LUISS Guido Carli
LIBERA UNIVERSITA' INTERNAZIONALE DEGLI STUDI SOCIALI

Dipartimento di Scienze Politiche

Corso di Laurea Magistrale in Relazioni Internazionali
Cattedra di Sviluppo sostenibile e flussi migratori

ENVIRONMENTAL SUSTAINABILITY AND HUMAN HEALTH IN THE FOOD SYSTEM

RELATORE
Prof. Alfonso Giordano

CANDIDATA:
Giulia Ciuffreda

CORRELATORE
Prof. Marcello Di Paola

ANNO ACCADEMICO 2012/2013

Index

Introduction

This work originates from the merging of a personal interest in nutrition and an academic interest in sustainable development. As consumers, it is a key point to ask oneself if there is a way to improve significantly the sustainability of personal dietary habits, while keeping a healthy lifestyle: choosing organic and fair trade products is effective? Or turning to vegetarianism or veganism would be better? Are these choices really beneficial to the body, in a world where diseases of affluence are so widespread and general knowledge about them so little? As academic students, it is interesting to understand how the non-sustainability of the current food system is connected to malnutrition, which dynamics and trends should be taken into account, and which solutions may improve both sustainability of the food chain and consumers' health status. In particular, beyond a descriptive analysis of interconnected topics, it may be useful to find out which stakeholder(s) hold the main power within the food chain and which "part", among producers, consumers, and public authorities, could concretely promote the adoption of sustainable diets.

The sustainability of the food production system and the correlation between diets and diseases of affluence have been treated as separate issues for a long time; dietary concerns systematically related to the inefficiencies of the food chain were those of food insecurity and subsequent undernutrition, which is only one half of malnutrition. Even though there are some studies from the '80s, a more or less consistent literature on sustainable diets and NR-NCD has developed only at the end of the '90s and in the 2000s. Yet, a comprehensive definition has been given by the FAO only in 2010, addressing sustainable diets as "*those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystem, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources"*. This definition summarizes all issues that had been investigated in earlier studies, and is widely recognized as the main and most complete one, in that it covers environmental sustainability, healthiness of diets, cultural acceptability, and economic issues, both in a present and future perspective.

Investigating the dynamics underlying all of the issues mentioned in the definition in one single research would have been too ambitious and would have probably generated too much confusion. This is the reason why some clear boundaries to this study have been set. Firstly, the research deals with agricultural and land livestock food products only, leaving out fishery and fish livestock; being aware that the two domains are too different to be treated together in an in-depth analysis, agriculture and livestock products' chain has been chosen because the vast majority of the foodstuffs that we eat comes from fields and meadows, and because farming is still the main source of income for the vast majority of the world's people. Second, the focus is centered on the two "extremes" of the chain, namely in-farm production and consumption, due to the already mentioned intention of providing a deeper analysis; however, the rest of the food chain has not been completely ignored: it has been included in essential points, where not considering the impact of all steps of food production would have severely diminished the value of this research. "Sustainability" is mainly taken as *environmental* sustainability, even though social and economic sustainability issues are covered when necessary. Last, "malnutrition" is mainly intended as overnutrition, since the primary interest of this research is to connect sustainable food with dietary habits preventing diseases of affluence, both in developed and developing countries.

The work is divided into four parts: the first chapter aims at providing an overview of socio-economic and demographic trends currently ongoing, environmental concerns, and the dietary transition; in particular, phenomena like population growth, demographic transition, economic growth, urbanization, and globalization will be described, and their potential impact as key drivers of environmental depletion and change in dietary styles will be evaluated. The second part investigates the food production system, with special attention to farming and livestock, as previously explained, plus an overview on the rest of the food chain; the critical issues of intensive food production responsible for environmental depletion will be outlined, to try to find sustainable alternatives to conventional production. The third section deals with food consumption and enters more specifically the question of sustainable diets: the meaning of the epidemiological transition and its links with the nutrition transition is firstly explained; then follows the attempt to outline how healthy dietary choices relate to

sustainable foods; last, some practical examples of sustainable diets are presented. In the last chapter the focus is shifted on the main challenges for the implementation of sustainable diets, namely the need to operationalize the definition via proper indicators, investments in agriculture, the role of producers and food industry in promoting health, and the role of consumers' behavior. This last part involves the potential task of public authorities, too.

A Changing World

This section aims at providing a general overview of trends and phenomena that are connected to agriculture and food consumption, in order to identify the main dimensions of the issues investigated in this work, and to evaluate the interactions among them. Thus, demographic and socio-economic trends will be analyzed first; then, tendencies previously outlined will be related to the current state of the environment, and, eventually, to shifts in dietary habits.

World Population Trends

It is a widely known fact that the world population has grown quite remarkably in the last decades (particularly in poor and developing countries), and that it is still growing. We have passed the ceiling of 7 billion people, but, since the average growth rate is decreasing, the world population is expected to stabilize at about 9 billion people around 2050. All regions are going through the so-called "demographic transition": economic and social development is leading towards lower birth rates and lower mortality rates. Of course, different areas and countries are facing different stages of the transition; developed countries have already completed the process, while less developed countries and, above all, least developed countries, are still in the middle or in early stages of the transition (see Fig. 1 below). According to UN data[1], regional percentage changes during the period 2013-2050 will be very high in Africa (53,7%) and Asia (36,2%), much slower in Latin America and North America (6,9% and 3,8%, respectively), almost absent in Oceania (0,8%), and negative in Europe (-1,4%). This will lead to a total population mainly coming from Asia (more than a half), Africa, and South America.

Despite such divergences, population growth rates have been falling everywhere since 1990 and projections show that this tendency will continue (Fig. 2). This means that the world population is still growing, but at a much slower pace than in the past. For the purposes of this work, two consequences must be taken into account: first, the world population is growing older, due to lower mortality rates and higher life

[1]United Nations (2013), "*World Population Prospects: The 2012 Revision*", internet: http://esa.un.org/ (consulted on June 20th, 2013)

expectancy at birth, meaning that health conditions of the elderly will be a major issue States will have to deal with; second, even though the growth rate in percentage is declining, the population is growing in absolute terms, so that food quality and quantity issues will still be a challenge for humanity.

Fig. 1: Population growth rate 1950-2010 (Source: UNDESA Population Division, 2013)

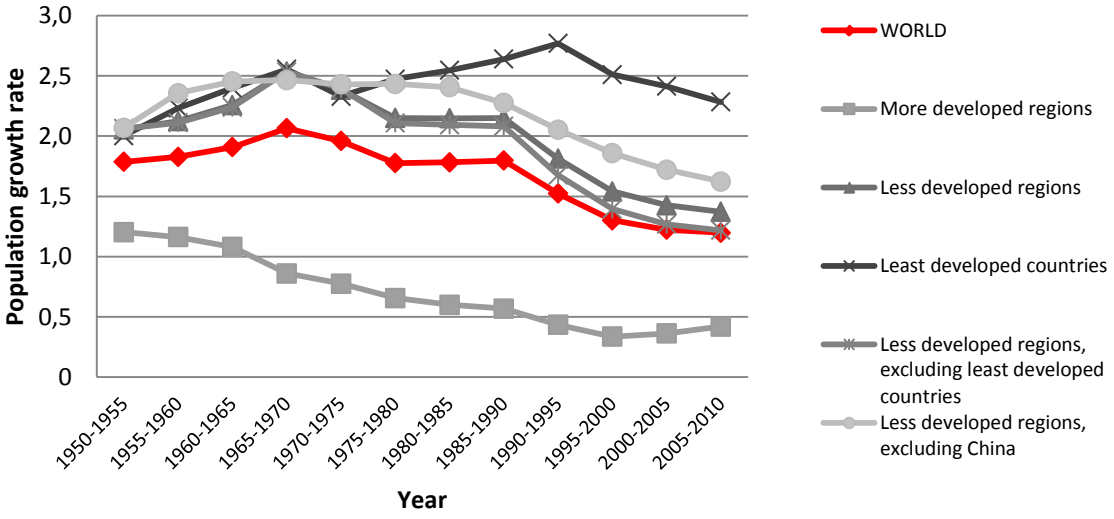
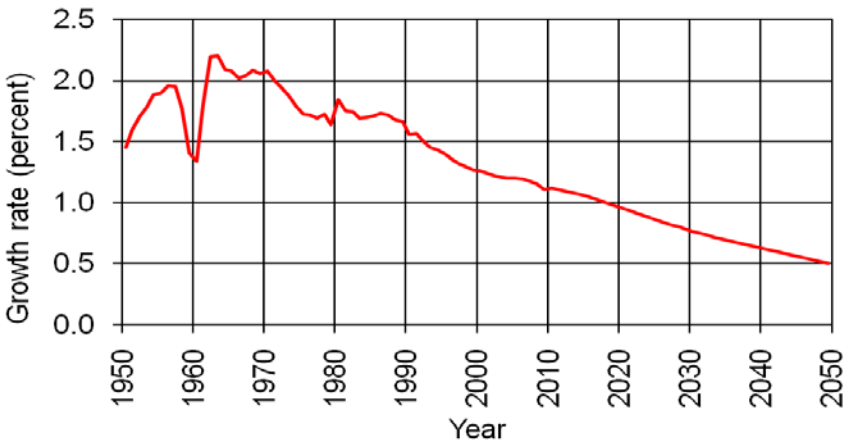


Fig. 2: World population growth rates projections 1950-2050 (Source: U.S. Census Bureau, 2011; author's elaboration)



Godfray *et al.* (2010)[2] state that, since economic development is causing higher purchasing power in many countries and higher food consumption, we will have to face

[2] Godfray H.C.J. *et al.*(2010), "Food Security: the Challenge of Feeding 9 Billion People", in *Science*, vol. 327 no. 5967, pp. 812-818

three main challenges: satisfying an increasing demand for animal products and processed food from a larger population, ensuring environmental and social sustainability at the same time, and reducing the amount of people suffering from chronic hunger. This study underlines that, while in the past greater needs have been met by increasing land and livestock surface, now this is possible only in a very limited way, mainly due to changes in land uses and environmental degradation phenomena. Thus, the suggested solution is to increase efficiency through a transition towards more sustainable agriculture systems. The aim should be that of closing the "yield gap", i.e. the difference between actual productivity and the best results achievable through technology and genetic material available; yet, this should be realized taking into account consequences on future productivity of methods applied. Rosegrant, Agcaoili-Sombilla, and Perez (1995)[3] suggest that food security in the future may be achieved by increasing three elements: investments in agriculture, investments in health and education, and incomes (to generate higher demand for food and higher purchasing power); despite global supply and demand are good on average, many regions are food insecure due to poverty, lack of knowledge, missing infrastructures for trade and local development.

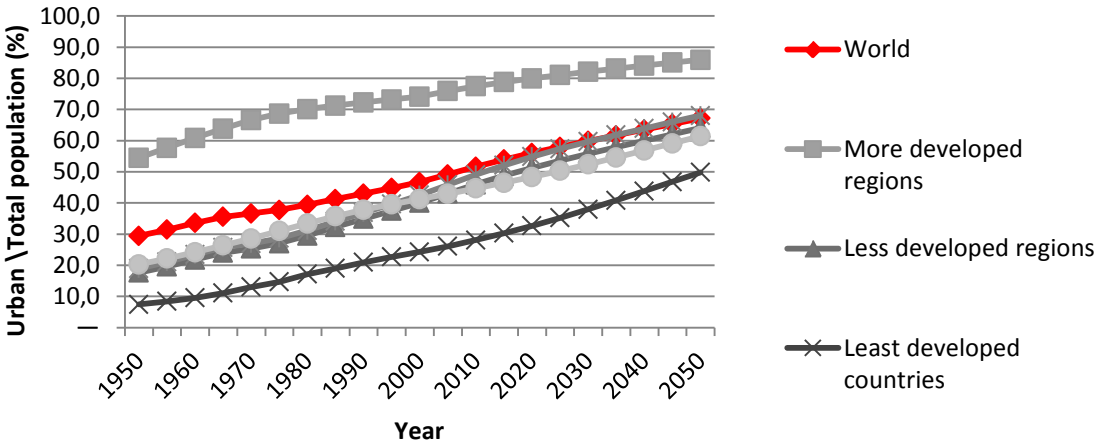
Not only the number of people is changing, but their redistribution between rural and urban areas is shifting, too, mostly in favour of the second alternative. Urbanization has a double meaning: on one hand, it is the increasing share of urban dwellers; on the other it implies the expansion of urban land uses[4]. Of course, the enlargement of land employed for urban-related functions and activities depends on the number of people residing in urban areas: the more urban population increases, the more rural surrounding areas will be turned into residential quarters, for instance. According to UN data (Fig.3), since 1950 there has been a steady growth in the percentage of urban dwellers on total population, both as a global average and in single development areas. Urbanization is mainly fuelled by rural-urban migration, due to the research for better income opportunities.

[3] Rosegrant M.W., Agcaoili-Sombilla M., and Perez N.D. (1995), "Global Food Projections to 2020: Implications for Investment", *Food, Agriculture, and the Environment Discussion Paper* 5, October 1995, Washington D.C.: International Food Policy Research Institute

[4] Satterthwaite D., McGranahan G., and Tacoli C. (2010), "Urbanization and its implication for food and farming", *Phil. Trans. R. Soc. B* vol. 365 no. 1554, pp. 2809-2820

Urbanization has an impact on environment and agriculture, for at least three reasons: first of all, cities require a lot of energy, produce a lot of waste, and account for a good percentage of polluting emissions; second, urban-rural migration is causing a shift in the workforce from jobs in agriculture to industry and services, so that the amount of consumers not producing food is growing; last, as it will be analyzed later on, urban lifestyles enhance the demand for energy-intensive food. Loss of agricultural land due to cities' physical expansion, reduced workforce, and increasing food demand have controversial effects: farmers may take advantage of rising food demand to increase their income and productivity, but if demand is too high and directed towards not-locally available products, global supply chains with larger ecological footprint may be the main beneficiaries of urbanization, at the expenses of local farmers.

Fig. 3: Urban population 1950-2050 (Source: UNDESA Population Department, 2013)



Some occurring dynamics may lead to the conclusion that the trend outlined above has been limited in the past and may be hindered in the future. Satterthwaite, McGranahan, and Tacoli (2010) point out that, especially during the '70s, there has been a net migration from cities to small towns or rural areas; yet, people were mostly moving from big cities towards small ones, so it may be more proper to identify this phenomenon as "de-metropolitanization", rather than de-urbanization. Besides, according to some, there may be a tendency of adult and elderly people to move to the country; again, it would be more accurate to refer to this dynamics as "urbanization of rural areas", not as "de-urbanization". As the scholars mentioned above have underlined, it would not mean a shift in the workforce back to agriculture: more likely,

industry and services workers will move towards the country, clustering around cities or creating new little urban centres. As a consequence, big cities may reduce in size, in favour of medium-small cities and new towns, so that those urban-rural migrants will still be consumers not producing food and, furthermore, will be exporting urban dietary lifestyles in less urbanized areas. In the end, according to Satterthwaite, McGranahan, and Tacoli, increasing urbanization is most likely, especially in developing countries, while phenomena of counter-urbanization could happen in low- and middle-income countries where urban poors keep strong connections with rural areas, as a result of failed migrations.

Urbanization is highly associated to globalization in several ways. Defining globalization and providing incontrovertible evidence is very hard: not only potential gains and losses are debated among experts, but its very existence is denied by many eminent scholars, and the discussion is still ongoing. In this work it will be assumed that, though counter-globalization trends do exist, there are some very strong globalizing forces at work in the world. Among all definitions of globalization provided, a very broad one is that accepted by FAO[5]: "*reduction in barriers to the cross-border movements of goods, services and capital; an increased flow of commodities, technology, information, financial capital, modes of distribution and marketing; and, to a certain extent, migration of people and labour*". This reduction in barriers and increasing transport and communication grids has, for example, allowed many cities to grow economically and, as a consequence, demographically, by relying on international trade. Globalization allows for easier international migration, providing for added workforce to cities. Considering food demand and the supply system, international trade allows for higher availability and diversity of food (which becomes a means of intercultural exchange, too), but it has also brought to a convergence of practices in food production, distribution, and consumption that have proved to be damaging the environment and human health.

[5] Kennedy G., Nantel G., and Shetty P.(2004), "Globalization of food systems in developing countries: a synthesis of country case studies", in FAO Paper no 83, "*Globalization of food systems in developing countries: impact on food security and nutrition*", Rome 2004, pp 1-26

State of the Environment and Food Availability

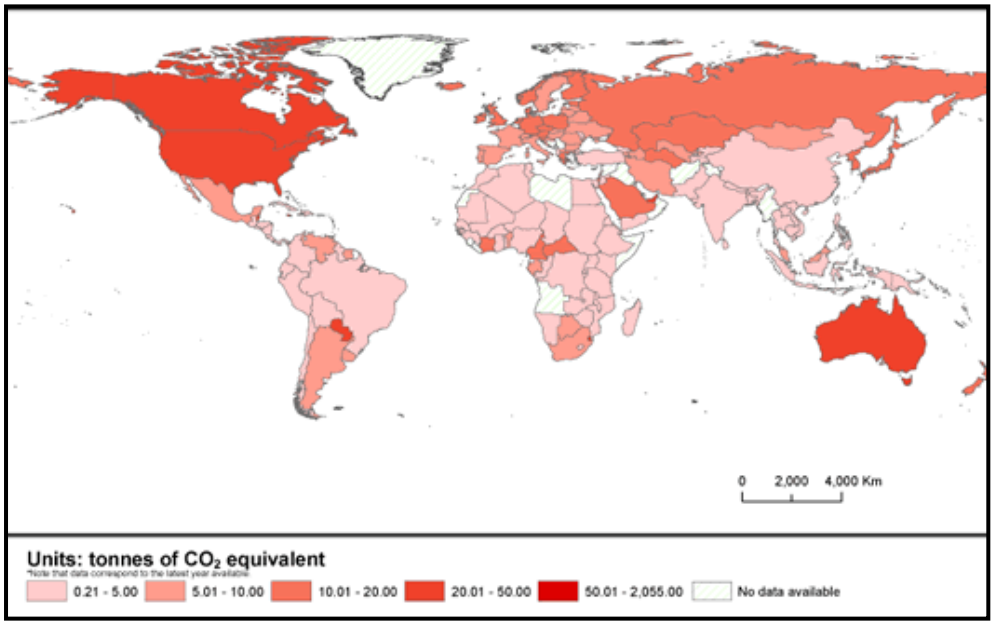
The fifth edition of UNEP Global Environmental Outlook[6] highlights that, though some objectives have been met, the world is still at risk, due to many unsolved issues and slow progress in action. The report analyzes a few different topics: atmosphere (including climate change), biodiversity, water management, marine pollution, extreme climatological disasters, land (including management, deforestation, and desertification), chemicals and waste. In particular, climate change, loss of biodiversity, and pollution seem to be the most delicate challenges, since little or no progress has been achieved.

Climate change is a natural phenomenon, but the majority of the academic community believes that this process is speeding up because of human activities-related atmospheric pollution; however, some scientists assert that rising temperatures are not caused by human activities, and, thus, are not a dangerous sign of the Earth's depletion. In this work, it will be taken as a valid hypothesis the one upheld by the majority of scientists, i.e. that climate change is being amplified by atmospheric pollution due to human greenhouse gas emissions; UNEP maintains this hypothesis, too. GEO 5 report states that greenhouse gas emissions and concentrations keep rising, so that temperatures seem to be increasing both globally and regionally, and there are no positive signs of regression of such tendency. Climate change has an influence on extreme climatological disasters, which are increasing in number and intensity: in particular, floods have more than doubled between the 1980s and the 2000s. Biodiversity loss is one of the most critical issue, since many species, habitats, and ecosystems are lost or at risk, mainly due to climate change and overexploitation of resources. Pollution of air, soil, and water is serious as well, and land overuse is causing major desertification and productivity decrease in drylands. Some consequences of environmental depletion have worldwide effects, while others, as it will be explained, have stronger effects on some specific regions, in most cases less developed areas.

[6] UNEP (2012), "*GEO 5 – Global Environmental Outlook*", internet : http://www.unep.org/geo/ (consulted on June 25th, 2013)

UNEP identifies some drivers of environmental change: population growth, urbanization, globalization, fossil fuel-based energy consumption and transport, and unsustainable consumption patterns.

Fig. 4: Greenhouse gas emissions per capita (Source: UNSTAT, 2010; author's elaboration)



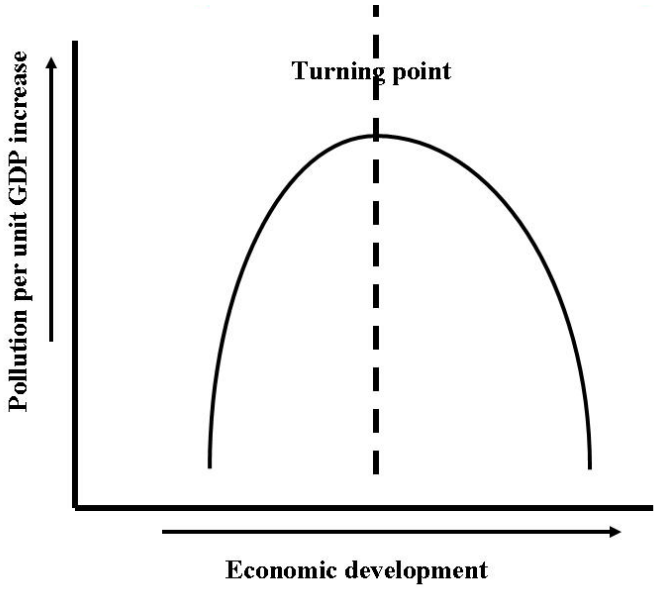
Much of the literature trying to find out the root causes of environmental degradation has held responsible economic growth, population growth, and urbanization.

In 1972, a famous-to-be report to the Club of Rome named *The Limits to Growth* has been published, based on the related book[7]. The authors have conducted an analysis of five elements (population, industrialization, pollution, food production, resources depletion) and functional interactions among them; their conclusion was that, if this trend continues, growth will stop well before 2100, due to the following process: increase in industrial capital stock will lead to rising input of resources, causing environmental pollution and resources depletion, which will need further capital stock to have the amount of resources needed for economic growth. This vicious cycle would end up in a collapse of the industrial base and the agriculture production, diminished availability of food, so that mortality rates would increase, inverting the trend of demographic growth. This "overshoot and collapse" scenario is, by the word of the

[7] Meadows D. H., Meadows D. L., Randers J., and Beherens W. W. (1972), *The limits to growth*, New York: New American Library

authors themselves, the result of a very simplified model, but it is held accountable in its basic implication: that mankind has always tried to push back natural limits through technology, but there will be a point (before 2100) when technology will not make humanity able anymore to go beyond biophysical boundaries. Their thesis is that, even in the most optimist scenario, this type of growth process will lead to collapse, thus it is necessary to work on building a global equilibrium based on sustainability, to alter this trend. This could be achieved through lower birth rates, stabilization of capital stock, and technological changes to limit resources shortages.

Fig. 5: Environmental Kuznets Curve (Source: www.eoearth.org ; author's elaboration)



The *Limits to Growth* analysis underlines the importance of the economic growth trend's effect on resources depletion. One powerful answer that was given to this interpretation is the "ecological modernization" approach[8], according to which global environmental problems can be solved without changing the current growth paradigm, since further development would lead to a reduction of environmental impact. This idea has been expressed through the "environmental Kuznets curve" (EKC), a model of growth-inequality relationship adapted to environment issues (Fig. 5).

[8] York R., Rosa E. A., and Dietz T (2003), "Footprints on the Earth: the Environmental Consequences of Modernity", American Sociological Review vol. 68, No. 2 (Apr., 2003), pp. 279-300

According to this model[9], the economic development causes an intensification of resources extraction and depletion, but further economic development leads to a structural change towards information-intensive economies, rising awareness and technology available, which, in the end, reduces environmental degradation. This approach has been endorsed by the World Bank as well[10], according to which rising incomes result in an increasing demand for environmental improvements to policy makers. Yet, it has been widely criticized as being too simplistic for policy making. Stern, Common, and Barbier (1996)[11] have analyzed five previous studies which tried to provide for some evidence of the EKC effectiveness as a model of analysis. The results of their research have been ambiguous and contradictory, leading the scholars to outline actual problems with hypothesis testing and estimation. First of all, simultaneity: the EKC hypothesizes a direct relation between growth and state of the environment, but does not consider any feedback; this is particularly true in developing countries, where trying to grow fast may have consequences so negative on the environment that growth itself would slow down. A second issue is that of international trade, as import of raw material or goods produced in foreign countries may reduce local impact, but may increase the environmental impact in the exporter country as well. Last, problems with data coverage and quality have been underlined. Furthermore, the EKC model does not consider worldwide and regional inequalities due to environmental depletion. In the end, Stern, Common, and Barbier believe that the EKC may be useful as descriptive statistics, but mixed empirical evidence shows that it is not appropriate to serve as basis for future projections. Besides, it does not give any policy advice; it does not mean that economic growth is useless, but that economic growth *alone* cannot be a solution, since there are many variables and feedback effects to take into account.

[9] Panayotou T. (1993), "Empirical tests and policy analysis of environmental degradation at different stages of economic development", *Working Paper WP238, Technology and Employment Programme*, Geneva: International Labor Office

[10] IBRD (1992), *World Development Report 1992: Development and the Environment*, New York: Oxford University Press

[11] Stern, D. I., Common M. S., and Barbier E. B. (1996), "Economic Growth and Environmental Degradation: the Environmental Kuznets Curve and Sustainable Development", World Development vol 24 no 7, pp. 1151-1160

As Newman (2006)[12] recalls, especially in the '60s, when environmental problems started to be addressed, scholars focused on population growth as the main cause: given that every individual consumes resources and produces wastes, every extra person was seen as contributing to resources depletion. This view has been put in a formula[13]: I = P x F, meaning that the impact (I) is caused by population (P) and per capita impact (F); the expanded version included technology as a contributing factor: I = P x A x T[14]. Though the equation includes three factors, population (P), per capita consumption (A), and technology (T), P was the one receiving more concern, along with A, since technology was seen as having a small impact, especially in less developed countries. This approach is known as "human ecology"; human ecologists emphasize the role of population growth, size, density, and structure on environmental change, since they believe that technology is always limited by ecological boundaries[15]. This population impact approach led some towards an "anti-urban approach"[16]: not only population growth, but also, and above all, population density causes high environmental impacts, since cities have a metabolic process requiring a lot of external inputs. However, Newman highlights that the population impact approach does not explain the global impact of cities and does not consider possible advantages of high-density settlements in terms of resources management.

