THE IMPACT OF ENVIRONMENTAL CHANGES ON FOOD SAFETY

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Abstract
Changes in the global environment are recognized as one of the most serious ones facing the world today. Of these, agriculture is a pivotal domain, as it faces significant changes as a result of the need to increase global food supply whilst the availability of soil and water resources are declining and of the increasing threats from environmental change. Nevertheless, these transformations unveil abundant opportunities to develop and promote food and living systems that have greater environmental, economic and social elasticity to risk. It is clear that such opportunities to perfect forward-thinking and practical solutions to these changes will require the development of a range of technical and institutional innovations, founded on current multidisciplinary knowledge. As such, changes in the environment are a major challenge for agriculture and agricultural policy-making. Agriculture needs to address the double change of reducing its greenhouse gas emissions (GHGs) while adapting to projected impacts of environmental change. In a talk given to the MIT Enterprise Forum in 2003, Nobel Laureate Richard E. Smalley pinpointed the fact that the biggest problems that humanity will face over the next 50 years are Energy, Water, Food, Environment, Poverty, Terrorism and War, Disease, Education, Democracy and Population. The twofold aim of the present study is to summarize the main findings regarding some of these problems, with a particular focus on the changes in environmental conditions, and to provide an overview of the impact of these transformations facing the global food and agricultural system. The review studies focuses on expanding the research for some specific changes to the environment, as well as their impact on food safety.

Keywords
food safety, environment, changes, impact, expectation

Introduction

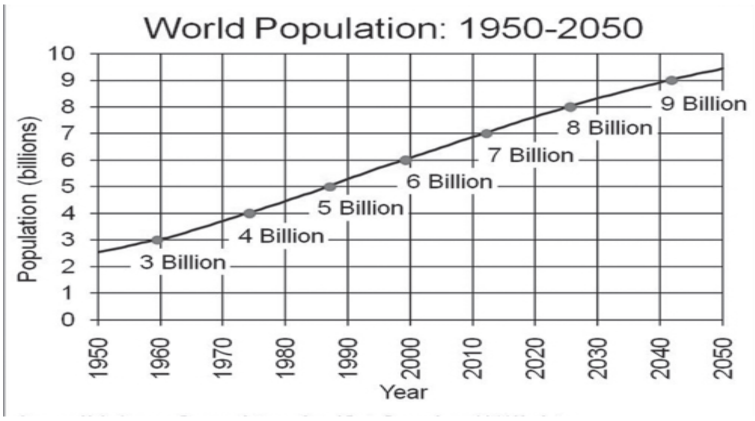
A pertinent question for any discussion regarding the future of humanity is that posed by Wiebe Keith, namely "Why look to 2050?". In answering it, he takes into consideration the following issues:

- Food prices and the economic crisis have increased the number of hungry to 2.02 billion in 2014, but over 800 million people have been living in hunger for decades;
- Sustainable reduction of poverty and food safety remain long-term challenges;
- Long-standing pressures to the environment will continue, especially due to population, income growth and urbanization;
- Some new such pressures are likely to remain or return in the long run (e.g. biofuels);
- Some short-run shocks are likely to become more frequent in the long run due to environmental change;
- The structure of agriculture is changing;
- Changes are long-term and wide-ranging, but policy responses are needed now.

The debate over what should be done about some, if not all of the aforementioned problems facing humanity sparked off in this century.

1. Are we facing a population overload?

In 1900, the global count stood at 1.6 billion people; by 2000, it had shot up to a whopping 6.1 billion people. Alarmingly still, last year, we passed the seven billion mark and forecasts predict that during this century the world will register the biggest population explosion in human history (Figure 1).



Source: U.S. Census Bureau, International Data Base, June 2014

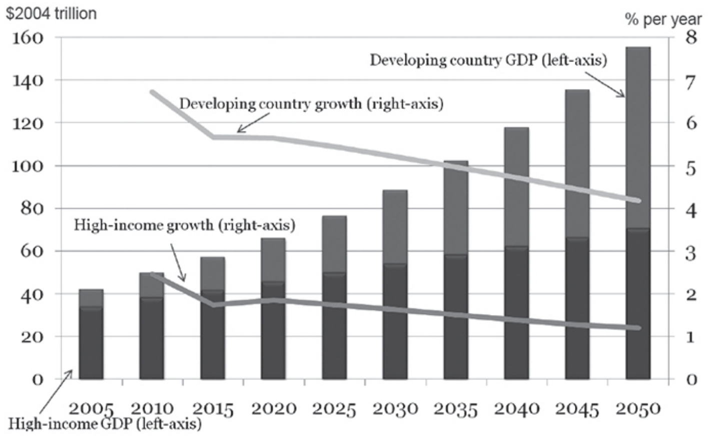
Fig. 1 Population growth (World Population: 1950–2050)

The issue of population overload brings to the forefront an interesting aspect, namely the fact that although global population continues to grow, admittedly at a slower pace, nearly all future population growth will occur in the world's less developed countries. Developed countries as a whole will experience little or no population growth in this century, and much of that growth will be the result of immigration from less developed countries. Consequently, the world's poorest countries are the ones which will have to bear the burden of population growth. In 1950, 1.7 billion people lived in less developed countries—about two-thirds of the world total; by 2050, those living in less developed countries will number over 8 billion, or 86 percent of the world population. In 1950, only about 200 million people out of those living in the less developed countries resided in countries which are currently considered to be "least developed" by the United Nations, but that population is expected to rise to nearly 2 billion by 2050. These statistics paint an alarming picture as those countries have especially low incomes, high economic vulnerability, and poor human development indicators and as such it will be almost impossible for these countries to find appropriate solutions to an ever-increasing population on their own (Population Reference Bureau, 2014).

2. Urbanization Expectation

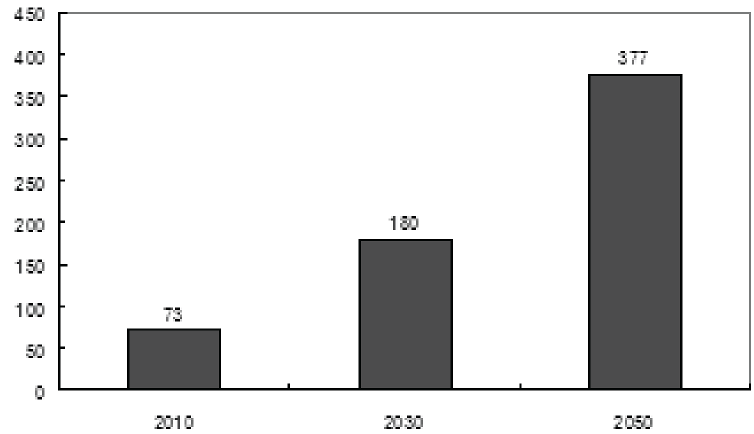
Urbanization is one of the key drivers of change in the world today. The world's urban population currently stands at around 4 billion but it is expected to almost double by 2050. This situation incurs a two-fold change, for both rural and urban areas, because many people, especially the young, will migrate from rural areas to urban areas over this period.

