to grasp" business as usual category of actual variability. But as they are easier to grasp now by farmers, they make an easier target for early adaptation measures (Padgham 2009).

It is therefore important to distinguish between these two categories of changes in order to distinguish two ways to adapt, with different time ranges: Increasing resilience, now, to get prepared for more variability and increasing adaptive capacities and preparedness for slow onset changes. And getting prepared to more variability is also a way to get prepared to change, whatever it is.

3) <u>Agriculture's impact on CC</u>

Agriculture has to produce more food. Agriculture will be impacted by climate change. It is also called upon to contribute to mitigate climate change. The question is how and to what extent agriculture and food systems can contribute to mitigate climate change, without compromising food and nutrition security.

Worldwide, agriculture (crop and livestock) is accounted for 13,5% of GHG emissions (IPCC 2007). That is for what happens in the fields and with the animals. But agriculture's role in the climate change issue - and, importantly, mitigation potential - should be considered in a wider perspective of the "food systems", including their incidence on forests, on the energy sector, on transport. First, because part of the emissions on the farm are de facto accounted for in other sectors, as electricity in farm buildings and fuel in farm and food transport. Second, because agriculture is also a major driver of deforestation, which accounts for 17,4% of GHG emissions (as such it is included in the study on the drivers of deforestation requested by COP 17 in Cancun to the SBSTA). Third, because, inside food systems, reductions of emissions in some areas could increase them elsewhere. For instance shorter food chains could reduce transport but increase agricultural emissions. There are no studies that quantify emissions from the global worldwide food system (Garnett 2011). A study in 2006 estimated that 31% of the EU's GHG emissions were associated with the food system (European Commission 2006). So, when looking at challenges and opportunities to reduce GHG emissions in agriculture, it is paramount to look beyond the farm, vertically into the whole food chain and horizontally across impacted land-uses such as forests.

The main direct sources of GHG emissions in the agricultural sector are not CO2. Agriculture is the source of nitrous oxide (N2O), 58% of total emissions, mostly by soils and through the application of fertilizers, and of methane (CH4), 47% of total emissions, essentially by livestock and rice. These emissions are dependent on natural processes and on agricultural practices, which makes them more difficult to control and measure. On the other hand agriculture is a unique sector in that, with forestry, it can capture CO2 and store it in biomass and soil, acting as a "sink".

As agricultural production is projected to increase in developing countries, so are agricultural emissions. IPCC (2007) estimates that N2O emissions are projected to increase by 35-60 % to 2030 and CH4 by 60 %. It also projects additional land being converted to agriculture.

There are two ways to mitigate while keeping with the "food security first" objective. First, to decorrelate production growth from emissions growth. This implies reduced emissions per kg of output (and in this calculation, we can include the effects in reduced deforestation). Second, enhance soil carbon sinks. IPCC estimates the global technical mitigation potential from agriculture to be 5500-6000 Mt CO2 eq/year by 2030. This is grossly equivalent to three quarters of the sector's emissions in 2030 (around 8200 MtCO2-eq). About 70% of this identified potential lies in non- OECD/EIT countries, 20% in OECD countries and 10% for EIT countries. IPCC estimates that nine tenth of the global mitigation potential of agriculture is linked, not to reduction of agricultural GHG (mainly CH_4 and N_2O) emissions, but to managing land carbon stocks: enhancing soil carbon sequestration, reduced tillage, improved grazing management, restoration of organic soils and restoration of degraded lands. This could lead to the false impression that reducing emissions per kg of output is not the main target. This is however misleading: direct gains through increased efficiency also imply a serie of indirect gains: First, it leads to reduced emissions from deforestation (not accounted in IPCC's calculations of the 90%) because of less land being necessary to produce the same amount of food. Second, it leads to reduced indirect emissions in the production of fertilizer or energy inputs used on the farm, everything else being equal (a potential of 770 $MtCO_2$-eq/yr by 2030 has been identified from reduction of fossil fuel use through improved on farm energy efficiency). And third, there are potential reductions through improved efficiency in food chains, including reduction of post harvest losses.

