New models for sustainable agriculture

Fondazione Barilla

il tuo cibo, la tua terra

people, environment, science, economy

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New models for sustainable agriculture
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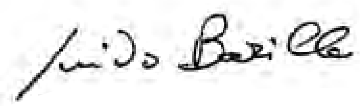
Dear Reader,
We live in an era when agriculture is demonstrating its fragility on a daily basis.
Despite its high complexity, for decades we have been accustomed to regard it as a field of activities that deliver modest added value and poor technical, avant-garde content and free from risk of structural discontinuity. As its importance has gradually diminished within the economies of Western countries, the degree of public attention has also declined.
The awakening could not have been more abrupt: for some years now, market crises, the decrease in the productivity growth rates and the emergence of serious distribution problems have brought the agri-food sector to the forefront of international political and economic debate.
In particular, concerns are emerging around the level of exposure to possible structural shocks of the global food chain. It is increasingly clear that agriculture will have to search for and find a new medium-long term balance in order to withstand the great phenomena of demographic, climate, geopolitical and economic change affecting the world.
Our interest in the subject of agricultural models stems from this awareness. The transition to a more sustainable kind of agriculture, in fact, can only take place through the gradual adoption of crop models that are increasingly able to produce healthy food of good quality and have access to the global commercial channels. These crop models must be in balance with the natural environment (thanks to appropriate profiles of productive efficiency), able to withstand the impact of climate change effects and harmonious with respect to the social contexts in which they should contribute to sustainable development.
Within this paper, we have described the different production models and the various options available, in light of their social and economic implications.In an effort to not limit ourselves to a simple description of reality, we used a model to simulate the impact of changes in agricultural practices on the current amount of food available worldwide.
It was thus possible to envisage different scenarios, assigning different values to the variables in play. The simulations carried out have confirmed the fragility of the global agricultural system and the urgency of corrective action. In particular, the search for approaches based on solutions in order to reduce energy consumption and with an in-depth knowledge of the content, will be prerequisites for sustainability.
References of research conducted by the Barilla Group will also be noted within this paper. There was no intention to use it as an opportunity for promoting the company – the Barilla Center for Food & Nutrition exists completely independently of the Barilla Group –, but rather, as a demonstration of what a company can actually do to help solve problems. For us, this experience was the confirmation of how significant, for the whole system of stakeholders, the impact of activities to generate sustainable and widespread economic value can be.

Enjoy the read,
Guido Barilla



THE VISION OF THE BARILLA CENTER FOR FOOD & NUTRITION

TO OFFER A VARIETY OF HIGHLY SCIENTIFIC CONTRIBUTIONS AND BECOME A VALUABLE SERVICE TO THE INSTITUTIONS, THE SCIENTIFIC COMMUNITY, THE MEDIA AND CIVIL SOCIETY OVER TIME; A MEETING POINT FOR ANYONE WHO CARES ABOUT FOOD, THE ENVIRONMENT, SUSTAINABLE DEVELOPMENT AND ITS IMPLICATIONS ON PEOPLE'S LIVES.

THE FUTURE OF FOOD IS GROWING WITH US

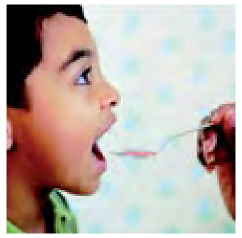
THE BARILLA CENTER FOR FOOD & NUTRITION

The Barilla Center for Food & Nutrition (BCFN) is a center of multidisciplinary analysis and proposals which aims to explore the major issues related to food and nutrition on a global scale.
Created in 2009, BCFN intends to listen to the demands emerging from society today by gathering experience and qualified expertise on a worldwide level and promoting a continuous and open dialogue. The complexity of the phenomena under investigation has made it necessary to adopt a methodology that goes beyond the boundaries of different disciplines.
These topics under study are broken down into four areas: *Sustainable Growth for Food*, *Food for Health*, *Food for All* and *Food for Culture*. The areas of analysis involve science, the environment, culture and the economy; within these areas, BCFN explores topics of interest, suggesting proposals to meet the food challenges of the future.

FOOD FOR SUSTAINABLE GROWTH

In the field of *Food for Sustainable Growth*, the Barilla Center for Food & Nutrition focuses on the issue of the optimization of natural resources within the framework of the food and agricultural sector. More specifically, the studies conducted so far have identified some critical issues and have evaluated the environmental impact of food production and consumption, putting forward a series of proposals and recommendations for individual and collective lifestyles which may have a positive effect on the environment and on natural resources.

FOOD FOR HEALTH



In the field of *Food for Health*, Barilla Center for Food & Nutrition
has decided to start its research work by analyzing the existing relationship between nutrition and health. It has studied in depth the recommendations provided by the most distinguished nutrition institutes in the world and the results of ad hoc panel discussions with some of the most accredited scientists at the international level. As a result, it has been able to provide civil society with a clear set of concrete proposals for more easily adopting a correct lifestyle and a healthy diet.

FOOD FOR ALL

In the field of *Food for All*, the Barilla Center for Food & Nutrition deals with the issue of food accessibility and malnutrition with the aim to reflect how to promote better governance of the food and agricultural sector on a global scale, in order to have a more equitable distribution of food and a better impact on social well-being, health and the environment.

FOOD FOR CULTURE

In the *Food for Culture* area, the Barilla Center for Food & Nutrition aims the relationship between man and food. In particular, BCFN has traced the most significant stages in the evolution of the man-food relationship, refocusing on the fundamental role of the Mediterranean diet.

In line with this approach, the activities of BCFN are guided by the Advisory Board, a body composed of experts from different but complementary sectors, which makes proposals, analyzes and develops the themes, and then drafts concrete recommendations.
One or more advisors have been individuated for each specific area: Barbara Buchner (expert on energy, climate change and the environment) and John Reilly (economist and expert on environmental issues) for the area *Food for Sustainable Growth*; Mario Monti (economist) for the area *Food For All*; Umberto Veronesi (oncologist), Gabriele Riccardi (nutritionist) and Camillo Ricordi (immunologist) for the area *Food for Health* and Claude Fischler (sociologist) for the area *Food for Culture*.

New models for sustainable agriculture constitutes the third step in a process initiated by the Barilla Center for Food & Nutrition with the papers *Is GMO agriculture sustainable?* (2010) and *Beyond GMOS: The agri-food biotechnologies* (2011). We began with the analysis of agri-food biotechnology, which has long been the focus of much debate, and then broadened the scope of the survey to the main characteristics of the different existing agricultural models in order to evaluate the profiles (current and prospective) of sustainability.

This paper attempts to investigate a key issue, especially for the future: the identification of agricultural practices and models that are truly sustainable, according to a holistic and multifunctional interpretation of "sustainability" in agriculture.

Sustainability in the food sector is, and will be, central in the near future, not only in developed countries – which, after years of intensive agriculture, are now facing the possible risks associated with energy crises and the scarcity of soil resources – but also in developing countries by which adopting less invasive modern agricultural models, could see an increase in the output and quality of their crops in a long-term vision.

Therefore, the objective of the document is to identify and examine the main factors underlying these dynamics by analyzing the most recent contributions of the scientific and institutional world, the case studies, and most interesting *best practices* worldwide in an effort to contribute to the current debate – which is fully implemented in the European Community – and offer analysis, reflection and macro policy directions in this regard.

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NEW MODELS FOR SUSTAINABLE AGRICULTURE

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EXECUTIVE SUMMARY

The complexity of the agricultural system requires considering a significant number of variables that, directly and indirectly, affect the results of agricultural in terms efficiency and sustainability.
Alongside the system of food production there are fundamental aspects concerning energy, soil quality, availability/use of water resources, (agro-)biodiversity and socio-economic effects that impact agriculture at the local level. The collective impact of migration, population and different agricultural models on food security and human health are particularly relevant. Dietary habits and the consequences of climate change must also be taken into account among the major "underlying" issues in the assessment of agricultural systems.
Agriculture, in all its complexity, demonstrates daily its fragility and its exposure to possible shocks that might occur at the expense of one or more of its constituent factors; therefore, it must find new forms of balance that would allow it to be sustainable in the long run.
Achieving a more sustainable agriculture will occur through the gradual adoption of agricultural models that must be: able to produce healthy food of good quality; able to access the global commercial channels; "in-balance" with respect to the natural environment (thanks to appropriate profiles of productive efficiency); able to withstand the impact of climate change; and, finally, intune with the harmonic social contexts in which they should contribute to sustainable development.
In general, alternative approaches to agriculture can be represented in different ways, but more or less there are three fundamental aspects: economic and commercial, technological, and environmental.
According to the FAO, the systems of agricultural production can be divided into three main categories:[1] High External Input (HEI) systems, Intermediate External Input (IEI) systems and Low External Input (LEI) systems. What is important, to this end, is the intensity of non-renewable resources consumed.
In an effort to not just give a simple description of the existing reality, but to interpret the types of current agricultural models and try to propose alternatives for the future, the Barilla Center for Food & Nutrition has made – in collaboration with the Millennium Institute – a model simulating the impact of changes in agricultural practices on the current amount of food available worldwide.
What impact could large external shocks have on world agriculture and its evolution? And, in particular, what are the effects in terms of the number of calories per capita per year available worldwide?
The proposed model allowed the simulation of different scenarios, assuming an availability of abundant energy or hypothesizing a future rapid increase in oil prices, which would be followed by a consequent significant growth in prices of inorganic fertilizers (and therefore, a reduction in their use).
The following three macro scenarios of the global agricultural system's evolution were tested to understand implications about its future:
- Scenario of Business As Usual (BAU): agricultural practices with a high level of external input will cover 60% of the global area/land cultivated in 2050;
- Scenario of Strong HEI Growth: agricultural practices with a high level of external input spread at an accelerated pace to cover 90% of the total cultivated area in 2050;
- Scenario of Stopped HEI Growth: there will be little spreading of the high external input, which will remain at the current level of 45% of the total cultivated land in 2050.

Results

Assuming a constant energy supply over the 80-year period observed, the production scenario with the highest yield – in terms of sustainability – was the Strong HEI Growth scenario, followed by the Business As Usual scenario (BAU) and, finally, by the Stopped HEI Growth model. In a context of simplified global development, in which possible reductions in the availability of all the elements that make up the profile of sustainability are not taken into consideration, nor any possible energy shocks, a pro Strong HEI Growth policy would generate a total availability of calories well above the required amount.
However, the Stopped HEI Growth scenario is also projected to be able to supplya more than adequate total caloric intake. This indicates that it seems there will be no problem of availability of total calories in the future.
Nevertheless, the assumption of a constant availability of energy over time is unrealistic in any case: fossil fuels are steadily decreasing and renewable energy sources are not yet a viable alternative. Therefore, it is plausible to assume that there might be a shock in the global energy supply at some point, which would put a strain on energy-intensive systems such as the HEI models.
These models become economically unsustainable and unprofitable, and serious problems would arise linked to the shift to more energy efficient models. The costs of the production change would be felt in terms of reduced output available and time spent in the acquisition of the know-how necessary for the transition.
The simulation results show that, in the case of reductions in energy availability starting in 2025, an approach to low external input would lead to a result of Worse-Before-Better (WBB), i.e., low productivity in the short-term with a return to higher levels of yield in the medium to long-term.
In the case of an energy crisis, the results depend strongly on the amount of time spent in shifting from HEI systems to a LEI (in the direction of a Stopped HEI Growth scenario) one. The results of Strong HEI Growth-Energy Shock and BAU-Energy Shock systems are less negative in the short-term.
Our simulation shows the fragility of the global agricultural system. A fragility we must deal with by promoting a balanced mix of agricultural models, built to cope with the phenomena of relative scarcity.
The reality, of course is much more complex than has been willfully represented. In addition to possible energy shocks, in fact, there are many other long-term risk factors: water availability, adaptation to atmospheric phenomena, etc.
However, the result strongly emphasizes one of the most relevant topics concerning the future: the search for knowledge-based, energy-reducing solutions will become one of the most crucial aspects of sustainability.

In the paper, there are some concrete examples of the application of the different agricultural models, also including the results of a study conducted by the Barilla Group to identify how to improve the sustainability of the main cereal crop used, that of durum wheat.

Conclusions

In light of the analyses, simulations and discussions carried out, what - overall – are the conclusions? The complexity of agriculture does not allow us to draw unequivocal conclusions. Nevertheless, evidence, reflections and trends emerge and converge towards a possible practical approach to true sustainability.
In particular, there are seven points of attention that we consider fundamental:

1 *Sustainable agriculture is characterized by a systemic conceptual and operational approach.*
For a future of sustainability, we must increasingly learn to "hold together," according to a multidisciplinary approach, the social, environmental, economic, and research and development aspects. Approaches aiming at pursuing partial goals, albeit in a very effective way, can at most reap some short-term success of one of the dimensions, but they do not help in winning the challenge of sustainability.

2 *Sustainable agriculture is based on a large number of agricultural practices that are already known.*
The knowledge available, comprised of scientific knowledge and proven practices, has crystallized into some excellent and practical guiding principles of truly sustainable farming. In short, these guidelines are to: cultivate a wider range of plant species, starting with a systematic use of crop rotations; minimize the mechanical working of the land; and maintain a protective cover on the surface of the organic soil. These practices/techniques – associated with the use of high-performance crop varieties, optimized use of organic and inorganic fertilizers, integrated management of pests and diseases through appropriate practices and, when necessary, the efficient management of water resources – allow, for the same macro reference model (HEI, LEI, IEI), the achievement of better performance in terms of sustainability.

3 *Agronomic "knowledge" is not very widespread.*
In the agricultural field, over the years, a wealth of available knowledge of extraordinary value has been accumulated that is only partially used today. In certain circumstances, this seems to happen due to a lack of effective processes of the transfer of know-how; in others, because it is believed that, at least partially, the technology available makes in-depth knowledge of the natural dynamics superfluous. What emerges is the need to strengthen the base of human capital in agriculture, bridging the gap between available knowledge and individual skills and of the system. Regarding this aspect, we will need to create significant investment plans because it is the prerequisite for any development in the direction of greater sustainability.

4 *Correct agricultural models for specific contexts: the objective is to reduce external inputs.*
In our opinion, there are no good or bad agricultural paradigms a priori. There are certainly HEI models which we believe will prove to be unsustainable in fact, and LEI models which cannot be implemented in all contexts. Alongside these, there is a wide range of realities, namely that of Intermediate External Input (IEI) systems adjacent to LEI systems that can be properly managed, in light of the above sustainability requirements. In other words, what matters is the trend line, i.e., the shift toward the more sustainable IEI models and the balance between models within macro regions.

Developing countries, instead, need to adapt and revisit models that are appropriate to the specific characteristics of the local reality.

5 *Biodiversity as a tool for proper risk management.*
A pragmatic approach, without prejudice, to the choice between agricultural models allows – at the level of policymaking – the maximization of the overall resilience of agricultural systems. Proper management of biodiversity and the coexistence of different models, all equally optimized as to sustainability, amplify the possibilities for responding to adverse events and specific objectives of the research system when there are alternatives (such as high quality vs. high volume).

6 *Investments in technology to make agriculture more able to adapt to change.*
Technology, in our view, also takes on a different connotation from the one that too often prevails. Today, in fact, when it comes to technology in agriculture, often it is referred only to the issue of productivity and yields, in the belief that they can be increased by improving the individual varieties. However, the fundamental ability is to adapt, which is expressed in the integrated and harmonious management of a wide range of tools and management logic: plant varieties that are resistant to stress, management of advanced systems of irrigation, the scientific approach to fertilization, etc.

7 *The external factors of sustainability in agriculture: food waste and losses, biofuels.*
We must not forget that a large part of the problems facing the agricultural system and food are extraneous to the choices of agricultural models and their research and optimization. Some phenomena combine to emphasize the centrality of production volumes at the expense of an altogether more balanced approach: this is, above all, a matter of food waste, which has reached truly disturbing proportions and represents a challenge for future agricultural sustainability. Along with this, there emerges a central issue for the purposes of resource allocation decisions in the agricultural sector (both financial and physical): the production of biofuels. As much for the "waste" issue as for that of "biofuel," inadequate management of the problem, on the one hand, and questionable choices in the field of energy policy, on the other, result in strong pressure placed on the system of agriculture to make up for deficiencies that it should not have to bear.

1. THE FUTURE OF AGRICULTURE AND SUSTAINABILITY

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1. THE FUTURE OF AGRICULTURE AND SUSTAINABILITY

SUSTAINABLE AGRICULTURE CAN BE DEFINED AS THE PRODUCTION OF FOOD THAT MAKES THE BEST USE OF THE GOODS AND SERVICES OF NATURE WITHOUT CAUSING DAMAGE

The Future of Agriculture and Sustainability is the third part of a series of position papers initiated by the Barilla Center for Food & Nutrition.[1] The first papers evaluated *Is GMO agriculture sustainable?* (2010) and *Beyond GMOs. The agri-food biotechnologies* (2011) respectively. Within this paper, we not only analyze agri-food biotechnology, but also different production models and their respective attributes in order to assess their sustainability.

The analysis of the agricultural system requires taking into consideration a significant number of variables that, directly or indirectly, affect the results in terms of agricultural efficiency and sustainability.

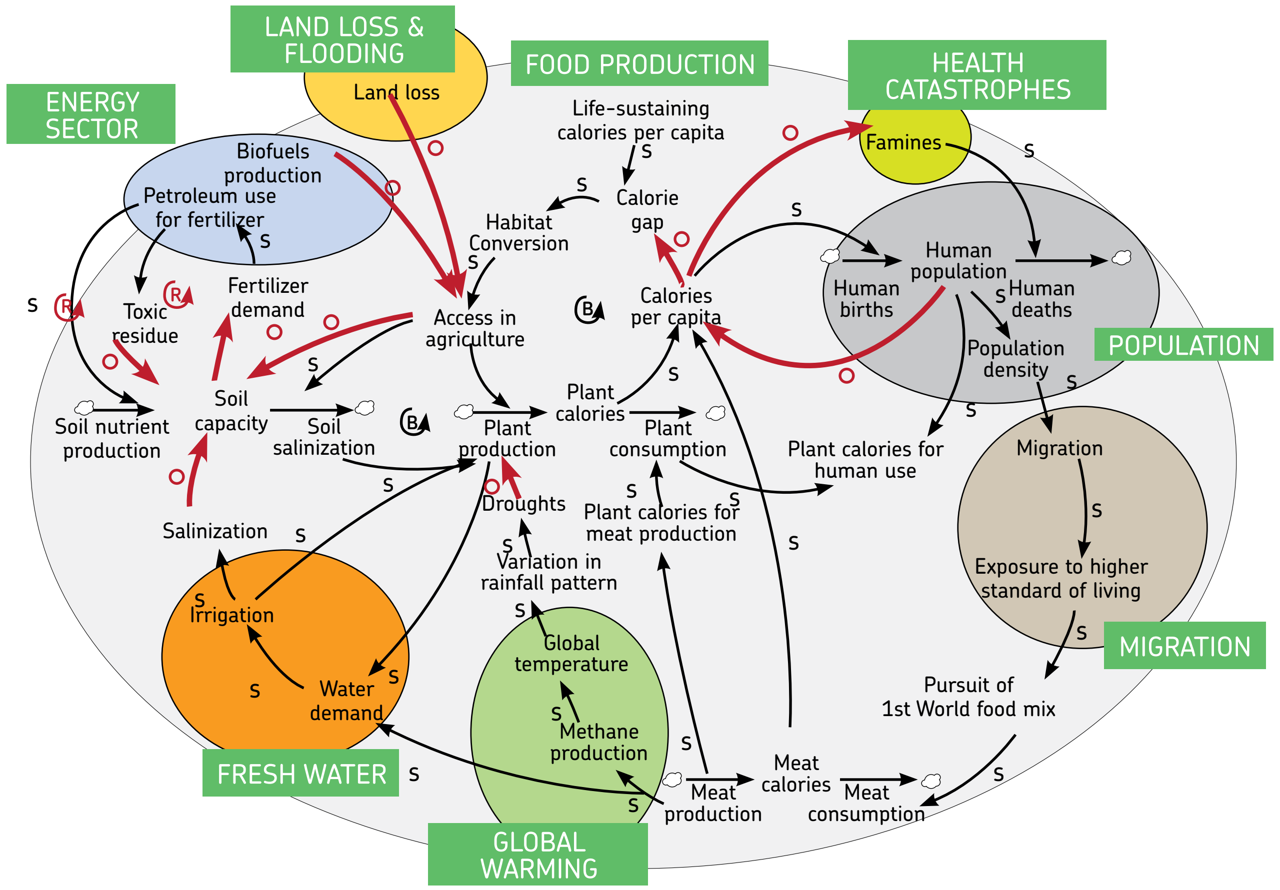
Alongside the system of food production, there are fundamental aspects concerning energy (use/production of energy, particularly from fossil fuels), soil quality (loss/depletion), availability/use of water resources (water scarcity and its use), (agri-)biodiversity and socioeconomic effects that impact agriculture at the local level. The collective impact of migration (especially in the most critical socio-economic backgrounds), population and different agricultural models on food security and human health (epidemics, undernourishment, malnutrition) are particularly relevant. Finally, the assessment of agricultural systems should take into consideration eating habits (current and future, Western and non-Western) and the consequences of climate change (the rise in average temperatures, changes in precipitation, extreme events, etc.).

The collective interaction of these variables describe an articulated and complex phenomenon – that of agriculture – which demonstrates its fragility daily. An example of this is the unresolved problem of access to food, which is expected to worsen due to the reduction of arable land, pollution and the erosion of genetic resources – and which, because of possible shocks that might occur at the expense of one or more of its constituent factors, will have to find new forms of equilibrium to be sustainable in the long run.

In light of such complexity, sustainable agriculture can be defined as "the production of food that makes the best use of the goods and services of nature, without damaging it."[2] So, as the FAO reminds us, it should "help to conserve natural resources, to assist in protecting the environment, be appropriate for the frame of reference – from the point of view of the techniques used – and, finally, be economically and socially acceptable."[3]

The reasons for the growing interest in more sustainable forms of agriculture, as compared to the models that are prevalent today, lie in the increased awareness of the environmental impact of farming, as well as the awareness concerning the possible scarcity (not only in the future) of the resources that have supported the development of agriculture so far, starting with oil.

Figure 1.1. The model developed by the IAASTD to represent the complex system of agriculture (S = Same; O = Opposite; R = Reinforcing; B = Balancing)

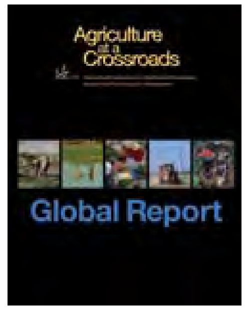


Source: IAASTD. 2011 (presented to the Advisory Board of BCFN on February 17. 2011).

The last 50 years have been characterized by the rapid development of agricultural activity – albeit asymmetrically between the different areas of the world – toward the adoption of technologies that increase the productivity of the factors employed and a general modernization of production techniques. In some geographical areas, ever since the Sixties and Seventies, the simultaneous introduction of plant varieties that are highly responsive to production inputs (High-yielding Varieties, HYV,), the practice of monoculture, widespread mechanization, agrochemicals (massive use of pesticides, herbicides, fungicides and synthetic fertilizers developed through the use of nitrogen, phosphorus and potassium) have contributed to an extraordinary increase; at least in the short to medium-term, in production volumes for the same person – especially with regard to wheat, corn and rice, as well as generating many economies of scale along the whole chain.