Consequently, when addressing urbanization changes, we are also directly or indirectly addressing rural and territorial development.



Source: Wiebe K.- FAO, 2009

Fig. 2 Income growth



Source: Buiter and Rahbari, 2011

Fig. 3 World real GDP growth 2010-2050 (2010 USD Trillions)

What do we have to do to ensure people's access to good nutrition in cities? What do we have to do to produce enough food for urban dwellers? What infrastructures are needed and what kind of food production is possible in cities? How can cities preserve the services of the surrounding ecosystems? These are just a few of the pivotal questions which link urbanization and food safety and which need effective and pertinent solutions from policy-makers in order to ensure that changes to the environment bring about development and economic growth (FAO, 2011). Urbanization determines changes in dietary preferences, but also in sources of income and vulnerability, while in rural areas structural transitions are taking place. Income growth (Figure 2) remains uneven across and within countries (Wiebe, 2009). It is expected that until 2050 the world economy will experience strong growth (Figure

3), with real GDP growth at PPP exchange rates of 4.6% per annum until 2030 and 3.8% for the period 2030-2050. This would cause global real GDP at PPP exchange rates to skyrocket from $73 trillion in 2010 to about $377 trillion in 2050 (Buiter and Rahbari, 2011).

3. Facts and Statistics on World Hunger and Poverty

The reasons why 850 million people go hungry each day - the vast majority being rural dwellers in the developing world - probably has less to do with food production than poverty – the rich never starve whilst the poor often do. Nevertheless, there is a fear currently that food shortages may themselves lead to instability, famine and mass migration precisely because of the overpopulation burden that the less developed countries have to bear, and which in turn plays an important role in levels of chronic hunger in these countries. According to FAO's most recent estimate, the number of people suffering from chronic hunger has increased from under 800 million in 1996 to over a billion today.

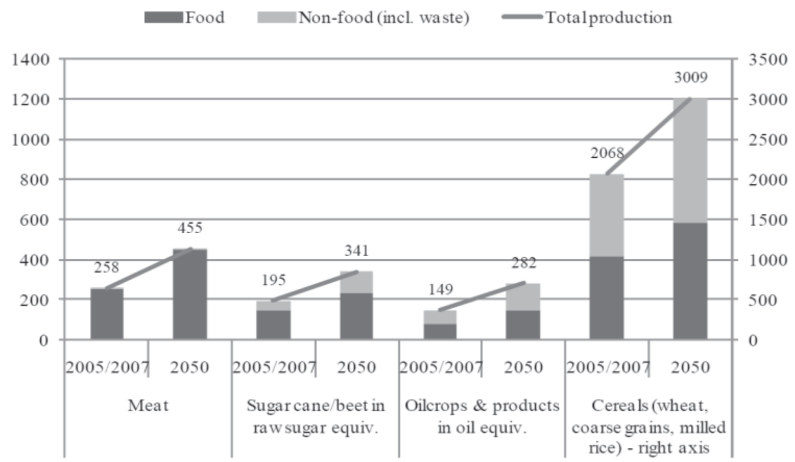
According to statistics, most of the world's hungry are in South Asia and sub-Saharan Africa. These regions have large rural populations, widespread poverty and extensive areas of low agricultural productivity due to steadily degrading resource bases, weak markets and high climatic risks (Vermeulen et al., 2012). Adding on to these problems, and as a result of them, the governments in these regions are themselves weak, inefficient and unable to address the pressing environmental issues their countries are facing.

Of the world's 1.1 billion extremely poor people, about 74 % (810 million) live in marginal areas and rely on small-scale agriculture, as governments in poor countries intentionally focus on urbanization, leaving the rural areas outside their policy focus. While the world currently produces enough food to feed everyone, at least one billion people remain food insecure. Although the incidence of hunger dropped from a ratio of one in three in 1960 to affecting roughly one in seven people by the 1990s, the trend reversed in the 1990s and the absolute number of people blighted by hunger is steadily growing.

In 2009, for the first time in history the population considered to be malnourished surpassed the one billion people threshold (Giovannucci et al., 2012). Although hugely problematic, this is not entirely surprising as life expectancy and per capita food production and consumption have been falling for a significant number of years in sub-Saharan Africa. An additional strain is put on poor African countries such as Malawi, Niger and Ethiopia as it is here that population is growing fastest, that the fertility of the land is falling most rapidly, and that the ability to absorb newcomers in cities is most weak. According to the 2012 Global Hunger Index (GHI), world hunger has declined somewhat since 1990 but remains a "serious" concern. Nevertheless, by simply citing the global average the dramatic differences among regions and countries remain hidden, thus rendering an incomplete picture which does not offer the useful and necessary information needed to stimulate solutions. Regionally, the highest GHI scores are in South Asia and Sub-Saharan Africa. South Asia managed to reduce its GHI score significantly between 1990 and 1996 mainly by reducing the share of underweight children, but could not maintain this rapid progress. Compared to South Asia, sub-Saharan African countries were only able to register income growth towards the turn of the millennium, but, nevertheless, their 2012 GHI score remains below that of South Asia (Grebmer et al., 2012).

In order to meet the world's increasing demand for food, an anticipated 70 percent boost in global food production will be necessary by 2050. However, the mere necessity for such a large increase in food production does not justify obtaining it by any means possible; on the contrary, this aim has to be achieved with a special consideration for the environment and as such most of the growth in food production will need to come from increased yields and productivity rather than from the use of additional agricultural land – a change met in prior

years. In turn, in order for the food system to become more productive, sustainable and reliable, agricultural raw materials will need to be grown precisely in those areas where resources provide the greatest production efficiency and where the crops can be renewed so that production can continue for many years.
The evolution of food production systems over the last decades has been characterized by an increased integration between agriculture, fishery and forestry and other economic activities. With respect to agriculture, studies show that global production should be increasing by 2015. This prediction is mainly supported by the fact that the projected growth rate of total world consumption of all agricultural products is 1.1 percent per annum from 2005/07-2050. Since at the world level (but not at country or regional level) analyses depart from the presumption that consumption is equal to production, this means global production in 2050 should experience a 60 percent increase from the levels recorded in 2005/07 (Alexandratos and Bruinsma, 2012). Concerning the main product groups, percentage increases shown by growth rates may be small compared with those of the past, but the absolute volumes involved are nonetheless substantial (Figure 4).