Undoubtedly, population growth and size *does* have an impact: Cincotta, Wisnewski, and Engelman (2000)[17] have collected data on population density in the 25 biodiversity hotspots identified in 1988 by the biologist Norman Myers, places where conservation policies should be particularly careful. The authors observed that in 1995 population density in the hotspots was 71% higher than the world average. Between 1995 and 2000, population has grown in all but one hotspot (the Caucasus), and in 19 hotspots population growth has been very fast (most hotspots are located in developing

[12] Newman P. (2006), "The environmental impact of cities", *Environment and Urbanization* vol. 18 no 2 October 2006, pp. 275-295

[13] Erlich P. R., Erlich A. H., and Stateren J. (1970), "*Population, Resources, Environment*", Freeman, S. Francisco

[14] Erlich P. R. and Stateren J. (1971), "Impact of Population Growth", *Science*, 171, 3977, Mar. 26, pp. 1212-1217

[15] York R., Rosa E. A., and Dietz T (2003), see reference list

[16] Newman P. (2006), see above

[17] Cincotta R. P., Wisnewski J, and Engelman R. (2000), "Human Population in the Biodiversity Hotspots", *Nature* vol. 404, April, 27th 2000, pp. 990-992

countries). Population density has generally increased in biodiversity hotspots, even though at different rates; Western Ghats/Sri Lanka, the Caribbean, and the Philippines have experienced higher rates in population growth and density. The research takes population size and density as a proxy variable for biodiversity risk, since human settlements have a deep impact on surrounding areas. Yet, one important result was that, though urban settlements entail high demand for wood, fuels, food, water, and waste productions, even in the absence of high-density human settlements biodiversity could be at risk, because of, for instance, commercial hunting.

This last assertion brings us back to the major critic moved by Newman to the population impact approach: low-density settlements do not automatically imply low impact. Newman observes that, for instance, in places where the population decreased because of economic decline (and subsequent migration), like Liverpool, there has not been any reduction in environmental impacts; the reason outlined is that the lack of investments in the area to convert high-impact technology to lower resources-dense systems. If population density is the main cause for damages to landscape, soil, water, and biodiversity, rural-urban migration might be desirable to reduce environmental pressure; yet, some evidence from Australia show that a decrease in rural population in certain areas has caused higher environmental impact and social issues[18].

High density settlements can be more efficient in managing resources demand and greenhouse gas emissions. Newman notices that cities seem to accelerate the demographic transition, since birth rates in urban contexts are lower than in rural ones; rural-urban migrants, too, tend to have less children, both as an automatic adaptation to the new environment, and as a result of social programs, gender equality, access to education and health care. Furthermore, Doodman (2009)[19] underlines that economies of scale, agglomeration, and proximity can help to minimize environmental hazards, because of several reasons. One reason is that local authorities can effectively promote greenhouse gas emissions curbing policies, since they have an effective power on local land planning and setting targets calibrated on local characteristics and habits. Another reason is technological innovation: cities are major catalysts for investments, so that

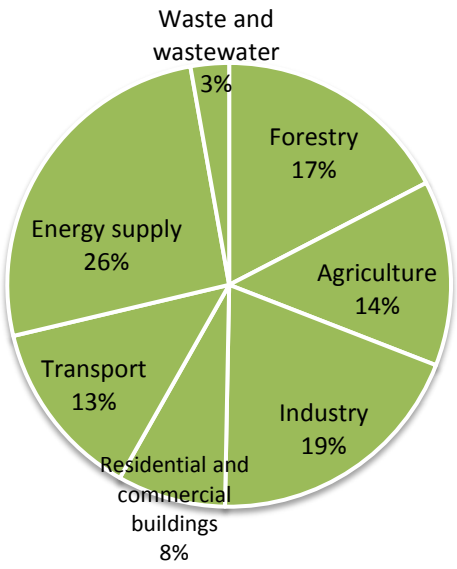
[18] Newman P. (2006), see above

[19] Doodman D. (2009), "Blaming cities for climate change? An analysis of greenhouse gas emissions inventory", *Environment and Urbanization* vol 21 no 1 April 2009, pp. 184-201

low-impact projects can be more easily experimented, such as integrated plants for energy saving, or ecological transportation; high-density urban areas allow citizens to move preferably by public transportation, or bicycles, or walking, than taking private cars. A third reason highlighted is that people's concentration can ease the spread of ideas, technology, and behaviours, so that social change towards more sustainable consumption habits can be adopted faster by a high number of people. Last, there can be other benefits due to local resources: in Vienna a more effective thermal insulation in homes and offices has been achieved. Doodman's conclusion is opposite to the population impact's supporters: not only high-density urbanization is not the main cause for climate change, but it can be a solution to the problem.

This assertion must be held accountable with some reservation, since the analysis does not include important issues, like indirect impacts due to international trade and globalization. However, it stresses the basic point, highlighted by IPCC data, that agriculture has a high environmental impact in terms of greenhouse gas emissions (Fig. 6). A study from Kalnay and Cai (2003)[20] on the United States remarks that both urbanization and agriculture effects (livestock included) are responsible for climate change.

Fig. 6: Anthropogenic greenhouse gas emissions by sector (Source: IPCC, Fourth Assessment Report: Climate Change, 2007)



[20] Kalnay E. and Cai M. (2003), "Impact of urbanization and land-use change on climate", *Nature* vol. 423, 29 May 2003, pp. 528-531

Population dynamics and economic growth have led to an increased demand for food that, combined with new technologies and chemicals, resulted in the so-called green revolution. Thus, agricultural practices started to be increasingly characterized by intensive single-crop plantations, agrochemicals, and mechanization. In the short run, the green revolution has improved productivity, and it has decreased food prices, forcing many local farmers to exit the market. Yet, single-crop plantation and use of agrochemicals are turning out to be counterproductive in the long run, since soil depletion and desertification are decreasing production and increasing food prices in many areas of the world[21]. Furthermore, the use of fossil fuel energy for machinery increases climate changing gas emissions. Because of the standardization of agricultural practices, the green revolution has been exported in developing countries, where demand for food was high and rising; one very famous example is India, where reforms promoted in the 80's have pushed the spread of intensive agriculture practices.

Beyond environmental depletion, the green revolution is having consequences on food security, too. Schmidthuber and Tubiello (2007)[22] have identified four aspects of food security: availability, stability, access, and utilization; according to this study, all four dimensions are negatively affected by climate change. Many scientists have observed positive effects on yields of higher percentages of CO_2, so that some have hypothesized that carbon dioxide negative effects on climate change could be counterbalanced by its positive effects on plantation and, as a consequence, on food security. Parry *et al.*(2004)[23] have conducted a study to assess the outcome of climate change on agriculture, taking into account both biophysical effects and socio-economic changes; they have hypothesized different scenarios and estimates with and without carbon dioxide effects. The main result was that, in most cases, yields would decrease despite carbon dioxide, except when assuming a (doubtful) full realization of positive effects and not considering potential interactions with chemicals, weeds, and nutrients. Furthermore, climate change is likely to affect different regions in a different way, with

[21] Barilla Center for Food and Nutrition (2012), "*Eating planet – Nutrirsi oggi: una sfida per l'uomo e per il pianeta*", Milano: Edizioni Ambiente

[22] Schmidthuber J. And Tubiello F. N. (2007), "Global food security under climate change", *PNAS* vol. 104 no 50, December 11th

[23] Parry M. L. (2004), "Effects of climate change on global food production under SRES emissions and socio-economic scenarios", *Global Environmental Change* vol 14 (2004), pp 53-67

heavier consequences in developing countries, thus worsening the world inequality. If yields decrease in less developed countries, where farming is the main source of income, chances of reducing food insecurity will further diminish. Thus, many believe that on the supply side a "*sustainable intensification*" [24] of food production is needed, by changing agronomic practices and reducing food waste.

From the literature presented, it can be remarked that though population impact, anti-urban, and economic growth approaches may be of some value, they tend to focus on one element (population growth, urbanization, and economic growth, respectively), leaving out many variables that can change substantially the outcome of the research. This is why Newman stresses the importance of the ecological footprint as an indicator of environmental impact; the ecological footprint approach provides for an analysis of the whole cycle of resources depletion, turning consumption into a landprint. Although it is largely artificial and does not give concrete policy suggestions on what to reduce first (land, water, or energy consumption), it offers a different point of view on the main causes for environmental depletion, focusing on per capita consumption. Measuring environmental impacts in terms of consumption allows us to include virtually all those variables affecting per capita demand of resources and waste production. Population growth, economic (and incomes) growth, and urbanization are only one part of the story; international trade and globalization, for instance, are responsible for environmental degradation in several ways: goods and raw material transportation is mainly fuelled by the use of non-renewable energy sources, production processes in imported goods may have a deep impact in the exporter country, etc.

Many have underlined [25] that environmental impacts derive from a general overconsumption of resources. Here, theories on the environmental impact of population growth, economic growth, and urbanization have been discussed; it has been said, too, that an analysis based on one main issue may prove to be too simplistic. According to UNEP [26], excessive consumption patterns are among the causes for environmental depletion; the starting point of the present research, which will focus on

[24] Godfray H.C.J. *et al.*(2010), see reference list

[25] For instance, see: Grimmond S. (2007), "Urbanization and global environmental change: local effects of urban warming", *The Geographical Journal,* vol. 173, Issue 1, March 2007, pp. 83-88

[26] UNEP (2012), see reference list

food production and consumption, is that the relationship among overconsumption, economic growth, population growth, urbanization, and globalization, both in food production and utilization, can be the key to understand the real impact of each issue, and related challenges.

World Dietary Trends

There is some evidence that the world dietary habits have been changing in an unprecedented way in the last decades, and that this shift is happening at a much faster pace today. Drewnowski and Popkin (1997)[27] have conducted a deep research on world dietary trends, stressing that official data show an ongoing nutrition transition affected by incomes, urbanization, and globalization, and that the way this transition is occurring has changed over time. Popkin (2004)[28] maintains that the nutrition transition includes three main elements: change in dietary habits, change in body composition, and reduced physical activity. For the purpose of the present work, the first issue will be analyzed in depth, while the other two will be included limited to their consequences on human health, together with dietary shifts. Overall, in the second half of the XX century there has been an increase in energy-dense food, in particular edible oils, fats, and sweeteners[29], which has been identified as a westernization of local diets, i.e. a shift from traditional food towards typical North-American eating habits. Even though each country and each region is experiencing a different path, reported data[30] show that between 1970 and 1995-1997 the world calories intake from meat and vegetable oils has increased by 33% and 46% respectively, while energy intake from starch roots and pulses has decreased by 30%; although cereals still make up the largest share of the world's diet, the energy intake from fat and sugar is increasing at the expenses of complex carbohydrates.

[27] Drewnowski A. and Popkin B. M. (1997), "The Nutrition Transition: New Trends in the Global Diet", *Nutrition Reviews* vol 55 no. 2, pp. 31-43

[28] Popkin B. M. (2004), "The Nutrition Transition: an Overview of the World Patterns of Change", *Nutrition Reviews* vol. 62 no 7, pp. S140-S143

[29] *Ibidem*

[30] Drewnowski A (2000), "Nutrition Transition and Global Dietary Trends", *Nutrition* vol. 16 no 7/8, pp. 31-43

Looking at updated data (see figures 7 and 8 below)[31], it can be observed that the global variation of food intake in the last 30 years appears to be very different in each continent, yet there is a general trend of steady consumption of cereals, starchy roots, pulses and, perhaps surprisingly, sugar and sweeteners; vegetables, fruits, edible oils, meat and dairy consumption tends to increase almost everywhere, while animal fats intake is quite steady, except from Asia. Unsurprisingly, the most "westernizing" area in terms of food intake is Asia, where a general rise of income (particularly in China and the "Asian Tigers") has led to an overall increased consumption, especially of foods typical of the North-American diet. In Africa the nutrition transition is proceeding more slowly, but still there are clear signs of an increase in demand for vegetable oils, meat, eggs, and milk (dairy consumption has not risen very much over time, but absolute quantity is rather high, compared to vegetables and fruits). Developed areas (Europe, Oceania, and the Americas) show less relevant variation, with Oceania displaying a counter-trend behavior about pulses, eggs, dairy, and meat; this is because consumption in the developed world is already high in absolute terms, as fig. 8 illustrates. One remark has to be done on "the Americas" grouping: North America (where the western diet comes from) and South America used to have very different dietary habits, so North-South aggregate data may not be extremely significant. We can hypothesize that developing South American states consumption tendency might be more similar to that of the Asian states: absolute quantity lower than average, but high percentage change. On the contrary, North American trends might be more similar to that of the other developed areas: high absolute quantities and low, if not negative, percentage changes.

[31] In FAO database food types are grouped as follows: cereals include wheat, maize, barley, rice, oats, millet, sorghum rye, other cereals; starchy roots include cassava, potatoes, sweet potatoes, yams, other roots; pulses include beans, peas, and other pulses; vegetables include tomatoes, onions, and other vegetables; fruits include oranges, mandarins, citrus, bananas, apples, pineapples, plantains, grapefruit, dates, grapes, and other fruits; sugar and sweeteners includes sugar, honey, and others; vegetable oils includes oil from soybean, groundnut, sunflower seed, rape and mustard, cottonseed, palm kernel, palm, sesame seed, coconut, olive, rice bran, maize germs, oil crops and others; meat includes bovine, mutton & goat, pig, poultry, others; animal fats includes butter and ghee, cream, raw fat, fish body and liver oil.

Fig. 7: Percentage change of regional consumption per food type (Kg/Yr per capita), over the period 1980-2009, (Source: FAOSTAT, 2012)

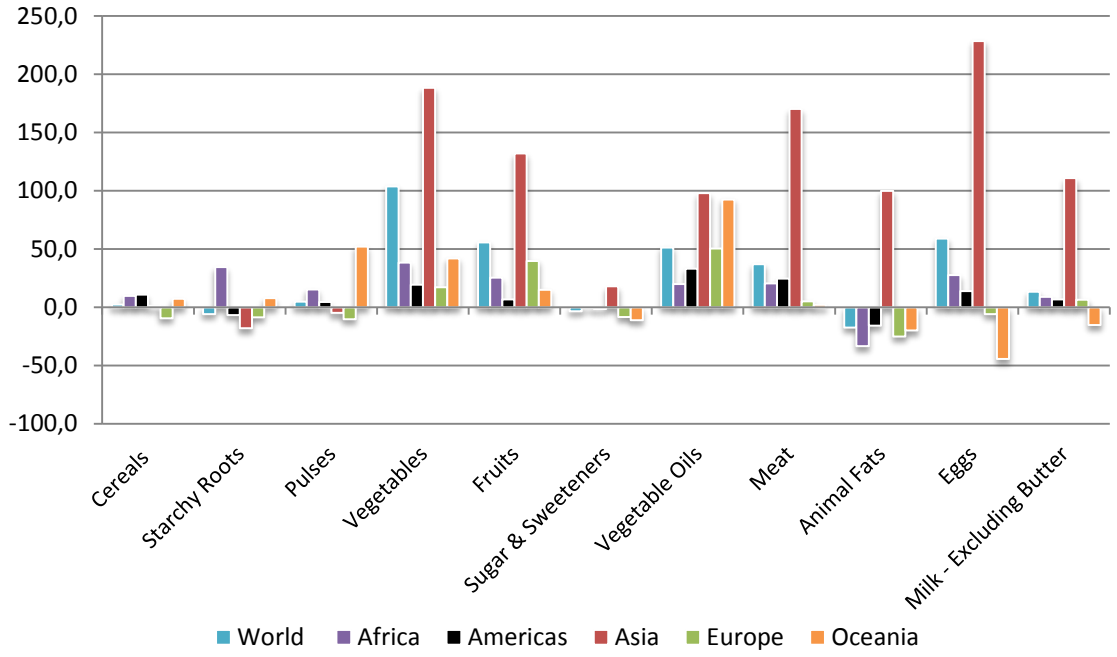
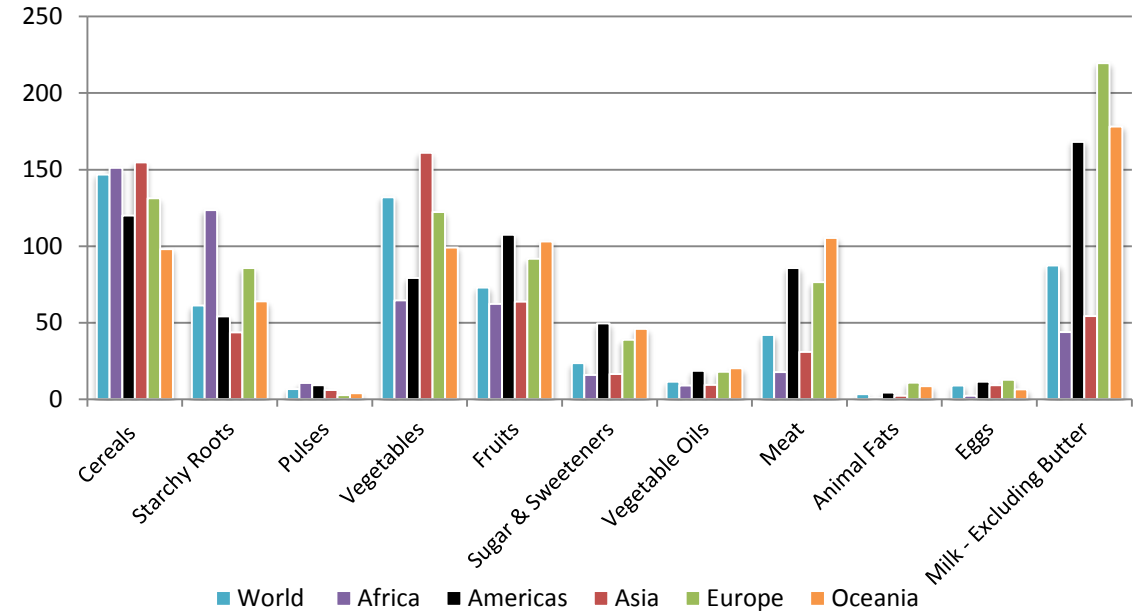


Fig. 8: Absolute regional consumption per food type in 2009, expressed in Kg/Yr per capita (Source: FAOSTAT, 2012)



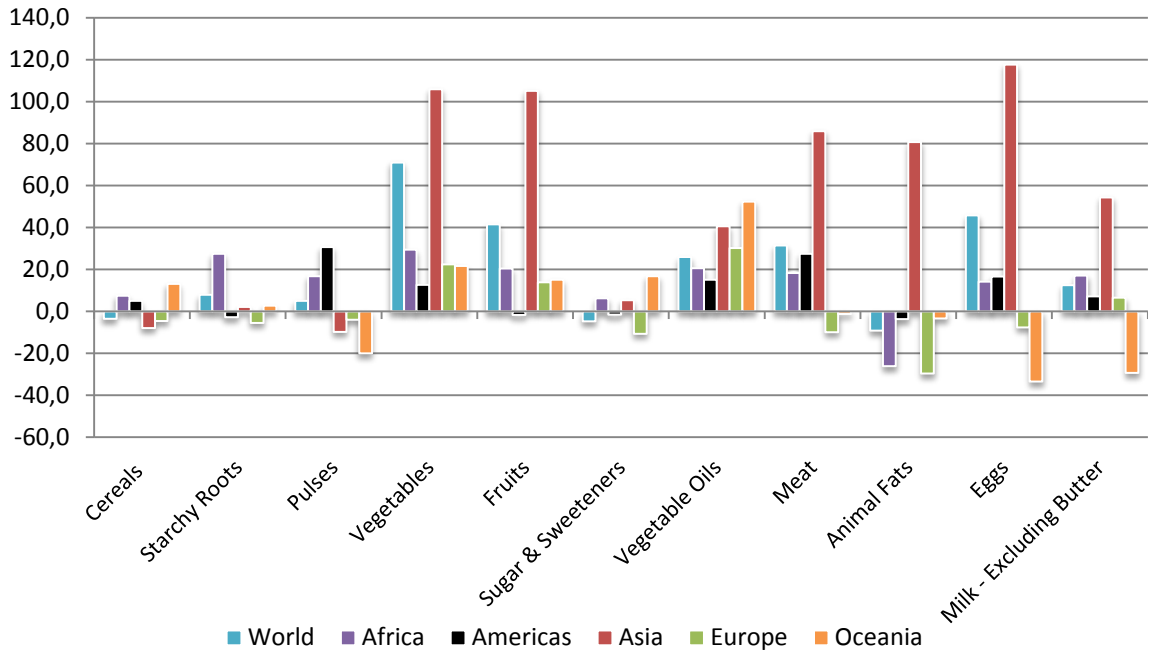
FAO researchers (2004)[32] have provided for a cross-country study, showing that dietary patterns are going through two main processes: convergence and adaptation. Changes in food prices and individual incomes seem to be driving food demand towards the same choices in all regions (polished grains, animal products, vegetable oils), while

[32] Kennedy G., Nantel G., and Shetty P.(2004), see reference list

changes in lifestyle seem to be leading towards similar adaptation phenomena (higher consumption of packaged and processed food) in different countries. This is also due to a certain idea of "being modern"; evidence from South Africa demonstrates that fried food is considered a sign of modern living, while boiled food is regarded as outdated.

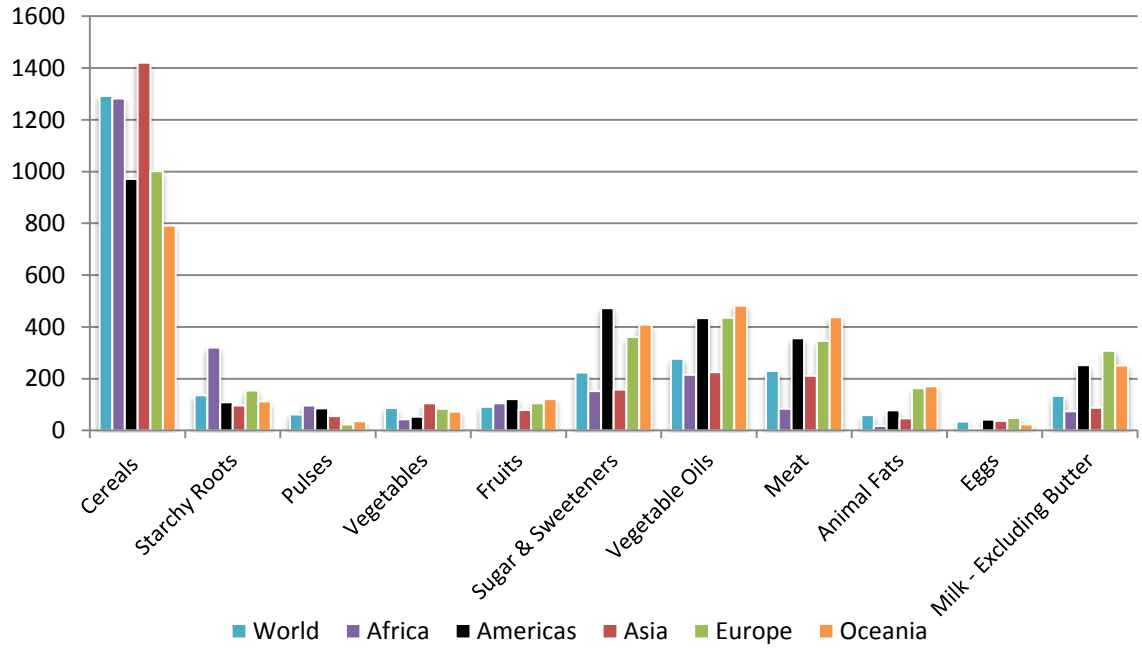
Beyond quantities of food demanded in terms of kilos per year, which give us a first indication of how consumption has changed, another important information to take into account in the analysis of the ongoing dietary shift is the relative weight of each food type in terms of calories per day. Figs. 9 and 10 below report data on Kcal/Day per capita of different food types. The percentage change of consumption shows tendencies extremely similar to fig. 8 above; taking into account such trends and looking at fig. 10, the conversion process observed by FAO researchers[33] finds some confirmation in 2009 data: divergences in regional percentage changes are leading to similar consumption habits in absolute terms. For instance, the consumption of fruits and vegetables in Asia and Africa has remarkably increased, but only to reach the average consumption patterns; the same, the intake of calories deriving from meat, animal fats, eggs and milk in Asia has risen exceptionally, so that the absolute calories amount is growing similar to that of developed regions.

Fig. 9: Percentage change of regional consumption per food type (KCal/Day per capita), over the period 1989-2009 (Source: FAOSTAT, 2012)



[33] *Ibidem*

Fig. 10: Absolute regional consumption per food type in 2009, expressed in KCal/Day per capita (Source: FAOSTAT, 2012)



This dietary transition, together with population growth, has led to an increasing demand for fish, meat and animal products, with a subsequent answer by the supply side, causing what has been defined as the "livestock revolution"[34]. Developed countries will, in absolute terms, keep a high consumption of animal fats and proteins, while developing countries account for 85% of global rising demand in cereals and meat. According to Steinfeld and Gerber (2010)[35], while the green revolution was a planned policy, the livestock revolution is occurring without any political planning, as a direct consequence of a remarkable increase of the demand for animal source foods, which is expected to increase by 68% (meat) and 57% (milk). Demand for meat implies a greater demand for cereals to feed livestock and a higher environmental impact of dietary habits, as it will be demonstrated in the next part. Yet, though the total world calories intake will rise in the developing world, food insecurity and undernutrition will persist. This livestock revolution, like the green revolution, is primarily involving developing countries, where the increase in the share of production and consumption will be more significant, causing heavier stress on resources and a need for rapid technological

[34] Pinstrup-Andersen P., Pandya-Lorch R., and Rosegrant M. W. (1999), "World Food Prospects: Critical Issues for the EarlyTwenty-First Century", *IFPRI Food Policy Report* October, Washington D.C.: International Food Policy Research Institute

[35] Steinfeld H., Gerber P. (2010), " Livestock production and the global environment: Consume less or produce better?", *PNAS* vol. 107 no. 43, October 26, 2010, pp. 18237-18238

change[36]. There is a need for policy regulation of the livestock industry, since it may bring opportunities, as well as dangers: in low-income countries, meat is an important source of nutrients to fight against undernutrition, but in wealthier countries it is bringing health problems, and, moreover, without proper techniques livestock management it causes environmental depletion.

