And...after? Review of the prospects for food security and agriculture

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Abstract

In light of the conference on the general theme of “Action for a sustainable world” the term “Food security” encourages forecasts. Food insecurity is a present issue, and is likely to worsen in the coming decades. Most scientists think that global food security is threatened by certain ongoing or future changes (identified differently depending on the authors). The other part of the conference’s theme “from theory to practice” forces us to examine the practices implemented to strengthen food security or – failing that- encourages us to scan the practical solutions advised by authors, in such a way that we propose a critical review of literature regarding food security linked with agriculture. The relationship between food security and agriculture is not straightforward on a local scale. Indeed, it is acknowledged that the conjunction of armed conflicts and climate disasters is the leading cause of malnutrition and food insecurity (FAO, 2017). However, on a world or continental scale, long-term food security is secured only by flourishing agriculture. To link food security and agriculture, we focus our literature review on a wider scale (world, continent, country) only. Moreover, we consider two time-scales around the 2050s and the 2100s. We sorted the papers according to the kind of envisioned change: i) continuation of past trends (OECD-FAO, 2017); ii) changes in physical factors only [via temperature and precipitations (Lobell et al., 2008), or via other effects of climate change (Calzadilla et al., 2010; Vincent, 2015; Quasem Al-Amin and Ahmed, 2016)]; iii) changes also relating to economic factors (Adams et al., 1998); or iv) relating to social factors (Dalhberg, 1994). The authors suggest various solutions, which we present in ascending order of societal structural changes. There are shifts in i) international trade of agricultural commodities (e.g. Calzadilla et al., 2011); ii) in agricultural practices alone: from the simplest modifications (Lobell et al., 2013; Burke and Lobell, 2010) to revolutions including high-tech and biotechnologies (Tait and Morris, 2000; Godfray et al., 2010); iii) in consumption practices: from the reduction of meat-based diets (Garnett, 2015) to extreme behaviors in extreme conditions (Denkenberger and Pearce, 2015). The most radical solutions are: iv) disruption of agricultural structures and practices (e.g. Altieri et al., 2015; Malézieux, 2012); and v) paradigm shifts and renewal of whole social structures (Dalhberg, 1994; Handoh and Hidaka, 2010). In general, authors acknowledge the physical factors to be more compelling for the farther horizon (2100) than for the nearer one (2050). However, the conclusions are not homogenous. For some authors, the adaptation will require more effort in the long term than now (i.e. we can wait). For others, the “adaptation” requires immediate and decisive actions for huge shifts involving agriculture, society and ways of life. The review highlights the rift among scientists, between authors proposing affordable solutions for agriculture and undemanding for the rest of the society, and those authors advocating a paradigm shift and new social structures, to address challenges of food security.

Keywords: food security- agriculture- solutions -forecast- climate change

1. Introduction

“The future will likely look like the pre-industrial era, the only difference being that we will go on with innovation and development of new techniques…compatible with “solar” limits.” (Servigne, 2013).

In light of the conference on the general theme of "Action for a sustainable world" the term "Food security" encourages forecasts, with at least three concerns. Food insecurity is a present issue[1], and is likely to worsen in the coming decades, especially in developing countries, where productivity may be reduced three times faster than in developed countries by 2050 (IPCC, 2007; Calzadilla et al., 2010). More generally, most scientists think that global food security is threatened by certain ongoing or future changes (identified differently according to the authors). Whatever the point, the issue of food insecurity involves humankind as a whole, because the pace of the exploitation of planet's resources does not allow for self-renewability. From the Paleolithic to the present day, per capita food energy demand has increased 5-fold (Simmons, 1989). The other part of the conference's theme "From theory to practice" forces us to examine the practices implemented to strengthen food security or – failing that- encourages us to scan the practical solutions advised by authors, in such a way that we propose a critical review of literature regarding food security linked with agriculture, and the proposed solutions.

2. Methods

The relationship between food security and agriculture is not straightforward on a local scale. Indeed, it is acknowledged that the conjunction of armed conflicts and climate disasters is the primary cause of malnutrition and food insecurity (FAO, 2017). However, on a world or continental scale, long-term food security is secured only by flourishing and productive agriculture. To enable a direct link between food security and agriculture, we choose to focus our literature review on a wider scale (world, continent or country) only. Moreover, we consider two time-scales: one around the years 2030-2050, and the second around 2080-2100.