Source: Alexandratos, N. and J. Bruinsma (2012)

Fig. 4 World production and use, major products (million tonnes)

To exemplify, world cereal production is projected to grow at a 0.9 percent rate per year from 2005/07 to 2050, down from the 1.9 percent increase per year recorded during the 1961-2007 timeframe. In raw numbers, this translates to a projected increase of another 940 million tones of cereal over the following 44 years, which unveils a significant difference from the 1,225 million tones produced globally between 1961/63 and 2005/07, increase which will determine the world cereal production to reach 3 billion tones by 2050 (Alexandratos and Bruinsma, 2012).
Nevertheless, it will not be easier to achieve such levels of global production growth than it was the past; rather, the contrary often holds for a number of reasons. Firstly, land and water resources are now much more stressed than in the past and are becoming increasingly scarcer, both in quantitative terms (per capita availability) and qualitative ones – as a consequence of soil degradation, salinization of irrigated areas and the competition for using land for other, more profitable, activities than food production (Alexandratos and Bruinsma, 2012). As a result, a second impediment to growing production levels arises, namely the fact that growth

of crop yields has slowed down considerably, and considerable fears are expressed that the trend may not reverse. The issue regarding this impediment is not whether yields would grow at the high rates recorded in the past, as it is already known that they are unlikely to do so, apart from the individual countries and crops. Rather, the more alarming issue is whether the lower growth potential, together with modest increases in cultivated land, is sufficient to meet the increased requirements of the very fast-paced growth in population. Furthermore, changes in the environment may negatively impact on the production potential of the already stressed agricultural resources in many areas of the world, offering thus a gloom prospect (Alexandratos and Bruinsma, 2012).
In general, the sustainability of the food production system is being questioned. Considerable doubts are cast on the possibility to continue doing more of the same, namely of using high levels of input in production, increasing the share of livestock in total output, expanding cultivated land and irrigation, and transporting products over long distances. Consequently, many scholars and analysts advocate the need for "sustainable intensification" of production (Society, 2009; Godfray et al., 2010; Nature, 2010).
According to the International Food Policy Research Institute, the annual growth in cereal yields is projected to fall to about one per cent during the next two decades, taking thus into consideration all of the aforementioned potential problems. On the other hand, the Food and Agricultural Organization offers a more optimistic yet unrealistic outlook, estimating that total food production of all sorts will grow annually at about 1.5 per cent over the next 30 years, keeping ahead of population growth, now running at 1.3 per cent a year (Diouf, 2012).
Considering the aforementioned impediments, a pertinent question that needs to be asked is whether it will be possible to devise solutions in order to achieve the projected quantities of production? As such, we shall further on show what we envision as possible combinations of land and water use and yield growth that could aid and determine the production projections.

4. Food prices

Global food prices rose twice as fast as inflation in the last decade, impoverishing millions at a time when poverty relief captured the world's attention. Huge price swings for wheat, maize, soybeans and rice - staple crops for much of the world - made matters worse, disrupting markets and harming both producers and consumers. The food riots that swept more than two dozen countries in 2008 and 2011 were the most eloquent examples of the negative effects of these trends, but they also invariably point to a deeper and more lasting concern: chronic food insafety (von Grebmer et al., 2012).
On average, food prices are expected to rise moderately in line with the average increases of temperature until 2050; some studies even foresee a mild decline in real prices until 2050. In addition, further projected increases in temperatures after 2050 are expected to determine substantial increases in prices (Tubiello et al., 2008).
Local food prices in developing countries increased 8.9 percent in 2011 alone, reflecting, on the one hand, frost conditions in several developing regions during the previous year (notably in Europe and Central Asia and the Horn of Africa) and, on the other hand, the sharp 24 percent increase in the dollar price of international food commodities. Furthermore, food prices in 2012 stood at 3 percentage points lower than in 2011, assuming a normal crop year. Despite the welcome normalization of domestic food price inflation, currently, domestic food prices in developing countries remain 25 percent higher than they were at the beginning of 2005, relative to non-food consumer prices. While incomes in developing countries have continued to rise, the sharp increase in food prices will have limited gains for many households, such as the urban poor, where food often represents more-than one-half of their total expenditures (The World Bank, 2012).

5. Environmental Change

The most general definition of environmental change is a change in the statistical properties of the environmental system when considered over long periods of time, regardless of cause (NSIDC, 2012). By contrast, fluctuations over periods shorter than a few decades, such as El Niño, do not represent environmental change.

The term sometimes is used to refer specifically to environmental change caused by human activity, as opposed to environmental changes that may have resulted as part of Earth's natural processes (The United Nations Framework Convention on Environmental Change, http://unfccc.int/essential_background/convention/background/items/1349. php, 1994). By utilizing these concepts in the context of environmental policy, the term environmental change has become synonymous with anthropogenic global warming. Within scientific journals, global warming refers to surface temperature increases while environmental change includes global warming and everything else that will be affected by increasing greenhouse gas levels (NASA, 2008).

6. Causes

In order to analyze the causes for these issues, it is necessary to depart from a very broad setting. The equilibrium temperature of the Earth and, hence, the particularities of the environment are determined by the rate at which energy is received from the sun and the rate at which it is lost to space. This energy is then distributed around the globe by winds, ocean currents, and other mechanisms to directly affect the environment of different regions.

Thus, factors that can shape the environment are called environmental forces or "forcing mechanisms" (EPA U.). These include processes such as variations in solar radiation, variations in the Earth's orbit, mountain building and continental drift and changes in greenhouse gas concentrations. Nevertheless, there are varieties of environmental changes taking place that can either amplify or diminish the initial forcing mechanisms. Some parts of the environmental system, such as the oceans and ice caps, respond slowly in reaction to environmental forcing mechanisms, while others respond more promptily.

Forcing mechanisms can be either "internal" or "external". The internal ones are natural processes within the environmental system itself (e.g., the thermohaline circulation). In contrast, external forcing mechanisms can be either natural (e.g., changes in solar output) or anthropogenic (e.g., increased emissions of greenhouse gases).

Irrespective of whether the initial forcing mechanism is internal or external, the response of the environmental system might be fast (e.g., a sudden cooling due to airborne volcanic ash reflecting sunlight), slow (e.g. thermal expansion of warming ocean water), or a combination of the two (e.g., sudden loss of albedo in the arctic ocean as sea ice melts, followed by more gradual thermal expansion of the water). Therefore, the environmental system can respond abruptly, but the full response to forcing mechanisms may not unfold completely for centuries or even longer.