On one hand, this model has ushered in a long period of high productivity and low food prices, but on the other hand, it has resulted in an intensive and often irreversible exploitation of the natural resources as the IAASTD's report *Agriculture at a Crossroads* reminds us: soil erosion, water contamination, pollution of rivers and water basins, deforestation and the loss of biodiversity. For this reason, over the past decade the growth of agricultural productivity has significantly dwindled, to a phase of "stagnation of yields". This is evident if one analyzes trends in the yield per hectare of corn and wheat in the U.S. (Figure 1.2.).

In the meantime, criticism of the model of intensive monoculture has led to experimentation with approaches that are more attentive to overall sustainability.



Food, agriculture anf the scarcity of natural resources[4]

The constant drive toward the yield and exploitation of land, particularly since the mid-twentieth century, has meant that the agricultural and food sector has been largely responsible for several phenomena, such as:

- the *serious deterioration of arable land*: 40% of the land is degraded or poor;
- the *gradual reduction of the extension of the great forests*: about 43% of the tropical and subtropical forests and 45% of temperate forests have been converted to land used for crops, including the conversion of about 13 million hectares of peat forests in Southeast Asia, mainly for the production of palm oil;
- the *bad use of agricultural land and forests*: about 30% of global emissions of greenhouse gases;
- the *intense exploitation of fishing areas*: 32% is overexploited, impoverished or depleted and 52% has been fully exploited;
- the *reduction of the available water supply*: by now about 70% is used;
- an *80% use of all phosphorus available*, with deposits rapidly decreasing in the three main producing countries;
- the *strong dependence on fossil fuels as an input* (e.g., for the production of fertilizers, irrigation, mechanization), with the risk of a "peak in the price of oil" and of climate change.

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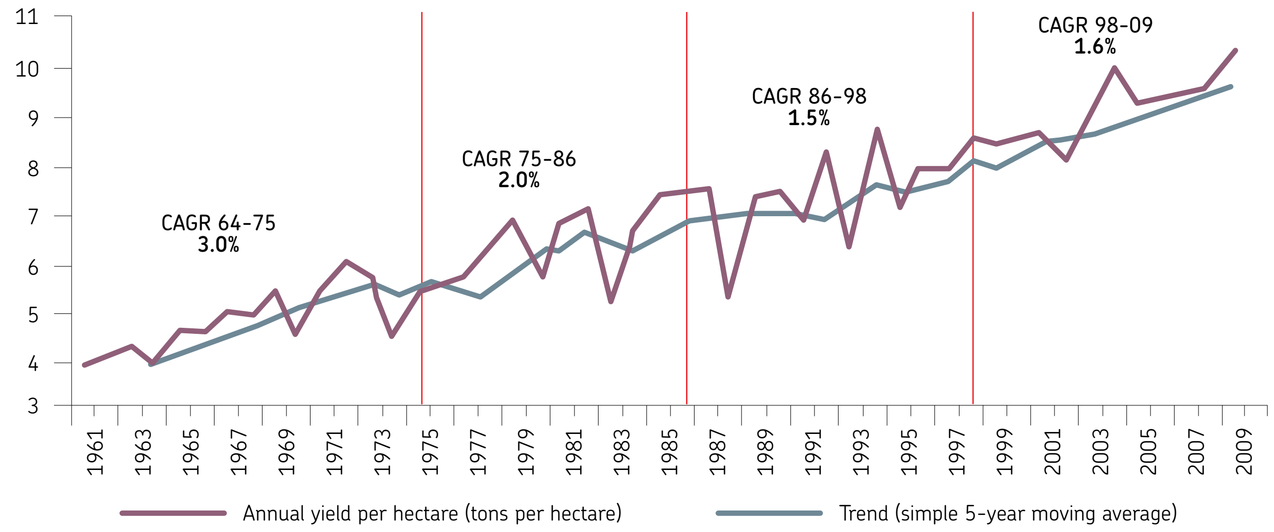
Figure 1.2. **Trend of the yield per hectare of corn – USA (tons per hectare, 1961-2009)**



CAGR = Compound Annual Growth Rate

Note: the yield per hectare is calculated as the ratio between the level of production and the area harvested for each year considered; the trend has been identified by using a 5-year moving average.

Source: reprocessing of data from the United States Department of Agriculture Database, 2010.

That is why the debate on the process of rethinking the logic of the prevailing models is so heated. With this in mind, it seems essential, first of all, to identify what the basic requirements are of the possible agricultural models and the issues to consider, in light of the sustainability requirements, namely:

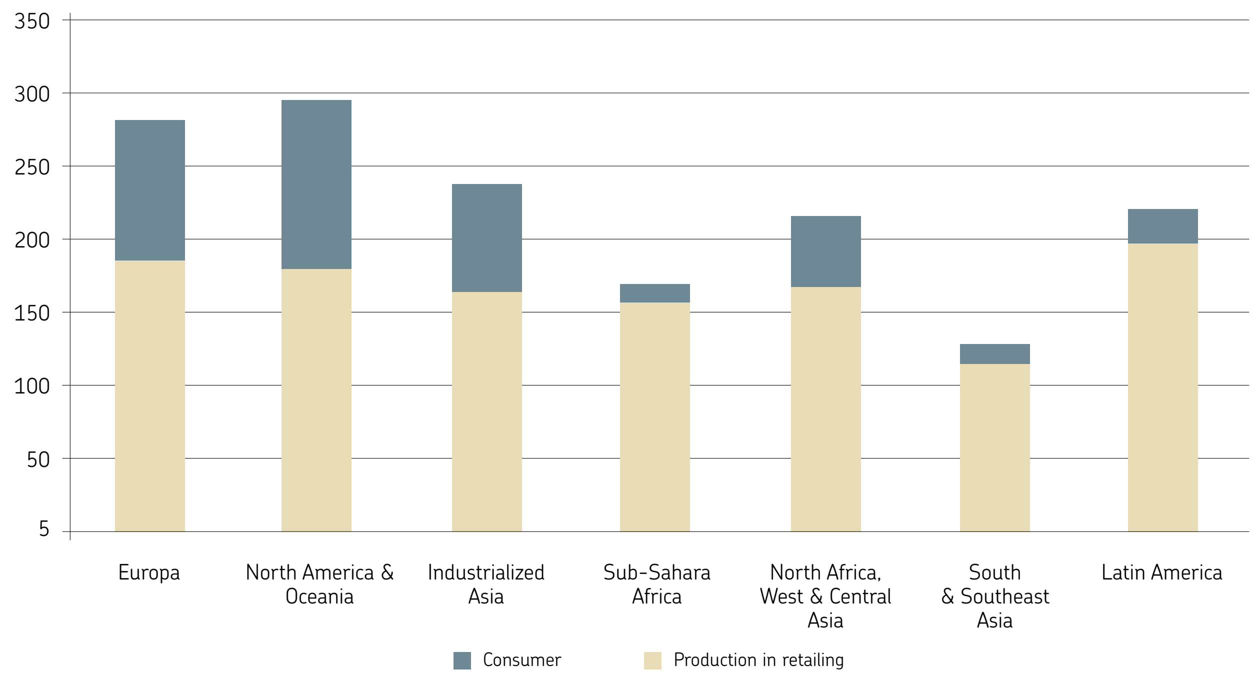
- The *issue of controlling crop diseases and pests* – for ensuring adequate yields, the stability of production and food security – will still be central in the future and will also, to a certain extent – with regard to diffusion and intensity – represent a side effect of industrial agriculture.
- What strongly emerges is the *need to identify techniques and approaches to address the changes taking place* (and expected to increase) in relation to two key factors: the *availability of water and the quality of the soil*.
- It will also still be *important to address the issue of agricultural productivity*: if it is true that the problems of access to food are more related to the distribution of the product than to any insufficiency in the volume of global agricultural production,[5] then it is equally clear that in some parts of the world, agricultural yields still constitute a serious problem, reaching levels below those already experienced, even in the most economically advanced countries. In this sense, the correct application of agricultural techniques aimed at improving yields, remains at the heart of the debate on innovation in agriculture, especially if looking at the area of the world that requires significant improvement in average living conditions. One of the areas of greatest interest is that of finding an effective combination of the use of advanced breeding tools (MAS, TILLING, etc.) and the implementation of assessment processes and improved farming techniques and crop management.[6]
- Directly and indirectly linked to all the issues listed above is a main problem related to global food security: *the nutritional quality of food products*. The current situation presents one of the most striking imbalances. While the number of people who are obese is increasing (especially in developed countries), there is the unsolved problem of entire populations that are malnourished (especially in developing countries), with serious implications in terms of the lack of macro- and micro-nutrients essential for a

THE GROWTH TREND OF AGRICULTURAL PRODUCTIVITY WAS SIGNIFICANTLY REDUCED UP TO A PHASE OF "STAGNATION OF YIELDS" healthy life, or even for survival. Agriculture also plays a decisive role in these issues.

- Another *fundamental issue* is that of resilience: in the coming decades, it is expected that climate changes will cause structural changes in the ecological conditions of entire macro-regions of the planet, as well as a growing number of environmental shocks. At that point, it will become necessary to use agricultural and risk management techniques that are able to successfully deal with emergencies.
- Equally *crucial is the problem of food waste and food losses* which – if mitigated – would help to fight hunger, improve food security in poorer countries and increase the income of farmers and of the consumers themselves, with positive impacts on the environment, thus avoiding loss of land, water and energy.
- Along with the issue of the loss/waste produced by world agriculture today, what emerges – with a significant impact in terms of future agricultural sustainability – is *the issue of the use of resources (financial and physical) in the agricultural sector for the production of biofuels*.
- Finally, the socio-economic aspects of sustainability must also be taken into account. Agriculture is an essential economic activity in many regions of the world, and the structure of production processes has a significant impact on the economic and social reality in which they take place. In particular, "economic and social sustainability" means, first of all, safeguarding and creating jobs in local agriculture and the improvement of living conditions in rural areas. Rural development, especially of small farmers in developing countries, should be a priority at the global level.

To summarize what has been expressed, we can say that when we use the concept of "sustainable agricultural models," we are referring to models of farming for producing healthy food of good quality, with requirements that will allow access to global marketing channels, "in-balance" with respect to the natural environment (thanks to appropriate profiles of productive efficiency), able to withstand the impact of the effects of climate change and in harmony with the social contexts in which they must contribute to sustainable development.

Figure 1.3. **Food waste & losses (kg/per capita/year) in the stages of consumption and pre-consumption, for the various areas**



Source: *Global Food Losses and Food Waste*, FAO, 2011.

Some data on malnutrition and undernourishment

According to recent FAO estimates, there are about 925 million people in the world today who suffer from hunger. Out of a population of about 6.9 billion people, the problem of malnutrition in the world concerns 13.4% of the total. As we know, the people most affected by this phenomenon, 98% of the total, are concentrated in developing countries. Along with hunger, equally worrying is malnutrition: the 5.6 million deaths annually among children under the age of five are, in fact, directly related to diseases such as diarrhea, pneumonia and malaria that, in the pres ence of anappropriate level and the proper composition of food, would not be lethal. It is also e timated that 684,000 child deaths could be avoided, all over the world, just by increasing access to vitamin A and zinc.[7]

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2. AGRICULTURE TODAY: THE MAIN "AGRICULTURAL MODELS"

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2.1 AN OUTLINE OF INTERPRETATION

IT IS POSSIBLE TO REPRESENT THE VARIOUS ALTERNATIVE APPROACHES TO AGRICULTURE BY BASICALLY REFERRING TO THREE ORDERS OF ISSUES: ECONOMIC AND COMMERCIAL ASPECTS, TECHNOLOGY AND SUSTAINABILITY

The most common agricultural model of our time has been defined with different termsconventional, modern, high-input and industrial – and is considered to be the evolution of agriculture in that it includes sophisticated technologies that have greatly increased the productivity of labor.

In the Sixties and Seventies, this model led to dramatic increases in production – particularly of corn, rice and wheat – through the introduction of high-yielding varieties (HYV), monocultures, widespread mechanization and the use of agrochemicals (pesticides, herbicides and fungicides). The period in which it was adopted and developed became known as the "Green Revolution" (GR) and subsequently it was adopted in emerging contexts, such as Latin America and Asia.

The practice of monoculture allows the farmer to specialize as to the factors of production used, adopting specific machines and agrochemicals and using them on many acres of land at once, thus increasing efficiency. Potentially, this leads to an economy of scale. Furthermore, the development of synthetic fertilizers formulated to provide the crops with nitrogen, phosphorus and potassium for optimal growth has helped to increase crop productivity. Therefore, the modern industrial agriculture and GR practices have resulted in the doubling of cereal production worldwide and the beginning of the surplus era.

In general, it is possible to represent the various alternative approaches to agriculture in different ways, even if all the descriptions – more or less concise – are basically made up of three orders of aspects: economic-commercial, technological and those concerning sustainability.

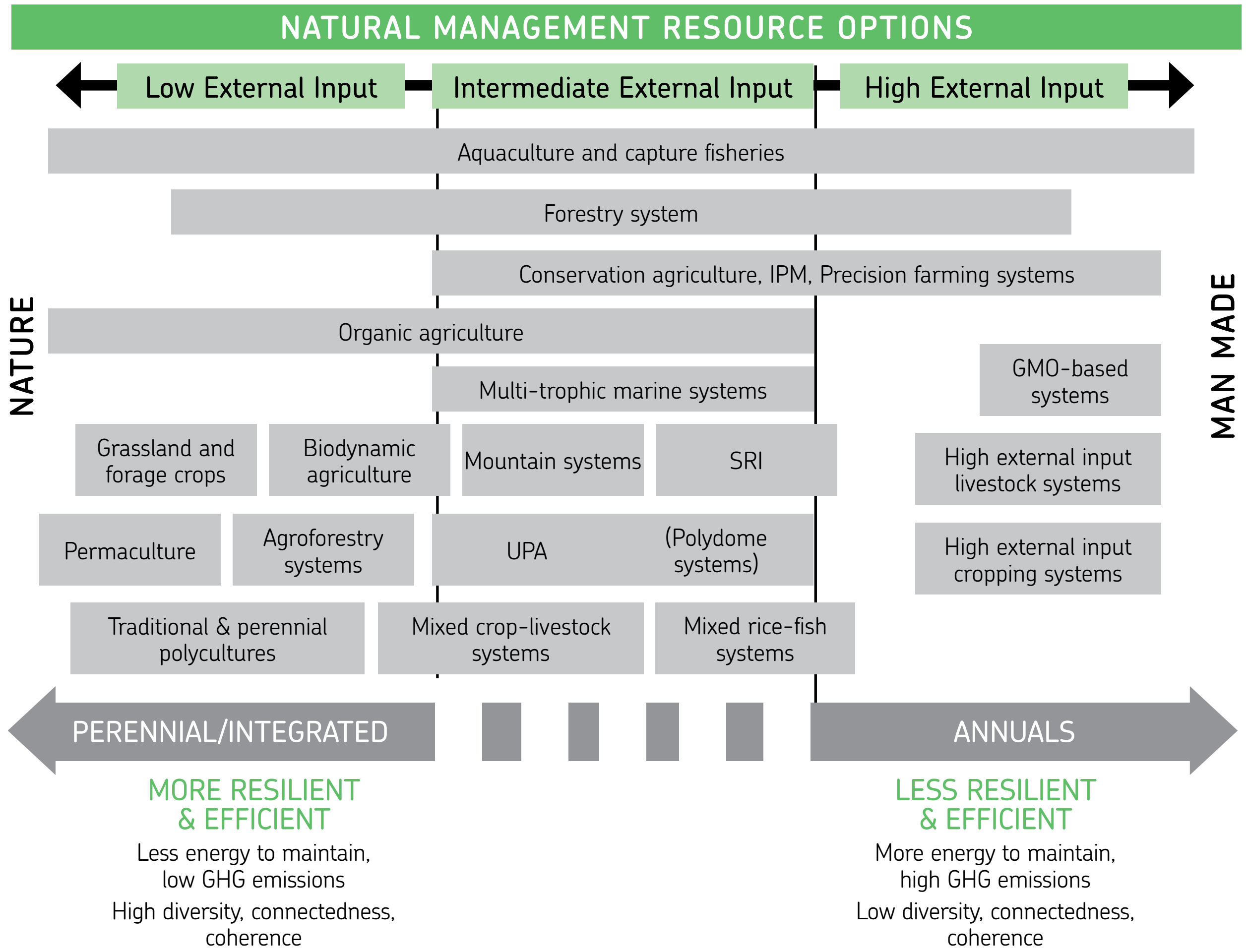
Among the different classifications proposed in the literature, of considerable interest is the one proposed by the FAO, according to which the many farming systems can be divided into three main categories:[1] the High External Input systems (HEI), the Intermediate External Input systems (IEI) and the Low External Input systems (LEI). What is particularly significant in this setting is the reference to the intensity of the non-renewable resources consumed.

Figure 2.1. shows the conformation of different production systems, depending on the degree of substitution between processes primarily based on inputs consisting of natural resources and processes mainly based on synthetic or technological inputs.

The HEI systems (High External Input) are characterized by their strong commercial orientation, the use of crop varieties with high yield, intense mechanization (which is accompanied by low labor intensity) and dependence on productive factors of a synthetic nature (fertilizers and agrochemicals). These models are aimed at maximizing production output in conditions of maximum efficiency due to achievable economies of scale. Monoculture and the cultivation of crops of genetically modified organisms (GMOs) represent the extremes of this approach.

At the other end of the spectrum lie the LEI systems (Low External Input) which are characterized by the use of traditional plant varieties, the use of labor-intensive techniques and knowledge, and the low use of chemicals.

Figure 2.1. The three main agricultural models according to the FAO



Source: FAO/OECD, *Food availability and natural resource use in a green economy context*, 2011.

Most agricultural models can be found at an intermediate level, with a range of possible gradations.

These are the so-called IEI models (Intermediate External Input), involving the use of improved crop varieties through conventional breeding techniques and hybridization, the search for a sustainable balance between mechanization and labor, the use of techniques with a high content of knowledge and the use of fertilizers and chemicals, according to integrated patterns of cultivation.

The sustainability of the different models is obviously different: in particular, the HEI systems seem to be able to ensure crop yields that are better in terms of product per area, but they are obtained with a high consumption of resources, which undoubtedly makes them more fragile as to the future prospect of a possible scarcity of resources. The LEI systems, however, are forced to "pay" for their minimal impact on resources in terms of crop yields that are typically lower.

In any case, this is a very simplified representation of the reality, which instead, is far more complex and dynamic. Therefore, it seems useful to briefly analyze the characteristics and specific cases of the application of some of the main agricultural models worldwide, taking into consideration the effects in terms of sustainability.

In particular, sustainable agricultural practices include: the promotion of biodiversity, the recycling of plant nutrients (nutrient cycling), protection against soil erosion, the conservation and protection of water, the minimum processing of the terrain, the absence of chemical products and synthetic fertilizers, and integration between agriculture and raising animals.

Agricultural models and good agricultural practices

The description of the possible models of agriculture according to a tripartite classification (HEI, LEI, IEI) leads to a significant simplification of the various agricultural models that actually exist in the world. This simplified representation has been used to facilitate the consideration of some important trends. In light of the analyses and evidence that has emerged from research, we believe that:

- A complete classification of "agricultural models" should start from the definition of typical situations regarding the use of key inputs, such as:
  - *genetic resources*: traditional local varieties, modern varieties obtained by conventional breeding, hybrids and GMOs;
  - *water resources*: rain-fed cultivation and crop irrigation;
  - *energy resources*: labor intensive and highly mechanized;
  - *soil resources (quantity)*: extensive farming and intensive agriculture;
  - *soil resources (quality)*: zero/minimum tillage and conventional plowing;
  - *nutritional resources*: organic fertilizers, natural fertilizers, inorganic and synthetic fertilizers;
  - *the fight against pathogens and weeds*: biological control, integrated pest management and the fight against synthetic chemical products.
- Each form of agriculture (or agricultural model) can never be assessed in the abstract, but must always be placed in a geographical context with regard to the climate, soil, and economic and social development.
- In each context, the objectives of productivity and sustainability can be pursued, at best simultaneously, with a specific form of agriculture; however, with the development of growing uncertainties about the factors that define the context (for example, climate change, the spreading of new pathogens, etc.), the coexistence of different agricultural models can provide an essential model of risk management. A main model can be applied to make the most of the opportunity of favorable conditions, but other models can still be kept active on a smaller scale, to be rapidly expandable when certain environmental conditions have changed. It seems possible, for example, to seize the opportunity of highly productive corn hybrids that require high inputs, while, however, at the same time also ensuring the reproduction of an adequate amount of seed of varieties of traditional corn to be used when local conditions have changed to the disadvantage of the hybrids (e.g., due to drought, pathogens, the exploding costs of fertilizer and energy, etc.).
- In an ideal world, where one can rationally plan the global agricultural production and where the distribution of food resources and access to food are ensured by efficient and equitable international systems, it would make sense to speak of the specialization of the planet's arable land in order to optimize the use of the scarce basic resources. Indeed, it is clear that it actually makes more sense to produce rain-fed cereals in temperate regions of the planet than to pursue the self-sufficiency of individual countries.
- The matter of "good agricultural practices" can be seen across the different agricultural models because, in some ways, they can be applied to each type of agriculture. Proper crop rotation, in contrast to crop repetition, has positive effects on the fertility of the soil. The same is true for all the other "best practices": from the calculation of the correct amount of seed, rational fertilization (dose, form, timing, splits), to pest management and *water harvesting*.

2.2 THE MAIN AGRICULTURAL MODELS IDENTIFIED TODAY: FROM TAXONOMY TO THEIR PRACTICAL APPLICATION

Traditional Agriculture

Traditional agriculture includes forms of breeding arising from the co-evolution of local social and environmental systems. It has a high ecological logic expressed through the intensive use of local knowledge and natural resources, including the management of agrobiodiversity as a form of a diversified agricultural system.

James P. Blair/National Geographic Stock

The case of Oaxaca (Mexico)

The CEDICAM (Center for Integral Development of the Mixteca Alta for farmers) was founded in 1980 by Jesus Leon and a group of farmers in Mixteca for the purpose of creating a democratic organization that would promote sustainable agriculture and the sharing of community projects. The Center was established to find a solution to the widespread environmental degrad ation in the region,which had been taking place since the beginning of its colonization, about five hundred years ago.

In fact, because of the large-scale deforestation carried out to allow for the grazing of animals, the area has become one of the most eroded in the world. According to scientists, up to five meters of the active layer of the soil may have been lost and 80% of the soil has eroded, amounting to 500,000 acres of land. To complicate the situation, due to NAFTA (North American Free Trade Agreement), the price of corn, grown with diversified traditional biological techniques, has been significantly reduced and farmers are no longer able to earn a living only with the corn trade, a situation that has led one third of the farmers in Oaxaca to emigrate to North America in search of work.

At first, it was thought that a solution could be the implementation of modern industrial agriculture, willingly accepted by the inhabitants of the region who hoped that this would once again bring them the economic prosperity the area needed. However, in the Eighties (prior to NAFTA), it became clear that this new system of agriculture, in fact, was not able to bring higher yields, but rather, would only further erode the soil and put the farmers into debt. Moreover, in the corn-growing Mixteca region, contamination also occurred in the criollo corn varieties from the GMO varieties, which threatened the loss of conservation practices that had been carried out for thousands of years.