Agriculture's contribution to mitigation efforts will be different in developed and developing countries:

- First because the contribution of agriculture to emissions is different, in line with different contributions of agriculture to economy. It is generally more important in developing countries, reduced in developed countries (with some exceptions such as New Zealand and Ireland). Furthermore, in developed countries deforestation happened a long time ago.
- Then because the possibilities to reduce emissions by kg of final product are higher in developing countries, as are also the possibilities of increased land efficiency
- Finally because the potential of increased carbon stocks in soils is higher in developing countries, including restoration of degraded land.

B: A comprehensive answer: towards more efficient and resilient food systems, from global to local.

In order to address these three intertwined challenges, food systems have to become, at the same time, more efficient and resilient, at every scale from the farm to global. They have to become more efficient in resource use: use less land, water, inputs to produce more food sustainably and to become more resilient to changes and shocks.

1) Efficiency and resilience

Agricultural production has to increase, particularly in developing countries, both in quantity and diversity to ensure food and nutrition security and to address the growing demand. Business as usual, this increase will translate in a proportionate increase in direct emissions from the agricultural sector and in increased indirect emissions both from land-use changes and deforestation and from production of inputs. To feed the world while contributing to climate change mitigation, there is a need to decorrelate the increase of emissions from the growth of food production .

Let us start by looking at the "physical" resource-efficiency of production - quantity of food produced per physical unit of resource (input, production factor)- , and at its implication in terms of GHG emissions. Three production factors have an important influence on total agricultural GHG emissions: (i) area, because to bring more surface under cultivation would require either deforestation or grasslands being converted to croplands, which would induce CO_2 emissions, and (ii) fertilizers whose production is an important source of CO_2 and which at the field level translate in nitrous oxide emissions, (iii) livestock which is an important source of methane and nitrous oxide, and, also machines both directly by energy use and indirectly by their production.

Growth in production can be achieved through an increased level of each of the different production factors (land, energy, water, fertilizers, capital, labor,,,) or through a more efficient use of production factors (i.e. by increasing the productivity of these: more food (Kcal) per square meter of land, per cow, per kg of fertilizer), or through a combination of both. Classically, increased efficiency in the use of input is normally captured within total factor productivity (TFP) growth. This is why, when GHG emissions are positively correlated with the level of input, improved "physical" efficiency in the use of inputs such as land and fertilizers is generally synonymous to improved “GHG-efficiency” and can be seen as an important mean to reduce emissions “everything else being equal” (in particular in the demand side, i.e: food security objectives being met). As seen above, GHG-efficiency (in terms of less GHG emissions per unit of food produced) has to be considered at various scales, across the whole food system, in order to address food and nutrition security (from production to consumption) and to avoid carbon leakages.

Which brings us to two questions: (i) to what extent is “physical” production efficiency correlated with “GHG-efficiency” (strong or weak relation)? And (ii) to what extent is “GHG-efficiency” correlated with “economic” efficiency (from the producer side) or “food-security” efficiency (from households’ side)? To answer the first question we need to assess for trade-offs between increasing resource efficiency regarding one or another input. For instance increase yield per hectare through increased use of fertilizers. Thus, for improvements involving variation of several “emitting” factors, a comprehensive assessment would be needed, using LCA methodologies or GHG accounting tools.

The second question is beyond the scope of this paper but a prerequisite is certainly the existence of an appropriate framework to “pose the problem”, which would include accounting for environmental and social externalities (positive and negative) of input use and production, and an appropriate pricing environment (into which more input use leads to proportionally higher costs).

Whatever the “efficiency” considered, there is a need to look at the question of allocation of factors and at the issue of scale. Indeed, production efficiency, GHG-efficiency, economic efficiency and food security efficiency do not always go hand in hand. For instance, to increase the part of workforce in the mix of factors of production might go against economic efficiency at the farm level, but has a positive effect on food security. In that respect, efficiency has to be evaluated at various scales and from various perspectives. Efficiency shall be assessed at each stage and through whole food chains and food systems. The efficiency of a practice shall be assessed inside a system.

“Resilience” here means the capacity of systems, communities, households or individuals to prevent, mitigate or cope with risk, and recover from shocks.