7. Internal forcing mechanisms

Natural changes in the components of Earth's environmental system and their interactions are the cause of internal environmental variations, or "internal forcing." Scientists generally define the five components of Earth's environmental system to include atmosphere, hydrosphere, biosphere and rocks and sediments (NASA Earth Observatory, 2011).

8. The cost of environmental change

Understanding the ways in which environmental change impacts on the world economy is, obviously, of paramount importance in order to devise ground-breaking adaptation policies and to effectively mitigate for tackling these issues. However, devising forward-thinking solutions to environmental changes and their impact on our lives, is a quite hard enterprise, for two main reasons (Roson and Mensbrugghe, 2010).

Firstly, environmental change is a systemic phenomenon, both in terms of natural and human systems. In the so-called "Earth System", physical elements like the oceans, winds, the stratosphere, etc., interact and thus influence global environmental conditions. In terms of socio-economic consequences, the increasingly close links between markets, as well as trade, propagate the effects of economic factors much more rapidly throughout the globalized economy than in the less interwoven markets of the past. As environmental change is an intrinsically systemic phenomenon, it is inherently affected by the complexity and uncertainty of these interwoven markets.

Secondly, the socio-economic impact of environmental change unravels on a number of different dimensions (e.g., sea level rise, human health, etc.), each of them with a particular mechanism and implications. To achieve a realistic assessment of the impacts, there is a need to adequately address each of these dimensions, in and of its own.

Undoubtedly, the world is set to pay a heavy price if it fails to tackle environmental change. In this sense, the findings a report commissioned by 20 governments, found that over 100 million people are likely to die and global economic growth will be cut by 3.2 percent of gross domestic product (GDP) by 2030 if steps are not taken to address and find solutions to environmental changes (Zeenews Bureau, 2012). Furthermore, Roson and Mensbrugghe's (2010) work devises a model of the ways in which environmental change impacts on the world economy by accounting for and estimating certain environemtn parameters which were thought to bear an impact on the economy at the global scale. As such, seven types of areas which hold an important impact are considered in the work: agriculture productivity, sea level rise, water availability, tourism, energy demand, human health and labor productivity. Catastrophic events and extreme weather are not taken into account (Roson and Mensbrugghe, 2010).

Similarly, the report by humanitarian organisation DARA says that as global average temperatures rise due to greenhouse gas emissions, the effects on the planet, particularly the melting ice caps, extreme weather, frost and rising sea levels, will threaten populations and livelihoods (Zeenews Bureau, 2012). The report itself was commissioned by the Environmental Vulnerable Forum, a partnership of 20 developing countries threatened by environmental change and which decided to take action on the pivotal isse of environmental change. It assessed that air pollution, hunger and disease account for five million deaths, as a result of environmental change and carbon-intensive economies, and that the toll would likely rise to six million a year by 2030 if current patterns of fossil fuel use continue. Worryingly enough, the report further assesses that over 90 percent of those deaths will occur in developing countries, as it analyzes the human and economic impact of environmental change on 184 countries in 2010 and 2030. Additionally, the report found that "a combined environmental carbon crisis is estimated to claim 100 million lives between now and the end of the next decade”. The report also found that the effects of environmental change had lowered global output by 1.6 percent of world GDP, or by about $1.2 trillion per year and losses could double to 3.2 percent of global GDP by 2030 if global temperatures are allowed to rise, surpassing 10 percent before 2100. It estimated the cost of moving the world to a low carbon economy at about 0.5 percent of GDP this decade (Zeenews Bureau, 2012). In the following, we briefly describe how the environmental change influences food safety and agriculture.

9. Agriculture and Food Safety under Environmental Change

During this century, agriculture faces an array of changes: more food and fibre has to be produced in order to feed a growing population while at the same time relying on a smaller rural labour force; more feed stocks are necessary for a potentially huge bioenergy market; progress needs to be made towards the overall development in the many agriculture-dependent developing countries; more efficient and sustainable production methods have to be adopted in order to adapt to environmental change (Bruinsma, 2009). The study done by the International Food Policy Research Institute (IFPRI), entitled ‘Environmental change: Impact on agriculture and costs of adaptation’, pinpointed some of the anticipated costs of environmental change:

- 25 million more children will be malnourished in 2050 due to environmental change provided no serious mitigation efforts or adaptation expenditures are made;
- Irrigated wheat yields in 2050 will be reduced by around 30% and irrigated rice yields by 15% in developing countries;
- Environmental change will increase prices in 2050 by 90% for wheat, 12% for rice and 35% for maize, on top of already higher prices;
- At least US$7 billion a year are necessary to improve agricultural productivity to prevent adverse effects on children.

It is widely acknowledged that environmental change is the unfortunate outcome of human activity including, but not limited to, industrial output, car exhaust, and deforestation. These types of activities increase the concentrations of carbon dioxide, methane, nitrous oxide and other greenhouse gases (GHGs) in the atmosphere. It is predicted that if the current trend in carbon emissions continues, temperatures will rise by about 1 degree C by the year 2030 and by 2 degree C by the next century.

This increase, however, is likely to impact different regions in various manners. The impact on agriculture, for example, will be more adverse in tropical areas than in temperate areas. As a result, those who are set to benefit most are precisely those living in already developed countries since cereal productivity is projected to rise in Canada, northern Europe and parts of Russia. In contrast, many of today’s poorest developing countries will be compelled to bear the burdens of the majority of the negative effects during the next 50 – 100 years, of which the most significant is the reduction in the extent of cropland and its productivity potential. By fat the most severely affected will be the countries in sub-Saharan Africa due to their inability to adequately adapt as a result of a combination of insufficient resources, bad governance, poor economic prospects and the increasing need for food imports (FAO, 2003).

According to the Intergovernmental Panel on Environmental Change (IPCC), in 2004 agriculture directly contributed to 13.5 per cent of global greenhouse gas emissions (GHGs). In addition, deforestation, mainly to convert land for agricultural uses, contributed a further 17 per cent (Figure 5). Hence, altogether, agriculture contributes about one third of global GHG emissions (Huang et al., 2010).

Similar to most other sectors, the carbon footprint is increasing in agriculture too, since farming is set to expand to produce more food for a growing world population. That automatically entails the need for more land-use change, more cultivation of crops, many more livestock, more demands for water and more use of fossil fuels. Added on to these is the fierce competition for land to be used for bioenergy production as well as for urban and environmental uses. Agriculture thus plays a double role, on the one hand being a source of GHGs contributing to environmental change, and on the other hand being itself affected by changes to the environment, as detailed previously. Projections for 2050 suggest an increase in both global mean temperatures and weather variability, including precipitations (IPCC, 2007). This will clearly affect the type and location of agricultural production worldwide, with implications for trade and living and compelling countries to specialize in cultivating new types of crops (Huang et al., 2010).