Drewnowski and Popkin (1997) have tried to investigate possible genetic and inner causes of fat- and sugar-rich food preferences observed all around the world. According to their findings, although human beings have directed their choices towards high-energy food to survive during the evolution process, there seems to be a regulatory mechanism for sugars, but not for fats. Sugar is highly desired by children, and less by adults; the same, proteins demand may be tied, to a certain extent, to internal mechanisms. On the contrary, the perception of fat in foods is often misguided and its consumption appears to be determined by economic factors, plus a general desire for a more diverse diet. Thus, socio-economic factors like urbanization, incomes and economic growth, prices dynamics, and globalization are regarded as the leading cause for the nutrition transition.

According to Drewnowski (2000), the nutrition transition is highly influenced by income levels and GNP, so that two steps can be identified: at an early stage of the transition there is an increase in oil and vegetable fats consumption, while in the second phase dietary habits move towards a higher intake of animal products and western processed foods. Developing countries may be an example of the first stage, while wealthier nations (like Japan) have already reached the second step. Between the '50s and the '70s, economic growth in Japan has been followed by an increase in fats intake: the traditional diet based on rice, fish, and soybeans has been enriched with meat (poultry, in particular), milk, and dairy products. Drewnowski and Popkin (1997) report that from 1946 to 1987, Japanese people have experienced a three-fold increase in fat intake (from 9% to 25% of daily energy), while cereals have been reduced from 66% to 39% of daily energy. Developed countries have already undergone this transition and now it seems that the most developed countries are experiencing a further change: while developing countries (especially in Asia) are going towards more energy-rich diets,

[36] *Ibidem*

in rich countries plant-based diet are spreading. The research mentioned above has found out that today GNP-nutrition shift ratio is less relevant than in the past. The analysis of 1962 data has outlined a strong connection between incomes and animal fats, while a less evident behavior has been observed with animal proteins and sweeteners; vegetable fat consumption was pretty constant and independent of GNP levels. The same study, conducted on 1990 data, has detected an increase of animal fat consumption in poor countries, and a reduction in rich countries, while results for animal proteins and sweeteners did not change substantially; consumption in vegetable fat remained independent of income levels, but significantly higher. The conclusion drawn from this study is that the nutrition transition is happening today at much lower incomes than before. This means that dietary shifts are much faster than in the past, with the result that in many developing countries chronic undernutrition and rising overnutrition are found together, causing a double burden for the State to deal with. The same hypothesis is maintained by Abrahams *et al.* (2011)[37] in a study on 40 Sub-Saharan countries: even though most of the countries analyzed appear to be in the early stages of the transition, the recession of famine and the concurrent increased access to low-cost western food (due to globalization and urbanization dynamics) are deeply affecting dietary habits and spending-up the transition in low- and middle-income countries.

China and India are an example of nutrition transition due to advanced living standards and improved economic performances, although income inequality is still high. A rapid increase in GDP per capita has led to a shift towards western lifestyle; in particular, all income groups have moved away from a cereal-based diet, seen as poverty status [38], to higher energy-dense diets. Reported data [39] show that, approximately from the mid-'70s to the mid '90s, Chinese people have sharply increased animal products consumption (almost eight-fold), and vegetable and fruit consumption, while in India global demand for dairy and edible oils has grown fast. A similar pattern

[37] Abrahams Z. *et al*. (2011), "Diet and mortality rates in Sub-Saharan Africa: stages in the nutrition transition" *BMC Public Health* 2011 11:801

[38] Popkin B. M. (2001), "Nutrition transition: The changing global nutrition challenge", *Asia Pacific Journal of Clinical Nutrition*, vol 10 (suppl.), pp. S13-S18

[39] Popkin B. M. *et al*. (2001), "Trends in Diet, Nutritional Status, and Diet-related Non-communicable Diseases in China and India: The Economic Costs of the Nutrition Transition", *Nutrition reviews* vol. 59 no. 12, pp. 379-390

has been followed by South America: all Latin American countries show an increase in animal protein and fat, sugar and processed food intake, occurred between 1970 and 1997; at the same time, despite being the principal source of energy, cereals' consumption has decreased. Yet, each of them is in a different step of the nutrition transition and wealthier countries (like Chile) or rapidly developing ones (Brazil) seem to be in a much advanced phase[40].

The main reason why dietary shifts are occurring at lower income levels than in the past, together with rising incomes, is a general reduction in "western" foods' prices, due to industrialization of agriculture and livestock. Price is very important in food selection and it can be affected by economic means, but it is difficult to find a balance between reducing calories intake of wealthier people without harming food insecure households[41]. Egypt, for instance, is undergoing an early phase of the nutrition transition[42], with growing consumption of polished grains (wheat and rice), animal products, fats, and vegetable oils. The shift from a kind of bread mainly made of corn flour to a wheat flour dependency is due to State subsidies, according to Galal (2002), which made wheat bread and flour less expensive, thus more preferable by consumers.

Satterthwaite, McGranahan, and Tacoli (2010) have remarked that urbanization, beyond economic growth, has a deep impact on food production and consumption, mainly for three reasons: first, cities' physical expansion causes losses of local agricultural lands, forcing people to rely on large international chains; second, urbanization in less developed countries is not always associated to income growth, so that there are large masses of urban poors suffering from food insecurity; last, increased consumption of meat. A FAO cross-country study[43] has shown as well that urban dwellers tend to consume more edible oils, animal products, sweeteners, and, to a minor extent, fruits and vegetables. Satterthwaite, McGranahan, and Tacoli (2010) believe that this last feature of urbanization is mainly due to higher incomes, not to urbanization itself. However, there is some evidence contrasting with this statement.

[40] Bermudez O. I. and Tucker K. L. (2003), "Trends in dietary patterns of Latin America populations", *Cad. Saude Publica*, vol 19 (sup. 1), pp. S87-S99

[41] Popkin B. M. (2001), see above

[42] Galal O. M. (2002), "The nutrition transition in Egypt: obesity, undernutrition, and the food consumption context", *Public Health Nutrition* vol. 5 no 1A, pp. 141-148

[43] Kennedy G., Nantel G., and Shetty P. (2004), see reference list

According to Ghassemi, Harrison, and Mohammad (2002)[44], Iran is experiencing a rapid dietary shift, in a context of a quick demographic transition (due to fertility rate control policy), urbanization, and social development, but the absence of a steady economic growth. Data provided in the above mentioned research show that, since 1985, urban population in Iran tends to move towards an inexpensive energy-dense diet, rich in bread, sugar, fats and oils, while animal proteins, fruit and vegetable consumption has decreased. Iran is a clear example of a fast transition, happening at low income levels and affecting urban poors above all, causing a double burden of undernutrition and overnutrition. Furthermore, a study conducted on China[45] shows that, keeping constant socio-demographic variables, income, and food prices, there is a "urban effect" on dietary habits, causing a shift towards western diets: higher consumption of superior grains, fats, animal products, sweeteners, and processed food.

This "urban effect", according to Popkin (2001), marks a significant difference between urban and rural dietary habits in low-income countries; on the contrary, in wealthier countries there seems to be a market penetration in rural areas, due to transportation and national distribution infrastructures, causing a convergence of rural habits towards urban dietary styles.

Another issue affecting dietary habits, usually subsequent to economic growth and urbanization, is globalization and spreading of mass media. This is a common feature of developing economies: for instance, in China, during the '70s, there was no television, no transportation, and (almost) no food trade; today, almost 90% of households own a television, transportation has developed, and industrial techniques are applied to the food chain, too[46]. It is hard to evaluate its real impact on food choices, because it is always mixed up with all other dimensions affecting lifestyle changes. As mentioned above, the nutrition transition implies a dietary convergence towards the North-American diet. This shift cannot be always connected to globalization dynamics: taking again China as an example, the dietary transition started when domestic production of vegetable oil increased, while changes in lifestyle pushed people to consume more food

[44] Ghassemi H., Harrison G., and Mohammad K. (2002), "An accelerated nutrition transition in Iran", *Public Health Nutrition* vol. 5 no 1A, pp. 149-155

[45] Popkin B. M. (1999), "Urbanization, lifestyle changes, and the nutrition transition", *World Development* vol. 27 no 11, pp. 1905-1916

[46] Popkin B. M. (2001), see reference list

away from home and to increase the use of sweeteners; a higher demand for animal products and fats caused more import, but foreign food or habits started to play a role in the country only later, when the transition had already started[47]. Globalization of food culture is also affecting Indigenous Peoples' communities with a long history of traditions separated from those of the countries they live in. A study on forty-four large cultural areas from the Canadian-Arctic[48] shows that there has been a sharp reduction in the consumption of traditional food, and subsequent higher consumption of fats, sugars, and proteins, especially among the youngsters and in more urbanized or connected areas.

On the contrary, in some cases globalization seems to have a good part in the transition: one is South Korea. This country underwent a process of modernization much earlier, compared to other Asian countries (except for Japan); according to Kim *et al.* (2000)[49], food shortages in South Korea have led to higher importation of wheat from the US in the '70s, originating a process that has led to a higher demand of foreign products and, as a consequence, the spread of fast food restaurants, food processing technologies, importation of meat. In the last thirty years, South Korean people have reduced consumption of plants in favour of animal products, anticipating the rest of the region; one remarkable feature of this country is that, contrary to most of the other ones, the dietary transition has not caused a marked rise in fat intake. One explanation that has been given[50] is that many socio-cultural movements to protect and retain the traditional diet have developed and spread through mass media, exploiting other features of globalization (for instance, by creating a chain of traditional Korean fast-food restaurants).

It is not in the purpose of the present work to assert that the nutrition transition is either entirely positive or negative; it depends on complex interactions of phenomena and it generates complex consequences as well. Some of them are positive (especially in terms of nutrients intake and dietary diversity for food insecure households), but some

[47] Drewnowski A. and Popkin B. M. (1997), see reference list

[48] Kuhnlein H. V. *et al.* (2004), "Arctic Indigenous Peoples experience the nutrition transition with changing dietary patterns and obesity", *The Journal of Nutrition* vol. 134 no 6, pp. 1447-1453

[49] Kim S. *et al.* (2000), "The Nutrition Transition in South Korea", *American Journal of Clinical Nutrition* vol. 71, pp. 44-53

[50] Kuhnlein H. V. *et al.* (2004), see above

of them are dangerous, both for the environment and for human health. From the studies analyzed, it can be concluded that it is highly unlikely that the transition will stop or reverse, thus it is important for policy-maker to understand its outcomes to outline measures in order to restrain drawbacks.

Food Production: Conventional Systems vs. Sustainable Methods

In the previous section it has been outlined that the nutrition transition is altering food consumption patterns, thus moving consumers' demand towards more energy-dense foods; it has been said, too, that, though some improvements have occurred, human-generated pressures on the environment are still high; environmental impacts are due to overconsumption trends caused by a mixture of socio-economical phenomena, such as globalization, urbanization, population growth and economic growth. Though urbanization has led to high-consumption agglomerates, it has been remarked that a good deal of environmental pressure derives from the agriculture and livestock sector.

In this part the last issue mentioned will be analyzed: the shift from traditional practices to industrial agriculture and livestock, although meant to improve global food security, is now a heavy burden to the environment. First of all, an analysis of intensive agriculture and livestock will be provided, to outline critical issues; then, low-impact models of food production will be presented, investigating their feasibility through academic studies, data, and practical evidence; last, the study will move on to the second part of the food chain, i.e. transport, processing, packaging, and retail.

Critical Issues of Intensive Farming and Livestock Management

To assess the environmental impact of food production, interconnected dynamics must be taken into account. The growing demand for agricultural products is due to the increasing world population, the need to ensure food security, and rising consumption of animal products, so that the need for feed-grains cultivation has risen, too. Thus, to face the demand both for human needs and animal livestock, farming had to find a way to achieve higher yields.

In a detailed study on food production, researchers of the Barilla Center for Food and Nutrition (BCFN)[51] have provided data on carbon footprint, water footprint, and

[51] Barilla Center for Food and Nutrition (2011), "*Doppia piramide: alimentazione sana per le persone, sostenibile per il pianeta*", Parma: BCFN

ecological footprint[52] of most food types. The Life-Cycle Assessment (LCA) analysis takes into account farm production, processing, packaging, transport, and cooking. Despite this part will focus on the production stage only, looking at a synthesis of wider data provided by the BCFN (see Table 1 below) gives a clear idea of the importance of changing diets in terms of resources consumption, even though land degradation is not included, thus underestimating the total impact of farmlands and livestock activities. The general outcome of the research is that more energy-dense foods require production methods having a deeper impact on the environment.

Table 1: Carbon footprint, water footprint, and ecological footprint of selected foods including production, processing, packaging, and transport (Source: BCFN, 2011)

Type of food (data per kilo)	Carbon footprint (CO_2 equivalent)	Water footprint (litres of water)	Ecological footprint (m^2 total)
Agricultural food			
Fruit	70	600	3
Greenhouse vegetables	4000	106	9
Seasonal vegetables	302	106	4
Pulses	1130	1800	16
Foods resulting from agricultural products processing			
Pasta	1564	1390	12
Rice	2750	3400	9
Bread	983	1300	6,7
Sugar	470	1500	4
Oil	3897	4900	14,6

[52] The Carbon footprint measures carbon dioxide emissions and all other greenhouse gases emission, converted in carbon dioxide emissions through proper coefficients, established by IPCC. The Water footprint indicates the amount of freshwater needed for a certain production, including rainwater absorbed by plants (green water), surface water and groundwater used (blue water), polluted water (grey water). The Ecological footprint determines the amount of land needed to provide for all services necessary to production, divided in: energy land, cropland, forest land, built-up land, fishing ground; this indicator is largely artificial (for instance, energy land is calculated as the amount of land needed to absorb carbon dioxide emissions), and does not include degraded land, but it is recognized by the academic community as a valid instrument, even though some methodological improvements are desirable.

Animal products (livestock)			
Red meat	30400	15500	106
White meat (pig)	4359	4800	36
White meat (avians)	3830	3900	33
Butter	8800	5000	75
Cheese	8784	5000	75
Milk	1000	3300	15
Eggs	5233	3300	14

The improvement of yields occurred in the last decades has been reached through the physical expansion of agricultural land and, above all, through the intensification of production. In other words, new consumption patterns have led farming enterprises to embrace intensive monocrop production systems to enhance yields remarkably. The main features of the so-called conventional (industrial) farming are: mechanization, greater use of fossil fuels, chemical fertilizers and pesticides, intensive monocrop cultivations. According to Foley *et al.* (2005)[53], nowadays almost 40% of the total land surface is employed in croplands and pastures (not to mention livestock), becoming one of the largest terrestrial biomes on earth; this figure is consistent with official FAOSTAT data[54], reporting that 38,47% of total land area is classified as agricultural land.

The way farming has evolved towards intensive croplands is causing a deep alteration on surrounding ecosystems. Environmental issues deriving from intensive agriculture and livestock, which are most of all climate-changing gas emissions, loss of biodiversity, and land degradation are examined below.

Sonesson, Davis and Ziegler (2010)[55] outline that, while post-farm activities are quite similar among food groups, implying similar impacts on the atmosphere, in-farm

[53] Foley, J.A. *et al.*(2005), "Global Consequences of Land Use", *Science* vol. 309, no. 570, July 2005, pp. 570-574

[54] FAOSTAT database (2012), internet: http://faostat3.fao.org (consulted on August, 14th, 2013)

[55] Sonesson U., Davis J., and Ziegler F. (2010), "Food Production and Emissions of Greenhouse Gases", *SIK-Report no. 802,* Göteborg: SIK – The Swedish Institute for Food and Biotechnology, ISBN 978-91-7290-291-6

activities differ substantially among food groups in terms of emissions. However, a common trait highlighted is that carbon dioxide emissions are relatively lower, compared to other biogenic greenhouse gas emissions: methane, nitrous oxide and dioxide. The research mentioned above offers a wide explanation of where does greenhouse gases emissions come from in each sector. Climate-changing gas emissions in agriculture are mostly due to the use of chemical fertilizers and pesticides; nitrogen, in particular, interacts with other particles present in soil and water, causing direct and indirect emissions of nitrous dioxide. Besides, agricultural operations requiring fossil fuels energy, as well as transportation of inputs necessary to production, result in carbon dioxide emissions. According to Smith *et al.* (1997)[56], there is a linear relationship between nitrogen fertilizers' quantity and nitrous oxide and dioxide emissions, even though other variables may affect the final result, such as fertilizers' timing, crop residues, water management, nitrification inhibitors, etc. Animal products' environmental impact depends on the kind of animal livestock. Sonesson, Davis and Ziegler report that red meat and dairy from beef cause a high level of methane emissions, due to enteric fermentation of ruminants; such emissions may be higher in nitrous dioxide if the cattle is fed with grains and soy, instead of non-edible grass. White meat from poultry has relatively less importance in direct climate-changing gas emissions, but poultry livestock needs a high amount of fossil-fuel energy; the same, white meat from pork causes less methane production than beef, but pigs need to be fed in grains, causing a rise in nitrous dioxide emissions. If we take into account all elements previously presented, as well as emissions due to deforestation and land-use change, it is clear how much intensive agriculture and livestock can affect local and global climate.

Another feature of the dramatic increase in food production has been the preference for the so-called High Yielding Varieties (HYV), meaning those breeds that perform better in intensive farms. Today, although there are more or less 50.000 edible

[56] Smith K. A. *et al.* (1997), "Emissions of N20 and NO associated with nitrogen fertilization in intensive agriculture, and the potential for mitigation", *Soil Use and Management*, vol. 13 Issue supplement s4, pp. 296-304

plants, rice, maize, and wheat provide for 60% of the global energy intake[57]. Thus, contrary to traditional farming, intensive agriculture relies on a few crops cultivated in wide areas, affecting all three types of biodiversity: genetic, specific, and ecosystemic. Furthermore, intensive agriculture has a double set of impacts on biodiversity: on the single field, it modifies natural vegetation and soil biota, on the landscape, the large size and homogeneity of cultivations affects the whole ecosystem, both directly and indirectly. Table 2 below lists the main benefits of biodiversity; increasing simplification of biological resources causes a progressive loss of natural services which are essential to agriculture itself.

Table 2: Benefits of biodiversity (Source: Interagency Report to the Mexican G20 presidency, 2012; author's elaboration)

Provisioning	Regulating	Supporting	Cultural
Food and nutrients	Pest regulation	Soil formation	Sacred groves as food and water sources
Fuel	Erosion control	Soil protection	Agricultural lifestyle varieties
Animal feed	Climate regulation	Nutrient cycling	Genetic material reservoirs
Medicines	Natural hazard regulation (droughts, floods and fire)	Water cycling	Pollinator sanctuaries
Fibres and cloth	Pollination		
Materials for industry			
Genetic material for improved varieties and yields			
Pest resistance			

Altieri (1999)[58] highlights that biodiversity has many economic advantages for farmers and consumers, namely dietary diversity, income diversification, efficient use of labour and resources, resistance to crop diseases, and efficient exploitation of different soil types; as a consequence, biological simplification hinders natural services, causing environmental damages and higher economic costs due to the growing need for external inputs.

Negative impacts of agriculture intensification on biodiversity are due, first of all, to the expansion of cultivated areas; this is causing, especially in developing countries, the

[57] OECD (2012), *Sustainable agriculture productivity growth and bridging the gap for small-family farms*, Interagency report to the Mexican G20 presidency, 12 June 2012, internet: www.oecd.org (consulted on July 15th, 2013)

[58] Altieri M. A. (1999), "The ecological role of biodiversity in agroecosystems", *Agriculture, ecosystems, and Environment* vol. 74 (1999), pp. 19-31

loss of many habitats and ecosystems. A study delivered by Donald (2004)[59] on plantations of cocoa, coffee, rice, oil palm, and soybeans in developing countries states that there has been a massive increase in cultivations of such commodities both in terms of physical area and intensification of methods, so that biomes hosting a large part of genetic and specific diversity, like tropical forests, are progressively disappearing in favour of monocrop cultivations. The replacement of a forest with crop fields generates the loss of those vegetation breeds destroyed, as well as the loss of all organisms and micro-organisms hosted. Yet, it is widely agreed that not all agricultural practices cause heavy damages to biodiversity.

Beyond expanding areas, the intensification of production systems is the main cause for biological simplification. According to Thrupp (2000)[60], agrobiodiversity, which means not only biodiversity itself but also the skills of farmers to exploit and preserve it, is mostly concentrated in Africa, Asia, and South America, where there is a tradition of cultivation of landraces, i.e. local breeds. Yet, the introduction of many HYV has endangered biodiversity in developing countries: the research mentioned above reports that in the Philippines more than 300 traditional rice varieties have been displaced, while in Senegal a highly nutritive local cereal (fonio) is threatened by the introduction of western-imported HYV monocrop cultivations. Thrupp and Altieri outline that monocrop cultivations are highly vulnerable to pests and diseases, so that farmers resort to chemical pesticides. Besides, a reduction in soil organisms and nutrients leads to the increasing use of chemical fertilizers, with subsequent release of higher quantities of climate changing gas. As previously outlined, one characteristic of intensive agriculture is the use of great quantities of chemical pesticides (there are more or less 1600 pesticides available nowadays), which, although should be projected to attack targeted organisms only, have a dangerous disruptive effect on biodiversity: bird wildlife and pollinator insects are the most affected species by poisonous effects of chemical pesticides[61].

[59] Donald, P.F. (2004), "Biodiversity Impact of Some Agricultural Commodity Production Systems", *Conservation biology* vol. 18 no 1, February 2004, pp. 17-37

[60] Thrupp, L. A. (2000), "Linking agricultural biodiversity and food security: the valuable role of agrobiodiversity for sustainable agriculture", *International Affairs* vol. 76 no.2, pp. 265-281

[61] Angelo M. J. (2009), "Corn, carbon and conservation: rethinking U.S. agricultural policy in a changing global environment" ExpressO Available at: http://works.bepress.com

The intensification of production systems and subsequent loss of biodiversity is attributable to livestock activities, too. Baumung and Hoffmann (2010)[62] state that the increasing demand for animal products, due to dietary shifts, is leading to widespread settlement of (intensive) livestock, even in developing countries where, traditionally, animals were not kept for food. Widening livestock areas causes the loss of ecosystems due to land-use change, and the spread of intensive methods causes environmental depletion. More often, the adoption of intensive livestock systems has been coupled with the increasing use of cross-breeding and non-local breeds, largely coming from developed countries, at the expenses of local resources (Campbell, Noonan-Mooney, and Mulongoy (2010)[63]). Baumung and Hoffmann outline that animal genetic resources loss is happening both at a specific and sub-specific level; for instance, only four out of forty domesticated avian and mammalian species are raised worldwide. Within-breed diversity plays a key role in animal genetic conservation and, like crops, decreasing biological diversity makes livestock more sensitive to diseases.

The third issue mentioned above, soil depletion, is mainly caused by the massive employment of chemical fertilizers and pesticides. According to Tilman *et al.* (2002)[64], these practices damage the environment, as only a part of chemicals is taken up by crops, while the rest is released in the ecosystem; besides, growing resistance to pesticides generates extra need for external inputs, causing further disruption of the environment, and so on. Evidence shows that the result of this vicious cycle is a growing expenditure of farmers to buy more fertilizers, while the progressive reduction in chemicals efficiency generates decreasing yields' growth anyways. In a study on developing countries, Scherr and Yadav (1996)[65] state that this process is highly risky, since not all land degradation phenomena are reversible, at least not in the short-medium run. Without appropriate policies, land degradation due to overexploitation will

[62] Baumung R. and Hoffmann I. (2010) "Animal genetic diversity and sustainable diets" in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 82-93

[63] Campbell K., Noonan-Mooney K., Mulongoy K. J. (2010), "Biodiversity, nutrition, and human wellbeing in the context of the Convention on Biological Diversity" in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 36-43

[64] Tilman D. *et al.* (2002), "Agricultural sustainability and intensive production practices", *Nature* vol. 418, 8 August 2002, pp. 671-677

[65] Scherr S. J. and Yadav S. (1996), "Land Degradation in the Developing World: Inplications for Food, Agriculture, and the Environment to 2020", *Food, Agriculture, and the Environment Discussion Paper 14*, May 1996, Washington D.C.: International Food Policy Research Institute

constitute a serious threat to yields and food security, especially in those regions with higher population density and growing demand for food. One example of disruptive land degradation effect has occurred in the Indian state of Haryana, according to the research delivered by Singh (2000)[66]. Haryana has undergone a first process of cropland expansion, prior to the '60s, and a subsequent intensification of practices through the introduction of HYV (rice and wheat, replacing pulses, bajra, sorghum), chemicals, and irrigation facilities. Yields improved so much that Haryana, together with Punjab, came to constitute 20% of national grain production. Growing population and pressures on land has led to soil degradation and extreme climatic events, as floods and droughts, becoming more evident and worrying since the '80s.

Phenomena of environmental depletion described above represent a serious risk for future food security. The conventional model of food production has not developed in a way suitable to climate change adaptation and is proving to be vulnerable to extreme climatic events, especially in developing countries. Biodiversity loss and environmental depletion is exposing farming to diseases and external shocks, due to a lower threshold of resilience compared to that guaranteed by a healthy ecosystem. This means that the more intensive methods will be protracted, the more the environment will be endangered, and productivity may start to decline over time. Many studies report that, even though crop yields are still positive, growth rate of major cereals' yields is stuck or decreasing[67]; one example is that of Bangladesh, where the introduction of non-local HYV has first led to increasing yields, but then productivity lowered by 10% (Thrupp). Besides, high external input farming is dependent on fossil-fuel energy: declining energy sources pave the way for a possible energy shock, adding another weakness to conventional agriculture.

Boehlje and Doering (2000)[68] highlight that the industrialization of agriculture, characterized by large-scale production and standardization of management and techniques, has improved efficiency by decreasing production costs per unit of output.

[66] Singh R. B. (2000), "Environmental consequences of agricultural development: a case study from the Green Revolution state of Haryana, India", *Agriculture, Ecosystem, and Environment*, vol. 82 (2002), pp. 97-103

[67] E. g., OECD (2012), see reference list

[68] Boehlje M. and Doering O. (2000), "Farm Policy in an Industrialized Agriculture", *Journal of Agribusiness*, vol. 18 no. 1, March 2000, pp. 53-60

Yet, if we consider efficiency under a different (and wider) perspective, at least two remarks can be opposed to this statement. First, environmental depletion caused by intensive practices generates negative externalities which are not included in the costs of production and in the price of foods. Pretty (2007)[69] identifies four characteristics of such externalities: they are often neglected, occur with a certain time lag, tend to damage social groups with less participation power, and their exact sources sometimes are not known. Agribusiness companies have their interests in denying environmental drawbacks of their activities, while the fact that the worst effects are not immediately visible and/or have the main impact on under-represented groups means that policy-makers do not always take these issues as a priority. Considering the cost of negative externalities, efficiency diminishes remarkably. Pretty reports that in the UK externalities amount to £ 1,5 billion and £ 3,8 billion if transport is included, which is more than net farm income. One important problem of including externalities in the food value chain is that of evaluating them: different methodologies lead to different estimates. Second, the conventional system has been extremely favourable to big enterprises adopting monocrop intensive practices, and to farmers with access to agricultural inputs, who found extremely convenient to specialize croplands so to be able to produce more and spend less for machinery and inputs. This has often occurred at the expenses of local smallholders families that cannot afford to buy external inputs, who found themselves cut out of the food market, resulting in a higher exposure to economic shocks and a progressive loss of traditional food. Smallholders' farming still represents the most important source of income in developing countries, so that the lack of access to markets and the high competitiveness of industrial production is hindering food security, due to lower incomes. Social drawbacks of the conventional agri-food system, as poverty, social exclusion, and food insecurity, are negative externalities as well; although very difficult to translate in comparable numbers, it is intuitive that if we include social costs widening the analysis to all groups, the model is even less efficient than it seems just by looking at monetary costs on total production ratio.