It was then that the CEDICAM began its reunification work in order to reconstruct the local ecosystem through the adoption of sustainable agriculture.

In 2008, Leon was awarded the Goldman Environmental Prize for his pioneering work in the area of reforestation carried out under the CEDICAM. He managed to unite farmers who, together, planted one million native trees in the Mixteca region to combat erosion and conserve the local biodiversity. Leon also turned to the use of the ancient indigenous practice of constructing canals to harvest rainwater and prevent runoff. Hundreds of miles of canals were built by a small number of peasants, who thus also increased their shared capital, in addition to water availability. Some farmers claim that the aquifers, which had been dry until shortly before then, were replenished due to the canals that kept the water in situ, allowing it to filter deep into the soil. Others say that the hills have once again revived and animals have begun to reappear. Leon has also promoted the use of greenhouses to produce vegetables for the families and has educated farmers concerning sustainable/basic agricultural practices. Now, many farmers propagate up to 200,000 trees and distribute them every year in order to combat erosion.

However, it should be emphasized that an important factor for the success of the project to make the region productive once again was certainly the fact that the peasants of CEDICAM understood that the ideas and products coming from the outside are not always the best for the local farmers of Mixteca. This meant that the traditional agricultural practices and the local diet were valued more highly than foreign products. And as a result of the work of CEDICAM, thanks to the economic improvement of the area, some of the people of Oaxaca who had emigrated to the United States have returned today to work again with their families.

The CEDICAM is an example of a movement transmitted from "farmer to farmer" in order to allow people to address the many problems of environmental degradation and poverty. One reason this project has been successful is that it arose from a local need, was developed by the local people and focused on real issues affecting the region. The locals know their own land and traditions better than anyone else and are, therefore, more effective partners to promote the development of social capital and food security of the community.

Conservation Agriculture

CONSERVATION AGRICULTURE IS A MODEL THAT PROMOTES LITTLE OR NO WORKING OF THE SOIL SO AS TO MAINTAIN AND PRESERVE ITS STRUCTURE

Conservation agriculture (CA) is a model that promotes minimal or no working of the soil in order to maintain and preserve its structure; in addition, it uses practices such as mulching and does not limit the use of GMO seeds or agrochemical products, as is the case with organic farming. The FAO promotes conservation agriculture in developing countries and defines it as an agricultural model that "aims to support sustainable and profitable agriculture and, consequently, its objective is the improvement of the living conditions of the farmers through the implementation of three principles: minimum tillage, mulching and crop rotation".

Both conservation agriculture and that of zero-tillage involve a minimal processing of the soil, planting in rows and the maintainance of crop residues. The proponents of conservation agriculture wish to preserve the soil's micro-organisms living in the surface soil and assist the plant in the absorption of water and nutrients. The zero-tillage also allows for maintaining the moisture of the soil, thus reducing water usage and improving the absorption and retention of CO_2.

According to Rasha Omar of the IFAD, about 95 million hectares around the world are managed through conservation agriculture: of these 25% is located in the United States, approximately 23% in Brazil and 18% in Argentina (Derpsch, 2005 – quoted by the IFAD) and in all three cases, these are almost always crops (mainly soybeans) that come from herbicide-tolerant GMOs.

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Zero-tillage in northern Kazakhstan

No-tillage (or zero-tillage) is a technique used in a highly conservative concept of agriculture. It has had a very rapid diffusion in northern Kazakhstan, so much so that from 2007-2008, it was estimated that the area under zero-tillage had doubled, reaching up to 1.2 million hectares. In northern Kazakhstan, in fact, there has been a decline of traditional plowing, while techniques of little or no tillage have been increasing steadily. This is undoubtedly due in large part to the granting of government subsidies for conservation agriculture, bestowed since 2008 thanks to support from the World Bank, the FAO, the GEF and the CGIAR. Today, farmers are beginning to see a 20-50% increase in yields compared to traditional cultivation, and reduced costs through the application of conservation agriculture techniques (Fileccia, 2009).

The zero-tillage farmers use special machines that can grind up crop residues and leave them on the soil surface, even if it means leaving heaps of stubbles on the ground. These two methods have proven very effective in maintaining soil moisture high and in reducing erosion due to wind and water. In this northern region of Kazakhstan, in fact, snow accounts for 35-40% of the annual rainfall and is an important part of the water supply in conservation agriculture (Fileccia, 2009). Its slow and steady melting allows the water to seep deep down, reaching the horizon of the root system and thus preventing soil erosion. The snow is retained more efficiently when crop residues are left on the ground, even up to a height of about 35-40 cm. (Fileccia, 2009). The lack of cultivation of the soil causes a reduction in costs, but this savings is often reinvested in the first five years in the purchase of herbicides, since it has been shown that the zero-tillage farming is more susceptible to weeds, because the weeds are not removed mechanically as in other agricultural models. Some studies have shown, however, that after the first five years, the application of herbicides is reduced and, in some cases, completely eliminated (Fileccia, 2009).

However, despite the benefits obtained in the medium and long term, the conversion to zero-tillage can be difficult for small farmers in this region due to the high cost of specialized machinery, such as a seed drill, which can cost up to 360-400,000 dollars (not including the costs of high-power tractors needed for their towing), but in fact, many farms converted to zero-tillage in Kazakhstan are quite large, with over 50,000 hectares of arable land. Thanks to the support of the government and the international community for its development, Kazakhstan has become one of the top ten countries in the world in terms of extension of areas cultivated with the no-tillage technique.

The case of Democratic People's Republic of Korea (DPRK)

From September 2002 until November 2005, the FAO carried out a project on conservation agriculture and food security aimed at obtaining food security for the Democratic People's Republic of Korea. About 80% of the population of North Korea lives in rural areas and their livelihood is closely linked to agriculture (FAO, 2007), but due to the harsh climate with temperatures ranging from -19°C in winter to 25°C in summer, the period suitable for cultivation is limited. In addition, following the severe storms of the Nineties, lack of fuel, seed quality, agrochemical products and reserves, most of the yields had decreased by 50% in six years (FAO, 2007). And finally, the soils ended up typically poor in organic matter and phosphorus. At this point, aware of these problems, the government encouraged the adoption of cropping systems that were an alternative to the traditional monoculture: this has helped to increase food production, while creating a barrier to soil erosion and declining fertility, also caused by traditional plowing (20 cm).
The objective of the FAO project in North Korea was to train farmers and experts on conservation agriculture practices and to increase yields in a sustainable manner. The conventional tillage, for example, should have been replaced by no-till technologies and cropping systems that, among other things, included green manure and cover crops. The experiment was conducted on plots of 50 acres belonging to three cooperatives; economic facilities were used for direct seeding deriving from experience in Brazil and were given in concession to farmers along with instructions for carrying out the alternation of wheat-soybean, corn-soybean and wheat-rice with catch crops of different leguminous crops in order to select those which were the most suitable to the reality of Korea.
The introduction of conservation agriculture practices in North Korea, for example, brought about a reduction in the number and weight of weeds after the first year, thanks to the mulching. There were also increases in yield compared to traditional work systems of 0.41 to 0.63 t/ha (FAO, 2007). However, in 2003, areas under no-tillage, but which had not made use of mulching, did not report any significant increase in the corn yields. Yields of wheat, however, were comparable if alternated with corn or soybeans. One of the three companies under study reported no increase in production, because it had not been able to correctly use the disc harrow (a tool used to cut the overburden). Consequently, the cover crop grew in such quantities as to compete with the corn, thereby reducing the yield.
All the farms recorded the relative improvement of the soil structure with an increase of nutrients and organic matter as compared to that of conservation agriculture (FAO, 2007). At best, thanks to the coverage of cornstalks and hairy vetch, the organic matter increased by 0.2%, the available nitrogen by 20-25 mg/kg of soil and the available phosphorus by 30-40 mg/kg of soil (FAO, 2007). In land cultivated with a conservation farming system, an increase in soil moisture was also found and it has been estimated that the mulching with straw was able to increase the moisture content by 10-20%, at different depths. The covered land also lost less topsoil (14-17% less than plowed land) and this was thanks to protection from the erosive action of water. Finally, an economic analysis was performed to determine if conservation agriculture is financially sustainable for Korean farmers. Taking into account the fuel consumption and labor hours required per hectare, it was estimated that conservation agriculture practices allowed for a 30-50% savings on the costs of production factors (FAO, 2007). In addition, using conservation agriculture practices, labor was halved and there was an average saving of 15.5 kg of fuel per hectare.
This experiment in North Korea has shown that conservation agriculture can be a valid alternative, both economically and ecologically sustainable, to conventional agriculture. As a result, farmers are convinced of the efficiency of conventional agriculture in their region and fifteen foreign companies have expressed interest in converting to conservation agriculture.

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Biodynamic Agriculture

The founder of biodynamic agriculture, Rudolf Steiner, spoke of the biodynamic agricultural model for the first time in a series of conferences held in 1924. Since then, the practice has spread throughout the world to include over 4200 biodynamic farms, with 128,000 hectares of land, in 43 countries (Turimek, 2009).
Biodynamic farming has the non-use of chemicals and synthetic fertilizers in common with organic farming, but instead uses manure as fertilizer, then calls for the rotation of crops, pest control carried out in a natural way, and diversification of crops and livestock.
However, biodynamic farming differs from organic farming and other agricultural models in the preparation of compost and plant protection products. There are eight preparations: 500, 501, 502-507 and 508, corresponding to cattle manure, silica, yarrow flowers, chamomile, dandelion, valerian, oak bark and nettle. Preparations 502-507 are added to the compost, while the others are diluted in water and sprayed directly on the field.
Moreover, biodynamic farmers follow the lunar cycle for planting and sowing, convinced of the validity of the effects that the moon could have on plant growth.

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The case of New Zealand

In 1993, a study was conducted in New Zealand to assess the differences between biodynamic and conventional farming in terms of soil fertility and profitability. Although the study was conducted for four years, all the farmers were certified as biodynamic farmers for at least eight years. Conventional and biodynamic farms were compared according to type of enterprise (crop production and livestock) and soil type. 85% of the biodynamic farms presented better soil structure in terms of ventilation, drainage and preparation of the seedbed, and almost all areas of biodynamic cultivation obtained a higher amount of organic matter in the soil compared to conventional agriculture farms. Consequently, the carbon-nitrogen ratio and the available nitrogen were greater in areas of biodynamic farming, and this, according to researchers, was thanks to the alternation of nutrients in the soil. The areas farmed with biodynamics also presented a higher amount of earthworms (175 per m^3 compared to 21 – Reganold, 1993) and significantly thicker arable soil (topsoil) of 2.2 cm.
On the other hand, whereas the cation exchange capacity and total nitrogen were found to be higher in the biodynamic farms, the available phosphorus and sulfur and the pH of the soil were often higher in companies with conventional agriculture. However, concentrations of other elements such as calcium, magnesium and potassium were very similar in the two systems (Reganold, 1993).
In addition, the results of the financial analysis showed that biodynamic farms are as solid as the conventional ones: a biodynamic cattle farm reported higher profits, two farms (one of which specializes in the production of milk) made lower profits than their conventional counterparts, and two others made similar profits to those of conventional farms (regarding vegetables and citrus fruits – Reganold, 1993). Most of these cases presented either less annual variability or greater financial stability, which is an important factor in sustainability and is becoming increasingly important because production costs will increase in coming years. However, the biodynamic products were sold at a 25% higher price and if the price were to increase further, it would have a significant impact on the financial sustainability of the biodynamic and organic farms.

Industrial Biological/Organic Agriculture

THE INDUSTRIAL ORGANIC AGRICULTURE AROSE IN THE UNITED STATES IN THE LATE NINETIES, WHEN THE USDA ESTABLISHED NATIONAL ORGANIC STANDARDS

There is no official definition of industrial organic farming, but we can say that it arose in the United States in the late Nineties, when the USDA established national organic standards.

The reason the USDA found it necessary to develop organic standards was due to the entry of large food companies within the organic market. After all, companies like Earthbound, Cascadian Farm and Horizon practice a form of agriculture that is not unlike modern industrial agriculture, capable of feeding the global food economy.

Economies of scale are obtained with the use of mechanization and monoculture, an aspect not contemplated by the organic principles, and consequently the biodiversity is often reduced in these large organic farms. However, among the environmental benefits of this production model is a ban on use of fertilizers and pesticides, which means greater protection of land, water courses and ultimately the consumers themselves.

Nevertheless, the sustainability of industrial organic farming has some ethically and socially negative aspects. For example, unlike organic farming, the industrial model is less tied to regionalism and practices adapted to local conditions; instead its products are shipped throughout the world (which allows Brazilian consumers to eat organic lobster from Maine), while the original organic movement promotes the purchase of local products and the strengthening of relations between communities and farmers.

For large food businesses, less stringent national organic standards provide an opportunity to benefit from economies of scale and to take advantage of the transition to organic production. However, the entry of large companies in a growing organic market has negative implications for small farmers because they find that they have less control over the prices and are often exploited by large companies that are able to produce more with less.

Industrial organic and biological models indeed seem to actually be two distinct models: the first is aimed at a high profit and the second has important social and ethical objectives. It would be more appropriate, therefore, to give the large organic farms, which are limited to meeting national standards, a name that is different from the one given to small organic farms, that aim to ensure food sovereignty and rural employment.

At the beginning of the movement in the early Sixties, thousands of small organic farms were purchased by large food companies. This was the case of the Cascadian farms which, once at the forefront of the "back to earth" organic movement, are now owned by General Mills; Dagoba is now owned by Hershey's and Horizon and Alta Dena are owned by Dean.

The advantage of the management buy-in of organic farming is the price reduction of many organic products, which currently represents precisely the main reason for their limited purchase by customers.

The case of Earthbound Farms in Carmel (California, USA)

Drew and Mayra Goodman founded Earthbound Farms with two and a half acres of raspberries and vegetables in Carmel, California. In 1986, they started the retail sale of ready-made salads and now have become the major producers of organic products and the most successful in the world, billing up to 450 million dollars in 2006 (Shapin, 2006). They need six companies to meet the demands of large retailers like Costco and Whole Foods and have large farms in six different areas of California, two in Arizona, one in Colorado, and in three regions of Mexico (Shapin, 2006).

Earthbound Farms has a huge influence on the organic market, seeing as they produce more than 70% of the organic lettuce sold in the United States.

In 2011, at Earthbound Farms, 36,000 acres were cultivated (about 15 thousand hectares) on its large farms, the largest of which is 680 acres (275 hectares).

On their website, the founders say that they avoid the use of "333,000 pounds (about 150 thousand kg) of toxic and persistent pesticides and more than 11,200,000 pounds (about 5000 tons) of chemical fertilizers." Moreover, they claim to "save about 1.8 million gallons (about 7000 liters) of oil by avoiding the use of pesticides and fertilizers made from petroleum, and to fight global warming by avoiding the release of carbon dioxide, a major greenhouse gas, into the atmosphere, equivalent to that produced by about 7800 cars." These numbers seem to be considerable, but to accurately calculate the emissions of carbon dioxide, the gases emitted by the trucks for the transport of compost and the mechanized harvest of thirty-six thousand acres need to be added to the equation. The transport chain of Earthbound products on the market is very similar to that of a traditional farm, and it is precisely for this reason that emissions produced going from Mexico to California to New York and in any other state along the way should be taken into consideration.

Organic Agriculture

IT IS BASED ON THE ECOLOGICAL PROCESSES, ON THE PRESERVATION OF BIODIVERSITY AND ON THE TRENDS OF THE PRODUCTION CYCLES UNDER LOCAL CONDITIONS

Organic agriculture has been defined by the IFOAM (International Foundation of Organic Agriculture Movements) as "a system of production that sustains the health of soils, ecosystems and people." It is based on ecological processes, on the preservation of biodiversity and adaptation to the production cycles of local conditions, rather than the use of expensive inputs.

Organic agriculture combines tradition, innovation and science for the benefit of the environment and promotes fair relationships, as well as a good quality of life, for all involved (IAASTD, 2009).

There are many definitions of organic farming, and more are being made in every new country.[2] We can summarize and say that what are considered to be organic farming practices (even though adopted also in agricultural models that do not qualify as "organic") include: the use of cover crops, crop rotation, green manure, composting and the use of catch crops.

From 2007 to 2010, the amount of certified organic farmland increased by 3 million hectares, equal to 9%. In 2010, the global market for certified organic products reached $55 billion, making it the fastest growing sector in the food business economy.

The massive increase in the popularity of organic products is mainly due to the perception of nutritional and health benefits (mostly environmental) that these bring.

The premium prices of organic products have led to the increase in the income of organic farmers, also benefiting the small landowners in developing countries.

In 2010, 37.2 million hectares of land were farmed organically, equal to an increase of 6.2% over the previous year. The countries with the largest number of organic producers are India (340,000), Uganda (180,000) and Mexico (130,000). In India, the main reason farmers choose to switch to organic production is linked to health benefits for the farmer and also for the consumer.

Anthony Stweart/National Geographic Stock

The case of Tigray (Ethiopia)

The "Tigray Project" in Ethiopia is one of the projects that demonstrates how the adoption of organic agriculture can substantially increase yields and, at the same time, result in increased access to food by the population groups considered to be the most vulnerable according to the indices of poverty (Edwards, 2007).

Tigray is located in the highlands of northern Ethiopia, where the diversity of crops is traditionally very high. The "Tigray Project" was created in 1996 with an experiment conducted by farmers and experts who want to find out if a community-based ecological approach for the restoration of soil and the improvement of production through ecological principles would be able to reduce soil degradation and improve the living conditions of poor small farmers (Edwards, 2010). For the "Tigray Project," the Institute for Sustainable Development, in collaboration with the Ministry of Agriculture and Rural Development and the Environmental Protection Authority (EPA) of Ethiopia adopted the principle of Extension Services (technique based on direct and constant technical assistance to farmers, keeping the world of research in touch with that of the field technicians – Edwards, 2010). Thanks to the success achieved and recognition by the government that this type of approach could be the "main strategy against land degradation and for the eradication of poverty in Ethiopia," the project has been extended to other Ethiopian regions (Edwards, 2010). A 2010 FAO publication of the "Tigray Project" listed its main activities: training courses and follow-up for the preparation and use of compost, including the monitoring of the impact on production, starting up the activity of soil and water conservation, the reduction of grazing and the feeding of animals with fresh herbs and woody plants, the creation of community ponds, small dams and river diversions, in order to collect and store water for use in the dry season, the promotion of water harvesting, beekeeping and use of bio-pesticides based on local knowledge; support for families with female heads of the household and composed of elderly people (the poorest of the poor), through the provision of seeds, spices and training courses for the cultivation of fruit trees and plants used as fodder to be sold locally; training courses for unemployed women who have completed compulsory education, enabling them to acquire the necessary skills to enter the work world; the sharing of experiences through cross visits and promoting the use of new and simple technologies and tools that are easy to find and use (such as foot pumps).

From 2001 until 2006, 5 and 10 years after the beginning of the project, yields were analyzed. Overall, the use of compost had doubled the yields of all crops: beans, barley, wheat, teff, hanfets (a mixture of barley and durum wheat) and millet (Edwards, 2007). Furthermore, there was also a general increase of biomass, although to an extent not comparable to the increase of yield.

According to the authors, one of the reasons for the increase in yield is that the farmers were encouraged to use their own seed varieties, which were therefore adapted to local conditions. In addition, farmers observed that the use of compost was more accessible, thanks to reductions in cost and the possibility of not having to resort to buying on credit (FAO, 2007).

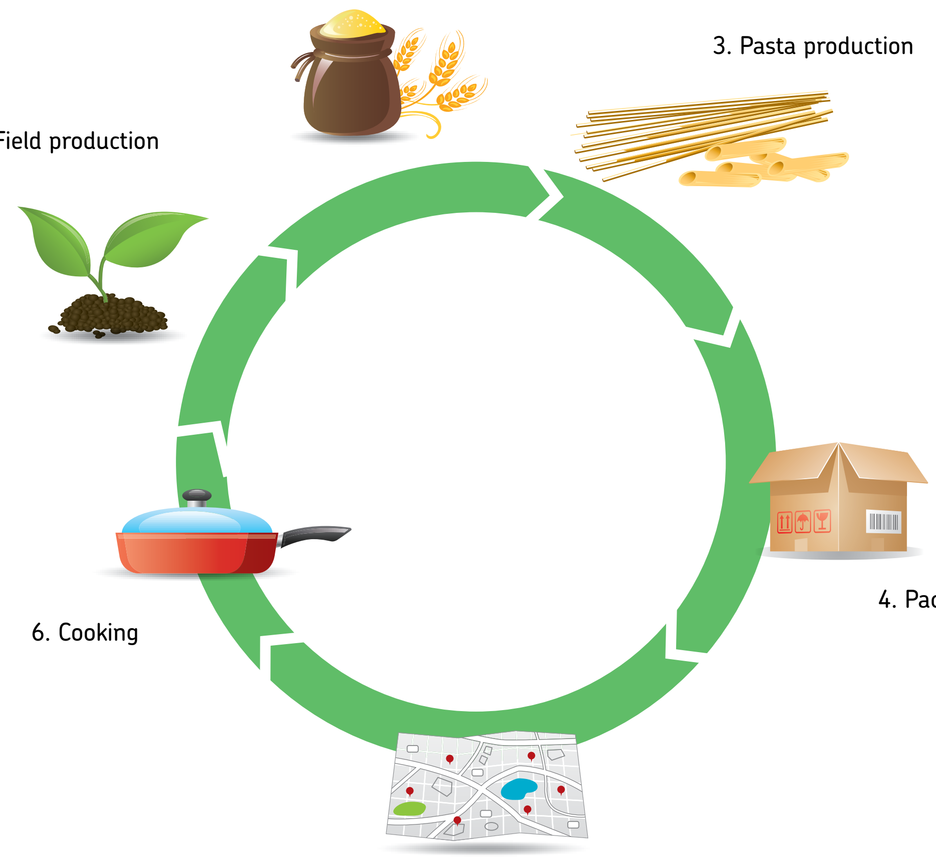
In 2010, the "Tigray Project" involved 20,000 farming families in Ethiopia.