Discussions about food security on a large scale depend on the kind of envisioned change. We sort the papers on the following basis: i) no consideration of specific changes; ii) changes are taken into account regarding the physical factors only [via temperature and precipitations only or via other effects of climate change]; iii) changes also relating to economic factors; or iv) social factors. We sort the envisioned solutions in accordance with the required magnitude of disruption of our present way of life.

3. Results and Discussion

This paragraph sets out the variety of factors taken into account to deal with changes in food security and/or agriculture, the variety of proposed solutions, and the messages delivered for various deadlines, before proposing the final discussion.

a. Consequences of changes in terms of Food Security

The consequences of the changes depend on the nature of the envisioned changes: either continuation of past trends; or considering physical factors only; or dealing also with economic factors; and finally accounting for social factors.

Continuation of past trends

Some authors deal only with the continuation of past trends. This is the case of the report (OECD-FAO, 2017), which envisions the world agricultural yield until the year 2026. The report explicitly states that it does not account for hazards like: "new pests and diseases, [of] increased variability in yields caused by climate change, and uncertainty around policies (page 54)". The authors guess that- in the future- the variability of the factors will remain in the same range of values as in the recent past. Moreover, their modeling forecasts of agricultural yields are determined by the demand side (for food, feed, biofuels, etc.). It is therefore assumed that food insecurity will remain at its present level. Conversely, Godfray et al. (2010) tackle the issue of the necessary strategies to be developed in order to feed 9 billion people in 2050. Nevertheless, as with the former report, they do not consider other changes than world population growth, and its correlated food demand, caused by the attainment of a better standard of living.

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[1] In 2016, the number of under-nourished people in the world was on the rise, as it has been since 2014 (FAO, 2017).

Only new physical factors are considered

Other authors account for some physical factors of change, but without considering the economic and social factors. Among them, the models by (Lobell et al., 2008) deal only with the average temperatures and rainfalls envisioned for 2030. They stipulate that the rise in temperatures might be of benefit to the agriculture of some northern regions, and acknowledge that food insecurity will be an issue for some regions, including those already suffering from this scourge. Vincent (2015) reminds us that "the low latitudes are particularly sensitive, because of large negative sensitivity of crop yields to extreme daytime temperatures around 30°C [-]. Production levels of major crops such as wheat, maize, and rice are projected to decline from 2050", which would entail dire consequences for the poor. According to Quasem Al-Amin and Ahmed (2016), climate change is the real food insecurity problem for the developing world, where agricultural production may be reduced by 10-25% by 2080, in the "business-as-usual" scenario. These authors are specifically involved in studying the Malaysian food security by 2065, and account for the damages caused by the yearly average temperature and rainfall fluctuations, the increase in CO_2 emissions, and the feedback on temperatures.

Agronomists could claim that plants are sensitive to extreme temperatures (and not to average ones) (MODEXTREM, 2016), and explain that it would take many years of investment and work to replace tundra with fertile soil (Dalhberg, 1994).

Change dealing with economic factors also

Adams et al. (1998) present a review of works which consider long-term economic effects of yield losses because of Global Warming (around 2050-2060), in order to discuss the potential patterns in food production and prices. They acknowledge that most studies do not incorporate some impacts "such as changes in the incidence and severity of agricultural pests and diseases and changes in soil erosion". All the same, they state that "few studies consider the effects of changes in the frequencies of extreme events such as droughts and floods, or changes in climatic variability."(page 29). The authors are more interested by the effect of Global Warming upon the economic welfare of the average American citizen, than by food insecurity itself. Calzadilla et al. (2010) study the effects of Global Warming on agriculture in 2020 and 2050 via water availability. They calculate effects on well-being, including the modifications of international trade. Here also, the link with food insecurity is not straightforward. Because the economic drivers (cheap energy and pervasive externalization of costs) entailing viability of agro-industrial systems will not last, Clark (2011) explains the ongoing emergence of novel agro-food systems.

Changes accounting for social factors

Some of the authors quoted above admit that overlooked social factors are important, which are complicating the equation of the Global Warming. "Costs and obstacles to adaptation have also been omitted." (Adams et al., 1998, page 29). To face the compelling changes in agriculture, Quasem Al-Amin and Ahmed (2016) suggest policy measures towards "income stabilization programs due to farmers income loss", because they are aware of the role of social adaptations in the success of agricultural policies. Dahlberg (1994) notes the growth of income inequalities among the global constraints and threats encountered by modern industrial societies. More specifically for the agricultural sector, the author denounces the historical dispossession of native lands and the subjugation of smallholders, a movement intensified by the technological green revolution, and by the ever-increasing emphasis put on cash crops for export, which have marginalized smallholders and subsistence agriculture. Radanne (2006) warns us that the inescapable shift will likely be violent. "We must keep in mind that these transitions can deeply increase economic and social disparity, and that they are often violent" (page 21).

b. Varieties of solutions

The authors suggest various solutions, ranging from (mainly) relying on international trade in agricultural commodities (e.g. Calzadilla et al., 2011; Adams et al., 1998) to a deep shifting in our ways of life.