[69] Pretty, J. (2007), "Agricultural sustainability: concepts, principles and evidence", *Philosophical Transactions of the Royal Society B*, vol. 363 (2008), pp. 447-465

Sustainable Food Production

Environmental concerns have generated an interest in sustainable agriculture over time; organic farming is the most famous sustainable system in developed countries, but not the only one. Pretty (2007) states that agricultural sustainability should: have no adverse effects on the environment, thus making the best use of resources available without damaging them; be accessible and effective for farmers; improve food productivity, while generating positive externalities on the environment. As a consequence, sustainable agriculture should be based on a few key principles: integration of food production with biological processes, minimization of external non-renewable inputs, exploitation of farmers' skills and knowledge, and collective working to solve common problems. What the current food production system does not take into account is that agricultural activities take place in a multifunctional ecosystem that would naturally provide for food, as well as non-food goods and services, such as pest regulation. Intensive industrial agriculture disturbs this equilibrium, as it is focused on food production only and, besides, makes use of external inputs that cause severe damages to those natural resources that commonly provide for non-food goods and services.

A research from the Barilla Center for Food and Nutrition outlines which are the most common sustainable agricultural practices[70] (the efficiency of which depends on the context where they are introduced). Traditional agriculture is based on integrated farming practices and local farmers' skills, including indigenous peoples' knowledge. Preservation farming implies a minimum or absent soil alteration (no-till farming) and crops alternation, while not excluding the use of OGM and the use of agrochemicals. This method is promoted by FAO in developing countries: in North Korea, for instance, FAO helped farmers to establish no-tillage agricultural projects with wheat-soybeans and maize-soybeans alternation; the economical analysis of the project's effectiveness outlines savings of 30-50% of production costs. Biodynamic agriculture shares with organic farming the total absence of agrochemicals, crops and livestock rotation, natural pest control; besides, it includes the preparation of plant protection and compost.

[70] Barilla Center for Food and Nutrition (2011), "*Nuovi modelli per un'agricoltura sostenibile"*, Parma: BCFN

Researchers remark the difference between *industrial* organic agriculture and organic agriculture: the first one is adopted by big transnational enterprises and is still based on monoculture intensive cropping, while the second one makes use of traditional practices and tends to encourage small farmers' activities and the consumption of local products. As the only shared feature between the two is the non-use of agrochemicals, they have to be considered completely separate models with different outcomes in terms of environmental and social sustainability. The BCFN researchers state that the participation of big enterprises to the organic sector leads small farmers to have less control on prices, resulting in a loss of competitiveness; reduced social sustainability and environmental depletion due to intensive cropping make industrial organic farming not very dissimilar from conventional farming, while the "true" organic farming is based on different principles. Other sustainable practices are: Integrated Pest Management (IPM) and integrated nutrient management, which tend to enhance the resilience for pest management and nutrient release, agro-forestry (incorporating multifunctional trees in croplands), livestock integration, aquaculture (incorporating shrimps in rice paddy).

Contrary to the conventional standardized management model, sustainable agriculture offers a wide variety of alternative practices to be adapted to the local contest; the common feature among all these methods is the holistic approach towards the ecosystem: basing on the awareness that ecosystems provide for many resources, not only food, sustainable agriculture aims at restoring those natural functions, unavoidably affected by human activities. Thus, agro-ecosystems management takes into consideration a certain variety of elements, beyond current productivity; this 360 degrees approach is the key of sustainability, because it includes the analysis of the consequences of current production practices on future productivity. Yet, as Pretty outlines, a system more coherent with natural cycles does not necessarily mean to "go back" towards a kind of agriculture that does not include technology; on the contrary, it means to go forward towards a more sustainable, efficient, and refined technology.

This implies that sustainable agriculture does not have to be extensive or low-output: it can be intensive, but the main objective is that of augmenting productivity through a sustainable intensification. The paradigm of Sustainable Crop Production

Intensification (SCPI) is defined by Murray (2010)[71] as producing more from the same area while reducing negative impacts. The research stresses the importance of an ecosystemic approach in farm management, and that implementation of sustainable intensification requires to take into account: accessibility to farmers, especially smallholders in developing countries, who would be able to reduce both spending on external inputs and environmental costs; management practices and technology suitable to the local context and to global phenomena of climate change, such as the choice of local crop varieties with high adaptability; proper public policy and institutional actions, to guarantee small farmers access to the market, provide for transport and conservation infrastructures, and improve communication technology. The outcome should be a good balance between environmental sustainability and economical profitability, to guarantee farmers' present and future food security.

Sustainable farming includes low-impact livestock, too. Oltjen and Beckett (1996)[72] have underlined the importance of ruminants in converting non-edible grass into edible proteins for humans, turning pastures and meadows into productive land. Furthermore, manure can be used as a natural soil fertilizer. Yet, ruminants' livestock is one big problem for the environment and food security, mainly for two reasons: most often, in intensive farms, animals are fed with edible grains, rather than non-edible grass, so that a wide part of the world's crop production is fed to livestock, forcing farmers to produce more and more crops; second, manure and waste from intensive livestock is difficult to manage, since soils receive an excessive quantity of nutrients, releasing them as climate changing gas. Other livestock animals have a lower impact (like pigs or poultry), but still intensive systems imply a wide use of grains and inefficient wastes management. Using non-edible grass and decreasing the environmental impact of feed-grains cultivations is a first step towards sustainable livestock. Other ways to diminish environmental impacts could be: a more efficient feed management, with reduced waste along the chain; integrated agriculture-livestock practices; animal husbandry systems. Yet, as Baumung and Hoffmann underline, consumers will play a major role. This is true for farming, too,

[71] Murray W. J. (2010), "Sustainable crop production intensification" in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 66-74

[72] Oltjen J. W. and Beckett J. L. (1996), "Role of ruminant livestock in sustainable agriculture systems", *Journal of Animal Science* vol. 74, pp. 1406-1409

but in animal livestock there are some sources of negative externalities that cannot be eliminated even through sustainable management, such as methane emissions from ruminants. In organic livestock management, for instance, cattle are fed with non-edible grass and roughage, rather than grains, and have a longer lifespan than conventional livestock, to increase cows' milk productive phase on total lifespan ratio; this leads to lower methane emissions on total lifespan, but higher methane emissions per unit of production because a higher proportion of roughage reduces cows' milk yields, while less beef meat is produced in the same amount of time than conventional livestock. One solution could be that of promoting low-input breeds, taking advantage of genetic diversity, so that low-impact forage can be used; besides, appropriate management could add non-food services to livestock activity, such as soil nutrient release in proper quantities (Baumung and Hoffmann). Yet, as researchers underline, reducing livestock impact means unavoidably to eliminate intensive systems in favour of more extensive practices; this could result in a less efficient production and higher costs for farmers, without the proper intervention of public policies. Here, the underlying problem is the growing consumption of animal products, which is occurring as a consequence of the global dietary transition, generating a much higher need for grains from intensive farming and an increasing number of animals to satisfy the global demand, in a background of land scarcity.

The success of sustainable practices in terms of environmental protection and improvements are widely recognized. FAO researchers[73] found that greenhouse gas emissions could be reduced by 20% by a conversion to organic farming or other sustainable techniques implying a total ban on chemical fertilizers. It has been previously outlined that one of the main causes for agricultural greenhouse gas release is the excess of industrial nitrogen in soils, due to the fact that only a minor part of nitrogen is absorbed by crops; one way of following natural processes in farming practices is recycling nitrogen through crop rotation and manure management, which serve as basis for all sustainable farming systems. Leguminous, for instance, are nitrogen-fixing plants and in crop rotation can be interchanged with grains, such as maize or wheat, "recharging" soils without releasing greenhouse gas. The same, manure

[73] Niggli U., Fliessbach A., Hepperly P. and Scialappa N. (2009), "Low Greenhouse Gas Agriculture: Mitigation and Adaptation Potential of Sustainable Farming Systems", FAO, April 2009, Rev. 2 - 2009

management generates a more balanced nutrient distribution; FAO researchers outline that conventional farms are dependent on external inputs, while livestock farms are subject to an excess of nutrients and soil pollution due to animal wastes: as a consequence, manure management and integrated agriculture-livestock farms would contribute to soil fertility and greenhouse gas mitigation. Besides, some practices not only release less climate changing gases, but contribute to carbon dioxide sequestering, too.

Such practices have positive externalities on biodiversity protection and soil health, too. In a study on organic farming, Hole *et al.* (2005)[74] report a comparison among 76 studies on the effects of organic practices on biodiversity: the majority of studies taken into account show a general higher species diversity in organic farming, compared to conventional ones. Even though researchers themselves outline that there are some obstacles to complete generalization of results (namely a minority of studies indicating little or no difference in biological diversity, possible methodological weak points, and lack of complete data), the overall conclusion of the research is a general benefit on biodiversity conservation of organic farming. Another accountable research maintains that organic farming[75] positively affects both farm and landscape biodiversity, and reduces agricultural environmental impacts. As explained by Altieri (1999), functional biodiversity can be effectively managed by farmers; agricultural strategies should, according to the research mentioned above, exploit natural complementarities and synergies. Agro-ecosystems are thus based on a planned biodiversity, and an associated biodiversity, i.e. organisms purposely included by farmers and organisms present in surrounding areas, subject to reciprocal conditioning. Altieri indicates traditional farming as a good model of efficiency and sustainability; this evaluation can be extended to all sustainable systems, since they are all based on the deep interconnections between agricultural production and biodiversity to reduce the need for external inputs. IPM, for instance, allows farmers to avoid chemical pesticides, while no-tillage practices avoid soil erosion and desertification by protecting strata of microhabitats. Preserving soil

[74] Hole D.G. *et al.* (2005), "Does organic farming benefit biodiversity?", *Biological conservation* vol. 122 (2005), pp. 113-130

[75] Paoletti F. (2010), "Organic farming: sustainability, biodiversity and diets" in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 254-261

structure through conservation practices is also essential to enhance soil carbon sequestration, contributing to climate change mitigation (see table below).

Table 3: Comparison of different practices' outcomes on soil carbon sequestration and yields (Source: FAO, 2009)

Components compared	Carbon gains (+) or losses (-) KG C HA-1 YR-1	Relative yields of the respective crop rotation
DOK Experiment, Research Institute FiBL and Federal Research Istitute Agroscope (Switzerland) Mäder, et al., 2002; Fliessbach, et al., 2007 - Running since 1977		
Organic, with composted farm yard manure	+ 42	83 %
Organic, with fresh farm yard manure	- 123	84 %
Integrated Production, with fresh farm yard manure and mineral fertilizer	- 84	100 %
Integrated Production, stockless, with mineral fertilizer	- 207	99 %
SADP, USDA-ARS, Beltsville, Maryland (USA) Teasdale, et al., 2007 - Running 1994 to 2002		
Organic, reduced tillage	+ 810 to + 1738	83 %
Conventional, no tillage	0	100 %
Rodale FST, Rodale Institute, Kurtztown, Pennsylvania (USA), Hepperly, et al., 2006; Pimentel, et al., 2005 - Running since 1981		
Organic, with farm yard manure	+ 1218	97 %
Organic, with legume based green manure	+ 857	92 %
Conventional	+ 217	100 %
Frick Reduced Tillage Trial, Research Institute FiBL, (Switzerland) Berner, et al., 2008 - Running since 2002		

Organic, with ploughing	0	100 %
Organic, with reduced tillage	+ 879	112 %
Scheyern Experimental Farm, University of Munich, (Germany) Rühling, et al. 2005 - Running since 1990		
Organic	+ 180	57 %
Conventional	- 120	100 %

Beyond environmental benefits, sustainable farming has many implication for rural development. Pugliese (2001)[76] points out four main elements of sustainable rural development: innovation, conservation, participation, integration; in all four areas organic farming (taken as a representative of all sustainable systems) plays a key role. Innovation is regarded as a strategic element, not only in terms of material technology, but also as organization and communication methods; organic farming is an innovative way of producing food by using available knowledge and practices in a new way and promoting high information levels. Conservation is the protection of agricultural systems' balance, including essential natural equilibriums, which is the aim of sustainable practices. Participation is defined as a key issue of rural development, which should be people-based; organic farming is considered as a tool for improving empowerment strategies, since it drives people to have a more conscious link with nature, it gives a high value to local farmers' skills and allows indigenous people to preserve and develop their knowledge. Last, integration of agricultural policies in wider policies: organic farming as a method of production can be integrated with other economic sectors, such as food marketing. Rural development and sustainable organic farming are thus linked in a multiple way and are interdependent with each other; sustainable agriculture seems to be not only a driver for environmental preservation and improvement, but also a tool for enhancing social and economic condition of rural people so to make them self-sufficient and food secure. Feenstra (2002)[77] states that

[76] Pugliese P. (2001), "Organic Farming and Sustainable Rural Development: A Multifaceted and Promising Convergence", *Sociologia Ruralis* vol 41 no. 1, January 2001, pp. 112-130

[77] Feenstra G (2002), "Creating space for sustainable food systems: lessons from the field", *Agriculture and Human Value* vol. 19 (2002), pp. 99-106

sustainable food systems can only be implemented by creating the necessary space for projects development: a social space meant both as physical areas (markets) and opportunities for intercommunity dialogue, a political space to institutionalize sustainable food systems, an intellectual space of education/training and evaluation of results, and an economic space to make the conversion profitable. In this view, local projects are appreciated as mechanisms for the development of infrastructures, body of research, social dialogue, etc.

In environmental issues small-scale and large-scale facts are closely interrelated. Gabriel *et al.* (2010)[78] provide for a comparison between organic and conventional farming in England and outline that organic farming seems to have much more positive effects on biodiversity at all scales (even though it depends on crops' types), but conclude that a wider extent of positive externalities of organic farming needs land management policies acting at the landscape level. According to Thrupp, it is a common mistake to think that a 100 % conversion to sustainable agriculture is feasible on small scale only. This study focuses on biodiversity conservation, but its conclusion may be widened to all environmental depletion phenomena. The approach of public institutions is considered as a key issue: the research outlines that policies and institutional changes have to be coordinated within and among all areas. Enhancing people's empowerment is regarded as essential, as well; this requires training, close cooperation among all protagonists, information technology, and a certain amount of time to change conventional approaches.

One huge critic to large-scale sustainable systems is related to yields levels: looking at table 3 above, it is clear that in many field studies the outcome is that sustainable farming is good for the environment but bad for production. As previously outlined, an effective model has to be profitable for farmers and producers to be applied on a large spatial and temporal scale; this is the challenge of sustainable intensification of crop production. Pimentel *et al.* (2005)[79] report that crop yields and economic benefit of conventional and organic farming may vary depending on crop, geographical region, and

[78] Gabriel D. *et al.* (2010), "Scale matters: the impact of organic farming on biodiversity at different spatial scales", *Ecology letters* vol. 13 (2010), pp. 858-869

[79] Pimentel D. *et al.* (2005), "Environmental, energetic, and economic comparison of organic and conventional farming systems", *BioScience* vol. 55 no. 7, July 2005, pp. 573-582

technology employed. Productivity field data vary consistently depending on the evaluation method; in a study on Greek organic and conventional olive farms[80], results are slightly in favour of organic farming, while in a study on organic and conventional agriculture in Finland[81], results show the opposite. Yet, in the latter study, researchers underline that in efficiency evaluations, negative externalities of the conventional production system due to environmental depletion have not been included.

Considering yields as the only indicator of a successful method may not be completely right; it is a good measure of production, but does not include all relevant factors. First of all, it must be taken into account that one weak point of the conventional system is its standardization of farm management and choices of production. For centuries Tibet has relied on a particular variety of barley typical of that climate, call tsampa, but during Mao's "leap ahead" Beijing decided to standardize all national production and wheat has replaced barley, causing disastrous results on regional production and turning a self-sufficient people to food insecurity. This is only one (very extreme) example, but it shows clearly the dynamics: most often, standardization does not allow to exploit typical local resources, so that development policies turn out to be ineffective or less efficient than expected. In the Finland study mentioned above, scholars state that lower organic farming productivity may be (at least partially) caused by the fact that not all crop varieties are suitable to local climate and soil conditions. Sustainable farming means, in first place, to take advantage of local resources by calibrating policies on regional peculiarities. FAO has stressed the significance of Globally Important Agricultural Heritage Systems (GIAHS), defined as "remarkable land use systems and landscapes which are rich in globally significant biological diversity evolving from the co-adaptation of a community with its environment and its needs and aspirations for sustainable development"[82]; GIAHS are considered as a potential benchmark for sustainable development, to be appraised both

[80] Tzouvelekas V., Pantzions C. J., Fotopoulos C. (2001), "Technical efficiency of alternative farming systems: the case of Greek organic and conventional olive-growing farms", *Food Policy* vol. 26 (2001), pp. 549-569

[81] Lansink A.O., Pietola K., Bäckman S. (2002), "Efficiency and productivity of conventional and organic farms in Finland 1994-1997", *European Review of Agricultural Economics* vol. 29 no. 1 (2002), pp. 51-65

[82] Koohafkan P. (2010), "Dynamic conservation of Globally Important Agricultural Heritage Systems: for a sustainable agriculture and rural development", in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 56-65

at a national and international level. Such practices are linked to local tradition and include all local knowledge on agriculture. One example given by Koohafkan is the rice-fish culture in China, typical of the Qingtian County, which incorporates fish into rice paddies to provide for natural fertilization, weed elimination, and microclimate regulation. Local communities in Qingtian are able to live on rice-fish cultivation, thanks to favorable policies promoted by the Chinese authorities; the local Bureau has recognized the importance of rice-fish cultivation as a sustainable practice providing for nutritious food, and as a tourism resource.

Another weak point of the conventional system, partially related to the first one, is the lack of adaptation capacity to changing conditions. Not taking advantage of what normally would grow stronger in a certain geographical region means to create a vulnerable production, much more sensitive to external shocks. In particular, the issue of climate change is getting urgent: it is a trend that, according to scientists, can be mitigated to a certain extent, but that must also be taken into account in food policies, since it may be impossible or extremely difficult to reverse it completely. Mitigation and adaptation to climate change is an essential feature of sustainable food systems that has a deep impact on food security and is not included in yields evaluations.

However, although yields growth is not the only relevant issue in production efficiency evaluation, still remains an important one. A 100% conversion to sustainable farming means that such practices will be expected to satisfy a huge demand for food by reaching a certain yield threshold. As outlined by Pretty (2009)[83], sustainable agriculture means to make the best use of genotypes available and exploiting agro-ecological condition favorable to certain breeds. In low or medium external input scenario, a key role is played by technology, the aim of which is not to push production beyond natural boundaries, but to make use of all available resources *within* environmental limits. Environmentally suitable technology makes the difference between (traditional) extensive cultivation and sustainable crop production intensification. Sustainable strategies can be enhanced via precision farming, making an important use of information technology through a variety of systems, such as GIS, GPS, and LBS.

[83] Pretty, J. (2009), "Can ecological agriculture feed nine billion people?", available at www.monthlyreview.org

Auernhammer (2001)[84] reports that electronic communication technology can be used with a mapping approach, through historical data on yield measurement and soil composition sampling, and a sensor approach, to monitor growth conditions when high yields are based on the use of agrochemicals. As well as it has been used in conventional agriculture to make an efficient use of nitrogen fertilizers, precision farming can be used in sustainable agriculture to outline local specific characteristics and related best available practices to improve yields. Auernhammer highlights the potential of precision farming to reduce environmental impacts, and calls for a greater use and development of communication and information technologies. One problem pointed out is that technology is costly for farmers; yet, Auernhammer maintains that the wider the yield gap is, the more efficient technology will be. This implies that in developing countries, where demand for food will increase and climate is usually more extreme than Europe or North America, precision farming technology would be highly efficient and could be an essential feature to close the yield gap, together with the improvement of infrastructures.

Another way of enhancing crop yields, though still controversial, is developing the applications of biotechnology to food production. Researchers from the Barilla Center for Food and Nutrition have indicated two main types of biotechnologies: GMO and non-GMO practices[85]. GMO technology works on genetic material, while non-GMO biotechnologies include a variety of practices not involving genetic manipulation, but aiming at making faster and more effective hybridation and interbreeding processes. The impact of agricultural GMO on human health and on the environment are still widely discussed. Environmental risks of GMO plantations are the potential loss of biodiversity, genetic contamination of surrounding areas, pesticides resistance, damages to flora and fauna in surrounding landscapes. Researchers underline that GMO are projected to fit into the conventional mono-cultural system and need a high quantity of chemicals to reach desired yields; moreover, GMO could further implement crops standardization, through globalization and worldwide spreading of artificial breeds. The

[84] Auernhammer H. (2001), "Precision farming – the environmental challenge", *Computers and Electronics in Agriculture* vol. 30 (2001), pp. 31-43

[85] Barilla Center for Food and Nutrition (2011), "*Oltre gli OGM. Le biotecnologie in ambito agroalimentare*", Codice Edizioni

negative perception of public opinion on such technologies, regarded as something completely unnatural and probably dangerous for human health, should also be carefully taken into account when evaluating the possibility of using them as a solution for food insecurity. Other non-GMO biotechnologies, instead, do not directly modify the genetic makeup of food, but aims at improving traditional practices of interbreeding by making use of scientific knowledge. The main objectives are to stabilize yields and close the yield gap, to enhance cultivations' resistance to pests and to climate stresses, to improve nutritional characteristics, and to provide for economic gain to farmers. One successful example mentioned by the BCFN researchers is that of the NERICA rice, created in the '90s by crossing two rice breeds which normally would hardly get mixed, to obtain a new rice variety, called NERICA, more suitable to the needs of western Africa: higher yields, more grains per unit, higher protein content. The NERICA rice is widely spread now in Africa, since it has revealed very good adaptation qualities. The main role of biotechnologies should be, on one hand, that of replacing external inputs with biological agents, and, on the other hand, to implement and fit in a new paradigm aiming at enhancing the system's resiliency and adaptation to ongoing changes. This can be possible by combining traditional knowledge, agronomy, and new technologies. In this sense, at the present moment non-GMO biotechnologies seem more suitable than GMO technologies, due to greater flexibility and diversification of practices, better consideration on behalf of the public opinion, and minor (supposed) environmental risks. Of course, all biotechnologies need to be improved; one great problem is that of anomalies hindering the whole production, that may be discovered too late to avoid serious damages to the agricultural sector. Of course, the implementation of interbreeding practices would require a careful consideration and preservation of local biodiversity.

It should be clear, however, that technology is not a solution by itself. A conversion to a dynamic sustainable agriculture poses a great challenge on policy-makers, since holistic and cross-sector coordinated policies are essential. The development of agricultural-related technology cannot disregard R&D financing and a policy on intellectual property rights that does not generate monopolistic or oligopolistic markets; local knowledge cannot be exploited without people's empowerment, while the

enhancement of yields is completely useless in poor countries without available infrastructures and markets. In a study Chinese County of Jinshan (Province of Hubei, central-western China Mainland)[86], researchers have developed a simulation model to evaluate the outcome of a long-term ecology agriculture approach in Jinshan. They have concluded that governmental policies to encourage sustainability and environmental-friendly technology availability are not enough without a proper information system and in presence of high transaction costs, underlying the vital importance of a comprehensive approach to sustainable agriculture promotion.

It has been previously outlined that yields level is often regarded as the key problem of a 100% conversion to sustainable agriculture, since food insecurity is still a problem in many countries and the world population is expected to rise. It has been said, too, that there are ways to improve sustainable agriculture yields, and that this is not a 360 degrees indicator, since sustainable practices seem to be more effective in a context of climate change and environmental vulnerability. There is another element to take into account: nowadays, a remarkable part of total food production is lost along the food chain.

Environmental impacts of the food supply chain

The complexity of food supply chains depends on the socio-economical context of each country or region; poor and early developing countries tend to have a more direct link between farmers/producers and consumers, while in industrialized and developed countries the food supply chain (FSC) is made up of several steps. On average, a complex FSC is made of: primary production, processing, packaging, transport (of both food and inputs), and retail. This process affects the environment by climate changing gas release and waste of packaging material and food. Compared to primary production, which causes nitrous oxide and methane emissions above all, in the rest of the food chain the most important greenhouse gas released is carbon dioxide, due to the use of fossil fuel energy and to refrigeration. The average impact of post farming activities, contrary to primary production, is more or less the same for every product in absolute terms, since

[86] Shi, T., Gill R. (2005), "Developing effective policies for the sustainable development of ecological agriculture in China: the case study of Jinshan County with a systems dynamics model", *Ecological Economics* vol. 53 (2005), pp. 223-246

they go through similar stages; yet, the relative weight of each node on items' total environmental impact differs depending on food groups: the relative percentage of greenhouse gas release in transport, for instance, is much higher for vegetables than for animal products, even though in absolute terms animal products have a higher environmental impact.