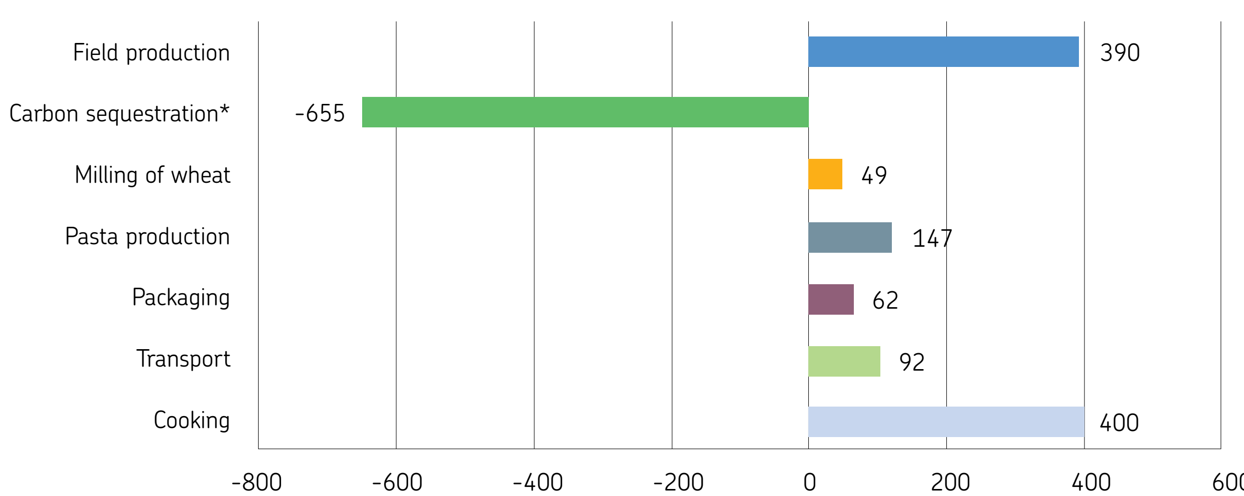
3. SUSTAINABILITY OF CROPPING SYSTEMS WITH DURUM WHEAT IN ITALY: THE CASE OF BARILLA

3. SUSTAINABILITY OF CROPPING SYSTEMS WITH DURUM WHEAT IN ITALY: THE CASE OF BARILLA

Sustainability in agriculture is one of the objectives of the Common Agricultural Policy. In this regard, sustainable agricultural systems are those production models that are able to produce foods that are adequate in quality and quantity,ensure a fair economic remuneration for the farmers and help safeguard the agricultural soil and natural resources. In other words, sustainability means "seeking a long-term maintenance of the agricultural production and soil fertility, while reducing environmental risks related to those very same agronomic practices."
But just how much impact does agricultural activity have on the entire life cycle of an agro-food product? To answer this question, the case of durum wheat semolina pasta was examined; its impacts have been analyzed through the Life Cycle Assessment (LCA), an objective method of evaluation and quantification of the environmental and energy loads and the potential impacts associated with a product/process/activity along the entire life cycle, from the acquisition of raw materials to end of life ("cradle to grave").
This analysis showed that the cultivation phase of wheat, with its agronomic practices, together with cooking, is one of the most important phases in terms of environmental impact (Figure 3.1.).
Using greenhouse gas emissions as an example, we can see that the major impacts associated with farming activities are due to the use of nitrogen fertilizers and mechanical operations, in particular for working the land.
These results, combined with a need to analyze and evaluate Italian agricultural systems where durum wheat is grown, led Barilla to launch a multidisciplinary study that simultaneously considers the economic, production, agronomic, environmental and food safety values.
The ultimate goal was to identify "sustainable" agricultural systems, validate the various areas of national production and to raise both the quality and quantity of raw material. Once validated, these systems should be introduced in the discipline of durum wheat cultivation.
From a methodological point of view, four main areas have been identified: the plains of the Lombardy-Veneto regions, Emilia-Romagna, Central Italy (Tuscany, Marche and Umbria) and Southern Italy and islands (Puglia, Basilicata and Sicily); the standard crop rotations identified are sufficiently representative of the rotations in which durum wheat is grown in Italy (Figure 3.2.).

Figure 3.1. Results of an LCA analysis of durum wheat for pasta

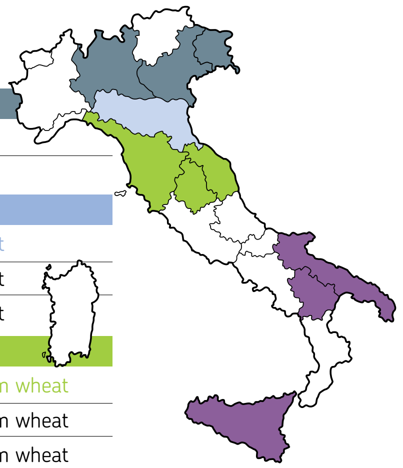




*Carbon sequestration means the amount of CO_2 that was absorbed by the wheat during its growth. The value is normally shown separately from the others and not added, in that from the scientific point of view, there is no agreement on how the reporting of this data should be done.

Source: *Environmental product declaration of Durum wheat semolina dried pasta produced in Italy*, in a cardboard box; S-P-00217; 10/03/2011. Data regarding the average Barilla production worldwide, www.environdec.com.

Figure 3.2. **Rotations taken into account in the 4 main areas**



LOMBARDY-VENETO REGIONS				
CORN*	Corn	Durum wheat	Corn	Corn
INDUSTRIAL	Soy	Durum wheat	Rapeseed	Corn
EMILIA-ROMAGNA				
CEREAL*	Corn	Durum wheat	Sorghum	Wheat
INDUSTRIAL	Soy	Durum wheat	Corn	Wheat
HORTICULTURE	Tomato	Durum wheat	Corn	Wheat
CENTRAL ITALY				
CEREAL*	Durum wheat	Durum wheat	Sorghum	Durum wheat
PROTEINS	Peas	Durum wheat	Peas	Durum wheat
FODDER	Alfalfa	Alfalfa	Alfalfa	Durum wheat
INDUSTRIAL	Sunflower	Durum wheat	Rapeseed	Durum wheat
SOUTHERN ITALY AND SICILY				
CEREAL MONOCULTURE*	Durum wheat	Durum wheat	Durum wheat	Durum wheat
FODDER	Forage	Durum wheat	Forage	Durum wheat
PROTEIC	Chick peas	Durum wheat	Chick peas	Durum wheat
INDUSTRIAL	Tomato	Durum wheat	Durum wheat	Durum wheat

*Standard crop rotation normally adopted in each area.

Source: *Sustainability of Cropping Systems with durum wheat*, in "Grano Duro News," 2011.

The agronomic and economic studies were supported by the environmental assessments conducted by using the LCA methodology and synthesized through the use of the following indicators: the Water Footprint, the Ecological Footprint and the Carbon Footprint, as shown in the following table:

	SYSTEM	Grain Yield (t/ha)	Carbon Footprint ($t\ CO_2/t$)	Water Footprint (m^3/ha)	Ecological Footprint (gha/t)	Gross Revenue (€/t)	Nitrogen use efficiency (kg/kg)	DON Risk (0-9)
CENTRAL ITALY	Cereal*	3,3	0,67	745	0,73	24,1	28,4	3,9
	Forage	4,3	0,30	478	0,47	99,4	66,7	0,0
	Industrial	5,3	0,43	502	0,49	138,8	45,3	0,0
	Protein	5,3	0,34	479	0,47	139,2	58,5	0,0
EMILIA-ROMAGNA	Cereal*	7,3	0,51	328	0,40	140,7	32,5	7,9
	Industrial	7,5	0,41	315	0,38	156,7	42,2	2,3
	Industrial Horticulture	7,5	0,36	315	0,38	151,1	47,1	1,7
LOMBARDY VENETO REGIONS	Industrial*	7,5	0,42	294	0,36	166,9	44,0	1,7
	Corn-growing	7,0	0,51	315	0,38	155,2	33,8	7,9
SOUTHERN ITALY AND SICILY	Cereal*	2,5	0,74	1429	1,11	23,3	32,4	1,1
	Forage	5,0	0,45	694	0,54	132,8	44,3	0,0
	Industrial Horticulture	4,2	0,53	874	0,68	111,8	38,7	0,0
	Protein	5,0	0,45	694	0,54	132,8	44,3	0,0

*Standard crop rotation normally adopted in each area.

Source: *Sustainability of Cropping Systems with durum wheat*, in "Grano Duro News," 2011.

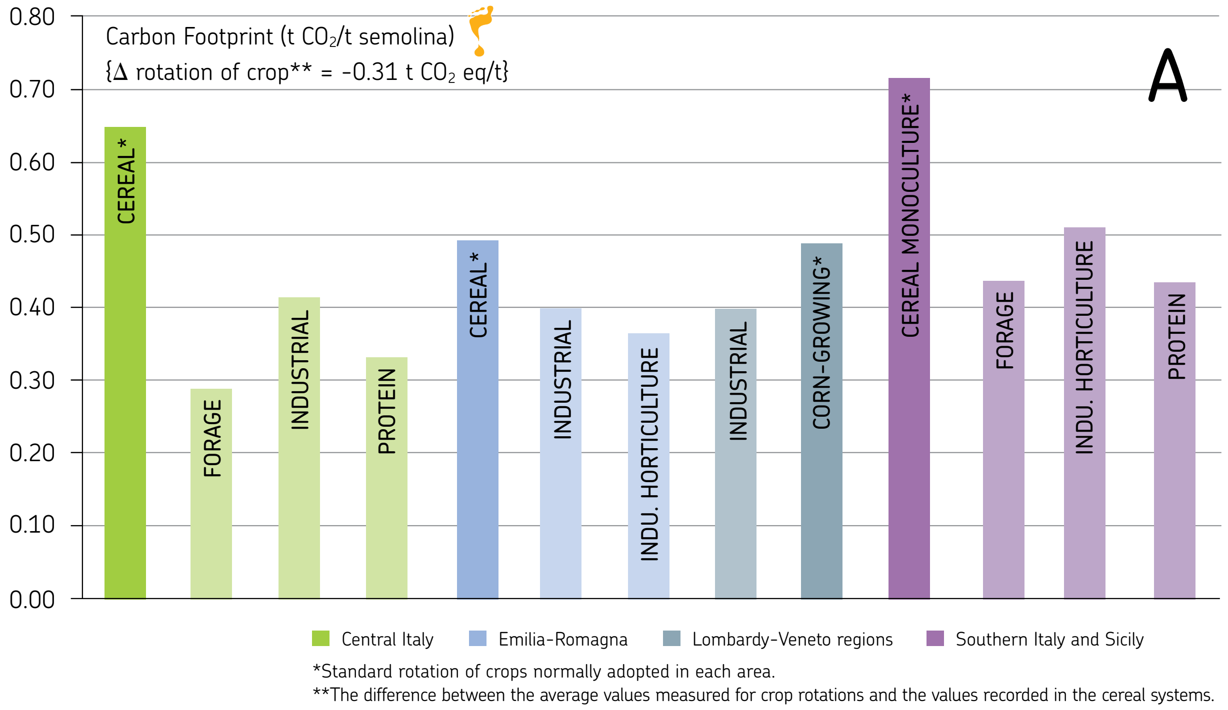
The selected indicators

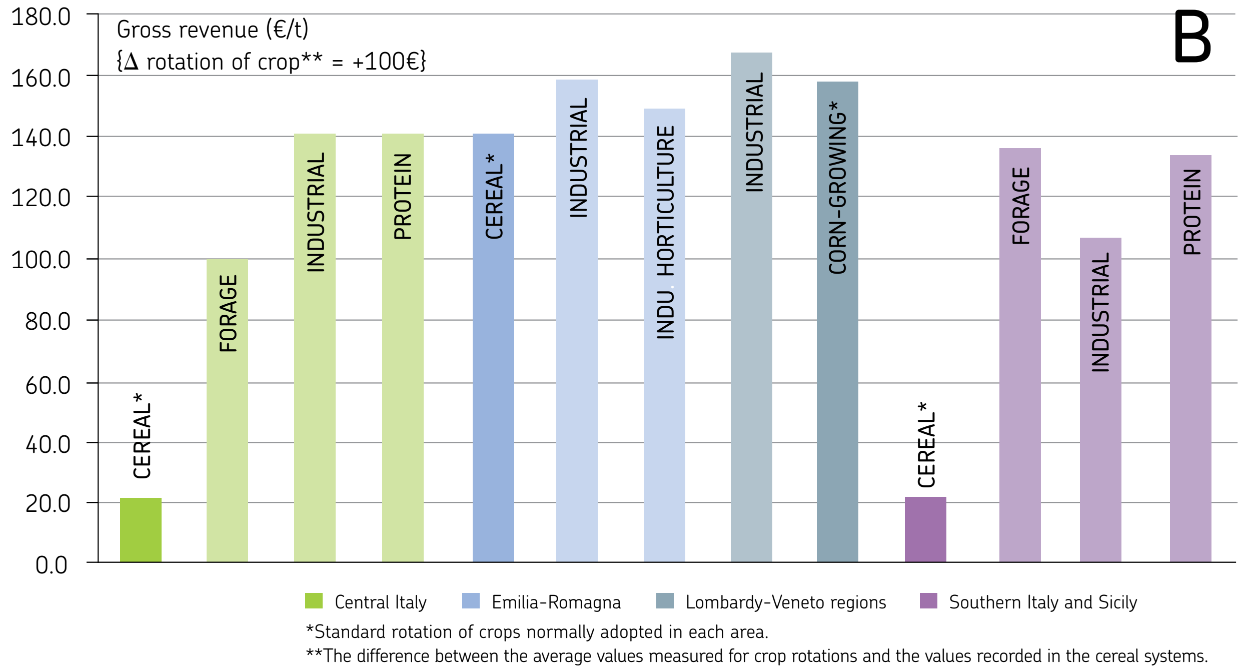
- *Wheat production*: for each system analyzed, the production of different crops have been analyzed, including durum wheat. In particular, for the latter, the data was reported in tons of grain per hectare to 13% humidity. The yields reported in the paper refer to medium-high productions for every turnover and consider the use of Good Agricultural Practices (GAP) for the various production processes.
- *Carbon Footprint*: represents the total amount of GHG (Greenhouse Gases), which are those substances in the atmosphere, both natural and anthropogenic, that are transparent to incoming solar radiation on Earth, but which can substantially retain the infrared radiation emitted by the surface of the Earth by the atmosphere and clouds. Greenhouse gases are expressed as mass of CO_2 equivalent, treating all gas emitted in terms of global warming effects of the CO_2, according to the conversion tables defined by the IPCC (International Panel on Climate Change). In the case of this study, the Carbon Footprint is expressed in tons of CO_2 equivalent per ton of durum wheat produced.
- *Water Footprint*: represents the consumption of water related to the production of goods and services. About 85% of the human Water Footprint is related to agricultural (and animal) production, 10% to industrial production and 5% to domestic consumption. In the case of this study, the indicator measures the water consumption of the cultivation of durum wheat in terms of the volume of water consumed during the various production processes and following the natural evaporation of the crops. Irrigation was not considered because it is a practice that is not usual in these distribution areas. The Water Footprint is expressed in cubic meters of water per ton of wheat produced.
- *Ecological Footprint*: measures the area of biologically productive land and sea needed to regenerate the resources consumed by a human population and absorb the corresponding waste. Using the Ecological Footprint, it is possible to estimate how many "Planet Earths" would be needed to support humanity if everybody lived according to a certain lifestyle. The present study used the measurement in "global hectares" per ton of wheat produced.
- *Gross Income (GI)*: represents the difference between the GMP (gross marketable production, updated according to prices in March, 2011) and the Cost of Production of the crops. The GMP does not take into account the costs of the direct support and/or indirect effects of the CAP, whereas the Cost of Production takes into account only the direct costs of cultivation (cultivation operations and technical means) and not those that are indirect (land use, financial interests, taxes and fines, etc.). In the present study, Gross Income was measured in Euros per ton of wheat produced.
- *Nitrogen use efficiency (NUtE)*: represents the amount of grain produced per unit of nitrogen distributed on the crop of durum wheat.
- *DON Risk*: expresses the risk of contamination of grain by Deoxynivalenol (DON), a dangerous mycotoxin that is developed by a group of pathogenic fungi (Fusarium spp.) that attack the ear of durum wheat. The mycotoxin risk index combines the meteorological factors conducive to the production of mycotoxins by Fusarium graminearum and F. culmorum with the predisposing factors, and the specifics of the productive unit, such as varietal susceptibility, crop precession, and the processing of soil. The mycotoxin risk index ranges from 0 (recorded when there are no conditions for the production of mycotoxins) to 9 (recorded when the conditions are very favorable for the production of mycotoxins).

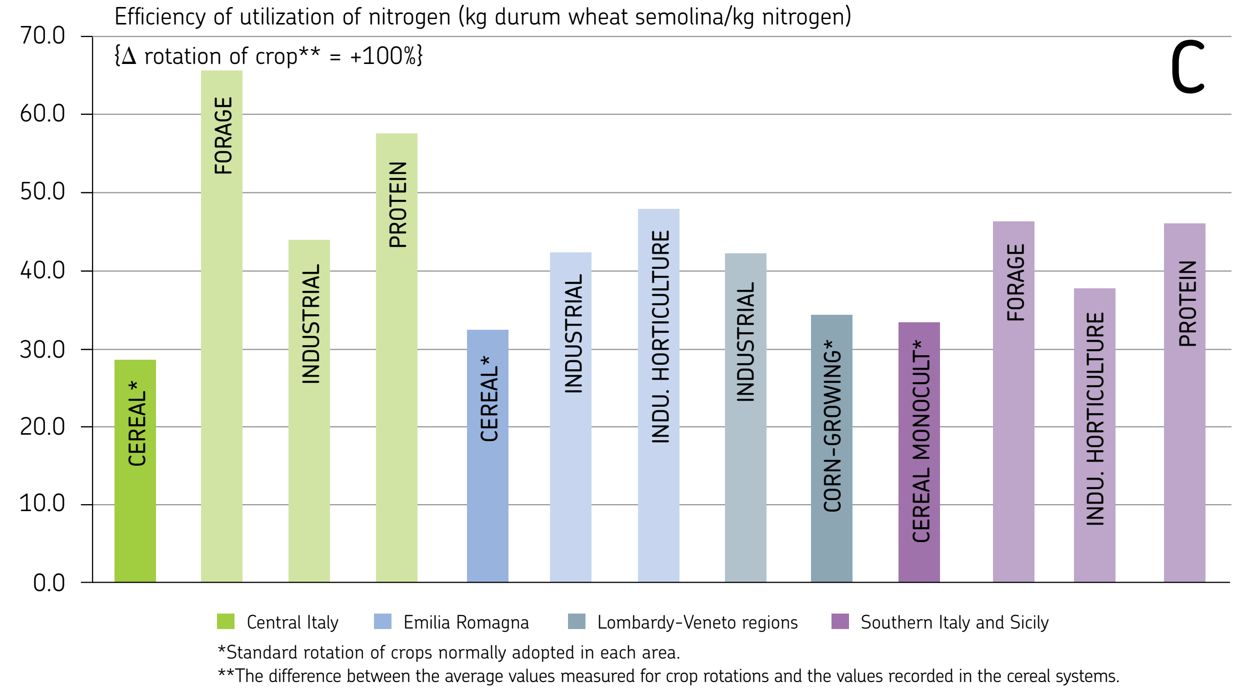
Results of the study

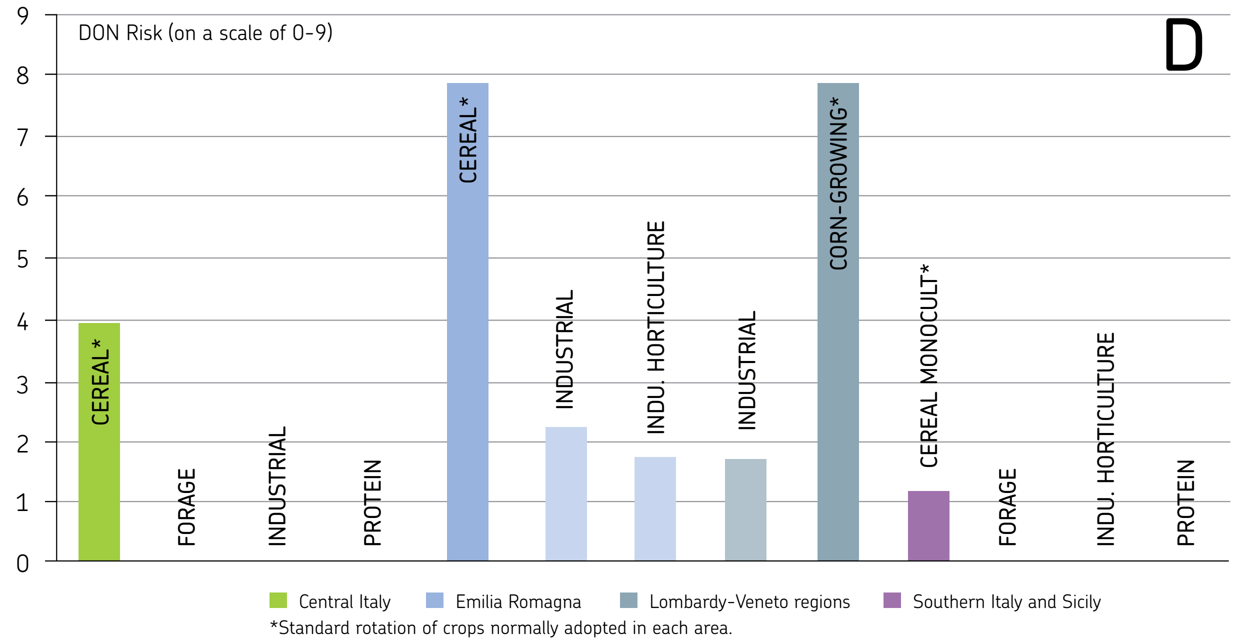
Figure 3.3. (A, B, C and D) reveals graphical results of the study of the effects of cultivation systems on the Carbon Footprint, Gross Revenue, Efficiency of utilization of nitrogen and DON risk.
With regard to the Carbon Footprint (Figure 3.3. A), within each macro area we can observe an interesting variation in cereal systems: in principle the cultivation technique of durum wheat has the most impact in terms of greenhouse gas emissions. This is partly explained by the fact that in such systems, in order to grow durum wheat, cultivation requires very expensive operations, such as plowing, in order to reduce the risk of mycotoxins or significantly increase the intake of artificial nitrogen, since cereal crops in rotation (common and durum wheat, corn and grain sorghum) remove large quantities of the element and leave crop residues that are not easily degradable by the microflora in the soil. On the other hand, especially where there are forage or protein crops in the rotation, the "environmental cost" decreases significantly. In these cases the residual nitrogen in the crop rotation makes a reduction of inputs of artificial nutrition possible, and it is possible to use conservative tillage techniques: minimum tillage or direct seeding.
The economic analysis of the cost of durum wheat also reflects the considerations mentioned above (Figure 3.3. B). The cereal systems, especially those of Central and Southern

Figure 3.3. **Effects of cropping systems on the Carbon Footprint (A), Gross revenue (B), Efficiency of the utilization of nitrogen(C) and DON Risk of durum wheat (D)**









Source: *Sustainability of Cropping Systems with durum wheat*, in "Grano Duro News," 2011.

Italy, are at the limit of affordability, considering that the prices of wheat applied are those of the Commodity Exchange recorded in Bologna at the time this paper was written (280 €/t).
The efficiency of nitrogen use in wheat was found to be higher in rotations in Central Italy, particularly at the end of the cycle of alfalfa, a crop that leaves large amounts of available nitrogen in the ground (Figure 3.3. C).
The DON Risk (Figure 3.3. D) was calculated by using the mathematical models from the Catholic University of Piacenza, which attribute half of the risks to climatic variables and the remaining half to agronomic factors (precession, type of tillage, variety, etc.). As is known, the risk of mycotoxin is greater in the areas of the North and in particular, in the farming systems of corn in the plains of Lombardy and Veneto, and of cereal in Emilia-Romagna. However, the risk remains, albeit at very low levels, even in the macro areas of Central and Southern Italy, where cereals are the predominant crop.