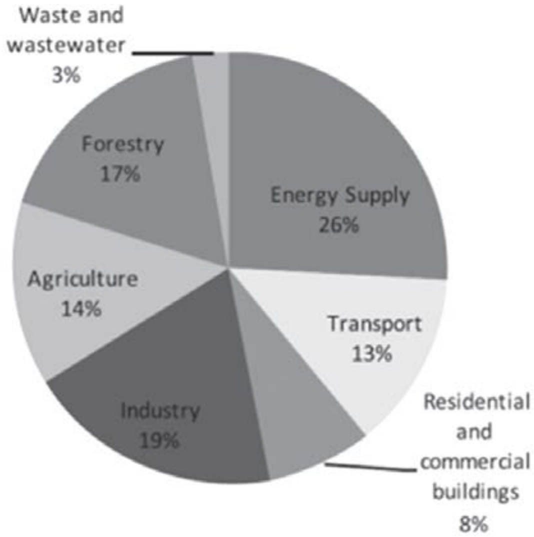


Fig. 5 Global GHG emissions by sector, in CO2 equivalents

“Agriculture is the sector most affected by changes in environmental patterns and will be increasingly vulnerable in the future” asserted the FAO in a press statement along with the fact that “especially at risk are developing countries, which are highly dependent on agriculture and have fewer resources and options to combat damage from environmental change”. Farming is most dependent on stable environmental and as such “the most serious threats will not be occasional severe frost or heat wave but subtle temperature shifts during key periods in the crop’s life cycle, as these are most disruptive to plants bred for optimal climatic conditions”, wrote Danielle Nierenberg and Brian Halweil in a Worldwatch report (Diouf, 2012). In the long-term, such an issue will effectively compel already poor countries, with insufficient resources and lacking infrastructure, to reconsider and adapt their crops, task which will seemingly be impossible in most cases.

Some of the impacts of environmental change on food production which are already visible and seem to be advancing at a higher rate than previously anticipated include the response of agricultural, pastoral and forest systems to simultaneous changes in atmospheric and climatic parameters:

- carbon dioxide, regarding which the question is where there are any saturation effects and if so, at what concentration level;
- mean temperature and its variability (day-night and summer-winter ratios);
- mean precipitation and its variability;
- other factors, including tropospheric ozone, UV-B and acid deposition;
- the impact of changes in the environmental and atmospheric composition on: disturbance regimes, including fires and pest and disease outbreaks, adaptation options (planting times, crop selection, irrigation, fertilization)
- new cultivars - the role of biotechnology, including transgenic crops (temperature, frost, pest and saltiness tolerance).

These parameters all depend on the actual future outcome for the environment and the expected impact on agriculture in temperate areas, which include OECD countries, and on whether effective measures will be taken to adapt or not (Huang et al., 2010).

10. Understanding the problem, targeting the solutions

To begin with, the first step is to understand the problem; but although this seems rudimental and easy, being able to acknowledge and analize the problem at hand is in itself a challenge. While environmental scientists are working to understand what is going to happen to the environment, there is currently much uncertainty in their projections. The reason behind this is the fact that predicting how these uncertain changes will affect agricultural and food systems is an extremely tedious and difficult task, one which invariably leaves a lot of room for error. What we can do, however, is look at the vulnerability of systems, in light of the possible changes to the environment. Vulnerability depends on both the sensitivity of the system to environmental shocks, and the adaptive capacity of the population (Moorhead, 2009).

11. Environmental change on food safety

Environmental change is expected to impact food safety in a number of different ways. Out of all the important effects that global warming and environmental change have on agricultural food production, both positive and negative, an assessment of food safety, should focus primarily and preponderently on the negative aspects (http://www.environmentalchangefoodsafety.org/many_impacts.html).

Unfortunately, the negative adverse effects predominate in number and overall effect and thus the higher the global temperature increase the more the negative effects predominate. Increasing the CO2 in the air potentially has a beneficial fertilizer effect on crops. However this only applies to a limited number of crops and even for those global warming may have a modest and brief benefit (IPCC, 2007). Undoubtedly, at certain levels of global warming, heat damage alone will counteract any benefit that CO2 may bring. The troposphere (also known as ground level ozone) is increases alongside temperatures, having a toxic effect on green plants, which then entails a double damage to crops from global warming. The absolute limit of crop tolerance in all regions of the world is a global average temperature increase of 3.0 degrees C (see Met Office NRC and IPCC). However this estimate relies on very inadequate environmental crop models, that do not capture many of the adverse effects and therefore does not provide a reliable estimate for food safety under environmental change. Atmospheric greenhouse gas pollution causes the following issues, that all impact adversely of food productivity and food safety by stimulating global warming, global environmental change, environmental variations, heavier precipitations, more floods, more severe storms, more cyclones, more heat waves and sudden temperature spikes, increased troposphere ozone, ocean acidification (with ocean warming) and sea level rise, more weeds, more insect pests (+ more pesticide resistance), more plant diseases.

In responding to the future changes which agriculture will have to face in order to meet the growing food demand, it is important to develop a coherent policy approach that should focus on the following areas (Huang et al., 2010):

- ensuring a stable policy environment that provides accurate information to consumers and producers about the costs and benefits of GHG mitigating / sequestering activities;
- implementing policies that steer the price of carbon in such a manner that incentives are created for producers and consumers to invest in low-GHG products, technologies and processes;
- designing policies that foster the application of existing technologies and invest in research and development for new technologies to reduce GHG emissions and increase productivity;
- building capacity to better understand and measure the impact of GHG on agricultural activities – essential for monitoring progress made in attaining the national and international environmental change goals;
- implementing or enhancing existing policies that facilitate adaptation by increasing producer elasticity to environmental change, and that compensate the most vulnerable groups, in particular in developing countries;
- encouraging more research on understanding and linking agronomy, ecology and economics, in particular taking into account the fact that nowadays, seasons are changing, temperatures are rising of both earth and seawater and the prospect for the future is that these trends will continue. Hence, it is high time that the global community as a whole comes forward to formulate a collective strategy for meeting or facing the biggest challenge of this century.

Both developed and developing nations are equally affected by these issues and have a direct and significant interest in addressing them and formulating pertinent and applicable solutions. As such, both developing and developed countries must take lesson from the recent Japanese nuclear disaster and come forward in order to formulate a collective strategy for tackling and finding solutions to the biggest challenge of this century (Iqbal and Ghauri, 2011).