Processing has a relative low impact on the environment, mainly caused by energy inefficiencies. Packaging is a controversial issue: on one hand, it contributes to waste production at the end of the chain, when food is used and packages are thrown away; yet, on the other hand, it allows for a safer protection of processed food, prolonging its shelf-life and providing for nutritional information, traceability, quality standards indications. It is a foregone conclusion, to say that governmental policies aiming at promoting a conversion to green energy and encouraging the use of renewable packaging material, would avoid the problems described above. Of course, consumers have a part in this process, either by choosing non-packaged fresh food when possible, or rewarding producers that employ renewable material (and then separating wastes). Being so, climate and environmental labeling would be of significant help to empower consumers in their choice.[87]

The current food economy is extensively transport-intense: agriculture and food processing need inputs and machinery that have to be carried to farms; if not processed and packaged within the farm, food needs to be transported elsewhere; then, it needs to be brought to retailers and, finally, consumers take it home with their private cars. Even excluding the last stage, it appears quite clearly how much food is moved from one place to another, before being used. The environmental impact of transportation depends first of all on the transport mode: air freight goods have a deeper impact on the environment, but it is not very common; one way of reducing transportation impact is undoubtedly that of resorting to green energy, instead of using fossil fuels. Another element is the refrigeration needed for perishable food, which, on one hand, releases greenhouse gases, but on the other hand diminishes food waste due to bad conservation; again, improving technology and energy-saving systems would improve environmental impacts of the FSC. Last, inefficiencies can derive from high-volume

[87] Sonesson U., Davis J., and Ziegler F. (2010), see reference list

packaging, which translates into a minor quantity of product transported in terms of weight, raising the ratio of carbon dioxide per unit[88]. A general improvement of infrastructures and technology, especially in developing countries, could help mitigating the environmental depletion due to food transportation. Some scholars state that the average difference between long and short food supply chains in terms of climate changing gas emissions is not very relevant, compared to other sources of environmental depletion along the food supply chain. For instance, in a study conducted on the United States, Weber and Matthews (2008)[89] conclude that transportation as a whole counts only for about 11% of total greenhouse gas emissions in the food sector, so that a dietary shift towards less energy-intense food would be more effective in reducing environmental impacts than trying to improve food transportation. This is only partly true, mainly for two reasons. First of all, as admitted by the same researchers, data are taken on average and are hardly precise, due to an intrinsic difficulty in estimating FSC's environmental damages. Second, if improvement of food transportation takes place in the context of a wider and long-sighted reform to promote energy greening in all commercial sectors requiring long-distance movements, reduced emissions of food transport would be a part (even if a little one) of a much wider and useful change. Besides, other scholars state exactly the opposite: Garnett (2011)[90], e.g., states that the globalization of the food system causes high transport emissions, so that conversion to clean energy is one urgent strategy to reduce climate-changing gas emissions in the FSC, together with energy efficiency and resource efficiency strategies.

The retail (and consumption) stage has a limited impact in terms of emissions, but presents another important issue: food wastage. FAO delineates food wastage as a notion covering both food waste and loss; while the former is defined as "the decrease in edible food mass at the production, post-harvest, processing, and distribution stages in the food supply chain" (caused by inefficiencies), the latter is identified as "food which is fit for consumption being discarded, usually at retail and consumer level" (resulting from a food culture spread especially in the developed world, where food waste is more

[88] *Ibidem*

[89] Weber, C. L. , and Matthews H. S. (2008), "Food-Miles and the Relative Climate Impacts of Food Choices in the United States", *Environmental Science and Technology* vol. 40 no. 10 (2008), pp. 3508-3513

[90] Garnett, T. (2011), "Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)?", *Food Policy* vol. 36 (2011), pp. S23-S32

affordable)[91]. Parfitt, Barthel and Macnaughton (2010)[92] outline three main drivers for food wastage: urbanization, dietary transition, and globalization of trade. Urbanization, with a subsequent reduction of people living and working in farms, has generated the need for more complex food supply chains to feed urban population, creating more space for food loss and waste. At the same time, rising household incomes have led people in developed and developing countries to prefer perishable foods (included animal products), with a greater risk of wastage. Last, globalization increases export opportunities and has favored the establishment, even in less developed countries, of supermarkets as the main vehicle for food provision: huge quantities of food imported to fill shelves are often thrown away due to inefficiencies in conservation systems or simply to overproduction. Generally speaking, food wastage in poor countries is mainly due to the lack of proper infrastructures and technology, while wastage in developed regions is due to a cultural shift that turned food into a simple always-available-commodity in consumers' minds. Although there is no consensus on food wastage data, it is considered a severe inefficiency of the current food system: not only there is an intrinsic paradox in a chain where some potential consumers starve, while food is thrown away somewhere else, but wastage means that greenhouse gas emissions needed to produce that food have been, as a matter of fact, a useless damage to the environment. It has to be mentioned, too, that food wastage is stocked in landfills, with all subsequent issues. One further consideration can be made: going back to yields growth, it would be much more efficient to produce, for instance, 70% instead of 100%, with zero food wastage, than producing 100% with 30% of food wastage along the chain. In other words, a complete conversion of conventional to sustainable farming is tightly linked to the development of an efficient and sustainable food chain.

A sustainable food supply chain must respond to environmental, social, energetic, and economic sustainability criteria. There are many schools of thought maintaining a dichotomy between local (sustainable) production, with a short food chain, and

[91] FAO (2011), *Food wastage footprint*, concept note, March 2012, internet: http://www.fao.org/ (consulted on July, 31th, 2013)

[92] Parfitt J., Barthel M., Macnaughton S. (2010), "Food waste within food supply chains: quantification and potential for change", *Philosophical Transactions of the Royal Society B* vol. 365 (2010), pp. 3065-3081

imported (unsustainable) food. As outlined by Smith (2008)[93], local production is generally evaluated as more sustainable, since it supports organic food methods, causes lower emissions due to transportation, and enhances rural economy. Although sometimes local food systems are not always as sustainable as we might think[94], it may be said that local systems employing sustainable methods and traditional knowledge *are* sustainable, especially in that they help local economy development. Yet, Smith points out that imported food provides for a dietary variety, which benefits consumers in terms of healthy eating and nutrients intake. Imported food does not necessarily come from huge, conventional, and environment-depleting agri-business farms, but may come from small- and medium-farmers who exploit export opportunities to improve their income. Even fair trade companies make use of such chains. This is to say that, although wider food chains are, to a certain extent, less verifiable, and tend to create oligopolistic markets hindering local production, not *all* imported or long-distance food is bad and unsustainable. Here, Governments, International Organization and NGOs play a key role in implementing effective policies to develop consumers' value for sustainability and healthy eating, to promote a market competitiveness based on sustainability and quality, rather than lower prices, and to stem the superpower of agribusiness lobbies in affecting policies and food prices.

[93] Smith, B. G. (2008), "Developing sustainable food supply chains", *Philosophical Transaction of the Royal Society B* vol. 363 (2008), pp. 849-861

[94] See, for instance, Ilbery B. and Maye D. (2005), "Food supply chains and sustainability: evidence from specialist food producers in the Scottish/English borders", *Land Use Policy* vol. 22 (2005), pp. 332-344

Food Consumption: Healthy and Sustainable Diets

Until this point we have focused on the food supply chain (in particular the production stage) to outline the main issues that nowadays constitute a challenge to environmental sustainability in agriculture and food production. Agricultural policies and on-farm choices (low-impact agricultural systems, for instance) account for one part of the story; in this section, the analysis will shift from the producers' to the consumers' side. The change in dietary habits connected to urbanization, globalization, and economic growth are having an impact on the environment, due to the conventional food supply paradigm and the increase in energy-dense food consumption, but is also affecting our health in several ways. Firstly, the critical concerns of the dietary transition will be analyzed; then, the idea of sustainable diets and its significance for the environment and our health will be presented; later on, some models of sustainable diets will be examined.

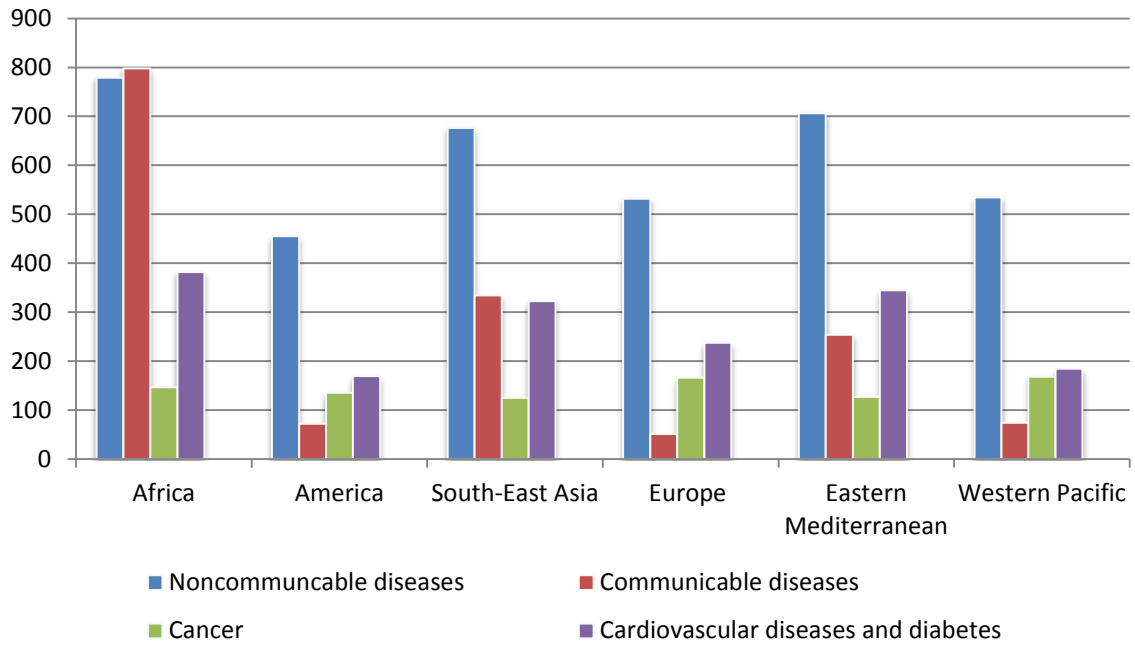
Critical Issues in Current Dietary Habits

In the first section, among the ongoing global trends, the nutrition transition has been examined: it consists of a general change in dietary habits towards the North American diet, augmentation of the Body Mass Index (BMI, a weight-height ratio), and decreasing physical activity. In particular, it can be noticed a remarkable increase in the consumption of processed food, animal foods, animal fats, sugars, and vegetable oils. One important characteristic of the twentieth century is the dramatic increase of life expectancy at birth; yet, a longer lifespan does not necessarily imply an equivalent improvement in average health conditions. On the contrary, we are witnessing a greater lifespan-healthspan gap: in other words, medicine can keep people alive, but a remarkable part of an individual's life is negatively affected by the incidence of some chronic illnesses. In 2012, for the first time in history, the global burden of diseases due to overnutrition has outreached the burden of undernutrition-related diseases; children

undernutrition is currently estimated to be the eighth global mortality risk factor, well below hypertension, high BMI, and hyperglycemia[95].

As shown by fig. 11 below, non-communicable diseases, cancer, CVD (cardiovascular diseases) and diabetes have become more relevant in affecting mortality rates than communicable diseases in all regions, including Africa, where the burden of communicable diseases is still much higher than all other regions. FAO and the World Health Organization state that the export of the western diet through the global market is causing an increasing epidemic of dietary-related non-communicable diseases (DR-NCD or "diseases of affluence") [96]. This process is known as epidemiologic transition, and is happening at a particular high speed in lower- and middle-income countries, according to Popkin and Gordon-Larsen (2004)[97].

Fig. 11: Cause-specific mortality rate per 100.000 population (Source: WHO, 2008)



An example of the epidemiologic transition can be observed in China, where market liberalization reforms promoted by Deng Xiaoping opened the borders to western products, foods and lifestyles. The economic growth has allowed China to fight

[95] Fronte M. (2013), "Il cibo come vettore di salute", in *Food for Health*, April 2013

[96] Joint WHO-FAO Experts Consultation (2003), *Diet, Nutrition, and the Prevention of Chronic Diseases*, WHO Technical Report Series no. 916, Geneva 2003

[97] Popkin B. M. and Gordon-Larsen P. (2004), "The nutrition transition: worldwide obesity and their determinants", *International Journal of Obesity* vol. 28 (2004), pp. S2-S9

effectively against undernutrition, making people able to increase high-quality nutrients intake in both urban and rural areas, by eating more animal products, edible oils, fruits and vegetables; yet, especially in urban areas, a rapid nutrition transition has gone underway, so that Chinese people's diet now often includes an excessive consumption of animal source foods and vegetable fats[98]. Yang, G. *et al.* (2008)[99] maintain that changing mortality patterns in China are due to two main elements: ageing population, so that causes of death are more associated with old age, and increase in high-risk behaviours, due to the nutrition transition. These scholars state that China has already completed the transition, since official data show that in 2000 82,9% of deaths were caused by DR-NCD, and risk factors are widely spreading among the youngsters: 18% of 15 years old teenagers suffer from hypertension, 18,9% of 18 years old teenagers are overweight, while 2,9% are obese. Besides, Popkin[100] states that negative consequence of bad dietary habits in Asian people seem to occur at a lower BMI than western people. Many other developing countries are showing the same fast-rising trend: in Thailand, for instance, the consumption of processed food is affecting the traditional Thai cuisine, based on rice and fish, so that obesity is increasing in all age groups and DR-NCD have become the major causes of death in the country[101]; in a research on India, Misra *et al.* (2011)[102] have observed that not only non-communicable diseases are becoming a challenge for the national public health, being India the country where diabete is most spread among the population, but have also found out that the epidemiologic transition is deeply affecting rural areas, contrary to previous beliefs according to which rural areas were much less affected than cities.

The main symptom of the global epidemiologic transition is the sharp rise of obesity and overweight population percentage. Overweight itself is not a real disease, but is an important risk factor that could lead to other chronic illnesses, like diabetes. On the contrary, obesity (BMI>30, according to the WHO) is both a risk factor for other

[98] Zhai F. *et al*. (2009), "Prospective study on nutrition transition in China", *Nutrition Reviews* vol. 67, suppl. 1, pp. S 56-S61

[99] Yang G. *et al.* (2008), "Emergence of chronic non-communicable diseases in China", *Lancet* vol. 372, November 8th, 2008, pp. 1697-1705

[100] Popkin B. M. (2004), see reference list

[101] Kosulwat V. (2002), "The nutrition and health transition in Thailand", *Public Health Nutrition* vol. 5 no. 1A, pp. 183-189

[102] Misra A. *et al.* (2011), "Nutrition transition in India: secular trends in dietary intake and their relationship to diet-related non-communicable diseases", *Journal of Diabetes*, vol. 3 (2011), pp. 278-282

pathologies and a pathology itself, connected to several body dysfunctions. The increase in obese population percentage is developing differently in each country, but three main characteristics can be identified[103]: first of all, it is undoubtedly a global problem, so that the neologism "*globesity*" has been created to describe this widespread issue[104]; secondly, it is growing especially in lower- and middle-income countries; last, the burden of obesity is shifting on the poor, coherently with the dynamics of the nutrition transition. Country-specific studies show that obesity rates vary according to social groups, age, and gender. In the USA, the percentage is higher for Afroamerican and Hispanic people, while in Canada some Arctic Indigenous People (Yukan and Inuit in particular) suffer from higher obesity percentages than the average Canadian population[105]. Obesity and overweight are the most evident result of the dietary shift: Western dietary habits lead to the ingestion of the so-called "empty calories": high energy-dense foods which provide for an excess of some macronutrients, namely fats and animal proteins, while causing a deficiency of micronutrients, like vitamins. Together with Western foods, developing countries have often imported Western lifestyles, resulting in less physical activity and more "casual" and processed meals, consumed out of home at irregular times, rich in edible oils and fats. Usually, especially in adults, obesity is a part of a general pathologic condition known as metabolic dysfunction, caused by and favoring an excessive accumulation of body fat, which may include hypercholesterolemia, hypertension, CVD, diabetes.

Beyond obesity, NR-NCD are diabetes, cardiovascular diseases, and some forms of cancer. The incidence of both type 1 diabete (an autoimmune disease, the body cannot produce the right amount of insulin) and type 2 (insulin-resistance, dysfunction in the use of insulin) keeps rising, especially the latter, which is tightly connected to diet and physical activity; the world average incidence of diabetes has been estimated at 6% [106], 90% of which is type 2 diabetes[107]. Cardio-vascular diseases are estimated to account for 30% of deaths in the world; CVD and heart diseases are typical of societies with a long

[103] Popkin B. M. and Gordon-Larsen P. (2004), see reference list

[104] Boscolo M. (2013), "Globesity: i costi sociali dell'obesità in un mondo più longevo", in *Food for Health*, April 2013

[105] Kuhnlein H. V. *et al.* (2004), see reference list

[106] All data presented in this paragraph (except when other sources are specified) are taken from Barilla Center for Food and Nutrition (2012), see reference list

[107] WHO (2013), internet: http://www.who.int (consulted on August 16th, 2013)

life expectancy, as they are more likely to develop later on in an individual's life. There is widespread agreement in literature on potential benefits of a balanced diet and body weight control to prevent diabetes and CVD: Puska (2002)[108], for instance, states that 90% of type 2 diabetes cases could be prevented, and that a proper diet can also reduce the need for drugs use against risk factors. Some cancers are dietary-related as well, in particular breast, prostate, and colorectal cancer. Bad dietary habits, connected to overweight or obesity, are the second main risk factor, further than smoke, affecting malignant cells' development. Beyond diabetes, CVD, and cancer, osteoporosis and some neurodegenerative illnesses have been put in a close relation with dietary styles. Losses or diminished absorption of Ca and vitamin D, which is the main cause for osteoporosis, is affected by the way we eat, not only due to a low amount of micronutrients intake, but also to the fact that micronutrients absorption in our body depends on several dietary-related elements[109]. Alzheimer, Parkinson, and other forms of senile dementia have been connected to micronutrients deficiencies like magnesium, vitamin E, vitamin C, etc. Furthermore, Kalmijn *et al.* (1997) have demonstrated the correlation between CVD and senile dementia[110]; high intake of fats and low intake of micronutrients are a major cause for CVD, which in turn seem to be risk factors for the insurgence of Alzheimer and senile dementia in old age, while hypercholesterolemia seems to have even a more direct effect on neurodegenerative pathologies.

One more dietary-related issue on health must be taken into account: those agrochemicals used in conventional agriculture are absorbed by plants and may enter the human body through diet. Pesticides, in particular, can enter our body via food and contaminated air and water; epidemiological studies have observed a significant

[108] Puska P. (2002), "Nutrition and global prevention on non-communicable diseases", *Asia Pacific Journal of Clinical Nutrition*, vol. 11(Suppl), pp. S755-S758

[109] Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Food and Nutrition Board (1999), "Dietary reference intakes for calcium, phosphorus, magnesium, vitamin D, and fluoride", Institute of Medicine, Washington, DC, National Academy Press

[110] Kalmijn S. *et al*. (1997), "Dietary fat intake and the risk of incident dementia in the Rotterdam Study", *Annals of Neurology* vol. 42, no. 5, pp. 776-782

association between pesticides exposure and some diseases, namely immunodeficiency, cancer, dysfunctions of the nervous, endocrinal and reproductive systems[111].

Healthy diets, sustainable diets

This general overview on the most widespread dietary-related non-communicable diseases aims at pointing out how much dietary styles can affect health; sometimes this close correlation is not perceived by people because most often the insurgence of such pathologies comes after years of (alleged) good health, when the body starts to collapse because of protracted bad habits. The vast majority of literature on the nutrition transition agrees on considering responsible western dietary styles for the remarkable incidence of DR-NCD, thus the suggested healthier diet should include a reduced consumption of animal and vegetable fats, sugars and sweeteners, and animal source foods, especially dairy and red meat[112].

HEALTHY DIETS

Many studies on the issue have focused on the increased consumption of meat, mainly for two reasons: it is the major feature of the nutrition transition, and cattle livestock is considered the most environmentally critical production in farm activities. Avoiding an extra consumption of meat in affluent societies would lead to minor risk factors for DR-NCD and a decrease in the potential human contact with infectious pathogens developed by animals and quickly spreading in intensive farms (like the H1N1 syndrome)[113]. The most "extreme" positions on the subject state that not consuming meat and animal products at all would be the best choice for the human body. If, on one hand, some studies have proven that vegetarians and vegans are less subject to certain diseases, e. g. lung cancer[114], on the other there may be a risk of insufficient intake of certain micronutrients (like Fe) not only in developing countries, where animal products are an important resource to fight against undernutrition, but also in affluent

[111] Horrigan L., Lawrence R. S., Walker P. (2002), "How Sustainable Agriculture Can Address the environmental and Human Health Harms of Industrial Agriculture", *Environmental Health Perspectives* vol. 110 no. 5, pp. 445-456

[112] Barilla Center for Food and Nutrition (2011), see reference list

[113] McMichael A. J. *et al.* (2007), Food, livestock production, energy, climate change, and health", *The Lancet*, vol. 30 (9594): 1253-1263

[114] Horrigan L., Lawrence R. S., Walker P. (2002), see above

societies[115]. One very famous and comprehensive study about the correlation between animal proteins and diseases of affluence is *The China Study*[116], a statistical analysis on China and Taiwan rural diets, compared with the previous literature on the health harms of the North-American diet. The main conclusion of this research is that meat and animal source foods are the main cause for DR-NCD, thus the key for a long and healthy life is eliminating them completely. While the previous literature has established a correlation between affluence diseases and "western food", which implies not only animal source food, but also sugars, vegetable oils and processed foods, *The China study* focuses on animal proteins only, aiming at demonstrating the same significant correlation. Although this research has an important value, in that it provides for a stunning width of data and summarizes the most important nutrition studies, the scientific community has moved several critics. Mainly, the value of some reference studies and their interpretation has been questioned, together with the interpretation and presentation of data on significant and non-significant correlations; besides, it has been said, too, that the study does not take into account some contrasting evidence from other country-studies, so that its conclusions cannot be accounted as universally scientifically compelling. On the whole, while there are interesting evaluations, *The China study* cannot be taken as a scientific evidence of the undeniable elixir of life-nature of vegan and vegetarian diets.

SUSTAINABLE DIETS

Once having sketched out what kind of choices would make diets healthier, it has to be outlined that not all healthy food combinations are also sustainable at the same time; Gussow and Clancy (1986)[117] have been the first to suggest that dietary guidelines provided by the Ministry of Health should take sustainability into account, opening a debate on the role of sustainability in nutrition issues. In the definition accepted by FAO, sustainable diets are "*those diets with low environmental impacts which contribute to*

[115] Macdiarmid J. I. *et al*. (2012), "Sustainable diets for the future: can we contribute to reducing greenhouse gas emissions by eating a healthy diet?", *American Journal of Clinical Nutrition* vol. 96, pp. 632-639

[116] Campbell T. C. and Campbell T. M. (2006), "*The China study: the most comprehensive study of nutrition ever conducted and the startling implications for diet, weight loss, and long-term health*", Dallas: BenBella Books, Inc.

[117] Gussow J. D., Clancy K, (1986), "Dietary guidelines for sustainability", *Journal of Nutritional Education* vol. 18, 1986, pp. 1-4

food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystem, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources"[118]. It is a wide definition, comprising environmental, social, and economic sustainability, and including even nutrition qualities, so that it reaffirms the unquestionable relation between human health and the health of the environment .

The way food and ecosystems are connected has been analyzed by different perspectives over time; Garnett (2013)[119] provides for an interesting categorization of studies on sustainable food security, separating them in three main perspectives, not by chronological order but by what/who receives more importance: efficiency-oriented, demand restraint, and food system transformation approach. In the first class of studies the focus is on food supply and the need to improve technology and managerial skills to enhance the efficiency of the production system, using the LCA analysis to point out where we have to intervene along the chain. The demand for food itself is not questioned, while the aim of these researches is that of ensuring everyone an affluent lifestyle without damaging ecosystems. Here, food security is identified with the quantity of food available, while nutrition is affected by a change in the products provided, not in the consumers' choices. In the second perspective, demand restraint, the burden is shifted on the consumers, who are charged with all the responsibility for environmental degradation connected to food production. Excessive consumption is seen as the key problem and the LCA analysis is used to outline how consumption styles affect the environment and which are the opportunity costs of the alternatives. The third set of studies has a more integrated vision, focusing on the whole food system; it is an enlarged perspective that catches the imbalances of a global food system where there is both nutrients excess and insufficiencies. Thus, environmental sustainability can be achieved through structural changes, in which the LCA approach has a limited utility, if not coordinated with an analysis of the socio-economic background. In this holistic

[118] International Scientific Symposium (2010), "*Biodiversity and sustainable diets united against hunger – Final document*", 3-5 November 2010, FAO Headquarters in Rome

[119] Garnett T. (2013), "Three perspectives on sustainable food security: efficiency, demand restraint, food system transformation. What role for LCA?", *Journal of Cleaner Production*, doi: 10.1016/j.jclepro.2013.07.045

approach sustainability is not only environmental, but also social end economical, and food security is evaluated in terms of quantity of food, as well as stability, access, and utilization. The definition of sustainable diets adopted by FAO may be more reflective of the third perspective. However, as the author underlines, the three approaches are not completely separated, even though different stakeholders may adopt different perspectives; shifting the focus from one issue to the other allows for a deeper analysis of topics and trade-offs of the food chain.

Undoubtedly, the connection between food choices of the consumer and his/her health status is a direct one: there are foods which are known to be unhealthy; taking on the consumer's perspective, especially in affluent countries, there is a wide range of alternatives among which people, provided with necessary information, can pick the healthiest and most environmentally sound one. According to Macdiarmid (2012)[120], the key to both people and ecosystems benefit is twofold: reduced overconsumption and reduced meat and dairy intake. Overconsumption is considered by some scholars as a form of food waste, since it implies an unnecessary use of food; reducing the overall energy intake would diminish damages to the body caused by the accumulation of fat and, at the same time, rebalancing the demand for food on real needs. However, it is underlined as well that positive effects of per capita consumption on the environment depends heavily on *what* is eaten, not only *how much*: high-protein diets, for instance, may have a reduced caloric intake, but a high environmental impact due to the consumption of animal source products. Besides, animal fats and creams eliminated during the production process to obtain less energy-dense foods pose a dilemma on whether wasting these resources or reintroducing them in the food chain by using them in the production of processed foods, thus counterbalancing the consumers' choice for low-fat foods.

The excessive consumption of meat and dairy products is typical of affluent societies and leads most often to a disproportionate intake of calories per day, particularly in the form of proteins and animal fats. Its reduction, besides being difficult in the short run, presents some hard issues to consider: the result in terms of health benefits and

[120] Macdiarmid J. I. (2012), "Is a healthy diet an environmentally sustainable diet?", *Proceedings of the Nutrition Society*, vol. 72, 2013, pp. 13-20

environmental improvements depends on how these calories are replaced. Macdiarmid highlights several options: one is that there is no replacement, so that overconsumption is diminished by reducing animal source foods intake; another option, very risky, is that meat calories are replaced with added sugars, which have a lower impact on the environment but disastrous consequences on the organism; fruits, vegetables and legumes may provide for nutrients, but they would be demanded in higher quantity, so that the overall result on land degradation, soil, air and water pollution may not be as good as expected; another option is replacing land livestock meat with fish, which is a low-fat source of proteins and micronutrients, but this would pose a problem of overexploitation of sea resources and pollution due to fish livestock.