Conclusions

The study conducted showed the possibility of assessing the "sustainability" of a crop or a cropping system using multi-disciplinary analysis, combining different environmental, agronomic, economic and food security indicators. This type of holistic view of the cropping system opens important perspectives of strategy and possible scenarios in order to achieve the objectives of a modern agriculture.
It is evident that the characteristics of a species, in this case durum wheat, are strongly linked to the context (system or model) in which it is grown. Not only do all of the parameters of "sustainability" change substantially, but so do the final quality and quantity of the material produced. But the most interesting thing is to discover that the application of traditional farming practices, and a proper crop rotation in particular, ensure environmentally sustainable production.
The next step is the "actual measurement in the field" of the most favorable cropping systems, which will be compared to traditional ones.
The next step is to directly involve farmers and industry experts, so that the concepts of sustainability and productivity come to be part of corporate strategies as two absolutely reconcilable aspects of agricultural production. In order to achieve this goal, beginning with the next sowing, pilot crops will be implemented in more favorable rotation contexts which are also more economically sustainable than the ones today, in a network of farms distributed throughout Italy (Figure 3.4.).
To better explain this to farmers, Barilla developed "Ten Commandments" for the sustainable cultivation of quality durum wheat.

THE APPLICATION OF TRADITIONAL FARMING PRACTICES, AND IN PARTICULAR PROPER CROP ROTATION, ENSURE ENVIRONMENTALLY SUSTAINABLE PRODUCTION

Figure 3.4. **Project Durum wheat and Sustainable Agricultural Systems. Provision of platforms for validation of the "Pilot" companies**

Source: *Sustainability of Cropping Systems with durum wheat*, in "Grano Duro News," 2011.

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Barilla's Ten Commandments for the sustainable cultivation of quality durum wheat

The results of the study conducted by the Barilla on Italian durum wheat show that the correct application of knowledge and agricultural practices not only helps in improving crop yields and the quality of products, thus allowing to increase the income generated by crops, but also helps reduce the environmental impacts (up to 40% less greenhouse gas emissions) due to an increased efficiency of fertilization. In light of the results of this study, Barilla developed "Ten Commandments" for the cultivation of durum wheat: a list of guiding principles for farmers who are facing the complex challenges of sustainable agriculture.

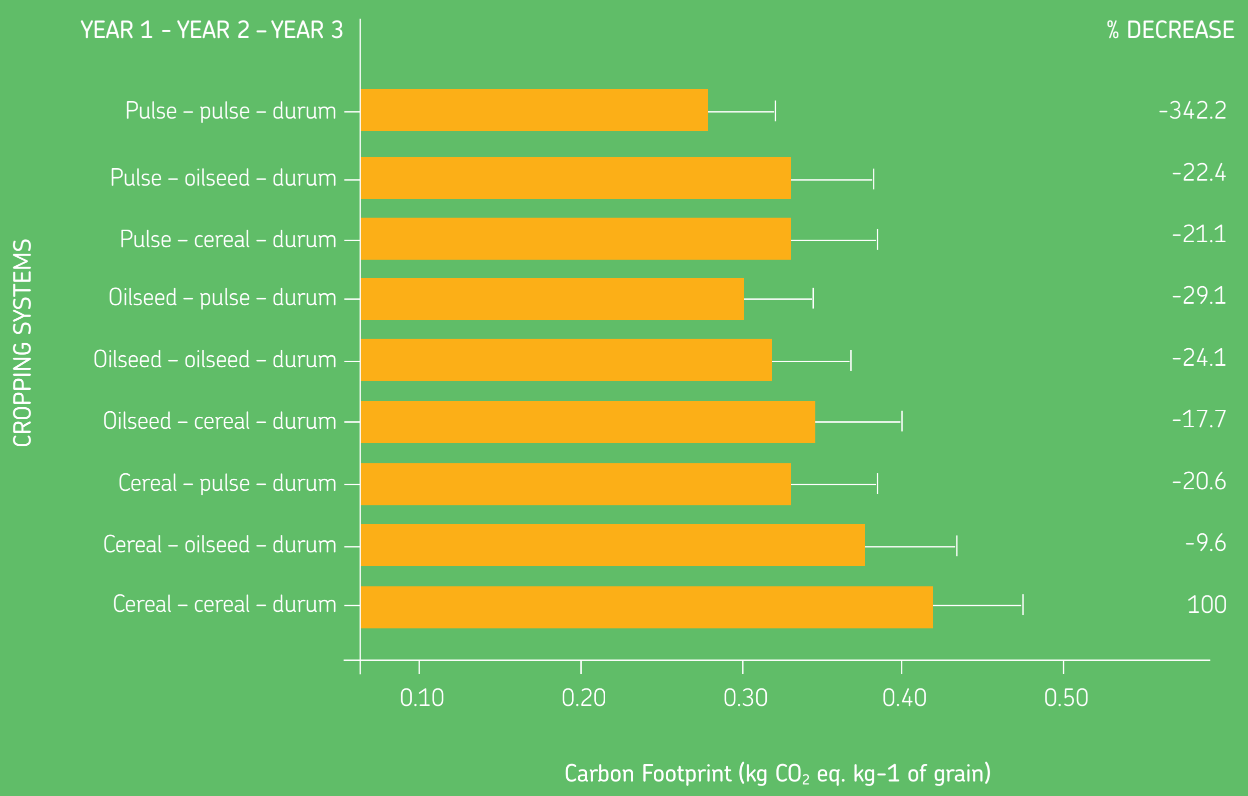
In this paper, enriched by the practical results of numerous experiments, considerable importance is given to the adoption of favorable crop rotations, to the efficient use of resources and the proper use of technical means. It is also shown how to correct agronomic practices, as well as how to contribute to the reduction of environmental impacts, thus enabling optimum production both qualitatively and quantitatively.

1. *Alternate crops*: plant durum wheat in a favorable crop rotation. Monoculture and rotations exclusively of cereal crops are, in fact, the cause of high environmental impacts and low profitability.
2. *Work the soil with respect for it*: choose the tillage in a flexible manner, using tools and depth of working that are adapted to the specific conditions, climate and cropping system in which durum wheat is inserted, according to the following guidelines.
3. *Use the best variety*: choose the variety to be sown in relation to the cultivation area and expectations in terms of productivity and technological quality.
4. *Use only certified and tanned seeds*: only certified seed ensures varietal identity (production capacity, technological quality and resistance to adversity) and seed quality (purity, germination).
5. *Sow at the right time*: each variety has an ideal time of planting, which can vary according to the cultivation area and weather conditions.
6. *Use the right amount of seeds*: choose the density of sowing in relation to the variety, the area, the time of sowing and soil conditions, since planting too thickly prevents the crop from making the best use of resources, promotes the development of diseases and causes enticements.
7. *Restrain weeds in a timely manner*: the treatment must be timely and appropriate to the type of weeds present and the environmental conditions and cropping practices.
8. *Dosage of nitrogen according to the needs of the plant*: the use of nitrogen fertilizer should be adequate, both in terms of quantities supplied and the periods in which they are used.
9. *Protect the plant from disease*: carry out the treatments of defense in relation to conditions of risk and adopt a comprehensive strategy that involves all aspects of cultivation.
10. *Extend sustainability to the farming system*: place the cultivation of the durum wheat in the cropping system (rotation) without limiting it to the context of individual crops, but, rather, apply sustainability measures to the overall management of the farm. © Barilla

The results of a study on durum wheat in Canada[1]

Improving cropping systems may help mitigate greenhouse gas emissions. This study determined the carbon footprint of durum wheat (*Triticum turgidum L.*) produced in diverse cropping systems.
Durum was grown in rotation systems which had different combinations of oilseed, pulse (legumes) and cereal crops at five site-years in Saskachewan, Canada. Total greenhouse gas emissions from the decomposition of crop residues along with various production inputs were used for the estimation of the carbon footprint. On average, the emissions from the decomposition of crop straw and roots accounted for 25% of the total emissions, those from the production, transportation, storage and delivery of fertilizers and pesticides to farm gates and their application 43%, and emissions from farming operations 32%.

Figure 3.5. **Carbon Footprint of durum wheat grown under different cropping systems in southwest Saskachewan, Canada. Data was calculated from the averages of three rotation cycles conducted in fields in the period of 1996-1998 (first cycle), 1997-1999 (second cycle) and 1998-2000 (third cycle). Bars are standard errors**



Source: Gan, Y., C. Liang, X. Wang, B. McConkey, *Lowering Carbon Footprint of Durum Wheat by Diversifying Cropping Systems*, in "Field Crops Research", 122 (3), pp. 199-206, Elsevier, 2011.

4. A MODEL OF ANALYSIS AND SIMULATION

4. A MODEL OF ANALYSIS AND SIMULATION

THE AMOUNT OF FOOD PRODUCED EACH YEAR IS ENOUGH TO FEED THE WORLD, EVEN IN THE FUTURE

In an attempt to interpret the types of current agricultural models and to propose alternatives for the future, the Barilla Center for Food & Nutrition has created, in collaboration with the Millennium Institute,[1] a simulation model to study the impact of changes in current agricultural practices on the amount of food available worldwide.[2] The results of this model are the basis for many of the ideas proposed so far.

The objective of the analysis is to understand how far-reaching external shocks, summarized here as a very significant increase in the price of oil, can have an impact on world agriculture and its evolution, expressed in terms of the agricultural models adopted.

In particular, two main patterns of agriculture have been identified and defined:

- a Low External Input model (LEI), characterized by a low energy intake and an elevated use of labor;[3]
- a High External Input model (HEI), characterized by a high consumption of energy and inorganic fertilizers.[4]

The two models mainly differ as to the different characteristics of sustainability over time. Considering a period of 80 years (1970-2050) and evaluating the impact on the amount of calories produced per capita annually, assumptions can be made concerning the choices of the most appropriate production policy.

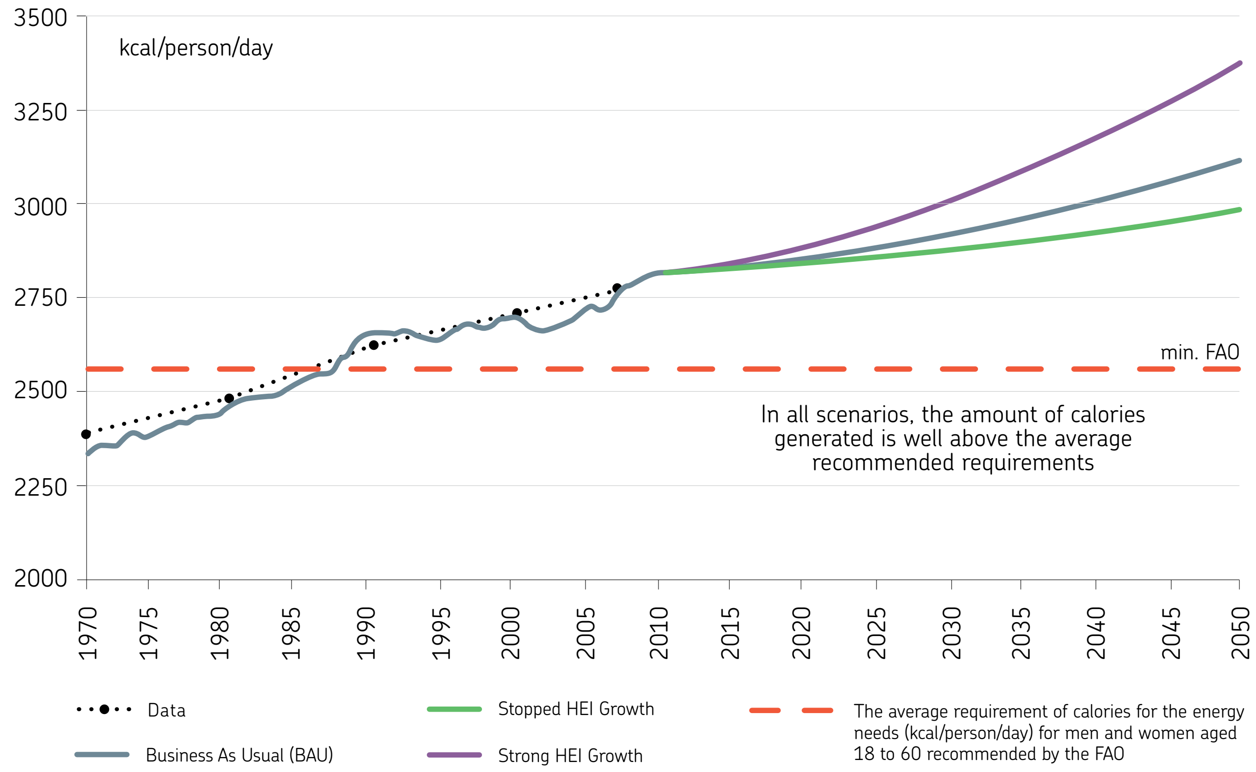
It is important to clarify that, starting from the simulations carried out,[5] the amount of food produced each year is enough to feed the world, even in the future taking into account a rate of productivity growth in line with the current demographic trends and projections made by the FAO and the OECD.[6] A significant portion of the problems the food system faces – as we mentioned – depends on critical issues related to distribution, tintended use and food product waste.

→ Under conditions of abundant energy supply, the simulation model includes three different scenarios (Figure 4.1.):

- Scenario of *Business As Usual (BAU)*: practices at a high level of external input will cover 60% of the total area cultivated in 2050;
- Scenario of *Strong HEI Growth*: practices with high external input will spread at an accelerated pace and will cover 90% of the total area cultivated in 2050;
- Scenario of *Stopped HEI Growth*: we will witness the poor dissemination of models of the high use of external inputs, which will retain their current share of 45% of the cultivated land in 2050.

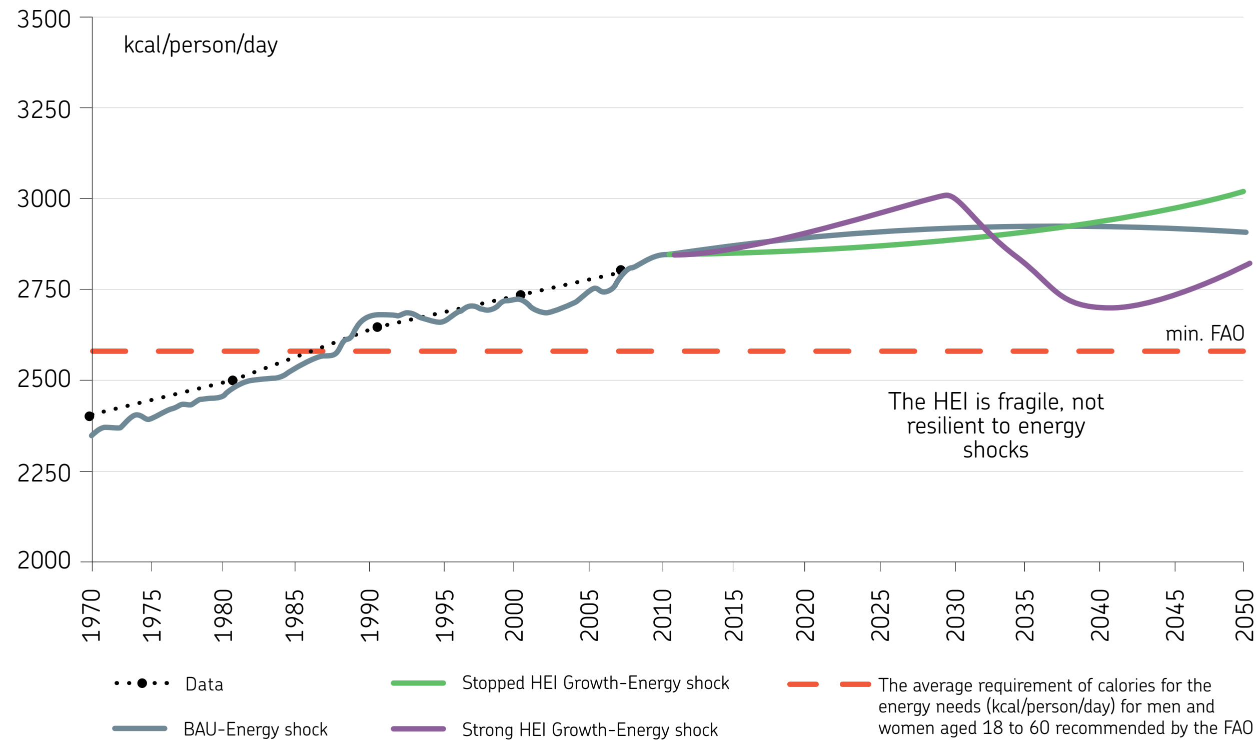
→ There is also a simulation (Figure 4.2.) of a rapid increase in oil prices between 2025 and 2030 (a context defined "Very High Energy Price"): oil prices will rise rapidly in 2030 to reach $200 a barrel, and then level off at around $280 per barrel in 2050. Because of the rapid rise in oil prices, the price of inorganic fertilizers will grow so much as to substantially

Figure 4.1. **Agricultural production for human nutrition**



Source: FAO data base.

Figure 4.2. **Agricultural production for human nutrition in a case of energy shock**



Source: FAO data base.

reduce their use; these conditions, will benefit only the high-value crops and in general only 50% of the area cultivated globally. Therefore, the effects were estimated on the number of calories per capita per year for each of the three basic scenarios (*BAU-Energy Shock, Strong HEI Growth-Energy Shock, Stopped HEI Growth-Energy Shock*).

THE THREE SCENARIOS ANALYZED: A) BAU-ENERGY SHOCK, B) STRONG HEI GROWTH-ENERGY SHOCK AND C) STOPPED HEI GROWTH-ENERGY SHOCK

What has been made is a simulation model that tries to understand what the result of a global shock could be, depending on the configuration of the global agricultural system. The discriminant variable is the use of energy as the primary factor of production.

If we hypothesize, for example, a constant availability of energy over the observed period of 80 years, the production scenario with a higher yield – in the scheme of sustainability– would be the one of Strong HEI Growth, followed by the Business As Usual (BAU) scenario and, finally, by the Stopped HEI Growth scenario (Figure 4.1). In a context of simplified global development, in which possible reductions in the availability of all the elements that make up the profile of sustainability are not taken into consideration, with the certainty of not being subject to energy shocks, a pro-Strong HEI Growth policy would generate a total availability of calories well above the required amount. It is interesting to note that also the Stopped HEI Growth scenario seems to be able to provide, a projected total caloric intake that is more than adequate. This indicates that there does not seem to be an issue with the availability of total calories. However, it must be said that this simulation model does not take into account the inequalities between different geographical areas, which, in fact, constitute the real problem. Moreover, the assumption of a constant availability of energy over time is unrealistic, because fossil fuels are steadily declining and renewable energy sources are not yet a viable alternative.

To conclude, it can be assumed that at some point in time, an energy shock of the global supply is likely to occur, which would put a strain on energy-intensive systems such as the HEI models. In fact, these models would become economically unsustainable and unprofitable, and serious problems related to the transition to more efficient models from the point of view of energy use would occur. The costs of the change in production would become evident in terms of the minor output available and of time spent in the acquisition of the know-how needed for the transition. Figure 4.2. shows the estimated affects of an energy shock on global energy output between 2025 and 2035.

The simulation results show how if reductions in energy availability occur starting in 2025, an approach to low external input would lead to a Worse-Before-Better (WBB) result, or low productivity in the short term with a return to higher levels of yield over the medium to long-term. If there is no reduction in the amount of energy available, the results are strongly influenced by the share of cereals for animal feed and biofuel production. In any case, a change in these assumptions would not change the results in terms of quality, leaving unchanged the ranking of the scenarios in terms of calories produced and the yield.

THE SIMULATION SHOWS THE FRAGILITY OF THE GLOBAL AGRICULTURAL SYSTEM

In the case of an energy crisis, the results greatly depend on the amount of time spent by the systems in shifting from the HEI agricultural model to the LEI model (in the direction of a Stopped HEI Growth scenario). In fact, in the short-term, the results of Strong HEI Growth-Energy Shock and BAU-Energy Shock are less negative.

The example shown here highlights the fragile nature of the global agricultural system. This frailty will have to be tackled positively by promoting a balanced mix of agricultural models, designed to cope with the phenomena of relative scarcity. Of course, the reality is much more complex than what has been willfully represented in this simulation for dissemination purposes. In addition to possible energy shocks, in fact, there are many other long-term risk factors: water availability, adaptation to atmospheric phenomena, etc.

However, in any case, the result presented is by no means trivial because it does illustrate one of the issues that will be very important in the future, when the search for solutions based on approaches to energy consumption content and an in-depth knowledge base (according to the logic of balance already described) will become one of the most crucial aspects of sustainability.

The future of agriculture

Beginning with the reflections on the method proposed in the previous paragraphs, we wish to offer our assessment on the future direction of the Common Agricultural Policy (CAP).
In November 2010, the European Union defined its strategic guidelines and directions of the policy for orienting the future CAP, with a time horizon of the next decade.
Agriculture in the EU today is part of a highly competitive globalized environment, due to the progressive integration of the world economy, the increasing liberalization of trade and the high degree of uncertainty and volatility that currently characterizes world agricultural markets. This poses significant challenges for European agriculture in 2020.
In particular, the EU is considering using the CAP reform to establish a new paradigm for European agriculture. The distinctive features of this have been summarized in the paper The CAP toward 2020: Meeting the food, natural resources and territorial challenges of the future and in the legislative proposals published on October 12, 2011. Agriculture will increasingly need to combine competitiveness and sustainable growth.
Firstly, the EU needs to continue to contribute to meet the increasing global demand for food. In fact, European agriculture needs to maintain and strengthen its production capacity, strengthening the foundation of the food sector, pursuing criteria of economic efficiency and enhancing its strategic positioning in the global context. Secondly, there are two further challenges that are particularly critical for the future of the farming industry, including in Europe, namely climate change and territorial balance. (Territorial challenges as defined by the Commission concern both the vitality of rural areas and the diversity of EU agriculture.)
With regard to environmental protection, a new proposal to dedicate 30% of direct payments to practices which make the most efficient use of natural resources has been met with much consternation by farm organizations. It reflects the significance attached by the EU to the global climate change issue and demonstrates a willingness to make unpopular decisions in favor of environmental protection.
For this reason, we are moving toward renewing our commitment to reduce greenhouse gas emissions caused by agriculture, even though there has already been a 20% reduction since 1990. We are also giving greater attention to the revitalization and the strengthening of the many rural areas still highly dependent on the primary sector for its fundamental role in combining efficiency, sustainability and food traditions.
Finally, among the substantial challenges facing European agriculture in the future, there will be the relative scarcity of natural resources (water and, especially, soil). These scarcities are likely to escalate, creating critical conditions in meeting the increasing demand for food commodities.
In the course of the numerous interviews conducted by the Barilla Center for Food & Nutrition with experts of EU agricultural policy, what has emerged is the close observation of the evolution of agricultural techniques and technologies for sustainability. These are not only technologies that could lead to developments in the seed sector, but also the more efficient use of scarce resources and the mitigation of the impacts of climate change to which these techniques could contribute.
In light of this analysis, and given the objectives defined in the overall European Strategy 2020, the CAP, in particular, should:
- preserve the food production potential on a sustainable basis throughout the EU: this condition must be reached with a view to ensuring the long-term food security for European citizens and to help meet the growing global demand for food commodities;
- support farming communities that provide European citizens with a wide variety of fine and quality food produced in a sustainable way, in accordance with the objectives that the EU has adopted in matters of environment, water, health and welfare of animals and plants, and public health;
- maintain viable rural communities, where agriculture is an important economic activity that can create local employment, with multiple socio-economic, environmental and territorial benefits.