Changing only agricultural practices

To face the agricultural challenges of the years 2030-2050, Lobell et al. (2008) guess that "shifting planting dates or switching to an existing crop variety" will not be enough, forcing farmers to "more costly measures including the development of new crop varieties and expansion of irrigation." (Lobell et al., 2008, page 607). Burke and Lobell (2010) add "water harvesting" and recognize the necessity to set up new institutions to address food production shortfalls. For adapting agriculture to the 2050s-2060s, Adams et al. (1998) suggest mitigating responses by increasing fertilizer or water use, and by the adoption of new crop varieties or by "changing planting dates, substituting cultivars or crops, changing irrigation practices, and changing land allocations to crop production, pasture and other uses" (Adams et al., 1998, page 28).

Tait and Morris (2000) guess that they need to gather stakeholders in order to find sustainable agricultural solutions, and bet on technical innovations, perhaps on a "technical revolution, through biotechnologies" to manage the externalities associated with intensive agriculture! Recently, for the Inland Pacific Northwestern region of the US and other equivalent regions, Pan et al. (2017) suggest playing with the agronomic management variables: conservation tillage and residue management, organic carbon (C) and nutrient recycling, refined N management, and crop diversification and intensification, thanks to new cultivars (canola, peas) and ICT sector. Some authors argue for sharing land between land-for-production on the one hand, and land-for-nature on the other, as set out by (Tscharntke et al., 2012).

Regarding Malaysia in 2065, Quasem Al-Amin and Ahmed (2016) suggest the following options to adapt farms: Irrigation scheduling; Weather and climate information systems; Higher cropping intensity; Diversification of cropping production on irrigated area; Integrated pest management (IPM); Protected cultivation; Post-harvesting technology; Income stabilization programs due to farmers income loss. They calculated the optimal adoption rate of these measures (whatever the measure), which would be 20% for the Malaysian State. One could comment that since the agricultural system is precisely a system, 20% of spending may be inefficient or also highly efficient, depending on the nature of the adaptations and on their very implementation. For 2050, in the highly-valued journal "Science", Godfray et al. (2010) suggest a catch-all of ideas split in 5 international strategies, and mainly based on the growth of agricultural yields thanks to technologies (ICT, genetically modified crops, cloned animals etc.), waste reduction, decreasing meat consumption, and expanding aquaculture. According to the authors, the whole can be made "sustainable", although they do not explain how.

Modifying food consumption practices

The more extreme proposal is set out in the paper by (Denkenberger and Pearce, 2015) which envisions – in quantitative mode only- the conversion of the Earth's entire biomass, in order to feed humankind for 5 years, in case of universal catastrophe (sun occultation). Bearing in mind social drivers, the idea is not to explain how to socially manage this conversion, but only to evaluate the quantities of convertible marine and terrestrial calories. More classically, Garnett (2015) proposes a synthesis of many studies, which find that diets with reduced animal product content (meat, eggs, dairy) release less GHGs or are less land use intensive. The lower the meat content, the lower the environmental impacts[2]. This is one of the solutions advised by Godfray et al. (2010) – but deemed to be the most difficult to undertake- to feed humankind by 2050.

Implementing more radical agricultural solutions entailing social shifts

Malézieux (2012) highlights the necessity to immediately rethink the management of natural resources, and suggests mimicking natural ecosystems to build new agro-ecosystems. The crucial issue is enhancing the crop diversity, to decrease the dependency on non-renewable resources, and to recreate areas devoted to biodiversity. It is the same for Altieri et al.

[2] In descending order the GHG intensity of diets are: no red meat, no meat (vegetarian), no animal products (vegan) (Hallström et al., 2015; Scarborough et al.,2014)

(2015) because “changes that will not radically modify the **monoculture nature** of dominant agro-ecosystems may moderate negative impact temporarily” only (Altieri et al., 2015, page 1). By 2050, the authors advise setting up polycultures, agroforestry systems, and crop-livestock mixed systems accompanied by organic soil management, water conservation and harvesting, and general enhancement of agrobiodiversity.