12. Adapting agriculture to environmental change

Agriculture in itself is responsible for about a third of the world's greenhouse-gas emissions. Activities specific to this domain, such as ploughing land and shifting ('slash and burn') cultivation, which are indispensable for expansion of agriculture and the realization of the objectives set in order to counteract the negative effects of climate change, release CO2 into the air, impacting thus negatively on the environment. A level of 40 percent of the human caused methane comes from the decomposition of organic matter in flooded rice paddies, this being only one example of an activity adjacent to agriculture which harms the environment. In addition, about 25 percent of the world methane emissions come from livestock. Similarly, agriculture is responsible for 80 percent of the human-made nitrous-oxide emissions through breakdown of fertilizer and that of manure and urine from livestock. However, agriculture's GHG emissions can be largely reduced, and much can be done to lessen their effect on production and on the livelihoods of farmers, especially in developing countries (FAO, 2003).

Adapting agriculture to environmental change is a pivotal domain for primary industry professionals, land managers, policy makers, researchers and students involved in preparing the world for the changes and opportunities of environmental change, for whom this field provides a landmark opportunity for growth, profit and innovation in order to create a better world.

The term ‘‘adaptation’’ encompasses the actions of adjusting practices, processes, and capital in response to the reality of and threat posed by environmental change, as well as the decisions devised as responses to this challenge, such as changes in social and institutional structures or altered technical options, that have the ability to positively impact on the potential or capacity for the former actions to be realized (IPCC, 2007).

Howden et al. (2007) emphasize the importance of greater focus on the adaptation of agriculture to environmental change by presenting several considerations as being of utmost importance:

1. Past emissions of greenhouse gases have already committed the globe to further warming of 0.1°C per decade for several decades, a level which has already impacted on our livelihoods and lifestyles making it therefore necessary and unavoidable that measures are taken in order to adapt to the new world realities.

2. The emissions of major greenhouse gases are continuing to increase, determining drastic changes in atmospheric CO2 concentration, global temperatures, and sea levels, which are already noticed by those involved at the high-level of the environmental change agenda, specifically by the Intergovernmental Panel on Environmental Change (IPCC), whose work already considers scenarios relating to such changes. Furthermore, the outcomes of some environmental changes are happening faster than previously considered likely. If these trends continue, a more proactive and rapid adaptation will be needed.

3. There is currently a stark lack of progress in developing global emission-reduction agreements beyond the Kyoto Protocol, leading to concerns about the level of future emissions, environmental changes and associated impacts.

4. The scenarios involving the maximum threshold for environmental change have changed as this threshold has been increasing over time, and these potentially higher global temperatures may have nonlinear and an increasingly detrimental impact on existing agricultural activities.

5. Environmental changes may also provide opportunities for agricultural investment, rewarding early action taken to capitalize on these options.

There is an immense diversity of agricultural practices because of: the vast range of environmental and other relevant variables; cultural, institutional, and economic factors; as well as the interactions between the aforementioned. This consequently entails that there is a correspondingly large array of possible adaptation options (Howden et al., 2007) which forther means that adapting agriculture to environmental change does not require reinventing agricultural practices. Instead, it requires adapting good agricultural practices to meet changing and often more difficult environmental conditions. To make sure the appropriate information is shared and put into practice, FAO’s work is pivotal, collaborating with its member countries to ensure growing capacities at the national, local and community levels and to raise awareness and prepare for the potential effects of environmental change. At the government level, the goal is to transform environmental change issues into a mainstream subject which can then be more easily tackled and resolved by ensuring inclusion of appropriate adaptation practices in agricultural policies and programmes. At the grassroots level, FAO provides local communities with site-specific analyses of the potential, specific impact of environmental change on agriculture and possible solutions for adapting their livelihoods more effectively to this ever-changing environment.

Thanks to FAO's active involvement, adaptation measures are either planned or taking place in the context of natural hazard prevention, environmental protection and sustainable resource management, proving thus also beneficial for adapting to climatic change in general. These measures are generally aimed more at reducing vulnerability to current environmental variations, than at preventing the potentially more extreme weather conditions projected to take place in the future.

Farmers can adopt coping mechanisms that withstand fluctuations in the environmental conditions through activities such as the use of frost-resistant or salt-resistant crop varieties, the more efficient use of water resources, and improved pest management. Changes in cultivation patterns can include the reduction of fertilizer use, the better management of rice production, the improvement of livestock diets and the better management of their manure.

In addition, national governments have an important role to play in enforcing land use policies which discourage slash and burn expansion and extensive (rather than intensive) livestock rearing, as well as raising the opportunities for rural employment (FAO, 2003).

13. New Changes for Agricultural Research

On the 7th and 8th of April 2008 the Management Committee of the Co-operative Research Programme: Biological Resource Management of Sustainable Agricultural Systems (CRP), upon the request of the Governing Body, met in Budapest to consider a "Vision for the Future" for the CRP program, with a view to contributing to the preparation of the CRP's mandate for 2010-2014(OECD, 2010).

First and foremost, this report takes into consideration the multiple roles of agriculture in the provision of public goods and services (OECD, 2010). Furthermore, it reflects on the CRP's present themes and makes suggestions regarding specific priority research areas for future work. The report then considers the governance structure of the CRP and in particular the respective roles of the GB and the MC and the links between the CRP and the Committee for Agriculture.

The Reflection Group finally found it appropriate to also include a number of suggestions for a communications strategy that might help in adding visibility to the Program. As a result, the Reflection Group focused on 12 areas of work, among which priority was given to agriculture and fisheries research in order to unravel a range of issues of particular relevance to the group's work. Nevertheless, the list is not exhaustive as the CRP is an institution aimed at continuously developing and thus guidance from the Committee for Agriculture is to be periodically sought with a view to prioritizing the work and ensure the continued policy relevance of the Program.

14. Landscape

The notion of landscape offers a useful framework for conceptualizing the integration of ecological processes and agricultural productivity at relevant spatial scales. The importance of landscape derives from the fact that healthy functioning landscapes, with their links to the urban environment, fulfilling an array of roles and delivering a range of services to society, some of which are non-economic and intangible in nature but equally important. This includes, but is not limited to services provided in areas such as leisure, health, tourism and the conservation of biodiversity.

Other, crucial services which are intrinsically connected to the landscapes they function in include the stabilization of water resources, significant buffering of environmental through carbon sequestration of soil and the role of vegetation cover. The importance of agriculture for these landscapes materializes in the fact that the former plays a key role in maintaining the latter and in turn landscapes deliver the aforementioned services, and others, to society.