The EU Commissioner for Agriculture and Rural Development – Dacian Cioloç – summed up the spirit underlying the guidelines developed so far when speaking of a Common Agricultural Policy that would be "greener, fairer, more efficient and more effective."
In summary, the three major challenges of the new CAP identified so far are:
- *1st objective*: food security;
- *2nd objective*: environment and climate change;
- *3rd objective*: territorial balance.

The tools under consideration for the practical implementation of the broad guidelines are numerous and complex. A more detailed explanation of the main technical options currently at the focus of the debate can be found in the Commission document: The CAP toward 2020: meeting the food, natural resources and territorial challenges of the future.
At this point one might ask what observations are possible concerning the initial documents/debates on the future of the CAP, given the considerations that the BCFN has produced and produces on agricultural issues and sustainability.
Firstly, as has been highlighted on several occasions by the BCFN, the issue of food security will be particularly relevant for the future. The CAP proposal does an admirable job in facing the challenge of food security, which is addressed through innovation and greater diffusion of agronomic knowledge, as well as a series of market management tools which would allow the EU institutions to intervene in the agricultural markets in times of instability.
This would maintain cohesion of a multidisciplinary approach including social, environmental and economic dimensions, and research and development, as part of an overall effort to create a sustainable agricultural model in Europe. The Commission is proposing €4.5 billion (double the current budget) for agricultural research through the new "European partnership for research and innovation." This is aimed at developing a strategy for sustainable increases in agricultural production and adaptation of production to consumer expectations. The CAP review affords the EU the opportunity/responsibility to define a path

toward the sustainability of agricultural models. This should shape the choices being made in that field worldwide, providing a reference point to orient agricultural sustainability. In addition, such a process could lead to a greater appreciation of the quality and added value of European food production in the challenging international markets.
In discussing sustainable agriculture, we must not ignore the role of biofuel production on European farmland. Where there is "competition" between "food destination" and "energy target" for the use of the scarce terrain, this production could be a crucial aspect. Precisely for this reason, particular attention should be given to the overall system of incentives/deterrents that will be outlined on the community level.
In line with the Barilla Center for Food & Nutrition's long-held position, the intention to revitalize rural communities is particularly welcome, since it is a precondition for effective management of the territory and land use. The richness/diversity of agricultural systems, typical of Europe, provides an added value that will be enhanced in the coming decade.
Without going into excessive detail, it is possible to show that operational tools such as cash transfers to farmers could be one of the main conduits for encouraging the spreading of good agricultural practices. In addition, it may assist in promoting effective commercial practices, thus reducing volatility of food prices, one of the challenges of food security whics are of such concern for the future.
It is worth remembering that the Barilla Center for Food & Nutrition has repeatedly stressed the importance of maintaining a "safety net" to guard against extremes of price volatility.
For that reason, the Barilla Center for Food & Nutrition can express support for the inclusion of a provision in the CAP proposal which suggests safety nets (intervention and private storage) for the agricultural aspects of the supply chain that are most at risk of crisis.
Furthermore, transfers could help to spread awareness of the importance of respecting, rediscovering and increasing the value of local traditions and cultures, economically sustaining those crops and productions best suited to different contexts within the local community, be it for tradition, eating habits and environmental impact.
The intention of the European Commission to thoroughly re-examine the use of production quotas, in line with the continued market orientation of the CAP, is positive and seems to be in line with the reflections made by the Barilla Center for Food & Nutrition regarding the fluidity and freedom of access of world food markets, even for those less-advantaged agricultural contexts.
Last but not least is the need for long-term initiatives and programs, to avoid the trap of short-term action. This is a topic on which the Barilla Center for Food & Nutrition has been very vocal in recent years.
An overall long-term plan would be valuable. This needs to focus on improving the economic and environmental efficiency of agricultural initiatives, the development of measures to ensure food security and quality, the development of sustainable agricultural techniques and technologies, and the creation of a viable process of transferring/sharing knowledge and skills concerning food, starting with those most related to territorial specificities. EU funds for research and innovation and will focus on projects relevant to farmers with a closer cooperation between scientists and farmers.
There are indications of a shift away from a "transfer" of knowledge from researchers to farmers, to the inclusion of farmers throughout the process.
There is no glimpse, however, of signs of enlargement of the agricultural sector and therefore of the planning of the processors and users that are part of that same sector

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5. CONCLUDING REFLECTIONS

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AGRICULTURE IS A COMPLEX AREA OF ACTIVITY THAT DOES NOT LEND ITSELF TO EASY SIMPLIFICATIONS

Agriculture is complex and does not lend itself to easy simplification, which is why it is difficult to draw unequivocal conclusions from this analysis. Nevertheless, some basic principles can be identified. This is a collection of evidence, reflections and guidelines that characterize a possible approach for creating true sustainability. In particular, there are seven points of attention that we consider essential and which are stated briefly below:

1 *Sustainable agriculture is characterized by a systemic conceptual and operational approach.*

For a future of sustainability, we must increasingly learn, according to a multidisciplinary approach, to "hold together" the social, environmental and economic aspects, as well as those of research and development. Approaches aiming at pursuing partial goals can only reap some short-term success of one of the aspects and consequently do not help in winning the challenge of sustainability. An example of this is the intention to revitalize rural communities, an essential condition for effective land management and land use. The richness/diversity of agricultural systems is, in fact, an added value in the perspective of combining efficiency and agricultural sustainability.

2 *Sustainable agriculture is based on a large number of already known agricultural practices.*

The knowledge available, made up of scientific knowledge and proven practices, has crystallized into some excellent and practical guiding principles of truly sustainable farming. There is, in fact,an ever-growing convergence around the best agricultural practices, specifically declined in different situations, which should be followed. These are[1]: systemically use crop rotations (as was standard practice in the past) on the same tracts of land; cultivate a wider range of plant species to arrive at a correct spatial distribution of trees, shrubs, pastures and crops in order to improve the resilience of the system; minimize mechanical working of the ground, in order to maintain the soil structure and organic matter; improve and maintain a protective cover on the surface of the organic soil using species of reduced cycle in the times between crops; and use cover crops or organic crop residues, in order to protect the soil surface, conserve water and nutrients, promote biological activity of the soil and contribute to the integrated management of pests and weeds. These techniques – associated with the use of crop varieties with high yield (resistant to biotic and abiotic stresses and with good nutritional value), the optimized use of organic and inorganic fertilizers, integrated management of pests and diseases through appropriate practices[2] (based on biodiversity, the selection and use of pesticides with low environmental impact) and, when necessary, efficient management of water resources – allow for better performance in terms of sustainability, with the same macro model of reference (HEI, LEI, IEI).[3] In Chapter 3 of this paper, there is a brief summary of the experiment conducted by Barilla through the recovery of these "good" guiding principles at the farms of some of its suppliers of raw materials. At present, the results are very encouraging.

3 *Agronomic "knowledge" is not very widespread.*

With the development of science, farming is increasingly characterized by the articulation and breadth of knowledge gained regarding the characteristics of the natural environment and the physiology of plant species. All this is combined with the practical experience accumulated over centuries of activity. In other words, there is a wealth of knowledge available of extraordinary value that is only partially used today. In certain surroundings, this seems to be due to the lack of effective processes for transferring knowledge. In others, this is because it is believed that the available technology, at least partially, makes in-depth knowledge of the natural dynamics superfluous. In summary, it could be argued that regardless of the model adopted (HEI, LEI, IEI), the biggest problem that global agriculture now faces is the need to strengthen its human capital base, bridging the gap between available knowledge, individual and system skills. With regard to this aspect, significant investment plans will be needed, because they are the prerequisite for any development in the direction of greater sustainability.

4 *Correct agricultural models for specific contexts: the objective is to reduce external inputs.*

That said, there are no good or bad agricultural models a priori. There are certainly HEI models that we believe will prove unsustainable and LEI models that cannot be implemented in all contexts; however there is a wide range of realities, namely, of IEI models adjacent to LEI models that can be managed appropriately, in light of the above requirements of sustainability.

The choice of model depends on the context. In geographical contexts in which the HEI systems with high economic performance are rooted (such as the U.S., Brazil and Argentina), it makes no sense to propose or suggest extreme choices of rupture and discontinuity. Instead, the adopted model's limitations on sustainability should be evaluated to make the necessary corrections. Likewise, Europe's way should be implemented with the IEI/LEI models, based on effective enforcement mechanisms of the application of knowledge.

In other words: what matters is the trend line, i.e., the shift toward more sustainable IEI models and the equilibrium with the models within the macro-regions.

A different reasoning must be made for developing countries where there are still no active agricultural models that are economically and socially sustainable; one has to return to and adapt models that are appropriate to the specific characteristics of the local reality.

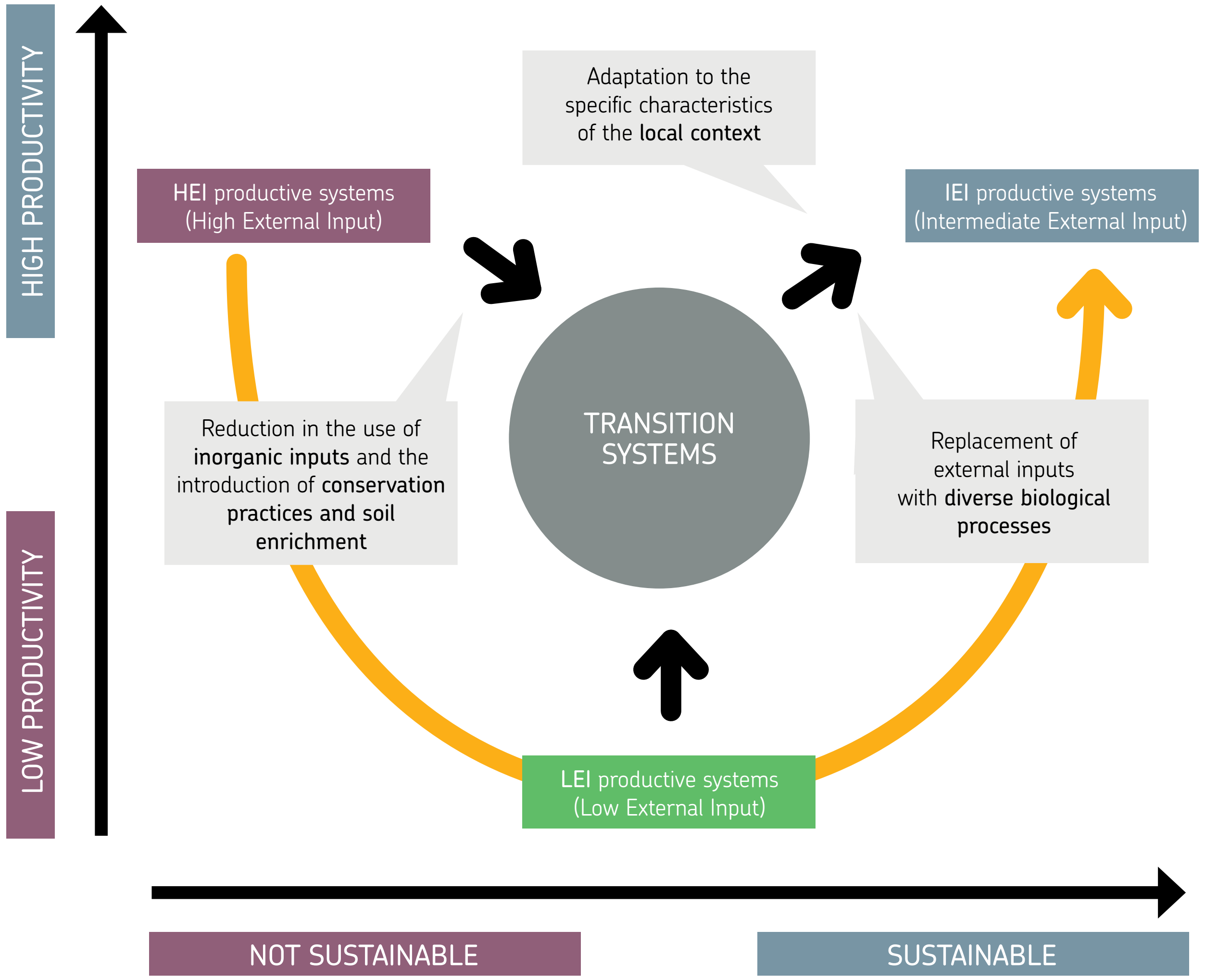
5 *Biodiversity as an instrument for correct risk management.*

A pragmatic approach, without prejudice, to the choice of agricultural models allows – at the level of policymaking – the maximization of the overall resilience of agricultural systems. Proper management of biodiversity and the coexistence of different models, all equally optimized concerning sustainability boosts the possibilities of response to adverse events and the search for specific objectives of the system, when these are alternative (e.g., maximum quality vs. large volumes).

6 *Investments in technology to make agriculture more able to adapt to change.*

According to the reading proposed within technology also takes on a different connotation from that which is too often prevalent in these times. Today, when it comes to technology in agriculture, one is often referring only to productivity and yields, thinking

Figure 5.1. **The transition toward sustainability**



Source: elaborated by The European House-Ambrosetti, 2011.

that these may be increased by improving the individual varieties. However, even more important is the adaptability that is expressed in the integrated and harmonious management of a wide range of tools and logic: plant varieties resistant to stress, management of advanced systems of irrigation, scientific approach to fertilization, etc.

7 *The external factors of sustainability in agriculture: food waste, losses, and biofuel.*
One cannot forget that a large part of the issues that plague agriculture and the agro-food system lie outside the choice of models and the search to optimize them. As seen in the opening, there are phenomena of great impact that affect the goals agriculture has set for itself, emphasizing beyond measure the matter of production volumes, at the expense of a more balanced approach. There is, above all, the issue of food waste, which is truly disturbing in its proportions and which is one of the challenges to sustainable agricultural in the future. Along with the matter of loss/waste that world agriculture produces today, there emerges a question that seems central to the choices regarding the allocation of resources in agriculture (both financially and physical): the production of biofuels.

For the issue of "waste," and "biofuels," the inadequate management of the problem, and questionable choices in the field of energy policy have resulted in strong pressure on the agricultural system to make up for deficiencies that it should not have to bear.

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APPENDIX

Alex Treadway/National Geographic Stock

HYPOTHESES, ASSUMPTIONS AND INTERMEDIATE RESULTS OF THE BCFN-MILLENNIUM INSTITUTE SIMULATION MODEL

Premise

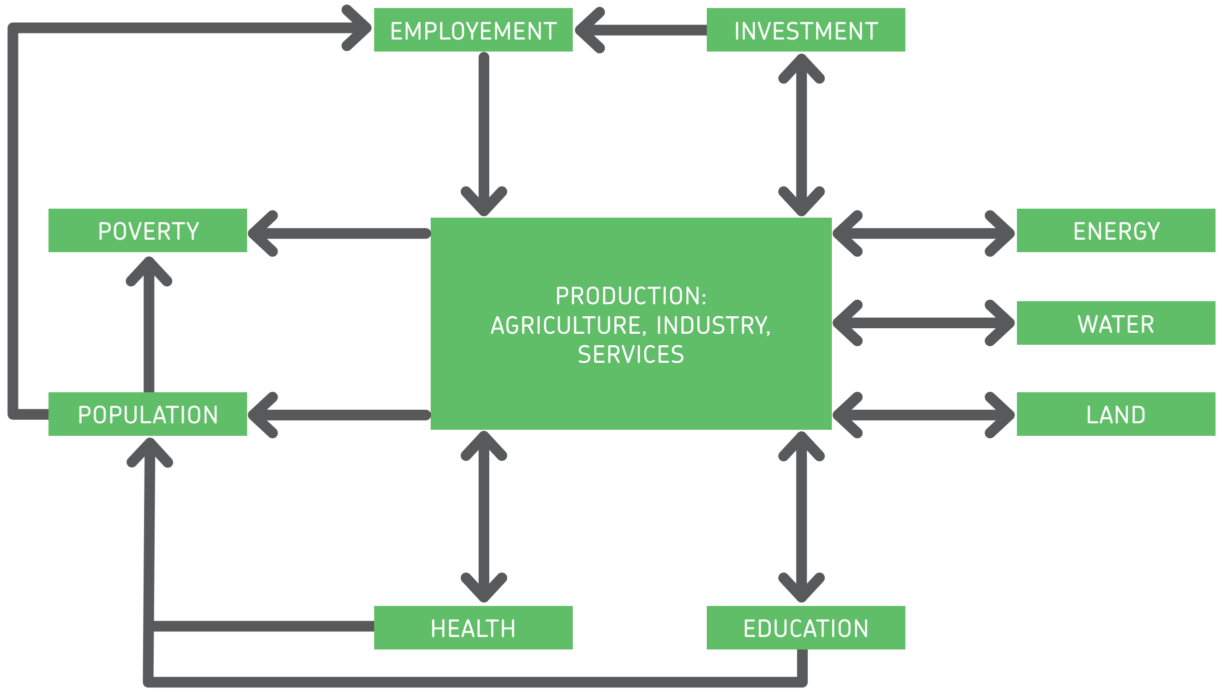
The Barilla Center for Food & Nutrition is conducting a study on the long-term impacts (until 2050) of different agricultural practices (or agricultural models). The study examines different scenarios with the aim of facilitating the understanding of the key mechanisms that link agriculture to the rest of the socio-economic-environmental system and its long-term implications. The initiative is part of a more extensive program of studies relating to the environment and sustainability, and this study on sustainable agriculture will provide a broader systemic perspective and ideas for the upcoming debate on the renewal of the EU's Common Agricultural Policy.
The Millennium Institute (MI), which supports the study of the long-term impacts (until 2050) of different agricultural practices (or agricultural models) conducted by the Barilla Center for Food & Nutrition, for this purpose, has developed and used a Threshold21 (T21) global model for the simulation of scenarios representative of long-term agriculture worldwide (1970-2050), taking into account agricultural development based on the different degrees of diffusion of the model that is currently prevailing (High External Input systems, or HEI) compared to the alternative model (Low External Input, or LEI). Each model is characterized by the amount of resources needed to support it, productivity and the environmental impacts involved. The simulations take extreme conditions into account in terms of resource limitations in the long-term (i.e., energy restriction), in order to assess the adequacy of the different models under these conditions.
The analysis particularly focuses on the aspect of teaching: the goal is not to provide exact predictions or highly probable scenarios, but rather, to examine plausible extreme situations and provide information on key systemic mechanisms that play a fundamental role in shaping the development of agriculture in the long-term.
In summary, the study has the following purposes:
- *Evaluate*, through an analysis of the scenarios, *the implications for the long-term sustainability of the two extreme agricultural models* (HEI vs. LEI).
- *Highlight how agriculture falls within the broader socio-economic-environmental system*.
This report provides a synthetic view of the structure of the model and the general hypotheses illustrates the fundamental assumptions that characterize the different scenarios, and describes and discusses the results of the different scenarios. The work is aimed at a wide audience, which is why this report was written in such a way as to avoid the technicalities of the modeling as much as possible.

Model Structure and Assumptions

General structure and linkage between sectors

This study is global in nature and the world will be treated as a singl e entity without further geographical breakdowns: the time horizon between 1970 and 2050. Therefore, the modeling focuses particularly on the mechanisms that regulate long-term, socio-economic-environmental development in general, with a specific interest in the agricultural sector. Accordingly, the description of this sector will be more detailed than that of the other sectors.
The model is composed of 10 sectors, all interacting dynamically, that provide an integrated perspective on long-term development. Figure A.1. illustrates the general structure of the model and the links between the sectors. For simplicity, only the main links are represented. More details are given in the following section.

Figure A.1. **Overview of the model structure: sectors and interactions**



Source: Millennium Institute, 2011.

The 10 sectors have the following key features:
- *Population*: divided according to age (81 classes) and sex. The fertility rate is determined by income (production sector) and education (education sector), while the mortality rate is determined based on life expectancy (health sector).
- *Education*: measured in terms of average years of schooling and determined on the basis of the total expenditure on education per pupil, which in turn is defined in terms of the share of the global GDP.
- *Health*: measured in terms of life expectancy at birth, separately for men and women. Life expectancy is determined by income (production sector) and the overall health expenditure per capita, in turn calculated as a share of the global GDP.
- *Employment*: represented separately for agriculture, industry and services sectors. For industry and services sectors, employment levels are calculated according to the level of physical capital (production sector) and education (education sector - higher levels of

education imply greater capital intensity). For agriculture, employment is also determined by the land cultivated (land sector).

- *Poverty*: measured in monetary terms (percentage of population below the poverty line) and in terms of nutrition. With regard to nutrition, the average levels per capita of calorie, protein and fat intake are determined on the basis of agricultural production (production sector). Moreover, the percentage of the population below the minimum levels of energy intake in the diet is determined using a log-normal distribution approach.
- *Production*: includes agricultural production, industrial production and services; it is determined by using an extended Cobb-Douglas production function with endogenous determination of the total productivity of the factors (PTF). For industry and service sectors, the key inputs are labor (industry employment) and capital; productivity is determined by the level of education (education sector) and health (health sector). For agriculture, the production is divided further into different activities and crops, as explained in more detail in the Appendix.
- *Land*: this sector considers 4 types of land areas: agricultural area, forest area, settlement area and other land (which includes all other land types not included in the previous aggregates). The growth of the agricultural and settlement areas is determined by population growth (population sector) and is limited by the small proportion of forest land and other land converted for such purposes. According to the FAO classification, the agricultural area is divided further into arable land and permanent crops, as well as permanent pastures and prairies.
- *Water*: this sector determines the use of water for agricultural, industrial and domestic/municipal activities. The demand of water for agricultural use is calculated based on cultivated area (land area) and the type of crop (production sector). The demand of water for industrial use is determined by the level of industrial production (production sector). The demand of water for domestic/municipal use is determined by the total population (population sector) and per capita income (production sector).
- *Energy*: the energy demand is divided into 5 types: oil, gas, coal, electricity from non-renewable sources and electricity from renewable sources. The demand for energy is broken down into the following sectors: agriculture, industry, services, transportation, residential transportation and others. The energy demand is based on the intensity of capital (production sector), the total population (population sector), income per capita (production sector), as well as on energy prices, the extent of network coverage and technical progress, defined as exogenous factors.
- *Investment*: the economic resources that are saved are invested in different sectors according to their relative size and the relative profitability of each sector.

Structure of Agriculture

Given the primary purpose of the study, an analysis of scenarios in relation to alternative agricultural models -, the agriculture sector has been described with a particular wealth of detail. Similarly, the sector on poverty concerning nutrition and the distribution of food is more in-depth than other sectors. The following paragraphs provide a description of the specific components of the model. Agricultural production is divided into crop production, production of food of animal origin and forestry production. The production of crops and foods of animal origin is subdivided further as shown in Figure A.2.

The 11 categories related to the production of crops cover the full range of global agricultural production, while the last remaining category – Other – represents only a very limited part of the production and mainly includes products that are immaterial in terms of nutrients (such as spices).