Stehfest *et al*. (2009)[121] have evaluated the environmental impact in terms of land use and climate changing gas emissions on four possible shifts in dietary habits, compared with a business-as-usual scenario. In the first three hypotheses, namely complete substitution of meat from ruminants, complete substitution of all meat, and complete substitution of all animal products, the simulation has shown a reduction in cropland area, due to a decrease in feed crops much more pronounced than the increase in food crops; besides, a consistent reduction in greenhouse gas emissions has been observed, especially in the third scenario. In the fourth case, that of a healthy diet with no complete substitution of meat and/or animal products, the positive impact on emissions and land was smaller than the other three options, but still significant, with a 10% reduction in climate changing gas emissions. The conclusion is that a change in dietary patterns can be effective in mitigating environmental depletion, although there are some sources of uncertainties in the model presented.

However, meat and dairy products are not the only products causing heavy environmental depletion. To go back to vegetarian and vegan diets, they may present several advantages, like a reduction in feed-grains production and lower emissions, but, in a background of conventional production practices, fossil fuels and agrochemicals employed in the raise of vegetables and fruits make this consumption style not

[121] Stehfest E. *et al.* (2009), "Climate benefits of changing diet", *Climate Change* vol. 95, 2009, pp. 83-102

sustainable in the long term as much as a meat-based diet[122]. Vegetarian meals are not necessarily less polluting than animal meals[123]; Reijnders and Soret (2003)[124] state that meals based on organic meat have a clear advantage in terms of lower impacts, compared to vegetarian/vegan products from intensive agriculture, high in fossil fuel use. Thus, vegetarian and vegan alternative food consumption are not necessary more healthy and more environmentally sound than omnivore diets. However, if we assume that the consumer turning to vegetarianism or veganism, whether for health or ethical reasons or both, is better informed than the average on these issues, so that his/her entire lifestyle is healthier and more "environmental-friendly", then this dietary choice may be a real index of considerable lower per capita impacts. Yet, the existence of a significant correlation between vegetarianism/veganism and awareness of individuals should be investigated in further studies.

Not all diets recommended as healthy by official standards of national and international institutions are sustainable, and a wider variety of foods available to the consumer seem to occur lowering the possibilities of reduction in polluting emissions[125]. Yet, basing on the calculation of the ecological footprint of key foodstuffs per each food type, BCFN researchers[126] have outlined a close inverse correlation between healthiness and environmental impact of products, developing an "environmental guide (reversed) pyramid", diametrically opposite to the food guide pyramid used as a visual representation of what medicine and nutrition science consider a healthy diet. The overall result is that those foods "protagonists" of the nutrition transition are recommended in lower quantities because of both health and environmental issues. The same conclusion is reached by a quantitative study on the EU[127]: since current food production makes for 31% of total global warming potential in the EU, a shift towards healthier diets would significantly improve environmental benefits. Moreover, the

[122] Pimentel D. and Pimentel M. (2003), "Sustainability of meat-based and plant-based diets and the environment", *American Journal of Clinical Nutrition* vol. 78 (Suppl.), 2003, pp. 660S-663S

[123] Carlsson-Kanyama A. (1998), "Climate change and dietary choices — how can emissions of greenhouse gases from food consumption be reduced?", *Food Policy* vol. 23 no. 3/4, pp. 277-293

[124] Reijnders L. and Soret S. (2003), "Quantification of the environmental impact of different dietary protein choices", *American Journal of Clinical Nutrition* vol. 78 (Suppl.), 2003, pp. 664S-668S

[125] Macdiarmid J. I. *et al.* (2012), see reference list

[126] Barilla Center for Food and Nutrition (2011), see reference list

[127] Wolf O. *et al.* (2011), "Do healthy diets in Europe matter to the environment? A quantitative analysis", *Journal of Policy Modeling* vol. 33, 2011, pp. 8-28

research shows that a change in the demand structure would affect livestock production: a decrease in demand could lower prices within the EU, reducing domestic production and fostering export, while shifting the supply system towards more extensive livestock practices[128].

However, in a research based on the LCA approach and applied on the USA, Duchin (2005)[129], while highlighting all mentioned benefits from the reduction in western foods consumption, points out that trade-offs on different dietary choices can only be dealt with by rethinking farming policies, modifying the system of prices and income support that has been established in the USA during the '30s to favor industrial agriculture. Wallén, Brandt and Wennersten (2004)[130] underline, too, that although consumption is a key issue in sustainable diets, the consumer has a limited power to choose environmentally sound products if the whole production system (or the vast majority of it) is based on fossil energy and unsustainable practices.

Lairon (2010)[131] provides for a vision of sustainable diets extremely focused on the production system: the urgent need for sustainable diets can be met by developing low-input agro-ecological food systems that should preserve local networks and cultural heritage. As shown in the previous chapter, production methods and proceedings along the food chain do have an impact, especially if there are more sustainable alternatives that can be developed using available knowledge and actual technology. The paradox of the spreading Western dietary habits is that, under a certain perspective, Western foods provide for an improved variety of nutrients available, especially animal proteins; on the other side, nutritional diversity is restricted by the standardization of production systems, which threatens local biodiversity and food culture.

[128] *Ibidem*

[129] Duchin F. (2005), "Sustainable consumption of food – A framework for analyzing scenarios about change in diets", *Journal of Industrial Ecology* vol. 9 no. 1-2, pp. 99-114

[130] Wallén A., Brandt N., Wennersten R. (2004), "Does the Swedish consumer's choice of food influence greenhouse gas emissions?", *Environmental Science and Policy* vol. 7, 2004, pp. 525-535

[131] Lairon D. (2010), "Biodiversity and sustainable nutrition with a food-based approach", in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 30-35

The nutrition transition implies global market dynamics which are altering traditional cropping systems and changes in land use, thus eroding local crops cultivation[132]. Biodiversity, beyond being essential for agro-ecosystems, is a source of nutritional diversity and, as a consequence, healthiness of nutrition habits are deeply hindered by dietary simplification[133]. For this reason, traditional and indigenous foods are being re-evaluated as a potential source of diversity, to be enhanced by knowledge and technology. One example is the set of initiatives promoted in favour of underutilized plant species with high nutrition qualities, which characterize many traditional diets. The aim is that of preserving rare species seeds from disappearance, as well as keeping track of the ancient knowledge needed to exploit properly these resources. To do this, plant conservation is promoted both *in situ* (conservation-through-use), via the implementation of local cultivations (especially in developing countries and among Indigenous People), and *ex-situ* seed banking (Millennium Seed Bank Partnership), to protect genetic material and germination protocols[134].

SOCIO-ECONOMIC SUSTAINABILITY

While part of the definition of sustainable diets provided by FAO is referred to environmental sustainability, this idea includes elements of socio-economic sustainability ("*Sustainable diets are […] culturally acceptable, accessible, economically fair and affordable; […] while optimizing natural and human resources*"). Although the present work is intended to focus on environmental issues, when investigating sustainable diets there are some other aspects that cannot be neglected.

It is broadly evident that the current world food system presents striking inequalities; there is a strong difference in food accessibility and stability among countries and social groups. Although in recent years inequalities in food availability seem to have decreased, Africa and Asia are still the regions mostly affected by food

[132] Johns P. and Eyzaguirre P. (2006), "Linking biodiversity, diet and health in policy and practice", *Proceedings of the Nutrition Society* vol. 65, 2006, pp. 182-189

[133] *Ibidem*

[134] Gold K. and McBurney R. P. H. (2010), "Conservation of plant diversity for sustainable diets", in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 108-114

insecurity [135], mainly due to low income levels and lack of infrastructures. Divergences in income levels lead to inequalities in terms of both calories per capita and quality of food consumed.

In developing countries, opportunities offered by the green revolution and the globalization of food chains have had controversial impacts on rural poverty. It has already been mentioned that long-distance food chains have a limited impact on the environment, if compared with environmental damages caused during the production and processing phases; yet, long-distance food chains do have an impact on local development of smallholders' activities, which are often undermined by large scale markets. To explain the dynamics of rural poverty, an example could serve well: a small farmer in a developing country who wishes to sell his products in the closest urban center has to bring food from the country to the city, but without proper infrastructures (good transportation networks and refrigeration facilities) this procedure becomes long, complicated and costly, while part of the product may decay, if perishable. As a result, the farmer is forced to raise prices, and even though he sells high-quality food, he will never be competitive with supermarkets, which are spreading even in least developed countries, so that his income would be rather low. In the end, the farmer may not afford to guarantee food security and basic services to his own family, and may not afford, as well, to benefit from the green revolution technologies or simply to improve private transportation facilities. This vicious cycle determines a continuative state of poverty that cannot be broken just by leaving international markets "free" to follow their "internal" dynamics. On the other side, globalization of food markets has brought some advantages to rural people through fair trade and local cooperatives projects. Local production provides for labour and increased expertise, while generating further economic activities connected to the food sector[136].

One severe consequence of rural poverty is the loss of traditional food cultures that have been part of a community for centuries; this could happen because of national or local policies favoring modern practices and thus suffocating traditional methods, or

[135] White T. (2000), "Diet and the distribution of environmental impact", *Ecological Economics* vol.34 no.234, pp. 145-153

[136] Videira N. *et al.* (2012), "Background paper on sustainable food consumption and growth", *First multinational knowledge brokerage event on sustainable food consumption*, 25-27 January 2012, Lisbon

because of massive rural-urban migration, so that there is practically no new generation to receive past knowledge on traditional food and farming. It has been particularly the case of many Indigenous People, who have suffered for decades from the lack of political representation in any State and, as a consequence, could not take advantage of policies specifically targeted for their needs. The protection of cultural diversity is a mean of protecting biodiversity, identities, and perpetrating traditional methods that, enhanced by technology and further knowledge, could turn useful to adapt food production to climate change and resource scarcity. Cultures that have survived for centuries, harmonizing their activities with natural cycles, have undoubtedly proven to have developed a healthy and sustainable food system [137]. Unfortunately, Indigenous People and rural communities are often the most food insecure groups.

Unequal incomes generate not only food insecurity in terms of food quantity, but reflects also on the quality of food purchased. Reisch, Eberle and Lorek (2013)[138] observe that there is a "*bifurcation process*" going on, according to which the nutrition transition is causing a clear separation among high-income social groups buying healthy and costly food, and lower income groups consuming mainly processed cheap food. Thus, in many contexts, especially urban ones, poverty does not imply lower calories intake (not only, at least), but is increasingly appearing as the consumption of high quantities of "empty calories". As a consequence, income inequalities are causing health inequalities, and a paradox visible in developed and rapidly developing countries: the diseases of affluence described above are increasingly affecting lower income groups. These dynamics may explain why, for instance, Arctic Indigenous People have shown higher obesity rates than the average Canadian population[139].

Besides, White[140] points out that dietary inequalities generate heavy differences in environmental impacts due to food consumption. Environmental impact inequalities seem to be much more pronounced than income divergences across the world's regions,

[137] Kuhnlein H. V. (2010), " Biodiversity and sustainability of Indigenous Peoples' foods and diets", in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 118-124

[138] Reisch L., Eberle U., Lorek S. (2013), " Sustainable food consumption: an overview of contemporary issues and policies", *Sustainability: Science, Practice, and Policy* vol. 9 no. 2, summer 2013, available at: http://sspp.proquest.com/

[139] Kuhnlein H. V. *et al.* (2004), see reference list

[140] White T. (2000), see above

so that developed countries consumption styles (which still score the higher absolute consumption in energy-dense foods) have a much heavier impact on the environment than developing countries, though their rates are increasing due to the nutrition transition. Consequently, there is a strong claim that advanced countries should take on their responsibilities in environmental diplomacy, since the environmental disruption that is harming the Planet (and peripheral areas in particular) is mostly due to their consumption styles, in terms of food and wider habits.

FINANCIAL SUSTAINABILITY

One more issue related to sustainable diet that has to be mention, and is sometimes underestimated in its importance, is the financial burden of health care and, in particular, NR-NCD.

WHO data (see fig. 12 and 13 below) show a global increase in health expenditure, both in terms of GDP percentage and as total per capita expenditure, with the highest percentage variation in the Western Pacific, South East Asia, and Eastern Mediterranean, i. e. the most rapidly developing countries.

Fig. 12: Total expenditure on health as a percentage of GDP (Source: WHO, 2012)

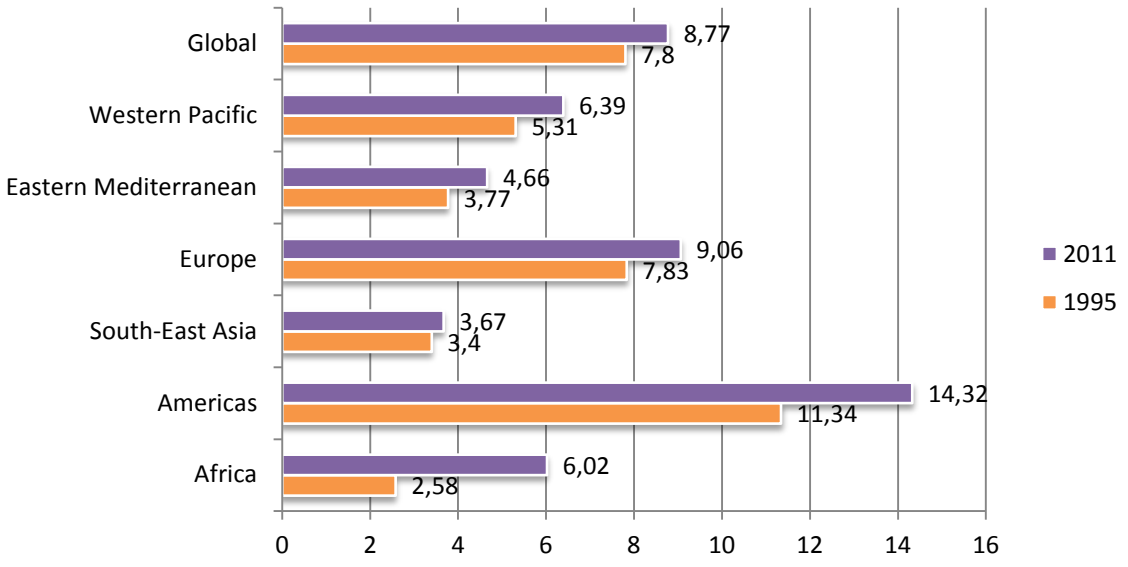
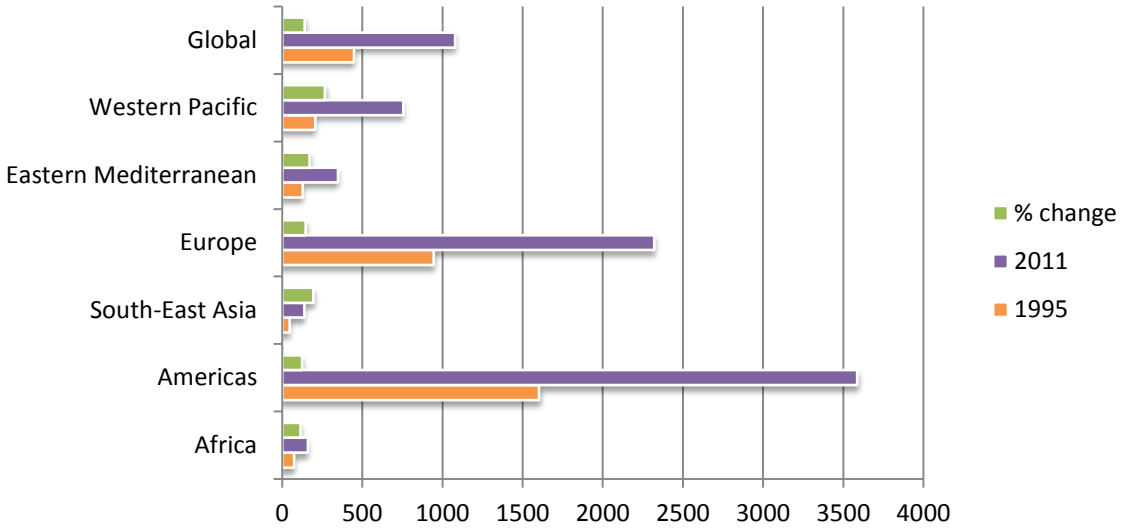


Fig. 13: Per capita total expenditure on health, PPP int. $ (Source: WHO, 2012)



In a research evaluating the global burden of non-communicable diseases (cancer, diabetes, CVD, respiratory illnesses, mental illnesses), Bloom *et al.* (2012)[141] outline that NCD are becoming more and more relevant to domestic health expenditure. In particular, CVD global cost (direct and indirect cost of illness) in 2010 has been estimated to be of US$ 863 billion, averagely US$ 125 per capita, and is expected to increase by 22% in 2030; diabetes costs are very high as well: US$ 500 billion total cost in 2010, expected to reach US$ 745 billion in 2030. These estimates do not take into account the loss of income due to working impediments caused by DR-NCD, which are calculated as US$ 15,6 and 0,9 trillion for CVD and diabetes, respectively, and is expected to rise sharply[142]. Although today the highest share of these costs is borne by in higher-income countries in absolute terms, in middle-income countries show the highest rate of increase.

Obesity is no more financially sustainable than CVD and diabetes: it has been estimated that the direct costs related to obesity, as a share of a country's total public expenditure, range between 0,7% and 2,8%; besides, it seems that obese people face 30% higher costs for drugs and medical care than normal weight people[143].

[141] Bloom, D. E. *et al.* (2012), "The Global Economic Burden of Noncommunicable Diseases", *PGDA Working Paper* No. 87, January 2012, Massachussets: Harvard School of Public Health

[142] *Ibidem*

[143] Withrow D. and Alter D. A. (2011), "The economic burden of obesity worldwide: a systematic review of the direct costs of obesity", *Obesity Reviews* no. 12, pp. 131.141

In a global context in which both public and private health expenditure is increasing and, meanwhile, the share of health expenditure due to NR-NCD is rising, too, people and public authorities will have to face a problem of financial sustainability of chronic illnesses. If we consider that most of such diseases are due or related to dietary lifestyles, then it might be said that improving food consumption and production system so to positively affect dietary habits would imply lower health costs and the possibility to take advantage of opportunity costs.

Sustainable diets: some practical examples

The BCFN identifies three dietary models as the most globally widespread: the North-American diet, which has been extensively covered in this work, the Mediterranean diet, based on the consumption of fruit, vegetables, whole cereals, legumes, fish and milk, and the Asian diet, mainly characterized by rice and fish, even though there are many different kinds[144].

Several studies previously mentioned regard the Mediterranean diet as the best alternative to the Western diet[145], at least for Western countries. The nutritional value of the Mediterranean Diet has been widely recognized since the first studies by Ancel Keys in the '60s, due to the high consumption of vegetable products, a moderate consumption of animal source foods and a very low consumption of sweets and processed foods. However, researchers have outlined several qualities of the Mediterranean diet beyond the simple nature of food kinds intake. Trichopoulou (2012)[146] states that there is an intrinsic sustainable value in the Mediterranean food culture; Padilla, Capone and Palma (2010)[147], as well, believe that there are several profiles of sustainability in the Mediterranean diet. First of all, it is incredibly precious for the preservation of biodiversity: the Mediterranean area is one of the 25 biodiversity hotspot indicated by naturalists and is as rich as the African tropical areas in locally-specific flora and fauna; extensive agricultural and livestock practices perpetrated for

[144] Barilla Center for Food and Nutrition (2012), see reference list

[145] E.g. Wolf O. *et al.*(2011), Videira N. *et al.* (2012), Duchin F. (2005), see reference list

[146] Trichopoulou A. (2012), "Diversity *v.* globalization: traditional foods at the epicentre", *Public Health Nutrition* vol. 15 no.6, pp. 951-954

[147] Padilla M., Capone R., Palma G. (2010), "Sustainability of the food chain from field top late: the case of the Mediterranean Diet", in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 231-240

centuries have created an exceptional landscape, e.g. secular olive trees plantations in Southern Italy. The high dietary variety of the Mediterranean diet comes from a wide range of crops cultivations and cropping methods, more or less intensive, valuable for tourism as well; in the latest years, the Mediterranean areas are experimenting a noticeable growth in the organic farming surface (the higher percentages in Slovenia, 6.2%, and Italy, 4,5%), exploiting traditional knowledge and technology available[148]. These territories have always been characterized by a strong connection to land and to ancient food and farming traditions; the conservation of cultural diversity is regarded as a necessary element for the preservation of biodiversity, so that a the new concept of "biocultural diversity" has been created to encompass this interconnection[149]. Without the intergenerational transfer of a culture that, in many rural contexts, can be found only in oral knowledge, the value of plants and breeds biodiversity would be lost.

Beyond the environmental and cultural importance of the Mediterranean Diet, there is a strong socio-economic outcome of such practices: the connection to local traditions tends to affect individuals in their food choices, leading them to prefer local products and thus allowing smallholder farmers, who lie at the basis of the Mediterranean agricultural sector, to survive[150]. However, the globalization of food systems and production methods is affecting the Mediterranean tradition, sometimes positively, via the introduction of sustainable technology developed somewhere else, many times negatively, by spreading Western dietary habits and intensive environmentally and socially unsustainable farming practices. The need to protect this heritage has led UNESCO to recognize it as an Intangible Cultural Heritage of Humanity in 2010.

Asian Diets are, to a certain extent, all similar to the Mediterranean Diet and based on ancient traditions as well. One example is the Chinese diet, based on the consumption of rice, fish, vegetables and fruit which, only in recent decades, has become rich in poultry meat, too. Although regarded as healthy and sustainable as much as the Mediterranean one, Asian dietary traditions have not been investigated the same way and have not had the same official recognitions, at least not among publications in

[148] *Ibidem*

[149] Petrillo P. (2010), "Biocultural diversity and the Mediterranean Diet", in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 224-230

[150] Padilla M., Capone R., Palma G. (2010), see above

Western languages. However, some traditional practices have been included among the globally important agricultural heritage systems (GIAHS) by the FAO[151]. Beyond the already mentioned rice-fish culture, typical of the County of Qingtian, there are other traditional rice production systems evaluated as global heritage: in China, the Province of Yunnan hosts the so-called Hani Rice Terrace, where almost 48 different types of rice are cultivated (although there were 195 previously), while in the Heqiao Village people raise a unique variety of rice, called "Wannian" or "Manggu", rich in micronutrients; in the Philippines the Ifugao Rice Terraces are cultivated following some organic techniques that have remained almost unchanged for 2000 years; in Japan, the Sado island, with its interconnection between different forestry and agro-ecosystems, provides for an incredible diversity in plants varieties, while the Noto Peninsula constitutes an example of holistic organic approach to fishing, agriculture and forestry. These are only a few examples, but there is a need for further research in Western literature over the possibilities offered by the Asian food heritage to develop sustainable food systems suitable for European and North-American climates, too.

One of the most important issues in developing sustainable diets is bio-cultural diversity; this means that, even though the Mediterranean and the Asian diets are extremely healthy for humans and for the environment, the key point is not to substitute the global spread of the Western Diet with the global spread of one of the two. There is plenty of traditional and indigenous food cultures that are as healthy and sustainable as the Mediterranean one, and much more suitable to the local context; the aim of developing sustainable diets is that of empowering such dietary heritage. For instance, Nigerian traditional diets, mainly based on local varieties of (organically raised) fruits, vegetables, legumes and cereals, starchy roots, herbs, spices, and meat from livestock, are extremely nutrient and healthy if properly prepared, so that children undernutrition can be fought through local food, breaking the poverty-hunger vicious cycle[152].

[151] Koohafkhan, P. (2010), see reference list

[152] Onimawo I. (2010), "Traditional food systems in assuring food security in Nigeria", in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 181-196

Sustainable Diets: Challenges

As previously stated, without denying the complexity of food dynamics, the present work has focused on healthy diets and environmental sustainability only, with a limited inclusion of socio-economic issues. In the former part it has been outlined that healthy and sustainable diets need to be implemented on the consumer's as well as on the producer's side, since, on one hand, the ultimate choice of what to eat is given to the individual, but, on the other, the mainstream food production system unavoidably affects this choice through several elements: availability of sustainable food, prices, etc. Having explained how advantageous can be for people and for the environment a more sustainable food production and consumption system, the aim now is that of pointing out the main challenges of a practical promotion of sustainable diets.

The Need for Significant Indicators

The above mentioned definition of sustainable diets, despite its undeniable value, solves only partially the problem of ascertaining what sustainable diets are or, more precisely, *how* they are. We know the qualitative aspect of a healthy and environmentally sound food production and consumption; we know, too, that Mediterranean, Asian, and other traditional diets have empirically proven to be a good example of healthy and sustainable diets, as well as the Western one has not proven to be so. However, we still have no quantitative means of analysis and evaluation. The promotion of sustainable food needs appropriate policies, but policy-making can be concretely effective only when having at its disposal verified information on a certain issue; thus, there is a need to operationalize the programmatic definition of sustainable diets and create some indices and indicators that would allow for the identification of thresholds to reach through public policies. Moreover, being able to measure sustainable diets in their multiple dimensions means to have a feedback on policies and results.

It is a most underestimated problem, so that there are a very few studies trying to translate into measurable and comprehensive values the definition of sustainable diets. The challenge here is twofold: efficient sector indicators for some important issues still have to be developed, and different sectors measurements have to be integrated. There

are, for instance, indicators of sustainability, like climate changing gas emissions (the most used one), or land use change, or loss of biodiversity estimates. However, to give an example, there is no agreed measure of agricultural productivity to compare conventional and sustainable systems. Most often, yields are used as indicator, whether in terms of output or in terms of income; most of the times comparisons are made between conventional and sustainable farms during the same period, or between pre- and post-conversion from conventional to sustainable farming of the same farms. Yields present only a part of productivity difference between conventional and sustainable agriculture, mainly because it does not take into account the main feature of sustainable farming: long-term positive externalities. While conventional farming depletes natural resources, in a process that leads to yields decrease after a peak of productivity, sustainable farming aims at preserving those resources through a total change of farm management practices, so to have a constant or growing productivity over time. Moreover, after the conversion there is a transition period in which yields are lower and the duration of this phase is unpredictable. There is still no index or indicators accounting for these elements, so that productivity estimates on which investments are most often based cannot be totally reliable. One interesting proposal by Kerselaers *et al.* (2007)[153] is to apply the Economic Conversion Potential to simulate income change from conversion to organic farming at the farm-level; the ECP compares the estimation of income in conventional farms and the estimated result of a new (sustainable) case-specific management plan using typical parameters of organic productions. Thus, the ECP encompasses the impact of the transition period, public decision-making framework, risks and uncertainties. Although the model may present some distortions and a need for improvement, it may be a good starting point to develop indices of production taking into account not only incomes or output, but also long-term benefits.