15. Spatial policy
The management of space and therefore of ecosystems is predicted to be a pivotal change which will take place in the future, which will also bear a significant impact on agriculture roles. The scale of impact, different possible uses of space, competitive claims over land from different user groups, and prices are only some of the issues linked to this domain, which will affect the place assigned to the agriculture agenda in process of devising policy regarding terrestrial space. The most pressing of them, by far, is the fierce competition with respect to the agricultural versus non-agricultural uses of space, including the uses of urban and coastal encroachments. Nevertheless, mapping the different uses of space does not seem to be a key feature of the policy-makers' agenda for addressing and finding solutions to the divergences between the conflicting user claims, on the one side, and societal needs, on the other side.

16. Invasive species and bio-safety
As a corollary of the increasing global interactions across countries and continents, the nature of invasive species has changed, along with the extent to and conditions in which they emerge, issue which only underlines the growing importance of biosafety, of being prepared to tackle the challenges arising in this field and of appropriately assessing the risks associated with it. The importance of this looking deeper into this change also arises from the fact that invasive pests and diseases are a two-fold cause of worry, threatening both agricultural productivity and biodiversity.

From a human perspective, the emerging issues of pathogens transmitted from animals to humans via various means (zoo diseases like SARS, avian "flu"), or directly to humans, animals and crops, are a legitimate cause of serious concern, as these pathogens can have devastating effects across the globe within a very short time span, and potentially causing global-level, uncontrollable epidemic. This is why understanding the spread of these pests and diseases, their early detection and assessment are crucial to developing appropriate policy responses for modern societies. In addition, risk assessment is needed to gauge the manner and extent to which these changes impact on societies around the globe.

17. Water
Water is pivotal to the development of agriculture, as this domain requires the use of extensive quantities of water and in some regions and for some crops agriculture may be the primary domain where water is directed. The trend of falling water tables entails that water as a resource is increasingly being exploited, but not replenished. Agriculture plays a key influence in the dynamics of water catchments and its over-dependence on water use may be seriously depleting the latter's availability and influencing its quality.

This nexus is becoming a widely recognized problem that needs to be underpinned with appropriate agriculture and food policy research and development.

18. Animal production
One of the results of increasing living standards across the developing world is a growing demand for animal protein, issue which has put pressure on the animal production systems. This in turn determines an array of possible negative consequences for the environment, with a significant impact on the use of water, feed and feed compounds. In addition, there is a fierce competition for alternative uses of the same resources.

Consequently, there is an urgent need to reconsider present production systems with a view to reducing the externalities of animal husbandry including the identification of new and improved protein sources, animal production practices and animal movement. It is recalled that animal production is an important source of greenhouse gases, notably methane. The role of aquaculture to provide alternative sources of protein and more generally the use of the oceans have a great potential to help reduce the stress on the terrestrial food production systems.

19. Forests

If sustainably managed, forests are a paramount source of carbon sequestration, which is of utmost necessity to society, much more important than social amenities, water retention, biodiversity and the environmental protection of land. Nevertheless, the continued deforestation and certain forest practices make this a key area in which innovation is ardently needed, most notably in countries which are not members of the OECD. In this respect, deforestation in the developing countries is a policy area in which coherence and development are lacking and should therefore be strengthened.

20. Bio-products and bio-processes

Nowadays, there is a growing demand for bio-products produced with biologically sound farming practices, precisely because of some of the aforementioned results of environmental change of which changes to invasive species is probably the most notable. While still a relatively small trend in the overall food market, this has become a non-negligible part of the consumers' demand schedule, but the predicted trend is towards a growing interest in bio-products and bioprocesses, which will therefore grow from the private sector into a legitimate industry.

The manner in which these developments interact and influence farming practices (e.g. food versus energy, pharmaceuticals, and novel non-food uses for agricultural products) is prone to conflicts of interest and is therefore likely that policy debate and agendas will need to take it increasingly more serious. Nevertheless, the science underlying the possible externality effects of such production systems is still seriously underdeveloped and represents a significant opportunity for devising novel and practical solutions.

21. Biodiversity

Biodiversity issues are increasingly coming to the forefront of the agriculture, forestry and fisheries policy debate. Modern management practices coupled with environmental change and other human activities (e.g. urbanization) consistently put pressures on biodiversity. The resultant loss of biodiversity not only threatens the functioning of terrestrial and marine ecosystems, but also the capacity of society to adapt to certain changes (e.g. diseases). It is therefore important that management practices take into consideration the protection and enhancement of biodiversity and those policies are being brought to bear to define the limits of tolerable impacts. Two particular areas of concern with respect to biodiversity are "subsidies" for biodiversity and how to deal with property rights for genetic resources.

22. Waste (and by-products)

The policy and research changes are to realize the potential and value of what might be regarded as waste. Recycling is an important objective for food production systems with a view to capturing the externalities. Animal husbandry is chief among the agriculture practices with major waste effects with impacts on the environment.

Research in this area seeks to understand the potential of waste for alternative uses, improve the use of waste, for example, in energy production, including better sources of fertilizer and conditioners of soil.

23. Food safety

Global food demand is undergoing major change in quantity and structure and will dramatically increase along with demographic changes. Globalization of food production systems may add an additional food safety risk. Both are likely to increase the uncertainty and vulnerability of the food production system. Research in this area can contribute to better identifying risks in food production chains through vulnerability, disease, outbreaks (biological and physical crises) and identify best practices among member countries in addressing such risks. The costs of inaction in this respect may add political risks and undermine the stability of societies.

24. Aquaculture and marine ecosystems

The marine ecosystem can also be an important provider of food and bio-energy products. Given pressures on terrestrial ecosystems, it would be advisable to increasingly focus on the ability of the oceans to reduce the stress on the productive capacity of the terrestrial ecosystem, while recognizing that some marine ecosystems are already under pressure. Research in this area could include better aquaculture practices and the use of algae in bio-energy production.

25. Energy use in food production

Food production systems are also responsible for adding to environmental change through the energy needed to grow crops and raise animals, transport, processing and distribution Research in this area on life cycle analysis could contribute to identifying food production systems with greater energy efficiency.

26. Governance

From other hand, the European Communities (2009) based on the "SCAR-WG assessment and tentative conclusions" on the second foresight report, the following recommendations in relation to research and innovation can be proposed (in no particular order):

- to further explore the full range of possibilities to reduce GHG emissions and to mitigate environmental change effects associated with "the agricultural sector"
- to understand not only the functioning of ecosystems but also their criticality. The elasticity of the combined bio- and socio/economic systems is at the heart of our ability to be able to address the changes that we face. This has strong implications for the knowledge that needs to be generated to address issues that impact on "agriculture" but which have a much wider base than this specific sector. Therefore, the systems approaches needed have to be highlighted
- to further develop low external input concepts which are more diversified and "greener" (the next generation of agricultural research) paving the way for alternative models that will include low input concepts, increased diversification, and a reconsideration of the way we produce, process, retail and purchase food, making sustainable development
- to quickly improve the capacities of the agricultural knowledge system so that it can address the new and severe changes in the required timescales.