Efficiency and resilience shall be pursued together and at various scales, in agricultural systems (see section 2 below), and in food chains (see section 3). Being efficient without being resilient would not be really helpful in the long term, given the fact that shocks will happen more often. Being resilient without being efficient, or without allowing for an increase in production would pose problem for food security in the long term and for support to livelihoods. In the pursuit of these two goals, there might be trade-offs, but there might be synergies. Increasing efficiency could lead to greater sensibility to certain shocks. For instance more productive livestock is more sensible to heat waves. On the contrary increased efficiency can be a factor of increased resilience. For instance increasing production in food importing countries will improve their resilience to price volatility.

2) Agricultural systems

As agriculture is an important driver of deforestation, reducing it by sustainable intensification on already cultivated land could have a major mitigation effect (Burney 2010, Belassen and Gitz 2008). There are validated technical solutions for increasing resource efficiency and resilience of agricultural systems (FAO 2010b).

To increase efficiency in the use of resources and resilience, sustainable intensification of crop production combines: better management of water, integrated nutrient management, conservation agriculture, better use of genetic resources, enhancement of ecosystems’ functions and diversification.

There is also an urgent need to improve the resource-use and production efficiency of livestock production systems, both to improve food security and to reduce GHG emissions intensity, taking into account the growing dichotomy between livestock kept by large numbers of small holders and pastoralists and those kept in intensive systems. To produce animal output from vegetal input involves a multiplier factor (in the sense that one calorie of animal product requires the production upstream of more than one calorie of vegetal to feed the animal). Thus any efficiency improvement in the livestock sector has a multiplier effect to improvements made in the feed sector. The livestock sector has also, at the same time, to get more resilient to climate change, particularly considering the impact of drought on grazing systems. Achieving these objectives will require to look at every aspect of livestock production from genetic resources, feeding, including pasture and rangeland management to disease control and manure management.

Diversified rotations, including crop varieties and species with different thermal/temperature and rain patterns requirements, are an effective way to reduce risks and increase efficiency.

Diversification can both increase the efficiency of systems and their resilience, at farm and local level. Integrated crop and livestock systems, at various levels of scale (on-farm and area-wide), increase the efficiency and environmental sustainability of both productions. When livestock and crops are produced together the waste of one is a resource for the other : manure increases crop production and crop residues and by-products feed the animals, improving their productivity. In these systems, livestock is a strategic element for adaptation. It is an alternative to cropping in areas becoming marginal for cropping. It is a way to escape poverty and a coping mechanism in variable environment. Animals constitute a capital to be converted in cash when needed.

Grasslands, including rangelands, shrub land, pasture land, and cropland sown with pasture, trees and fodder crops represent 70 percent of the world's agricultural area. Many management techniques intended to increase forage production have the potential to increase soil carbon stocks, thus sequestering atmospheric carbon in soils. Improving grazing land management is estimated to have the highest technical potential amongst all possible agricultural mitigation sources, over 1.5 billion tons CO2 eq/year (IPCC 2007).

Landscape approaches enable to, collectively, better manage land, water and biodiversity with resulted increases in both efficiency and resilience

3) Food chains

There also important possibilities to increase efficiency all along the food chains, first by reducing food losses and improving energy efficiency.

Food losses are impressive. Food lost means also emissions in vain, especially at the end of the food chain, considering that food also gradually embeds indirect emissions due to its transport and its conservation. Global differences between regions for the same type of products reveal potential improvements (Gustavsson et al. 2011). Losses of cereals are half higher in Europe than in Sub Saharian Africa. Losses of milk are the double in Sub Saharan Africa than in Europe. The repartition of the losses along the food chain are very different, depending on the products and the regions. For instance, in Africa cereals are lost in the first stages. In Europe, they are lost mostly at the consumer stage: 25% against 1% in Africa. For fruits and vegetables, the differences between regions are also striking. In Africa processing and distribution are the weak links, which highlights the need of investments in these stages. In Europe it is at the production and consumption stages that most of the losses occur. These wide differences show possibilities of improvement.

And there are techniques available to reduce food losses in developing countries. Household metallic silos for conservation of cereals or tubers are one of them, actively promoted by various organisations, including FAO and NGOs. For instance use of metallic silos in Afghanistan had reduced storage loss from 15-20 percent to less than 1-2 percent. Their fabrication is local, creating jobs, small enterprises and possibilities of diversification. They enable farmers to preserve food, therefore making them less vulnerable, either as sellers or buyers, to price fluctuations on local markets.