In fact, radically new agricultural practices will disrupt societies as a whole. Despite not suggesting radical social changes, Adams et al. (1998) are aware of the issue of agricultural structures for the US. They quote the “changes in cultivated acreage by crop, total cultivated acreage, irrigation water consumption, farm employment and other changes in factor demands. The consequences of changes in factor demands on regional or local economies are largely unexplored but are potentially important” (Adams et al., 1998, page 29). Few authors widen the scope to envision the issue of food security and agriculture together. The famous meta-analysis of Badgley et al. (2007) demonstrates that organic agriculture can contribute significantly to the global food supply without increasing the agricultural land-base. Indeed, long-term yields of both conventional and organic agriculture are comparable, and nitrogen potentially available from fixation by leguminous cover crops is enough to replace the synthetic fertilizers currently in use. Clark (2011) advocates switching the whole of agriculture towards real organic[3]. She goes even further by suggesting the implementation of novel agro-food systems based on more perennials and less on large-seeded annuals, and emphasizes “local/decentralized food production; seasonal consumption expectations and minimal processed foods.” So, the new system will abandon monocrop cultivation.

Dahlberg (1994) calls for a transition from current modes of industrial agricultural production, which will involve “a basic restructuring of the interactions and relationships between natural systems, social systems and technological systems” (Dahlberg, 1994, page 170). The author notes the inefficiency of fossil energy in use in industrial agriculture, where 10 calories of energy are required to deliver 1 food calorie on our dinner plates. He explains that we are unlikely to mobilize the funding which will be necessary to relocate agriculture to the north. He laments the explosion in cattle population because of meat demand, highlights the severity of biodiversity and cultural diversity losses, and reminds us the damage caused by unequal growth. The priority is to maintain and to enhance the “remaining indigenous and traditional food and fiber systems that have demonstrated their regenerative capacities over the centuries” (idem, page 173), then “reforming existing housing and ways of life to make them less resource-and job-dependent” (idem, page 175). Shifts will be required in the evaluative criteria we employ –whether for society at large or for a particular sector like agriculture. The shift -from economic and production criteria- to health criteria is one of the key elements. More recently, Servigne (2013) claims that future agriculture will not have to manage food production only, but also to heal the ecosystems functions. Agriculture will be based on renewable energy only (sun and biomass, wind, and methanation) and on cattle and human work also. The author envisions the emergence of multistage agro-ecosystems (e.g. agroforestry), in order to take maximum advantage from solar flux.

c. Different time-scales

What can we say about the influence of the envisioned time-scales upon the delivered message? Few authors venture beyond 2050. Nevertheless, there is a consensus about both ideas that the Global Warming consequences will be much more harmful from 2050, and that unexpected events are increasingly frequent. The messages delivered for the various deadlines are not fundamentally different. In other words, the urgency of the temporal horizon does not affect the nature of the message. Authors advocating a societal shift demand strong initiatives as soon as possible, according to the amplitude of the necessary change in mindset.

d. Discussion

When it comes to facing the future challenge of food insecurity, there is a split among the authors between those who suggest affordable solutions that are not demanding for the rest of the society, and others who advocate new social

[3] By comparison to North America organic standards.

structures. Some authors are perfectly aware of this debate. Handoh and Hidaka (2010) conceptualize two tracks towards solutions: 1) "a consciousness Revolution that leads to mankind's attitude to the environment and to adopting a pre-industrial life style"; or ii) "a super energy revolution that leads to full utilization of photovoltaic power generation", to produce sufficient dietary resources to sustain the world population. Tait and Morris (2000) explain how the coming changes make it necessary "to initiate fundamental change in the nature of modern farming systems themselves", even if they exclude this possibility at the same time: "However, this may be impossible to achieve under some future scenarios, or at least is likely to take longer to achieve." (Tait and Morris, 2000, page 257). The two competing views have been dubbed the Critical limits view, "which would require future farming systems to accept the ecosystem-imposed limits on the number of people in the world and the lifestyle they can enjoy"; and the Competing Objectives view, which "would balance agricultural sustainability with economic viability, reduction of environmental harm and fulfilling public demands for food and landscape benefits. " (Tait and Morris, 2000, page 247).