Figure A.2. **Suddivisions of the production of crops and foods of animal origin**

CROP PRODUCTION	PRODUCTION OF FOOD OF ANIMAL ORIGIN
Cereals for food (including rice, wheat and millet)	Meat
Cereals for fodder (all the other cereals)	Dairy products
Fibrous crops	Eggs
Fruit	Fish (exogenous)
Oilseed crops	
Legumes	
Roots/tubers	
Nuts	
Vegetables	
Sugar crops	
Other	

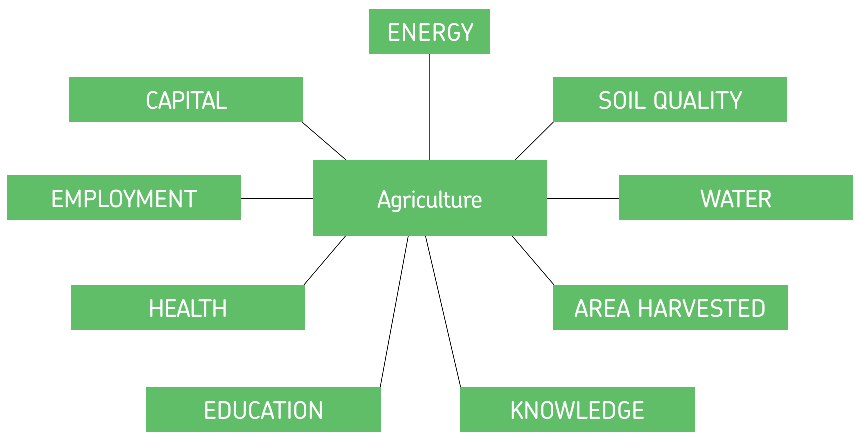
Source: Millennium Institute elaboration of FAO data, 2011.

The production is determined for each category of crops according to 9 main factors (Figure A.3.): physical capital, energy, soil quality, water, cultivated area, knowledge, education, health and employment. While most of these factors are determined in the areas described above, the availability of knowledge in the agriculture sector and of soil quality is calculated in specially processed, specific sub-sectors.

The combination of knowledge about farming techniques and seed varieties and fertilizers is considered a key component of knowledge in the agricultural sector. The accumulated expenditure for R&D in agriculture is used as a proxy for such a combination of knowledge. Private and public R&D investments, determined in terms of shares of added value generated by agriculture, are listed separately. With regard to soil quality, the density of macronutrients in the top layer of soil is used as a reference, specifically nitrogen, phosphorus and potassium. The nutrient density decreases with the growth of crops and increases with the use of inorganic and organic fertilizers and other organic methods.

The production of meat, dairy products and eggs is determined according to the area designated for permanent pastures and meadows, the quantity of feed grain produced,

Figure A.3. **Key resources that influence agricultural production**



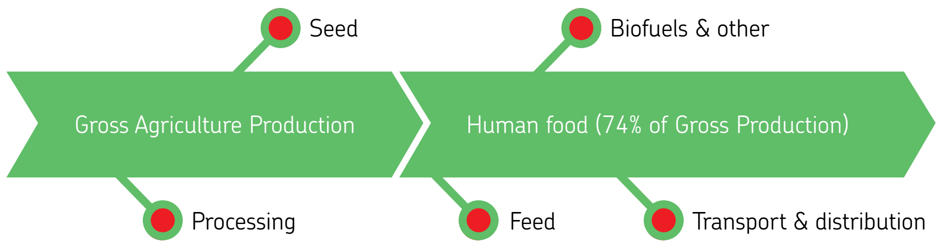
Source: Millennium Institute, 2011.

and the productivity of agriculture. The production of fish is exogenous, as it does not fall within the scope of this study.

The flow of the production of food crops (thus excluding fibrous crops) and foods of animal origin are used to determine the average levels of nutrition, including the amount of calories, proteins and fats per person per day. To calculate these levels, the agricultural productions – net loss of crop –, other uses and losses are further subtracted (Figure A.4.): losses during processing, the amount used for sowing (if applicable), the amount used for animal fodder (if applicable), the amount used to produce biofuels and other non-food products and the losses incurred during shipping and distribution. What remains is the amount of agricultural production that is actually available for human consumption. Therefore, the average levels of nutrition per capita are determined by applying the corresponding average content of nutrients in each of the 10 crops and each of the four food products of animal origin.

The average levels of nutrition are also used to determine the distribution of food by applying a lognormal approach. This allows one to calculate the proportion of the population below the minimum dietary standards. In addition, it determines the proportion of food waste at the household level in order to calculate the overall proportion of food that is not consumed.

Figure A.4. **Flow of agricultural food production in 2009**



Source: FAO data base.

Agricultural models and scenarios

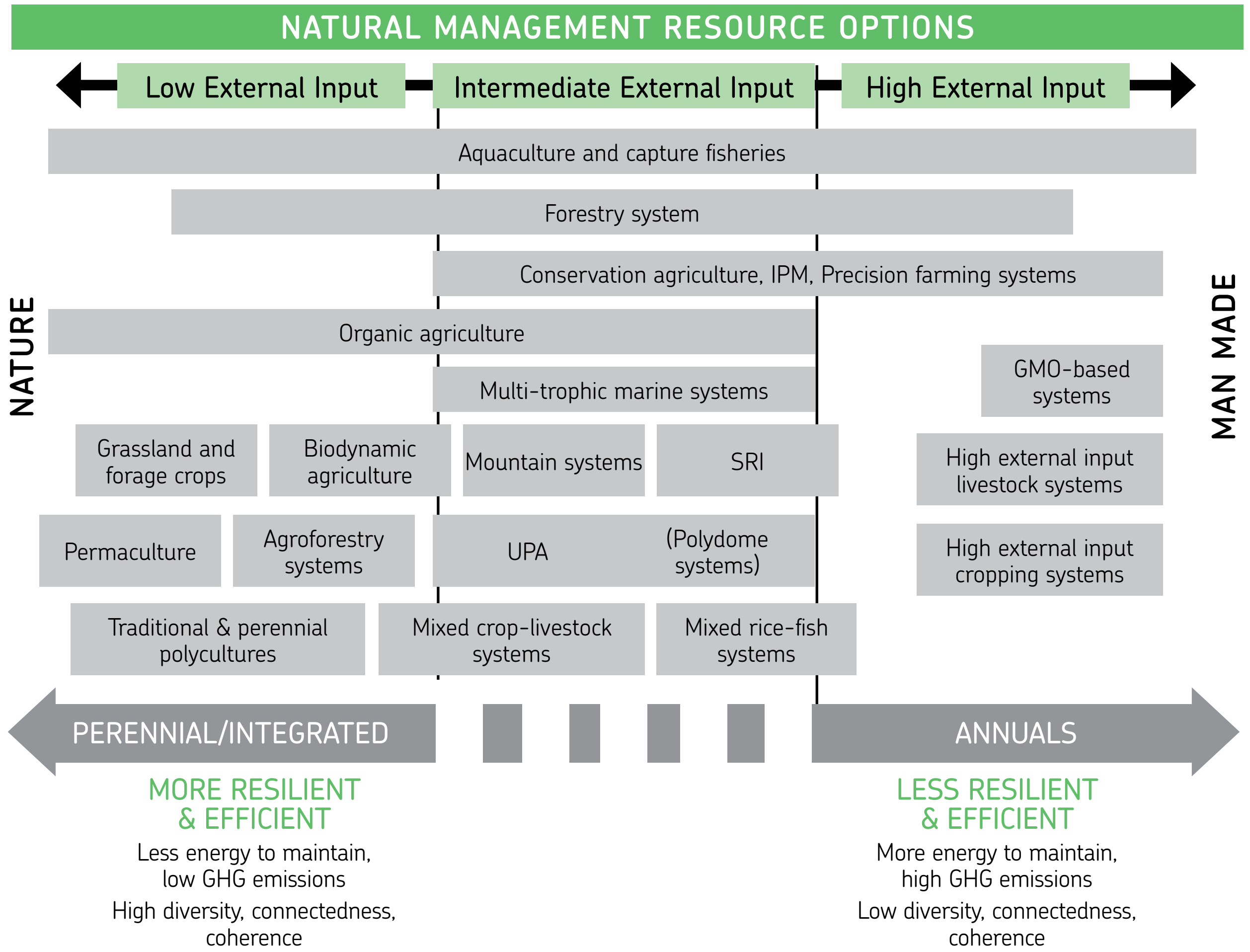
Characteristics of different agricultural models

The FAO (2011) provides a first, broad definition for the two types of agricultural models considered in this analysis, supplemented further by additional assumptions described herein. The FAO defines the HEI and LEI agricultural models as follows:

- High External Input (HEI) systems:
  - Orientation to the commercial market;
  - Use of high-yielding improved varieties;
  - Mechanization with low human labor intensity;
  - Almost complete reliance on external inputs of synthetic nature (fertilizers, pharmaceuticals, etc.).
- Low External Input (LEI) systems:
  - Broader trend toward subsistence and less oriented toward the market;
  - Use of traditional cultivars;
  - Techniques with high content of knowledge and labor;
  - Little or no use of external nutrients, no use of synthetic chemicals to control pests and diseases, but strong emphasis on nutrient cycles on-site.

In fact, there is a continuum of combinations of HEI and LEI practices and, therefore, it is not possible to classify a real case as belonging entirely to the HEI or the LEI system.

Figure A.5. **Overview of different LEI, IEI and HEI system, according to the FAO**



Source: FAO/OECD, *Food Availability and Natural Resource use in a green economy context*, 2011.

As already noted above, the FAO identifies a wide variety of farming systems with respect to the relative intensity of use of external inputs.

For simplicity, the analysis quantitatively characterizes the two different agricultural models (LEI and HEI) as follows:

Hypothesis 1: the Low External Input (LEI) farming system uses about 35% more labor per hectare of cultivated land than the High External Input (HEI) farming system.

This hypothesis is based on the results of the following studies:

- The Soil Association (2006) calculated that organic agriculture in the United Kingdom provided 32% more jobs per farm than conventional farming.
- In Denmark, a conversion from conventional agriculture to organic agriculture increased the need for human labor by 35% (Barthelemy, 1999).
- A study carried out in Turkey on the production of raisins in 82 conventional and organic farms concluded that the inputs of human labor were on average higher (approximately 10%) for the organic farms (Gündogmus *et al.*, 2006).
- Organic systems need about 15% more labor on average (Sorby, 2002; Granatstein, 2003).
- In addition to performing tasks of weeding, cultivation and care of plants and animals (largely done with machinery and chemicals in conventional systems), farmers who rely on the organic system plant cover crops, spread manure and produce fertilizer (FAO 2007).

Hypothesis 2: farming with the Low External Input (LEI) system uses about 50% less energy per hectare of cultivated land than farming with the High External Input (HEI) system.

- According to the Soil Association (2006), the largest share of energy used in conventional agriculture – on average, 37% of the total – was represented by synthetic pesticides and mineral fertilizers, especially nitrogen and, to a lesser extent, phosphorus and potassium.
- Refsgaard and his collaborators (1998) found that the consumption of energy associated with the use of fertilizers represented between 25% and 68% of total energy use, depending on the type of crop and growing conditions.
- A study carried out in Turkey on the production of raisins in 82 conventional and organic farms concluded that the average energy inputs were lower (around 38%) on the organic farms (Gündogmus *et al.*, 2006).
- Pimentel (2005) estimated that between 28% and 32% less energy is used in organic farming.
- Farming practices and the use of machinery greatly affect the use of energy on individual farms, but there is no evidence that organic farming requires less energy for the mechanical processes. For example, several studies reported that the production of organic potatoes and carrots requires high energy input per unit of output due to mechanical weed control (Stolze *et al.*, 2000; Williams *et al.*, 2006; Bos *et al.*, 2007).
- Typically, organic agriculture production uses 30 to 50% less energy than comparable non-organic farming (FAO, 2007). Although organic farming uses energy more efficiently on average, it often requires an indirect trade-off of energy-intensive inputs with additional hours of human labor, about a third more than conventional farming.

Hypothesis 3: the density of nitrogen in the top layer of soil in the Low External Input (LEI) agriculture system is about 30% less than in the High External Input (HEI) agriculture system and, therefore, the yields of the LEI farming are lower.

- The crop rotations with legumes in the LEI system resulted in an intake of nitrogen in the model, derived mainly from biological nitrogen fixation of 90 kg per hectare per year. This contribution was equal to only 35 to 50% of that for a crop in the HEI system and, therefore, the yields were correspondingly lower (Wolf, 2002).
- Comparison of productivity of LEI vs. HEI: less than about 9% for the LEI system (Stanhill, 1990).
- Comparison of Productivity of LEI vs. HEI: more than 80% for the LEI system in developing countries and less than about 8% for the LEI system in industrialized countries (Badgley *et al.*, 2007).
- The transition from the HEI to the LEI system is not easy: it gets worse before getting better results (Badgley *et al.*, 2007) and the transition period lasts five years (Pimentel, 2005).

The scenarios formulated

The scenarios have been analyzed taking into account agricultural development based on different degrees of diffusion of the currently prevailing model (High External Input, or HEI systems) compared to the alternative model (Low External Input, or LEI systems). Each model is characterized by the amount of resources needed to support it, the productivity, and the environmental impacts involved. The simulations have taken into account the extreme conditions in terms of resource limitations in the long term (i.e., limitations in terms of energy resources, water and land) to assess the adequacy of the different models under these conditions.

There is the intensive use of inorganic fertilizers as a proxy to estimate the prevalence of past and present HEI systems. Based on that estimate, in 1970 approximately 30% of the total cultivated area was managed with HEI systems, and this value reached 45% in 2010. Based on the current trend, it is possible to formulate several scenarios, including:

- Scenario of Business As Usual (BAU): the practices with a high level of external input continue to spread as in the past, coming to cover 60% of the total cultivated area in 2050;

- Scenario of Strong HEI Growth: the practices with a high level of external input spread at an accelerated pace to cover 90% of the total cultivated area in 2050;
- Scenario of Stopped HEI Growth: practices at a high level of external input do not spread any further and their coverage remains constant at the current level (45% of the total cultivated area).

These three scenarios are examined in the light of two different sets of assumptions in relation to the availability of energy, and more specifically:

- all the normal scenarios (I): oil prices rise gradually to reach $130/ barrel in 2035 (IEA average projection), then grow further to reach $170/barrel in 2050 (dollar figures in real terms of the year 2001);
- all the normal scenarios (II): inorganic fertilizer prices remain affordable for most farmers, thereby not inhibiting their spreading;
- all the Energy scenarios (I): oil prices rise faster than the reference value between 2025 and 2030, reaching $200/barrel in 2030, then increasing further to reach $280/barrel in 2050 (dollar figures in real terms, 2001);
- all the Energy scenarios (II): due to the rapid increase in oil prices, the prices of inorganic fertilizers increase substantially with a consequent reduction in their use: no more than 50% of the total cultivated area is fertilized in areas where the farms have a higher added-value potential.

Finally, all scenarios put forward the following hypotheses regarding the use of agricultural production:

- A gradual increase in meat production per capita: from 40 kg/person/year in 2010 to about 65 kg/person/year in 2050 (BAU);
- An increase in the share of cereals (except rice, wheat and millet), oilseed crops and sugar crops used for biofuels and other non-food purposes:
  - Cereals: from the current 6% to 10% in 2050;
  - Oilseed crops: from the current 7.5% to 15% in 2050;
  - Sugar crops: from the current 0.5% to 2% in 2050.

Scenario Results

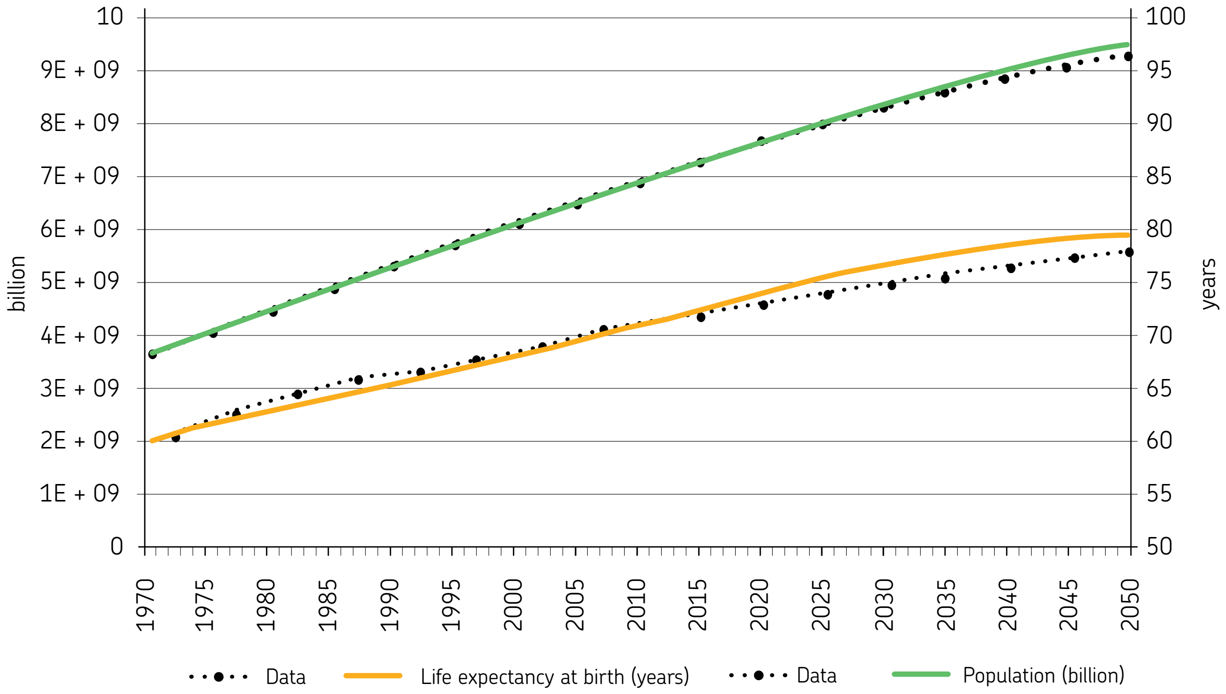
General socio-economic and environmental developments in the BAU scenario

The following is an overview of the results of the Business As Usual scenario (BAU) in the 1970-2050 period. For the 1970-2010 period, series of historic data on over 250 indicators were collected, with the aim of comparing them with the results of the model. Therefore, the results of a series of general indicators are discussed, which include: total population, life expectancy, average duration of schooling, the real rate of the GDP growth, GDP per capita, agricultural area, forest area, total water demand and overall energy demand. The time-line graphs show multiple lines that include a series of data and model projections. In the presence of multiple indicators, additional lines are highlighted with different colors (see figure legends). In some cases, when there are authoritative projections up to 2050, the line of historical data also extends up to 2050 (from 2010 to 2050).

However, the simulation results should not be construed as forecasts, but rather, as a projection obtained from a series of basic assumptions.

In summary, the BAU scenario indicates that by 2050 the global population will slightly exceed 9 billion people, a slightly higher figure than the one calculated by the UN Population Division (Figure A.6.). This finding is consistent with the pattern of life expectancy at birth, which gave slightly higher projections (about 80 years for women in 2050). In addition, there is a substantial increase in the average duration of schooling, which in 2050 will come to be roughly 7.25 years.

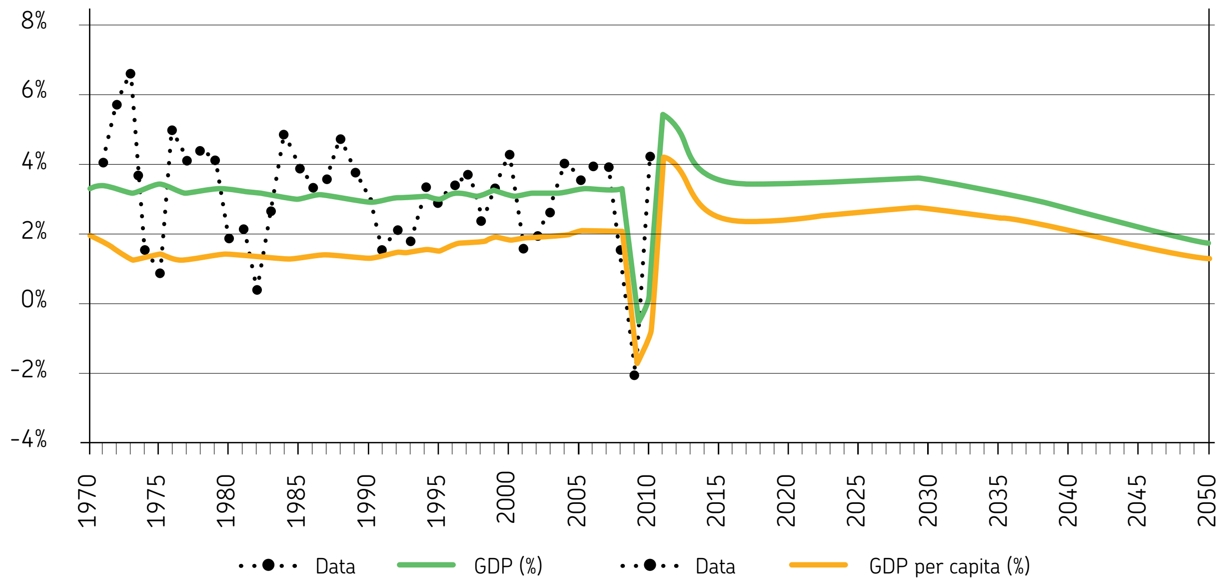
Figure A.6. **Population and life expectancy from birth**



Source: data/projections by UN POP and T21 projections.

While these social developments are positive, they are, at the same time, both the result and the cause of rapid economic growth. With regard to the GDP per capita, real growth is estimated to be 2.7% in 2030, before falling gradually back to about 1.25% in 2050 (Figure A.7.). This rapid increase is supported, in particular, by the growth in the industry and services sectors, which appears rather slow (in terms of added value) in the agricultural sector.

Figure A.7. **Real growth of the GDP per capita**



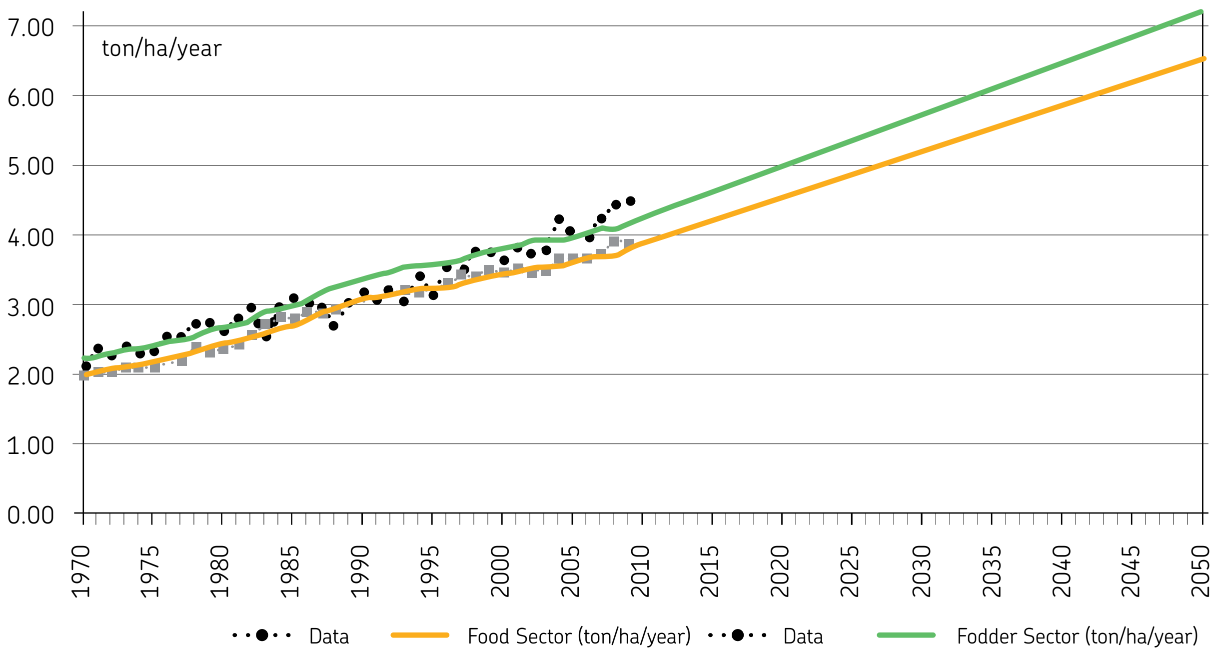
Source: World Bank data and T21 projections.