All along the food chains, until consumption, there are potentials to improve energy efficiency, in transport, conservation, transformation and cooking. In Africa 90% of the extracted wood is used for domestic purposes, mostly cooking. Improved energy saving cooking stoves contribute thus to reduce deforestation. However there could be trade-offs between reducing food losses and reducing energy consumption, especially when looking at reducing losses of fresh perishable products (which consumption is increasing), such as meat, dairy products, fish, fruits and vegetables. The analysis shall therefore encompass the whole food chain in order to be able to consider all impacts, including indirect ones, and all potential solutions. For instance transforming fresh products transported on long distances in less perishable products can reduce losses and emissions induced by conservation and transport as slower means can be used.

C: Increase systemic efficiency and resilience: policies, institutions, finances.

Appropriate policies, institutions and finances are essential to increase systemic resilience and efficiency at local, national and international level and to achieve needed changes in agricultural and food systems.

1) Manage risks

Climate change will add more risks to production and aggravate existing risks, especially for the more vulnerable. Increased variability and uncertainty make ever more necessary the establishment of risk management strategies to address every type of risk, whether climate, animal or plant diseases or even economic. Such strategies shall aim to limit losses ex ante by monitoring risks, assessing vulnerability, identifying (ex-ante) damage reduction measures and acting at the earliest stage of the event. They shall include quick reparation of losses to productive assets in order to avoid long term consequences.

2) Enable farmers to overcome financial barriers to change

Whatever the change in farming systems it involves costs. Even if a new practice will provide the same or an increased income in the long run, there are barriers to adoption: Up front costs, income foregone during the transition period or additional risks during the transition period which all have to be covered. Take for instance mitigation measures. Mitigation measures in the agricultural sector are considered among the cheapest, with a quarter of the technical mitigation potential being estimated as costing less than 20$/tCO2 (IPCC 2007). But these estimations compare the income with a new practice to the income without the practice. They do not take into account transition costs, nor the costs of the enabling environment, such as extension services for instance. These costs have to be assessed and taken into account (FAO 2009a).

3) Invest in agriculture in developing countries

There is already a gap today in funding for investment in developing countries. The needs will increase. FAO estimated that cumulative gross investment requirements for agriculture in developing countries add up to nearly US$9.2 trillion until 2050 or nearly US$210 billion annually (FAO 2009c). Therefore the decreasing trend in funding has to be reversed. It includes increasing the share of Official Development Assistance directed to agriculture. Domestic efforts have to be pursued at the appropriate level.

To achieve the radical changes required there is a very strong need for agricultural research and development. But efforts are slowing, on every continent, since the eighties, the period of the Green Revolution in Asia. So if we are to achieve a change of the same magnitude, investment in agricultural research and development has to increase dramatically.

4) Enable trade to build efficiency and resilience

Trade is a very powerful tool to build efficiency and resilience. Small holders have to be linked to markets with proper infrastructures either material and immaterial.

International trade is an essential factor of resilience but at the same time it transmits the effects of shocks and as such can also be a factor of systemic risk. Price volatility is a major threat to the efficiency of the international markets as buffer of climatic irregularities.

5) Comprehensive governance, from local to international

To improve efficiency and resilience of food systems at every scale requires comprehensive governance, at every level, local national, regional and international. It shall involve all stakeholders, farmers, agro industry, retailers, consumers and public authorities.

At a global scale, there is an urgent necessity to better consider the interrelations between agriculture and food security and climate change. The international community needs to establish appropriate links between the international fora discussing Food Security issues and Climate Change. Fortunately, this is starting to happen.

The Cancun Agreement contains major points for the agricultural sector. The adoption of the Cancun Adaptation Framework gives a new importance to adaptation. The creation of the Green Climate Fund with the aim of a balanced allocation between adaptation and mitigation will provide new opportunities. The establishment of REDD+, to protect forests against deforestation and degradation, aknowledges the need to better address the drivers of deforestation, including agriculture. Many developing countries are including actions in the agricultural sector in their “NAMA’s”, nationally appropriate mitigation actions.

Food production is threatened. To tackle the issue at a global level, Food and Nutrition Security has to be fully accounted for in climate change policies. Reversely, Climate change has to be fully accounted for in food security policies. The Committee on World Food Security has requested its High Level Panel of Experts on Food Security and Nutrition a study on the links between the two issues.

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