Anyways, even supposing that current environmental indicators could be as precise as needed, and considering that there are significant aggregate indicators of health status, too, like mortality due to NR-NCD or percentages of obese population, there is still no comprehensive integrated framework to investigate and promote sustainable

[153] Kerselaers E. *et al.* (2007), "Modelling farm-level economic potential for conversion to organic farming", *Agricultural Systems* vol. 94, 2007, pp. 671-682

diets. International organizations have remarked the need for a better quantification[154] both in terms of new indices and in terms of existing measurements enhancement.

Improving quantification is far from being easy, for many reasons: firstly, the food chain is made of several steps, each accounting for a different part of the problem; second, sustainability has many meanings and each element can be further divided into more specific topics, most of which should be included; also, the analysis conducted in previous chapters has outlined the existence of some trade-offs in sustainability and healthy choices, which have to be considered, too: for instance, the reduction of meat consumption per day cannot be taken as a positive indicator *per se*, because it may be a sign of an improved health status of some people, but on the other side it may indicate insufficient nutrients intake of other social strata, or it may imply the substitution of meat and animal source foods with sugars and nutritionally empty processed foods. Besides, projected indicators should be as adaptable as possible to any national, international or sub-national level, thus containing some "flexibility factor" making them comparable. The first step is, of course, that of dividing the problem into single parts, which may be the different phases of the food chain, for instance. However, another difficulty arises when such measures must be somehow integrated among themselves, to provide for a comprehensive index. On one hand, the gross amount of data has to be synthesized, but, at the same time, avoiding to lose too many information; one suggested solution is that of a composite index developed from a set of indicators, like the Multi-Dimensional Poverty Index[155].

Although there are some attempts, researches on more advanced indicators and indices are not very spread, so that at times sector studies are negatively affected by the lack of comparable data.

Investments in Food Production

Having said that a core feature of sustainable diets is an environmentally sound food production system, the next step is to determine how a conversion can be implemented: investments play a key role in this transformation. As previously outlined, sustainable

[154] Fanzo J., Cogill B., Mattei F. (2012), "Metrics of Sustainable Diets and Food Systems", *Bioversity International Technical Brief*, Rome, Italy

[155] *Ibidem*

farming does not mean a simple elimination of agrochemicals: abandoning conventional agriculture implies investments to change completely in-farm management practices, substituting machinery, choosing cultivation techniques and crop varieties specifically suitable to that area, hiring experienced personnel or provide for professional training, etc.

Investments in agriculture may come from private domestic sources, public spending, private FDI and public foreign investments (especially in less developed countries helped by development partners for capital formation). More or less everywhere, domestic private investments account for the majority of the total amount, followed by government investments, which seem to have decreased over time[156]. The importance of the public sector in developing agriculture lies mainly in two broad areas of actions: investments aiming at positively affecting the development of farming, and policies creating favorable conditions for private investments. Such policies may be extremely different in nature. Firstly, a good governance is essential for a good outcome: corruption and unclear dynamics due to strong private corporate interest do not allow for any policy intending to promote efficiency end sustainability. Then, governments have to offer some guarantees to investors, namely certainty of land rights and material, and intellectual property, insurances against risks, antitrust market regulation. Another essential issue is the creation of opportunities: encouraging credit accessibility, building infrastructures, ensuring access to local and international markets and, especially in developing countries, generating an environment favorable to the whole food chain, so that farmers can have access to inputs and can benefit from a range of potential buyers, not only individuals (in a direct farmer-consumer chain), but retailers, too. Finally, the State has a certain power to intervene into market dynamics: taxation and incentives can promote some kinds of investments rather than others, while labour market intervention can endorse professional training through a proper social security framework. The majority of private investors are small and medium farmers who are not willing to take on risky investments; to create an effective environment, actions should be carried out in a coordinated framework, encompassing if not all elements listed above, at least a good deal of them: if farmers are not provided

[156] FAO (2012), "*The state of food and agriculture 2012 – Investing in agriculture for a better future*", FAO Publishing, Rome

with risk insurances, land property, and access to markets, the sole credit availability is not enough to foster investments; the same, an excessive taxation on inputs and revenues may hinder the likelihood of small and medium farmers to upgrade their activity, not only in developing countries, but in developed regions, too. So, the first role of the public sector should be that of carrying out efforts to build a holistic strategy to enable rural development.

The importance given by governments to the agricultural sector is measurable through the variation of expenditure compared to other areas. Data provided by FAO[157] on 51 developing countries show that public expenditure in all regions have been increasing in absolute terms, but decreasing as a percentage of GDP, in favour of other public expenditures, namely defence, education, health and social security. Besides, not all expenditure in agriculture are investments, so that they constitute an even minor share of GDP. The importance of public investment in agriculture is related to several issues: mainly, these interventions are driven by efficiency consideration, in that the State may counterbalance market inefficiencies, and by concerns on poverty and equality, in particular food insecurity of lower income people. However, one great risk of promoting an excessive public intervention is the so-called "crowding-out effect": high governmental investment rates may lead to reduced private investments, so that the economy becomes too dependent on the public action and less dynamic; even if the public expenditure in agriculture would increase, the lack of self-sufficiency would stuck the agricultural sector. Besides, governmental plans can suffer from failures, too. An interesting view is provided by Mogues *et al.* (2012)[158], according to whom public agricultural expenditure has the main function of counterbalancing market imperfections: public goods share agricultural technology and knowledge, especially in case of private underprovision of goods due to profit-driven logics; public information networks compensate asymmetries; while regulation limits imperfect competition. Mogues *et al.* provide for evidence on the impact of public investments in agriculture: public investments in agricultural R&D show a high social rate of return on investments (ROI), even greater than any other spending sector, thus giving a significant contribution

[157] *Ibidem*

[158] Mogues T. *et al.* (2012), "The impacts of public investments in and for agriculture", *IFPRI Discussion Paper* no. 01217, October 2012

in reducing poverty, even though there is a certain degree of variability depending on the country and the kind of investment. Besides, it seems that agricultural research is the only field where ROI have not been declining over time; considering the high returns on investments, Mogues *et al.* outline that there is a significant underinvestment, especially in developing regions (Asia, Africa, Latin America), where total agricultural investments as a percentage of GDP are significantly lower than developed regions. Beyond positive externalities on poverty rates, agricultural R&D shows an effect on health and food security through bio-fortification, i.e. the spread of micronutrients-enhanced variety of crops. Positive returns on agricultural investments, especially in underdeveloped regions or less-favored provinces, has been reported by FAO, too: investments on R&D, education, and infrastructures have an impressive return in terms of both agricultural performance and poverty reduction[159]. Conclusions on crowding-out effect on private capital formation is mixed, but there is no strong evidence[160] (probably because agricultural investments are not that high).

One example of public investment in agriculture is that of farmers' education and training programs. Van Den Berg and Jiggins (2007)[161] report the outcomes of Integrated Pest Management Field Farmer Schools (IPM FFS) in developing countries where, even though mass communication may have an impact, investments in agriculture are low. The aim of such projects is that of providing for learning opportunities and adaptation capacities; interesting results have been reached in Indonesia, where the overall results have been a reduction in pesticides use and an increase in yields, together with the development of problem-solving skills and collective action. Even though results in the long-terms are less positive than expected, due to the fact that FFS have not provided for sufficient skills to enable farmers to conduct empirical studies, the overall result is a significant formation of human and social capital.

Given that agricultural investments bring high returns in terms of performance efficiency, we can go back to the initial statement of this section: investments are a key issue of sustainable food production. One kind of cross-sector investments which are

[159] FAO (2012), see reference list

[160] Mogues T. *et al.* (2012), see above

[161] Van Den Berg H. and Jiggins J. (2007), "Investing in farmers – The impacts of Farmers Field Schools in Relation to Integrated Pest Management", *World Development* vol. 35 no.4, pp.663-686

essential for sustainable agriculture is that of "green investments"; due to the width of this concept there is still no internationally agreed definition, but there are some noteworthy attempts to outline the core principles[162]. Green investments are related to climate change adaptation and mitigation policies and, in the public agricultural sector, green investments can be directed at various assets: enhancement of physical capital through the replacement of fossil fuels with clean energy machinery and technology; education and knowledge-sharing programs in mitigation and adaptation strategies to improve farmers' "green" skills (like the FFS on IPM); renovation of farm management to fit new technology and skills into a comprehensive climate changing adaptation and mitigation framework.

However, greening agriculture is a process that goes far beyond green investments realization, in the definition shaped by the OECD[163]. Investing in sustainable agriculture means promoting a different view of food production and, thus, a different view of investments and priorities. R&D, farmers' training, and effectiveness of farm management take on a major importance, since all forms of sustainable farming are knowledge-intensive and need to be made affordable to farmers; however, together with technological improvement, social learning processes and community building through wider participation networks seem to lay at the core of sustainable management, especially in developing countries[164].

There is a need for global and national public policies to stimulate sustainable farming investments by integrating considerations on environmental externalities into the typical production-oriented approach; incorporating the value of natural capital into policy planning would remove (at least partially) market distortions due to externalities. Agriculture has an impact, which could be either positive or negative, on natural resources: taking into account this long-run effects in a background of resource scarcity would probably drive investments and policies towards sustainable practices, rather than conventional ones; yet, the main hardship is the quantification of externalities,

[162] Inderst G., Kaminker Ch., Stewart F. (2012), "Defining and measuring green investments: Implications for institutional investors' asset allocations", *OECD Working Papers on Finance, Insurance, and Private Pensions* no. 24, OECD Publishing

[163] *Ibidem*

[164] Lee, D. R. (2005), "Agricultural sustainability and technology adoption: issues and policies for developing countries", *American Journal of Agricultural Economy* vol. 84 no.5, pp. 1325-1334

since agro-ecosystems are complicated and many factors interact among each other, so that it is difficult to assess positive and negative impacts without creating further distortions[165]. One way of doing this is to establish payments for environmental services, a type of incentive which could be in the form of direct transfers or others that rewards producers adopting conservation strategies, such as biodiversity protection, green management, etc. This strategy could serve to enhance awareness in farmers, who do not always catch the advantages brought by positive externalities[166]. As a matter of facts, unclear or incorrect perception of sustainable farming benefits is a major source of private under-investment in practices like organic farming, which are too often seen as an ethical choice rather than a long-term production enhancement strategy. One example is given by Wilson and Tisdell (2001)[167] on the use of pesticides: agrochemicals are costly to farmers not only because of direct price increases, but also due to indirect and delayed costs, namely hospitalization expenses (exposure to pesticides has strong adverse effects on human health) and production losses caused by sick days and, on the other side, long-term environmental damages. According to Wilson and Tisdell, some main causes for this is the lack of awareness about consequences and underestimation of costs. Anyways, some other major reasons are tightly linked to the system itself: the market system encourages the adoption of agrochemicals, even because they are an essential part of some high yielding varieties spread by the green revolution; besides, incentives to investments in agriculture have often taken the form of loans to farmers for inputs, including agro-chemicals.

A further set of instruments to create enabling conditions for investments in sustainable farming is to create an "economic space" for such products: sustainable production gets profitable when there is a buyer: thus, strengthening the food supply chain for organic products is a major issue; UNEP underlines that among national policies to be implemented, public procurement of sustainable food is a main one[168]. Of course, raising awareness in consumers to drive their choices towards sustainably

[165] FAO (2012), see reference list

[166] Lee D. R. (2005), see above

[167] Wilson C. and Tisdell C. (2001), "Why farmers continue to use pesticides despite environmental, health and sustainability costs", *Ecological Economics* vol. 39, 2001, pp. 449-462

[168] UNEP (2011), *Agriculture – Investing in natural capital*, internet: http://www.unep.org/greeneconomy/ (Consulted on August 25th, 2013)

produced food is an issue that public authorities and NGO have to deal with, as it will be discussed later on, to create a strong food supply chain for organic food.

Promoting sustainable farming is therefore a complicated task that requires policy-makers to focus on implementing new strategies of rural development and to adopt a wide range of measures. On one hand, this is clearly reflected in the plethora of EU measures on organic farming since the '80s. Over time, legal instruments directed at regulating standards and thresholds, financial instruments made up to ease conversion, and communicative instruments to create social knowledge and awareness have been integrated to support and encourage national action plans. On the other hand, such policies need to be highly location-specific, so that there cannot be one solution for any country or region: as a consequence, the complexity of this task also lies in the necessary internal coordination among national governments, local authorities, and rural institutions.

Considerations over case-specific policies cannot leave out the issue of smallholder farming development. Even though, especially in developed countries, consumers get in touch with big retailers and, through them, big food producers, smallholders still constitute the vast majority of farmers all over the world. Data provided by international organizations report that in 81 countries, covering two thirds of the world population, smallholders owning less than 1 ha account for 72,6% of farmers, while small farmers owning 2-5 ha constitute 21,6% of the total amount and only 0,4% of farmers own more than 100 ha; of course, the distribution of small farmers vary across regions: they are mostly located in Asia, Africa and Latin America, but small scale farming policies are also a concern in the US, where 91% of farms rate less than 250.000 USD sales, and in the EU, where 49% of farms measure less than 2 ha and 67% less than 5 ha[169]. Smallholder agriculture presents challenges, but offers many possibilities as well. In the previous section the dynamics of rural poverty have been described: small farmers are in a peculiar and vulnerable position because they would need investments in education, know-how, and technologies to compensate land scarcity, but in the absence of sound public policies it is smallholders themselves that invest in agriculture, conditions being

[169] HLPE (2013), *Investing in smallholder agriculture for food security*, A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome

favorable. However, favorable conditions have to be created by the public sector, if market imperfections cause barriers to accessibility. As they constitute the major source of income in developing countries and account for a high percentage of farming activities in developed countries, policies promoting sustainability of food production and consumption should be primarily addressed to them.

A strategic approach towards smallholder farming starts with a recognition of the diversity of their conditions and the analysis of this kind of agriculture and the specific risks to which it is exposed; through an efficient information system and a bottom-up approach, small farmers should be enabled to access necessary assets for sustainable production and to enter local and international markets[170].

Involving Nutrition Concerns: Considerations on Production, Processing and Retail

The last *"State of food and agriculture"* provided by the FAO[171] highlights the need to include nutrition issues in food and agriculture policies, especially to implement nutrition-oriented research.

The idea of nutrition-sensitive agriculture that is being investigated by recent literature is "*a concept that aims to narrow the gap between available and accessible food and the food needed for a healthy and balanced diet for all people"*[172]. In agriculture, a nutrition-oriented approach is tightly linked to biodiversity and sustainable soil and water management: year-round farming of diverse food ensures the availability to local and non-local consumers of all nutrients; at the same time, sustainable soil and water management means that plants are able to absorb vitamins, mineral, and other micronutrients which are often missing in depleted soils. The attention to micronutrients intake is extremely important not only in the fight against undernutrition, but also in the prevention of diseases of affluence, since the latter are characterized by an overconsumption of some macronutrients and a deficiency in micronutrients.

[170] *Ibidem*

[171] FAO (2012), "*The state of food and agriculture 2013 –Food system for better nutrition*", FAO Publishing, Rome

[172] Jaenicke H., Virchow D. (2013), "Entry points into a nutrition-sensitive agriculture", *Food Security*, August 2013, pp. 1-14

The concept of nutrition-sensitive agriculture is critically dependent on some essential elements, which are identified by Jaenicke and Virchow[173] as: enabling policies, cross-sector and public-private collaboration, increased awareness of institutions and citizens' capacity building, focus on vulnerable groups, and issues of the food chain. Public policies should aim at encouraging the development of nutritional-sensitive agriculture through initiatives that may be similar to those undertaken to promote sustainable agriculture, or rather, should include nutritionally sound measures *within* policies for sustainable food production and through the strengthening of the farming sector. Thus, incentives and investments to promote sustainability are ought to include nutritional considerations. this is possible only through an integrated approach that would encompass a cooperation among public authorities of the sector involved, as well as forms of public-private partnership.

To develop the concept of nutritional-sensitive agriculture the focus on the sole farming sector is not enough; as a matter of fact, we could rather talk about a nutrition-sensitive *food chain*. The development of processing and modern marketing of food has caused agricultural and livestock products to go through some steps before arriving to consumers, in which nutritional qualities of foods is altered either in a positive or in a negative way. Processing can be an opportunity to enhance nutritional characteristics of a product, like soy milk enriched in Ca and vitamins, which today is a valuable alternative to cow milk; however, processed and packaged food is one of the main cause for the nutrition and epidemiologic transition. There have been some studies and investigative reports on the responsibility of food processing industries in the conscious "poisoning" of consumers' health, similarly to tobacco industries. Several foods have been demonstrated to cause addiction, due to their capacity to activate neurocircuits as drugs can do (even if less the effect is much less strong)[174]. Basically, it seems that the proper combination of fat, salt and sugar, all extremely dangerous for health if taken in excessive quantities, contained in many processed foodstuff are responsible for neurocircuits activation; according to some[175], the "food giants" have improved internal

[173] *Ibidem*

[174] Gearhardt A. N. *et al.* (2010), "Can food be addictive? Public health and policy implications", *Addiction* no. 106, pp. 1208-1212

[175] Moss, M. (2013), *"Salt, sugar, fat: how the food giants hooked us"*, Random House

knowledge on these characteristics and exploited them to sell more products, aiming at reaching children above all to affect their taste development since childhood, in a general framework where healthier foodstuff is more costly.

The food chain is often considered, by common knowledge, to be affected by consumers' demand. However, this is only partly true: the food chain itself can have a strong influence on consumption patterns[176], as well as production choices. Vorley (2001)[177] outlines that the ownership of intangible assets (often determining barriers to advanced technology availability) and the control of information depend on industrial size and concentration, so that the clustering and alliance of big corporations, even within antitrust limitations, damages smaller food producers, fostering rural poverty. In particular, being the current food supply chain *buyer-driven*, where the "buyer" is not the consumer but the large-scale retailer, it is the latter who holds the power of choosing what food processors want from farmers[178], as well as which products will be largely available to consumers (eventually merging or clustering with food processing industries). Even though farmers lie at the basis of the food chain, post-farm steps of complex chains have gained more and more power in affecting food production and consumption choices. Moreover, top-down policies to promote sustainability have sometimes had strong drawbacks: sustainability requirements and labeling, without policies enabling small farmers and producers to conform to thresholds, have ended up in creating barriers to market accessibility, contributing to the accumulation of power and capitals in the hand of big transnational corporations, whose behavior is not always verifiable. The opinion according to which things have slightly changed in recent times and that food supply chains seem to be more demand-oriented than in the past[179] may be partly true, but it is questionable under certain aspects. However, marketing and retail can bring opportunities by creating "economic space" for small farmers' products and for organic (sustainable) foods, especially in presence of policies and market instruments rewarding sustainable and healthy foods. Within the European Union we

[176] Jaenicke H., Virchow D. (2013), see above

[177] Vorley, B. (2001), "The chains of agriculture: sustainability and restructuring agri-food markets", internet: http://pubs.iied.org/ (Consulted on August 25th, 2013)

[178] *Ibidem*

[179] Falguera V., Aliguer N., Falguera M. (2012), "An integrated approach to current trends in food consumption: Moving toward functional and organic products?", *Food Control* no. 26, pp 274-281

are witnessing a growing market for organic products, incentives to sustainable agriculture, improved labeling systems, enhanced bargaining power of consumer associations and health agencies, supported by a favorable attitude of policy-makers in some countries, and, as a consequence, a wider choice for consumers. Yet, this may not be the same in developing and low-income regions; even in industrialized countries healthier foods are much more costly, so that urban poors, for instance, cannot afford it. In low- and middle-income countries the price of sustainable and healthy food is far less affordable. Besides, where civil society has not evolved so much, while big corporations have strong ties with politics (China, to give an example), consumers lack the power to influence significantly the food chain; as a consequence, not only regulation and market instruments would develop more slowly, but without labeling there would be very little incentives for food enterprise to adopt safety and sustainability standards.

The conversion to sustainable food production needs a restructuring of the agri-food markets and the re-balancing of power relations, as Vorley maintains. Producers and consumers should regain sovereignty over food choices. Yet, it is extremely difficult to believe that processing and retailing industries would turn back to have a simple role of connection means between the two; even less credible would be demanding the elimination of any complex food chain (not considering that it would mean the fall of a whole economic sector and unemployment boosting). Restructuring the agri-food market could mean the transformation of processing and retailing through policies implementing competition on sustainability and healthiness, as well as cooperation among stakeholders. Processed food can turn to be healthier and more sustainable, if food industries are incentivized to change production methods and marketing strategies, aiming at competing not only for taste, but also for good nutrition. Retailers, as well, have a very important task, which is that of making food available to consumers and give sustainable producers earning opportunities: the objective should be that of implementing this role and providing good food at an acceptable price, rather than junk food. Of course, all of this could be realized only in a framework of efficient regulation an control of standards, targeted economic policies and corporate responsibility.

Consumers' Attitude and Behaviour

Among the elements regarded as essentials by Jaenicke and Virchow[180] there are some specifically targeting food consumption styles. The promotion of policies to foster sustainable diets needs, on one hand, a process of sensitivization and awareness raising of policy-makers, and, on the other, the development of people's capacity to choose and handle food in a nutritionally (and sustainable) sound way. In particular, public programs should target vulnerable and strategic groups above all: women, children and urban (poor) consumers; Both in cases of undernutrition and overnutrition, these categories are particularly important. Women, in particular, are still regarded as those who are responsible for food purchasing and meals preparation even in urbanized and industrialized contexts; besides, in many countries women are significantly more affected by malnutrition (in all its forms) than men. A gender-based perspective would require the inclusion of women in decision making and initiatives, as well as the provision of equal earning opportunities in rural and urban contexts. Children are another sensitive group, being highly influenced by the surrounding environment: family in first place (one further reason to promote women awareness and capacity-building), and school. Meals served to children, as well as cooking lessons can positively affect children taste so that they would be rapidly able to distinguish healthy foods to ask for to their parents, or even to cook simple things by themselves. Urban consumers, especially poors, are the most affected by overnutrition in both developed and developing countries; most of the times they either cannot afford healthy foods, or do not have the proper information/education to make the healthiest choice among affordable alternatives: the rising number of self-declared standards and the use of voluntary labeling as a competitive weapon is creating confusion. Hassan-Wassef (2012) [181] underlines the importance of reshaping dietary education, the set of instruments designed to help people choosing the best available: simple information communication is not enough, because people may not have the necessary knowledge to use such information. According to the author, the reason why obesity and CVD have become population-level illnesses is to be searched in societal systemic imbalances in

[180] Jaenicke H., Virchow D. (2013), see reference list

[181] Hassan-Wassef H. (2012), "Redesigning dietary education", in *CIHEAM, MediTERRA 2012*, Presse de Sciences Po, Annuels, 2012, pp. 399.422

food intake, rather than genetic predisposition. Part of the responsibility is ascribed to mass media, TV in particular: in the '70s-'80s there were no means to counterbalance junk food promotional advertising; today things have changed with the growing popularity of cooking programs and the spread of the internet. However, mass media are still a "*double-edged sword*"[182], as TV advertising still plays an important role and, besides, the internet contains such a number of contrasting data, suggestions, and information that can be even more confusing.

As in the case of sustainable food production, the key to promote sustainable and healthy food consumption is a holistic policy to inform, educate, and enable consumers to change their behaviour. Evidence shows that the lack of a comprehensive approach to food choice advices is almost ineffective: Harland *et al.* (2012)[183] have conducted a statistical analysis of the effectiveness of the *eatwell plate* (the information framework provided by the UK Food Standard Agency to help consumers, renovated in 2007) and supporting instruments, like the *eight tips for healthy eating*. The results have been largely disappointing: only 1% of the sample group met all six targets, 4% met five targets out of six, while 51% did not achieve any of the targets set by researchers. Besides, the sustainability of foods (measured in terms of greenhouse gas emissions) is not clearly quantifiable, and no suggestions on more environmentally sound alternatives is provided. The failure of such strategy is due to, according to researchers, a lack of a comprehensive approach to understand the drivers of behavior change, which depends on the perceived benefits of a certain choice.

On the contrary, one successful strategy has been that promoted in Sweden since 2007, resulting from a combination of two main elements. The first one is the new set of dietary guidelines, including greenhouse gas emissions indicators as a determinant element, together with nutrition qualities, for correct food choices. The second part of the Swedish policy is a the promotion of the *Klimatmärkning för Mat* (Climate labeling for food) project, resulting in the adoption of the KRAV label as the main (and almost only) label for organic food production. This has been possible thanks to a particularly favourable cooperative environment: the two main political parties have worked

[182] *Ibidem*

[183] Harland J. I. *et al.* (2012), "Achieving *eatwell plate* recommendations: is this a route to improving both sustainability and healthy eating?", *British Nutrition Foundation Nutrition Bulletin* no. 37, pp. 324-343

together, then joined by the major Swedish industry groups and food producers, that have pledged not to use it as a competitive weapon avoiding the creation of multiple labels. Of course foreign producers, as well as some domestic farmers and food producers have protested, but in the end the strategy has been adopted and, although labeling may be only the first step, has shown positive signs[184].

One main difficult of promoting sustainable diet is turning *attitudes* into *behaviours*; in a study on Belgian consumers, who are generally interested and sensitive to healthiness and sustainability of food, Vermeir and Vebeke (2008)[185] have noticed a deep attitude-behaviour gap: 52% of interested consumers, in the end, did not buy the food advertised by researchers as healthy and sustainable. The attitude-behaviour gap is often determined by prices and income, as confirmed by other studies[186]; however, Vermeir and Vebeke have outlined some personal factors, beyond contextual elements, that affect consumers' behaviour, namely inner values and confidence in information provided. Their conclusion is that changing behaviours strategies should include communication approaches providing for educational messages as well as needs satisfaction; availability of products in main retailers or indications on where to find specific foods; and "*heuristics*"[187], i.e. facilitating consumers' choices by fostering the introduction of a system of brands, labels and quality marks considered trustable in the individual's routine. As underlined by Vermeir and Vebeke, there cannot be one strategy to reach all consumers, but policies should be targeted. For instance, Tobler *et al.* (2011)[188] point out that sustainable food consumption choices vary across age groups: young people are more driven by environmental concerns, the elderly are driven by health concerns above all, while middle-age people choose their diet basing on both issues. If different groups/individuals are affected by different concerns, public policies promoting both environmental and health benefits would not only show a new

[184] Czarnezki J. J. (2011), "The future of food eco-labeling: organic, carbon footprint, and environmental lifecycle analysis", 30 *Stanford Environmental Law Journal* 24 (2011)

[185] Vermeir I. Verbeke W. (2008), "Sustainable food consumption among young adults in Belgium: theory of planned behavior and the role of confidence and values", *Ecological Economics* no. 63, 2008, pp. 542-553

[186] Guyomard H. *et al.* (2012), "Eating patterns and food systems: critical knowledge requirements for policy design and implementation", *Agriculture and Food Security* vol. 1 no. 13

[187] *Ibidem*

[188] Tobler C. *et al.* (2011), "Eating green. Consumers' willingness to adopt ecological food consumption behaviors", *Appetite* no. 57 (2011) 674-682

approach of policy-makers towards the two issues, but it would probably be more effective in reaching a larger share of the population.