In terms of land use, the BAU scenario foresees a stabilization in the use of land for agricultural purposes, which in turn implies a consolidation of the reserves of forest areas. However, stabilization in the dynamics of the land does not slow the growth of the agricultural sector, as shown later. It is expected that, in the long-term, the demand for water and energy will increase substantially, reaching 6,300 km^3/year and 750 quadrillion BTU/year, respectively, in 2050.

BAU Results for the Indicators Related to Agriculture

Here we discuss the results for specific indicators of agriculture, including: the yield of cereals, calories per person per day, the percentage of the population that is undernourished, water demand for agriculture, and energy demand for agriculture.
According to projections, the yield of cereals for food and those for fodder will have similar rowth rates, driven by increasing mechanization, higher human capital, more in-depth knowledge in the sector and a higher concentration of nutrients in the surface layer of the soil. More specifically, it is expected that in 2050 the yield of cereals for food will rise to 5.6 tons/ha (from the current 3.3), while that for the fodder sector will reach 6.2 tons/ha (from the current 3.7) (Figure A.8.).

Figure A.8. **Yield of cereals for the food industry and for the fodder industry**

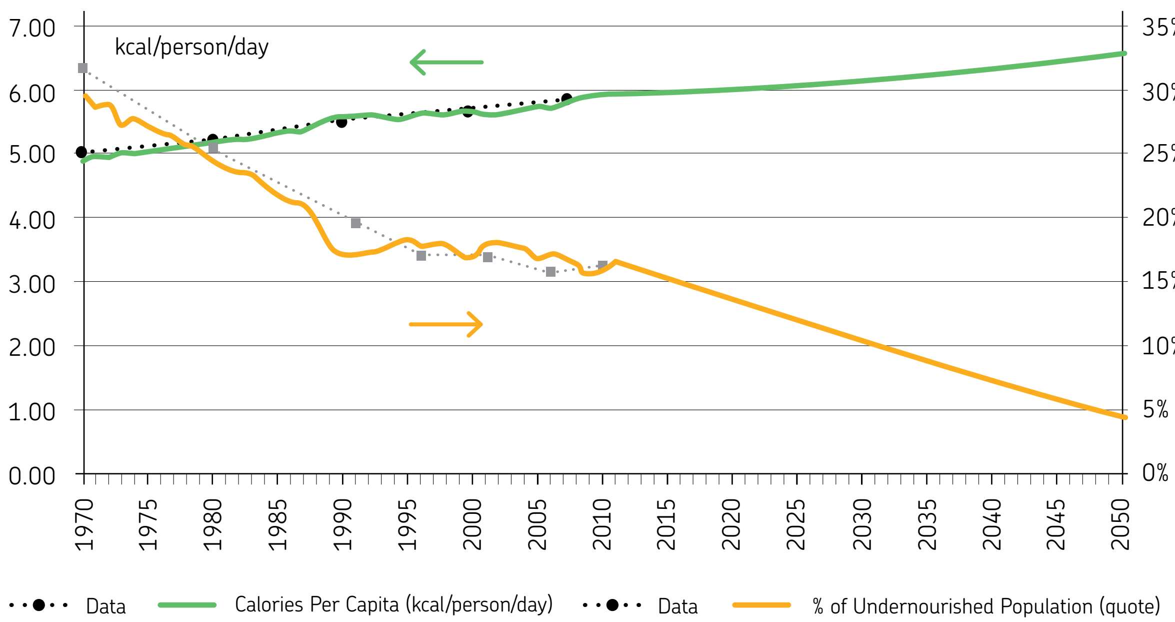


Source: FAO data and T21 projections.

The combination of the increase observed in yield and a gradual slowdown in population growth leads to a continuous increase in the amount of calories available on a per capita basis (Figure A.9.).
The projection indicates approximately 3145 kcal/person/day of foods for human nutrition by 2050. So sudden an increase of calories available per capita leads to a smaller percentage of the malnourished population, which, by 2050 will have dropped to around 3.5%. Translated into absolute figures, by 2050 the number of individuals who suffer from hunger will have decreased to 345 million. This BAU projection depicts a rapidly changing agricultural sector, which changes to meet the needs of the growing world population and will eventually be able to generate almost enough output to overcome hunger in the world.

In contrast, the BAU scenario also implies a greater impact of agriculture on the natural environment. In particular, it is expected that the demand for energy in agriculture will grow from the current 7 quadrillion BTU/year to about 8.5 in 2050. A similar increase in the demand for water is also expected (although at a more moderate speed), so that the current value of 2.8 km^3/year will grow to about 3 in 2050. The more modest increase of the water demand is due to the stabilization of the cultivated areas, the gradual increase in the percentage of irrigated areas, and the continuous improvement of water management.

Figure A.9. **Production of calories per capita and percentage of malnourished population**

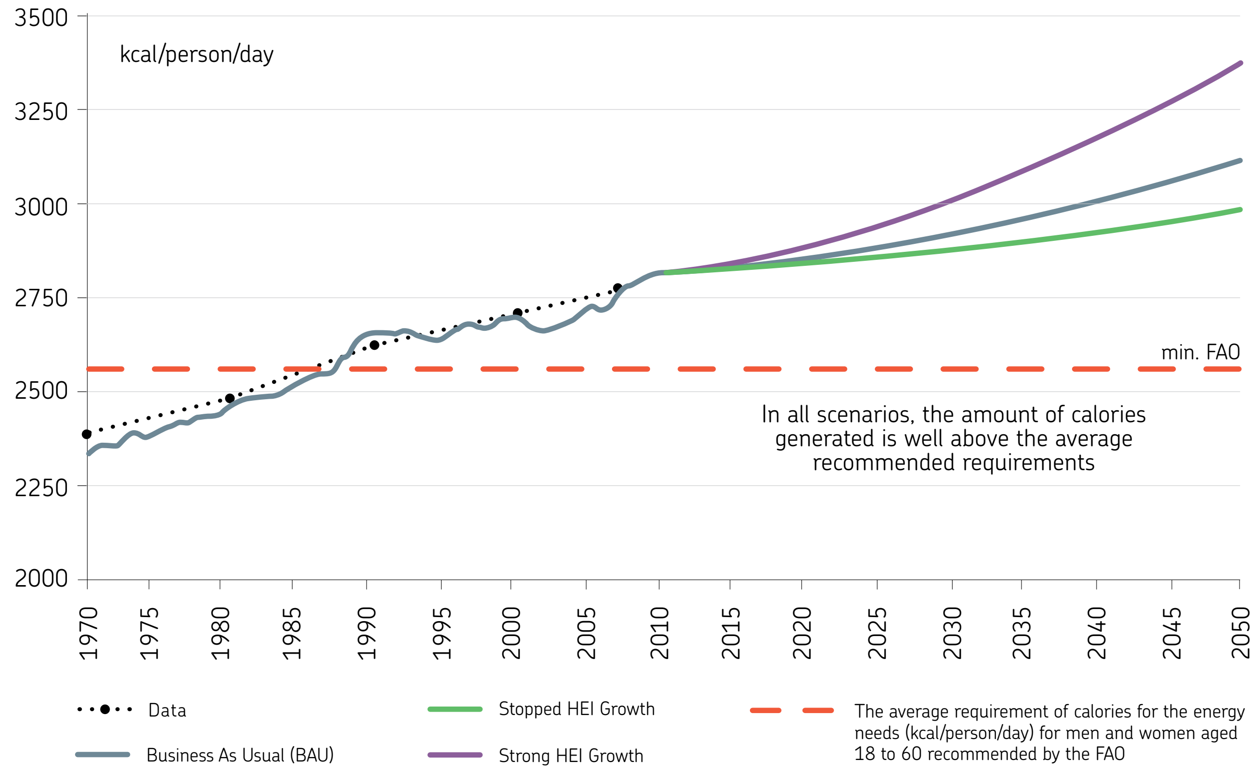


Source: FAO data and T21 projections.

Comparative Analysis of the Results of different Scenarios

The following presents the results of the alternative scenarios (BAU, Stopped HEI Growth, Strong HEI Growth), first assuming the absence of a future limitation of energy and then, assuming a substantial limit linked to the availability of energy.
We now analyze the results of a specific indicator that summarizes the issues related to agricultural production and the use of the product: calories per capita from foods for human nutrition. To simplify matters, the results of a single indicator are shown (although the model gives rise to several important indicators of nutrition) and, specifically, the calories of food per capita have been chosen because of their importance in human nutrition.
As mentioned above, assuming that there are significant restrictions related to the availability of energy, the BAU scenario shows a steady growth in the amount of calories produced for human nutrition, which in 2050 will reach 3145 kcal/person/day (Figure A.10.). This data is in line with the FAO projections for 2050, equal to 3130 kcal/person/day (FAO, 2011).
In the Stopped HEI Growth scenario, productivity growth is slower as compared to the BAU scenario, because inorganic fertilizers are used in smaller quantities. As a result, the increase in calories produced for human nutrition will be lower, and by 2050, will have reached 3015 kcal/person/day.
Due to the higher concentration of macronutrients being artificially added to the soil, in the Strong HEI Growth scenario the amount of calories produced for human nutrition is growing faster and will have reached 3410 kcal/person/day in 2050.
In the event of a substantial decrease in energy availability starting in 2025 (all the Energy

Figure A.10. **Agricultural production for human nutrition**



Source: FAO data base.

Shock scenarios, Figure A.11.), the increase in the amount of calories for human nutrition would continue unchanged until 2025, but would then slowdown in different ways according to the specific scenarios.

In the BAU-Energy Shock scenario, there is a gradual decrease in the amount of calories produced for human nutrition beginning in 2025 before stabilizing and then seeing growth again toward 2035.

This decrease is due to the combination of two factors: first, the increase in oil prices that has direct negative effects on productivity and yield, because as the cost increases, the use of oil-powered vehicles (such as tractors, water pumps, etc.) decreases; and secondly, the reduced access to fertilizers forces some farmers, who in other circumstances would practice a HEI type of agriculture, to switch to LEI (in the direction of a Stopped HEI Growth scenario) farming.

This forced switch to the LEI system is an expensive process because part of the existing physical capital must be substituted/adapted and because it requires the acquisition of additional knowledge.

In addition, conversion to LEI farming is an expensive process in terms of time: it inevitably takes some time before the farmers realize that the increase observed in energy prices is not transitory, and before they acquire the human and physical capital needed to implement the LEI practices. These resources might not be immediately available at the time of rising energy prices and declining productivity.

At the same time, when the LEI production systems have not yet been implemented, but the fertilizers are still available in the quantities needed, the land is further impoverished.

Finally, once the LEI practices are implemented, it takes about five years before the soil is fertile again. Overall, it is assumed that the average transition from HEI to LEI farming requires about 10 years, given the conditions of limited access to energy resources and inorganic fertilizers. This period represents the loss of a decade in terms of increased yields.

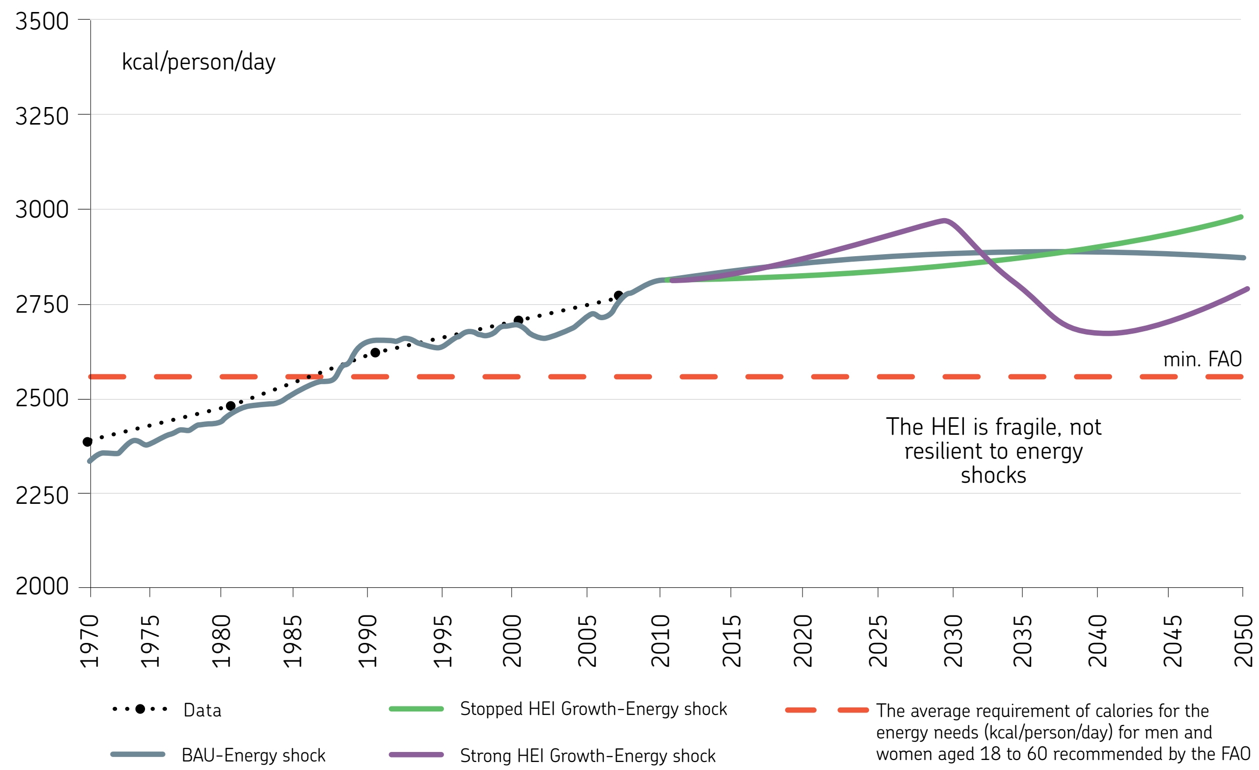
The forced transition from HEI to LEI has more drastic effects in the Strong HEI Growth-Energy Shock scenario; in this case the yield and, consequently, the amount of calories produced for human nutrition suffer a substantial decline in 2025, before resuming growth in the last 15 years of the scenario. The most significant decrease in yield is due to the fact that in this scenario, a higher percentage of farms must change from the HEI to the LEI one, since for the HEI scenario we assume there is a higher final level of dissemination of the HEI practices (90% in 2050).

Finally, the impact of the sudden rise in oil prices and reduced access to inorganic fertilizers is lower than in the Stopped HEI Growth-Energy Shock scenario. This is due to the fact that in the Stopped HEI Growth scenario, a smaller percentage of the cultivated area is managed according to HEI practices: the level estimated for 2050 remains at the current 45%. In this context, the 50% reduction in the availability of inorganic fertilizers does not represent a limitation for agricultural productivity because the target level of distribution of HEI practices remains below 50%. Therefore, the decline in the growth of yields that is observed is only due to the direct impact of the increase in oil prices on the cost/use of mechanical means powered by oil.

The simulation results showed that, if after 2025 substantial limitations of energy availability should be detected, an approach of low external input could lead to a Worse-Before-Better result (WBB), with lower productivity in the short-term but increased productivity in the long-term.

The results of the simulation of the scenarios without substantial energy limitations are significantly influenced by the assumptions regarding the amount of cereals used for fodder and the amount of crops grown for biofuels. However, any changes in these assumptions do not entail a substantial change in the results in qualitative terms: the ranking of the scenarios in terms of yield and calories produced remains unchanged.

Figure A.11. **Agricultural production for human nutrition in case of an energy shock**



Source: FAO data base.

The results of the simulation of the Energy Shock scenarios are particularly sensitive to the amount of time assumed to be necessary for the transition from HEI to LEI. In fact the results of Strong HEI Growth-Energy Shock and BAU-Energy Shock scenarios are less negative. However, even if the transit time were significantly lower (five years), the positioning of the scenarios in terms of yield and calories produced would remain the same (the difference in quantitative terms is still quite low).

Summary and Conclusions of simulation

In summary, in the BAU scenario, agricultural production grows at a constant rate, generating a continuous increase in the amount of calories per capita for human nutrition. This leads to a significant reduction of the population that is malrnourished, reaching 345 million in 2050 (3.5%). The HEI scenario generates an even higher level of yield and, consequently, increased production for all crops; while on the contrary, the Stopped HEI Growth scenario generates yields and production that are slightly lower than with the BAU system. This is mainly due to the lower density of nutrients in the soil that characterizes the LEI type of agriculture as compared to that of HEI. Consequently, the amount of food calories available per person per day is higher in the HEI scenario compared to the BAU system, whereas it is lower in the LEI scenario. The relative difference between the scenarios is less when considering the quantity of the population that is malnourished, which means that the additional production generated within the HEI scenario is only partly for the benefit of the poor.
On the contrary, the Strong HEI Growth scenario has a greater environmental impact than the BAU scenario, particularly with regard to energy demand. In the Energy Shock scenario, it is hypothesized that the more intense exploitation of the natural resources would not be practical due to the limited availability of those very resources. What follows is a rapid reduction of the yields for the Strong HEI Growth-Energy Shock scenario, with lower levels than those of all the other scenarios. Therefore, agricultural production grows slower in the Strong HEI Growth-Energy Shock scenario compared to the BAU-Energy Shock and Stopped HEI Growth-Energy Shock scenarios, and the quantity of calories available per person by 2050 is less compared to the other scenarios.
This figure can be traced to a number of factors. First, farmers do not react immediately to changes in prices, but expect to see if the changes are temporary. Secondly, to change farming practices it is necessary to acquire a certain amount of knowledge on LEI agriculture. Thirdly, the available capital may not be suitable for LEI agriculture and may need to be replaced. And finally, the transition from monoculture to polyculture involves changes in marketing structures that, in turn, also require time. It is hypothesized that this adaptation results in an average delay of 10 years, with a faster reaction time in countries of medium/high incomes and longer reaction times in low-income countries.
The consequence of this delay in adapting is that the HEI practices are continued for several years under unfavorable conditions (for example, in the absence of fertilizers), with a consequent impoverishment of the soil. Under these conditions the capital accumulated so far in terms of R&D is, therefore, only partially useful, and thus, productivity drops further. Once the transition from a HEI system of agriculture to a LEI has occurred, the soil has a below-average productivity, and it will take a few years before it returns to being fully productive. In the meantime, a considerable proportion of the potential agricultural production is lost, namely a decade of potential increase in the yield.
The impact of these dynamics on nutrition is important both in terms of the average amount of calories per capita and in terms of the percentage of the population that is malnourished. Just as important is the impact of this transition on the natural resources: energy demand is substantially reduced. However, this decline is gradual, confirming the fact that the process of replacing and upgrading physical capital is slow and progressive.

NOTES AND REFERENCES

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EXECUTIVE SUMMARY

1. FAO/OECD "Expert Meeting on Greening the Economy with Agriculture," Paris, September 5-7, 2011. In precedence, see also IIASA/FAO, "Global Agro-Ecological Zone Assessment input levels," 2010.

CHAPTER 1

1. Referred to as BCFN.

2. "Food production that makes the best use of nature's goods and services while not damaging these assets" (Pretty, 2005).

3. FAO, 2008.

4. FAO/OECD, "Expert Meeting on Greening the Economy with Agriculture," Paris, 5–7 September, 2011.

5. In this regard, see Chapter 4.

6. For a comprehensive overview of the major global challenges facing the agricultural sector – specifically with the goal of sustainability – refer to: *Final Report and Background documents* by the FAO, "International Technical Conference on Agricultural biotechnologies in Developing Countries: Options and opportunities in Crops, Forestry, Livestock, Fisheries and Agro-industry to face the Challenges of Food Insecurity and Climate Change," 2010. For a further discussion of the role of food biotechnology in promoting agricultural sustainability, refer to the position paper *Beyond GMOs. The agro-food biotechnologies*, created by the Barilla Center for Food & Nutrition in 2011.

7. World Food Programme, Annual Report 2007.

CHAPTER 2

1. FAO/OECD, "Expert Meeting on Greening the Economy with Agriculture," Paris, September 5- 7, 2011. Also see, by the IIASA-FAO, "Global Agro-Ecological Zone Assessment Input Levels" (2010).

2. In Europe, and other countries, regulations exist that codify the distinctive features of organic farming in a clear and comprehensive way.

CHAPTER 3

1. Gran, Y., C. Liang, X. Wang, B. Mc Conkey, *Lowering Carbon Footprintof Durum Wheat by Diversifying Cropping Systems*, in "Field Crop Research", 122 (3), pp. 199-206, Elseviez, 2011.

CHAPTER 4

1. Millennium Institute (MI) "is an independent and non-partisan nonprofit organization committed to promoting systems literacy and dynamic modeling tools to attain sustainable development worldwide" (website of the Millennium Institute, "Who We Are").

2. In the following pages is a summary of assumptions and results of the model: a detailed description of the methodology used for its construction, hypotheses and underlying assumptions, and the overall results may be found in the Appendix of this document.

3. The model of low external input agricultural production, LEI (Low External Input), uses about 35% more work per hectare of land cultivated than a model with high external input, HEI (High External Input). Low external input agriculture (LEI) uses about 50% less energy per hectare than a high-input model (HEI).

4. The difference in yield between HEI and LEI is a topic that is still widely debated. Although numerous studies indicate that HEI generally has relatively better yields (Badgley *et al.*, 2007, Stanhill, 1990), the yield of each type of production model depends on the economic, social and environmental context in which it is applied. For the purposes of this study, we introduce the hypothesis that in low external input agriculture (LEI), the density of nitrogen in soils is about 30% lower than in high external input agriculture (HEI); consequently, the yield per hectare is lower in the LEI model. This gap tends to shrink in the long run due to a general improvement of knowledge for the efficient application of the LEI model.

5. Figure 4.1. shows how the amount of calories produced is constantly growing.

6. For further information, see the FAO/OECD study, *Food Availability and Natural Resource Use in the Green Economy Context*, p. 19.

CHAPTER 5

1. *Save and Grow – A Policymaker's Guide to the Sustainable Intensification of Smallholder Crop Production*, FAO, 2011.

2. IPM, or Integrated Pest Management.

3. HEI - High External Input; LEI - Low External Input; iEI - Intermediate External Input.

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