For advocates of the "Competing Objectives" views, like Lobell et al. (2013), the main issue is to know "where to invest?" to prepare the agriculture of the future, but always in the same framework of mono-varietal and industrialized agriculture. They do not seem to be aware of the existence of the climate-agriculture-energy nexus, which makes it impossible to change one element without also making the other structurally change. They deal with agriculture as if it were a sector like any other, and in particular like a controllable machine, without understanding the shortcomings of their modellings.

For the supporters of the "Critical Limits" views, it is mandatory to accept the ecosystem-imposed limits, and therefore to change our ways of life, without being nevertheless Malthusian. The major challenge is to demonstrate that there are agricultural systems respecting ecosystem integrity, yet nevertheless as efficient – if not more efficient in the long term- as the agro-industrial systems. That is why the core of the scientific work in this view is in favor of agro-ecology and multispecies systems. Indeed, here we find a criterion (if we need only one, here it is) which no doubt differentiates the advocates of the two groups. To reconcile biodiversity and productivity, the advocates of the "Critical Limits" view advocate intercropped systems, mixing different species on the same plot (Nair, 2017), while the others assume – often implicitly- that the plots in future agriculture will be monospecific. Indeed, it is a necessary condition for the continuation of agro-industrial practices.

The split line is visible also insofar as the implemented scientific methods are in general different. Indeed, the works carried out by the former group rely on statistical data, on a large scale, because data on the agro-industrial monoculture are already widely available. Conversely, when it comes to designing frugal agro-ecosystems, only sparse and small-scale local monographs are available (with notable exceptions). Even when these monographs are collated (Auerbach et al., 2013) it is less easy to envision regional or worldwide forecasts, with the same weight as the authors of the previous group.

The same split is materialized by the way of considering people who are not involved in agricultural sector at the present time. Under the former viewpoint, citizens are considered to be consumers first. In the best case, they are elicited to give their opinion as stakeholders. So, the citizens will be affected because they are expected to become reasonable and to consume less meat, and/or because their purchasing power will be lowered by the rise in food prices. But they are not required to play a more active role in the ongoing change. Under the latter view, the citizens are seen like potential activists of frugal agro-ecosystems, and sometimes, authors hint that citizens will have to be directly involved in the farming work. In this case, the authors advocate a radical structural change, which will disrupt human societies as a whole.

The few factors taken into account (for food security or the future of agriculture) are quite a surprise. Drawing only on the food's energy demand and on production of entropy, Handoh and Hidaka (2010) worked out that the sustainability of the human-environment interactions of the present era (called pre-informational and which started in 1960) has an order of duration of 100 to 400 years. In fact, to deal with food security, the contextual evolutions to be accounted for go far beyond world population growth or Global Warming alone. It is quite easy to find works about the future of energy, cities, or globalization. Nevertheless, the future of agriculture in those troubled contexts is rarely dealt with, and moreover rarely taken seriously enough, i.e. placed at the center of the discussion. When will we realize that it is becoming unclear how to feed ourselves? That our time schedule and daily concerns are turning back (as was the case with our ancestors for centuries) first and foremost towards activities directly contributing to nutrition? It is mandatory[4] to make a choice, by recognizing what is a top priority, and what is not.

4. Conclusions

In general, the supporters of the "Competing Objectives" view acknowledge that the effects of climate change will worsen over time. The supporters of the "Critical Limits" view advocate radical modifications of social structures. They explain the necessity to prepare for the transition as soon as possible, in order to mitigate –as far as possible- the harmful but inevitable effects.

Today, the debate between advocates of human causes of climate change on the one hand, and climate change skeptics on the other hand, seems to be closed. Hence, it is time to decide on another debate, and take up our position. Do we need to follow those who advise adapting the future agriculture with marginal adjustments and technologies whose most obvious advantages are compatibility with the present state of advanced societies? Conversely, should we not keep up with the pace of researchers who urge us to enforce radical changes? They advocate vital changes, which might disrupt the internal organization of our societies, as was the case with the very invention of agriculture...

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[4] Here is an example of decision to be taken. Cattle entail CH_4 emissions which contribute to climate change (FAO, 2006). Nevertheless, offsetting the emissions-and so eradicating cattle- would be a big mistake. The emissions from other sources (industrial, travelling, housing) must be eradicated as a matter of priority. It would be favorable to reduce the world herd size, but in the future, manure, traction and transport provided by cattle will be crucial to food production. Indeed, as observed by Tapio et al. (2017) the experts agree on the future necessity to use biofuels on farms. But biofuels, too rare and expensive, will not be available for such a trivial usage (Radanne, 2006).

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