Conclusions

Biotechnology is a broad discipline that studies the potential use of natural and modified organisms and systems in agriculture, medicine, environment and many other fields. It uses a wide range of techniques, from relatively simple breeding to highly sophisticated molecular and cellular manipulations to produce specific desired traits in plants, animals or microorganisms, often requiring extensive knowledge of the genetics of the target organisms. The evolution of plant breeding is a classic example of how improved biological understanding has been adapted to provide more effective methods of meeting the demands of a changing world. Plant biotechnology offers significant improvements in virtually every area of crop production and utilization, with potential benefits to farmers, the food industry, consumers and the environment. Biotechnology is not a separate science, but rather a mix of disciplines, such as biochemistry and physiology, microbiology, genetics, molecular biology, and cell biology. Biotechnology consists of a gradient of technologies, ranging from the long-established and widely used techniques of traditional biotechnology (for example, food fermentation and biogas production), through to novel and continuously evolving techniques, such as genetic engineering and genomics.

Biotechnology could also be seen as an integration of new techniques emerging from modern biotechnology with the well-established approaches of traditional biotechnology, such as crop and livestock breeding, food production, fermentation products and processes, and the production of pharmaceuticals. The diversity of techniques that constitute modern biotechnology offers much promise to serve the pressing needs of sustainable development in the agriculture, industrial and health sector. For developing countries the change will be to develop biotechnology based innovation systems that are able to adapt relevant knowledge and technologies that can contribute to economic growth and also improve environment, health and livelihoods. Agricultural biotechnology is becoming a progressively more important factor in shaping agricultural production systems worldwide, including developing countries. Biotechnology and genomics are the most promising tools for addressing new agricultural changes.

The ultimate vision of the plan is a sustainable, resource-conserving, and highly innovative bio-based economy. Plans for the future center around four essential principles:

- The production of safe, high quality food and feed in sufficient quantities;
- Sustainable agriculture;
- The development of plants for the production of renewable resources and energy;
- Increasing competitiveness while maintaining the freedom of choice for consumers.

However, farmers and pastoralists have manipulated the genetic make-up of plants and animals since agriculture began more than 10 000 years ago. Farmers managed the process of domestication over millennia, through many cycles of selection of the best-adapted individuals. This exploitation of the natural variation in biological organisms has given us the crops, plantation trees, farm animals and farmed fish of today, which often differ radically from their early ancestors.

Adoption of modern practices of agriculture, starting from the use of superior germ plasm for improvement in plant characteristics by modern biotechnological methods and traditional plant breeding technologies, coupled to innovative farm practices, have influenced food production. Research in plant biotechnology has previously focused primarily on agronomic characteristics to improve resistance or tolerance to biotic and abiotic stresses in particular crop plants. While this effort has been relatively successful, new products that can meet the demands for increased yield and quality are limited, although recent efforts are showing some promise. These include improvement of the nutritional quality of food for human and livestock health, and the development of ingredients with superior properties for food manufacturing and processing. Systematic efforts to improve the quality and quantity of carbohydrates, proteins, lipid, vitamins and minerals in staple cereal or vegetable crops have made encouraging progress and led to the development of new approaches.

Using advanced biotechnology tools, genetic resources can be more precisely characterized, efficiently improved and tailored to specific needs. The technologies can be used to support the development of sustainable production systems for food, feed and crops for industrial purposes, such as bio fuel. Novel agro processing techniques using biotechnology can add downstream value to crops and their byproducts. Modern agricultural biotechnology, which includes disciplines such as genetic engineering, bioinformatics, structural and functional genomics, and synthetic genomics, is a comparatively young field of science. Thus, we have so far only seen the beginning of what promises to be a very exciting and maybe also revolutionary technology.

Agricultural biotechnology is however not a solution or a means in itself and largely depends on the existence of effective breeding programs. Thus, agricultural biotechnology can never replace conventional breeding, but can be a vitally important tool in supporting sustainable agricultural production and breeding systems to be highly adaptive and effective in serving local needs. The grand change in plant biotechnology therefore lies foremost in increasing crop productivity at orders of magnitude, which has never been achieved so far, but not much less in improving plant quality to be optimal for its traditional uses, e.g., food and feed, but also to provide tailor-made biomaterials for a vast range of industrial applications including the provision of energy for a range of purposes, which can only be achieved if the enabling technologies are also further developed allowing advancements in plant breeding at unprecedented speed. This will lead to address new changes for Plant Biotechnology:

- Increase crop productivity especially in adverse environments;
- Management of herbicide tolerance;
- Management of resistance to pests;
- Management of resistance to diseases;
- Improvement of genetic engineering technologies to enhance public perception;
- Improvement of harvest index;
- Improvement of nutrient cycling in agricultural ecosystems.

To meet the changes a broad interdisciplinary approach needs to be taken next to the scientific and technological prerequisites that have to be met. Multidisciplinary is not only needed to transfer knowledge generated with model plants into crops, or even highly environmentally specialized varieties, but also to stimulate public acceptance and thus decreasing regulatory restraints. Technologically we will need to be able to generally simplify genetic manipulation of any plant species, and be able to precisely engineer genomes beyond simply inserting transgenes introducing also a range of traits simultaneously, next to taking maximal advantage of the knowledge generated in any sub-discipline of Plant Science.

Fishing on an industrial scale to provide for billions has dramatically altered marine diversity. Individual farmers breeding livestock or keeping chickens, when multiplied by millions, have caused biodiversity changes in which more than 90% of the weight of all terrestrial vertebrates is now made up of humans and the animals we have domesticated. The quest for resources to supply us all with materials and the trappings of life has depleted the forests, polluted rivers and soils and even carved the tops of mountains. And the fuels used by each of us for energy have produced combined emissions that are already altering the planet's environment.

By 2050, it is estimated that we could triple our resource consumption to a whopping 140 billion tones of minerals, ores, fossil fuels and biomass per year. Our food requirement alone is expected to double by then. Is our ever-increasing human population propelling us to our doom? Is there a limit to how many people can be sustained on a finite planet – and, if so, have we already passed it? Agriculture is still considered a sideshow in the environmental arena and a decision has been lacking over several years of U.N. environmental negotiations. World agriculture in this century will face three major changes: how to feed a growing world population, how to contribute to reducing the still–high prevalence of rural poverty in the world, and how to respond to increased concerns about managing the natural resource base. Agriculture will be massively impacted by environmental change, both the increase in extreme conditions and the rising temperatures. We need global action to ensure food safety under environmental change.

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