There is one last issue to take into account in dealing with sustainable food consumption, which has already been mentioned. Regulation and compulsory public standards, improved information/education strategies, and labeling may help consumers to *know* how their diet should be. However, exactly like production standards work if farmers receive economic facilities to reach those standards, consumers will purchase sustainable and healthy food only if price-income ratios would make it affordable. This is why market-based instruments are so important, like incentives for healthy foodstuff and taxes on harmful foods: these can be applied to producers to incorporate negative environmental and social externalities into prices; another possibility is to make them weight on consumers, either as a tax on environmentally unsustainable food choices or as a sort of “health insurance”, since the consumer is consciously buying something that will damage his health and that will entail an expenditure for the national health system in the future. These policies can be coupled with conditioned grants for poorer strata of the population to purchase foods officially recognized as constituting a sustainable diet. The strategy here described implies a strong commitment of the State to invest and spend on promoting sustainable diets, at least for the first years.

Concluding Remarks

The ongoing environmental depletion is connected to worldwide socio-economic and demographic trends; however, the key determinant for the current state of the environment is overconsumption of resources. In the food sector, overconsumption means both the excessive exploitation of natural resources and energy use, which makes the conventional system not sustainable in the long run, and the increase of per capita consumption of energy-dense food, i.e. the global nutrition transition towards the Western diet.

Population growth and increasing per capita demand have led to the evolution of the food production system towards industrial agriculture, characterized by the use of fossil energy, external inputs, and intensive monocrop or livestock raising. Besides, dietary shifts towards more energy-dense (and resources-intensive) foods, like red meat, is worsening the pressure of farming activities on ecosystems. The way the conventional system is damaging the environment poses serious threats to future productivity and, thus, to future food security; such considerations have raised interest in sustainable farming practices. Sustainable production intensification, based on traditional knowledge and new technology in a locally-specific approach, would thus be environmentally and socio-economically sustainable, while representing a possible response to the increase in food demand. Globalization and dietary shift towards perishable foods have created remarkable wastes along the food chain; evidence presented by some researchers shows that local food systems are not necessarily more sustainable that long-distance food chains, so that it might be more important to implement the sustainability of the whole production through proper policies, rather than *a* priori banning long food chains as a bad thing.

The same overconsumption caused by the nutrition transition, which is making the food production system more and more inappropriate, is causing an epidemiologic transition from communicable to non-communicable (dietary-related) diseases. Suggestions for a healthier diet include the reduction in excessive energy intake, as well as the reduction of consumption of animal source foods, sugars, and fats; from the research carried out, it seems that vegetarian alternatives are not necessarily healthier than (balanced) omnivore diets. About sustainability of foods, on the perspective of the

consumer, the reduced intake of foods typical of the Western diet would significantly reduce per capita consumption, even though there are some trade-offs to take into account (like the meat-fish substitution). Again, vegetarian and vegan dietary styles have not proven to be necessarily more sustainable than omnivore diets including organic meat, for instance. Some studies focus on the production side and the promotion of sustainable farming to foster sustainable diets, since the consumer is considered to have a limited power to affect food production impacts. So, although the ultimate choice of what to eat is given to the individual, the mainstream food production system unavoidably affects this choice.

The value of sustainable diets goes beyond healthiness and environmental sustainability: they can promote rural development and smallholders' food security, reduced private and public health expenditure, conservation of some traditional cultures entailing sustainable food systems, like the Mediterranean or the Asian diets.

Even though we can provide for some examples of sustainable diets, we are still not able to elaborate complex indices to operationalize the concept and make complete information available to policy-makers. However, the lack of indicators and indices does not hinder completely the chance to act on the food production system to make it sustainable, even if in more uncertain conditions. The key for public authorities will be that of investing, especially in R&D, farmers' education and smallholder farming development, and promoting investments in the conversion to sustainable farming through actions like the internalization of externalities and public procurement.

However, investing in sustainable agriculture is not enough to effectively foster sustainable diets on the supply side: a nutrition-sensitive food chain should be developed, so that not only investments in agriculture would encompass nutrition considerations, but the attention to the healthiness of food should be spread all along the chain, too. Even though consumers may have some power, especially in developed countries with more or less strong associations, the food chain does affect food consumption choices. A conversion towards sustainable and healthy food implies, in first place, the re-gaining of both the agricultural sector and consumers of their decision power and, at the same time, a more active and positive role of the middle stages of the chain, such as retailers. Anyways, despite the influence of the food supply chain in

shaping consumption styles (and, as a consequence, health status and environmental per capita impact), consumers do play a part; thus, they have to be properly informed, educated, and supported to be put in the conditions to turn their healthy (and sustainable) attitudes into a concrete behaviour. This is possible through public standards regulation, voluntary labeling, consumers' education, and especially through market instruments incentivizing healthier and more sustainable choices. In the intention to reduce food environmental impact and increase people's benefit, consumers have a (more or less limited) power to choose and to affect the market; on the other side, food producers, processing and retailing industries play a role in guaranteeing the availability of such a choice. However, both sides have to be somehow educated and encouraged towards the adoption of sustainable diets by public authorities: the Swedish experience on labeling has shown that food producers and industries' commitment is essential, as well as the agreement among stakeholders may be crucial for policies effectiveness.

Reference List

Abrahams Z. *et al*. (2011), "Diet and mortality rates in Sub-Saharan Africa: stages in the nutrition transition" *BMC Public Health* 2011 11:801

Altieri M. A. (1999), "The ecological role of biodiversity in agroecosystems", *Agriculture, ecosystems, and Environment* vol. 74 (1999), pp. 19-31

Auernhammer H. (2001), "Precision farming – the environmental challenge", *Computers and Electronics in Agriculture* vol. 30 (2001), pp. 31-43

Barilla Center for Food and Nutrition (2011), "*Doppia piramide: alimentazione sana per le persone, sostenibile per il pianeta*", Codice Edizioni

Barilla Center for Food and Nutrition (2011), "*Nuovi modelli per un'agricoltura sostenibile"*, Codice Edizioni

Barilla Center for Food and Nutrition (2011), "*Oltre gli OGM. Le biotecnologie in ambito agroalimentare*", Codice Edizioni

Barilla Center for Food and Nutrition (2012), "*Eating planet – Nutrirsi oggi: una sfida per l'uomo e per il pianeta*", Milano: Edizioni Ambiente

Baumung R. and Hoffmann I. (2010) "Animal genetic diversity and sustainable diets" in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 82-93

Bermudez O. I. and Tucker K. L. (2003), "Trends in dietary patterns of Latin America populations", *Cad. Saude Publica*, vol 19 (sup. 1), pp. S87-S99

Bloom, D. E. *et al.* (2012), "The Global Economic Burden of Noncommunicable Diseases", *PGDA Working Paper* No. 87, January 2012, Massachussets: Harvard School of Public Health

Boehlje M. and Doering O. (2000), "Farm Policy in an Industrialized Agriculture", *Journal of Agribusiness*, vol. 18 no. 1, March 2000, pp. 53-60

Boscolo M. (2013), "Globesity: i costi sociali dell'obesità in un mondo più longevo", in *Food for Health*, April 2013

Campbell K., Noonan-Mooney K., Mulongoy K. J. (2010), "Biodiversity, nutrition, and human wellbeing in the context of the Convention on Biological Diversity" in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 36-43

Campbell T. C. and Campbell T. M. (2006), "*The China study: the most comprehensive study of nutrition ever conducted and the startling implications for diet, weight loss, and long-term health*", Dallas: BenBella Books, Inc.

Carlsson-Kanyama A. (1998), "Climate change and dietary choices — how can emissions of greenhouse gases from food consumption be reduced?", *Food Policy* vol. 23 no. 3/4, pp. 277-293

Cincotta R. P., Wisnewski J, and Engelman R. (2000), "Human Population in the Biodiversity Hotspots", *Nature* vol. 404, April, 27th 2000, pp. 990-992

Czarnezki J. J. (2011), "The future of food eco-labeling: organic, carbon footprint, and environmental lifecycle analysis", 30 *Stanford Environmental Law Journal* 24 (2011)

Donald, P.F. (2004), "Biodiversity Impact of Some Agricultural Commodity Production Systems", *Conservation biology* vol. 18 no 1, February 2004, pp. 17-37

Doodman D. (2009), "Blaming cities for climate change? An analysis of greenhouse gas emissions inventory, *Environment and Urbanization* vol 21 no 1 April 2009, pp. 184-201

Drewnowski A (2000), "Nutrition Transition and Global Dietary Trends", *Nutrition* vol. 16 no 7/8, pp. 31-43

Drewnowski A. and Popkin B. M. (1997), "The Nutrition Transition: New Trends in the Global Diet", *Nutrition Reviews* vol 55 no. 2, pp. 31-43

Duchin F. (2005), "Sustainable consumption of food – A framework for analyzing scenarios about change in diets", *Journal of Industrial Ecology* vol. 9 no. 1-2, pp. 99-114

Erlich P. R. and Holdren J. (1971), "Impact of Population Growth", *Science*, 171, 3977, Mar. 26, pp. 1212-1217

Erlich P. R., Erlich A. H., and Holdren J. (1970), "*Population, Resources, Environment*", Freeman, S. Francisco

Falguera V., Aliguer N., Falguera M. (2012), "An integrated approach to current trends in food consumption: Moving toward functional and organic products?", *Food Control* no. 26, pp 274-281

Fanzo J., Cogill B., Mattei F. (2012), "Metrics of Sustainable Diets and Food Systems", *Bioversity International Technical Brief*, Rome, Italy

FAO (2012), "*The state of food and agriculture 2012 – Investing in agriculture for a better future*", FAO Publishing, Rome

FAO (2012), "*The state of food and agriculture 2013 –Food system for better nutrition*", FAO Publishing, Rome

Feenstra G (2002), "Creating space for sustainable food systems: lessons from the field", *Agriculture and Human Value* vol. 19 (2002), pp. 99-106

Foley, J.A. *et al.*(2005), "Global Consequences of Land Use", *Science* vol. 309, no. 570, July 2005, pp. 570-574

Fronte M. (2013), "Il cibo come vettore di salute", in *Food for Health*, April 2013

Gabriel D. *et al.* (2010), "Scale matters: the impact of organic farming on biodiversity at different spatial scales", *Ecology letters* vol 13 (2010), pp. 858-869

Galal O. M. (2002), "The nutrition transition in Egypt: obesity, undernutrition, and the food consumption context", *Public Health Nutrition* vol. 5 no 1A, pp. 141-148

Garnett T. (2013), "Three perspectives on sustainable food security: efficiency, demand restraint, food system transformation. What role for LCA?", *Journal of Cleaner Production*, doi: 10.1016/j.jclepro.2013.07.045

Garnett, T. (2011), “Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)?”, *Food Policy* vol. 36 (2011), pp. S23-S32

Gearhardt A. N. *et al.* (2010), “Can food be addictive? Public health and policy implications”, *Addiction* no. 106, pp. 1208-1212

Ghassemi H., Harrison G., and Mohammad K. (2002), “An accelerated nutrition transition in Iran”, *Public Health Nutrition* vol. 5 no 1A, pp. 149-155

Godfray H.C.J. *et al.*(2010), “Food Security: the Challenge of Feeding 9 Billion People”, in *Science*, vol. 327 no. 5967, pp. 812-818

Gold K. and McBurney R. P. H. (2010), “Conservation of plant diversity for sustainable diets”, in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 108-114

Grimmond S. (2007), “Urbanization and global environmental change: local effects of urban warming”, *The Geographical Journal,* vol. 173, Issue 1, March 2007, pp. 83-88

Gussow J. D., Clancy K, (1986), “Dietary guidelines for sustainability”, *Journal of Nutritional Education* vol. 18, 1986, pp. 1-4

Guyomard H. *et al.* (2012), “Eating patterns and food systems: critical knowledge requirements for policy design and implementation”, *Agriculture and Food Security* vol. 1 no. 13

Harland J. I. *et al.* (2012), “Achieving *eatwell plate* recommendations: is this a route to improving both sustainability and healthy eating?”, *British Nutrition Foundation Nutrition Bulletin* no. 37, pp. 324-343

Hassan-Wassef H. (2012), “Redesigning dietary education”, in *CIHEAM, MediTERRA 2012*, Presse de Sciences Po, Annuels, 2012, pp. 399.422

HLPE (2013), *Investing in smallholder agriculture for food security*, A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome

Hole D.G. *et al.* (2005), “Does organic farming benefit biodiversity?”, *Biological conservation* vol. 122 (2005), pp. 113-130

Horrigan L., Lawrence R. S., Walker P. (2002), “How Sustainable Agriculture Can Address the environmental and Human Health Harms of Industrial Agriculture”, *Environmental Health Perspectives* vol. 110 no. 5, pp. 445-456

IBRD (1992), *World Development Report 1992: Development and the Environment*, New York: Oxford University Press

Ilbery B. and Maye D. (2005), “Food supply chains and sustainability: evidence from specialist food producers in the Scottish/English borders”, *Land Use Policy* vol. 22 (2005), pp. 332-344

Inderst G., Kaminker Ch., Stewart F. (2012), “Defining and measuring green investments: Implications for institutional investors’ asset allocations”, *OECD Working Papers on Finance, Insurance, and Private Pensions* no. 24, OECD Publishing

Jaenicke H., Virchow D. (2013), “Entry points into a nutrition-sensitive agriculture”, *Food Security*, August 2013, pp. 1-14

Johns P. and Eyzaguirre P. (2006), “Linking biodiversity, diet and health in policy and practice”, *Proceedings of the Nutrition Society* vol. 65, 2006, pp. 182-189

Joint WHO-FAO Experts Consultation (2003), *Diet, Nutrition, and the Prevention of Chronic Diseases*, WHO Technical Report Series no. 916, Geneva 2003

Kalmijn S. *et al*. (1997), “Dietary fat intake and the risk of incident dementia in the Rotterdam Study”, *Annals of Neurology* vol. 42, no. 5, pp. 776-782

Kalnay E. and Cai M. (2003), “Impact of urbanization and land-use change on climate”, *Nature* vol 423, 29 May 2003, pp. 528-531

Kennedy G., Nantel G., and Shetty P.(2004), “Globalization of food systems in developing countries: a synthesis of country case studies”, in FAO Paper no 83, “*Globalization of food systems in developing countries: impact on food security and nutrition*”, Rome 2004, pp 1-26

Kerselaers E. *et al.* (2007), “Modelling farm-level economic potential for conversion to organic farming”, *Agricultural Systems* vol. 94, 2007, pp. 671-682

Kim S. *et al.* (2000), “The Nutrition Transition in South Korea”, *American Journal of Clinical Nutrition* vol. 71, pp. 44-53

Koohafkan P. (2010), “Dynamic conservation of Globally Important Agricultural Heritage Systems: for a sustainable agriculture and rural development”, in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 56-65

Kosulwat V. (2002), “The nutrition and health transition in Thailand”, *Public Health Nutrition* vol. 5 no. 1A, pp. 183-189

Kuhnlein H. V. (2010), “ Biodiversity and sustainability of Indigenous Peoples’ foods and diets”, in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 118-124

Kuhnlein H. V. *et al.* (2004), “Arctic Indigenous Peoples experience the nutrition transition with changing dietary patterns and obesity”, *The Journal of Nutrition* vol. 134 no 6, pp. 1447-1453

Lairon D. (2010), “Biodiversity and sustainable nutrition with a food-based approach”, in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 30-35

Lansink A.O., Pietola K., Bäckman S. (2002), “Efficiency and productivity of conventional and organic farms in Finland 1994-1997”, *European Review of Agricultural Economics* vol. 29 no. 1 (2002), pp. 51-65

Lee, D. R. (2005), “Agricultural sustainability and technology adoption: issues and policies for developing countries”, *American Journal of Agricultural Economy* vol. 84 no.5, pp. 1325-1334

Macdiarmid J. I. (2012), “Is a healthy diet an environmentally sustainable diet?”, *Proceedings of the Nutrition Society*, vol. 72, 2013, pp. 13-20

Macdiarmid J. I. *et al*. (2012), "Sustainable diets for the future: can we contribute to reducing greenhouse gas emissions by eating a healthy diet?", *American Journal of Clinical Nutrition* vol. 96, pp. 632-639

McMichael A. J. *et al.* (2007), Food, livestock production, energy, climate change, and health", *The Lancet*, vol. 30 (9594): 1253-1263

Meadows D. H., Meadows D. L., Randers J., and Beherens W. W. (1972), *The limits to growth*, New York: New American Library

Misra A. *et al.* (2011), "Nutrition transition in India: secular trends in dietary intake and their relationship to diet-related non-communicable diseases", *Journal of Diabetes*, vol. 3 (2011), pp. 278-282

Mogues, T. *et al.* (2012), " The Impacts of Public Investment in and for Agriculture", *IFPRI Discussion Paper* no. 01217, October 2012

Moss, M. (2013), *"Salt, sugar, fat: how the food giants hooked us"*, Random House

Murray W. J. (2010), "Sustainable crop production intensification", in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 66-74

Newman P. (2006), "The environmental impact of cities", *Environment and Urbanization* vol. 18 no 2 October 2006, pp. 275-295

Niggli U., Fliessbach A., Hepperly P. and Scialappa N. (2009), "Low Greenhouse Gas Agriculture: Mitigation and Adaptation Potential of Sustainable Farming Systems", FAO, April 2009, Rev. 2 – 2009

Oltjen J. W. and Beckett J. L. (1996), "Role of ruminant livestock in sustainable agriculture systems", *Journal of Animal Science* vol. 74, pp. 1406-1409

Onimawo I. (2010), "Traditional food systems in assuring food security in Nigeria", in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 181-196

Padilla M., Capone R., Palma G. (2010), "Sustainability of the food chain from field top late: the case of the Mediterranean Diet", in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 231-240

Panayotou T. (1993), "Empirical tests and policy analysis of environmental degradation at different stages of economic development", *Working Paper WP238, Technology and Employment Programme*, Geneva: International Labor Office

Paoletti F. (2010), "Organic farming: sustainability, biodiversity and diets" in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 254-261

Parfitt J., Barthel M., Macnaughton S. (2010), "Food waste within food supply chains: quantification and potential for change", *Philosophical Transactions of the Royal Society B* vol. 365 (2010), pp. 3065-3081

Parry M. L. (2004), "Effects of climate change on global food production under SRES emissions and socio-economic scenarios", *Global Environmental Change* vol 14 (2004), pp 53-67

Petrillo P. (2010), “Biocultural diversity and the Mediterranean Diet”, in Burlingame B. and Dernini S. (ed.) *Sustainable diet and biodiversity*, FAO – Food and Agriculture Organization, pp. 224-230

Pimentel D. and Pimentel M. (2003), “Sustainability of meat-based and plant-based diets and the environment”, *American Journal of Clinical Nutrition* vol. 78 (Suppl.), 2003, pp. 660 S-663S

Pimentel D. *et al.* (2005), “Environmental, energetic, and economic comparison of organic and conventional farming systems”, *BioScience* vol. 55 no. 7, July 2005, pp. 573-582

Popkin B. M. (1999), “Urbanization, lifestyle changes, and the nutrition transition”, *World Development* vol. 27 no 11, pp. 1905-1916

Popkin B. M. (2001), “Nutrition transition: The changing global nutrition challenge”, *Asia Pacific Journal of Clinical Nutrition*, vol 10 (suppl.), pp. S13-S18

Popkin B. M. (2004), “The Nutrition Transition: an Overview of the World Patterns of Change”, *Nutrition Reviews* vol. 62 no 7, pp. S140-S143

Popkin B. M. and Gordon-Larsen P. (2004), “The nutrition transition: worldwide obesity and their determinants”, *International Journal of Obesity* vol. 28 (2004), pp. S2-S9

Popkin B. M. *et al*. (2001), “Trends in Diet, Nutritional Status, and Diet-related Non-communicable Diseases in China and India: The Economic Costs of the Nutrition Transition”, *Nutrition reviews* vol. 59 no. 12, pp. 379-390

Pretty, J. (2007), “Agricultural sustainability: concepts, principles and evidence”, *Philosophical Transactions of the Royal Society B*, vol. 363 (2008), pp. 447-465

Pugliese P. (2001), “Organic Farming and Sustainable Rural Development: A Multifaceted and Promising Convergence”, *Sociologia Ruralis* vol 41 no. 1, January 2001, pp. 112-130

Puska P. (2002), “Nutrition and global prevention on non-communicable diseases”, *Asia Pacific Journal of Clinical Nutrition*, vol. 11(Suppl), pp. S755-S758

Reijnders L. and Soret S. (2003), “Quantification of the environmental impact of different dietary protein choices”, *American Journal of Clinical Nutrition* vol. 78 (Suppl.), 2003, pp. 664S-668S

Rosegrant M.W., Agcaoili-Sombilla M., and Perez N.D. (1995), “Global Food Projections to 2020: Implications for Investment”, *Food, Agriculture, and the Environment Discussion Paper* 5, October 1995, Washington D.C.: International Food Policy Research Institute

Satterthwaite D., McGranahan G., and Tacoli C. (2010), “Urbanization and its implication for food and farming”, *Phil. Trans. R. Soc. B* vol. 365 no. 1554, pp. 2809-2820

Scherr S. J. and Yadav S. (1996), “Land Degradation in the Developing World: Inplications for Food, Agriculture, and the Environment to 2020”, *Food, Agriculture, and the Environment Discussion Paper 14*, May 1996, Washington D.C.: International Food Policy Research Institute

Schmidthuber J. And Tubiello F. N. (2007), "Global food security under climate change", *PNAS* vol. 104 no 50, December 11th

Shi, T., Gill R. (2005), "Developing effective policies for the sustainable development of ecological agriculture in China: the case study of Jinshan County with a systems dynamics model", *Ecological Economics* vol. 53 (2005), pp. 223-246

Singh R. B. (2000), "Environmental consequences of agricultural development: a case study from the Green Revolution state of Haryana, India", *Agriculture, Ecosystem, and Environment*, vol. 82 (2002), pp. 97-103

Smith K. A. *et al.* (1997), "Emissions of N20 and NO associated with nitrogen fertilization in intensive agriculture, and the potential for mitigation", *Soil Use and Management*, vol. 13 Issue supplement s4, pp. 296-304

Smith, B. G. (2008), "Developing sustainable food supply chains", *Philosophical Transaction of the Royal Society B* vol. 363 (2008), pp. 849-861

Sonesson U., Davis J., and Ziegler F. (2010), "Food Production and Emissions of Greenhouse Gases", *SIK-Report no. 802,* Göteborg: SIK – The Swedish Institute for Food and Biotechnology, ISBN 978-91-7290-291-6

Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Food and Nutrition Board (1999), "Dietary reference intakes for calcium, phosphorus, magnesium, vitamin D, and fluoride", Institute of Medicine, Washington, DC, National Academy Press

Stehfest E. *et al.* (2009), "Climate benefits of changing diet", *Climate Change* vol. 95, 2009, pp. 83-102

Steinfeld H., Gerber P. (2010), " Livestock production and the global environment: Consume less or produce better?", *PNAS* vol. 107 no. 43, October 26, 2010, pp. 18237-18238

Stern, D. I., Common M. S., and Barbier E. B. (1996), "Economic Growth and Environmental Degradation: the Environmental Kuznets Curve and Sustainable Development", *World Development* vol 24 no 7, pp. 1151-1160

Thrupp, L. A. (2000), "Linking agricultural biodiversity and food security: the valuable role of agrobiodiversity for sustainable agriculture", *International Affairs* vol. 76 no.2, pp. 265-281

Tilman D. *et al.* (2002), "Agricultural sustainability and intensive production practices", *Nature* vol. 418, 8 August 2002, pp. 671-677

Tobler C. *et al.* (2011), "Eating green. Consumers' willingness to adopt ecological food consumption behaviors", *Appetite* no. 57 (2011) 674-682

Trichopoulou A. (2012), "Diversity *v.* globalization: traditional foods at the epicentre", *Public Health Nutrition* vol. 15 no.6, pp. 951-954

Tzouvelekas V., Pantzions C. J., Fotopoulos C. (2001), "Technical efficiency of alternative farming systems: the case of Greek organic and conventional olive-growing farms", *Food Policy* vol. 26 (2001), pp. 549-569

Van Den Berg H. and Jiggins J. (2007), “Investing in farmers – The impacts of Farmers Field Schools in Relation to Integrated Pest Management”, *World Development* vol. 35 no.4, pp.663-686

Vermeir I. Verbeke W. (2008), “Sustainable food consumption among young adults in Belgium: theory of planned behavior and the role of confidence and values”, *Ecological Economics* no. 63, 2008, pp. 542-553

Videira N. *et al.* (2012), “Background paper on sustainable food consumption and growth”, *First multinational knowledge brokerage event on sustainable food consumption*, 25-27 January 2012, Lisbon

Wallén A., Brandt N., Wennersten R. (2004), “Does the Swedish consumer’s choice of food influence greenhouse gas emissions?”, *Environmental Science and Policy* vol. 7, 2004, pp. 525-535

Weber, C. L. , and Matthews H. S. (2008), “Food-Miles and the Relative Climate Impacts of Food Choices in the United States”, *Environmental Science and Technology* vol. 40 no. 10 (2008), pp. 3508-3513

White T. (2000), “Diet and the distribution of environmental impact”, *Ecological Economics* vol.34 no.234, pp. 145-153

Wilson C. and Tisdell C. (2001), “Why farmers continue to use pesticides despite environmental, health and sustainability costs”, *Ecological Economics* vol. 39, 2001, pp. 449-462

Withrow D. and Alter D. A. (2011), “The economic burden of obesity worldwide: a systematic review of the direct costs of obesity”, *Obesity Reviews* no. 12, pp. 131.141

Wolf O. *et al.* (2011), “Do healthy diets in Europe matter to the environment? A quantitative analysis”, *Journal of Policy Modeling* vol. 33, 2011, pp. 8-28

Yang G. *et al.* (2008), “Emergence of chronic non-communicable diseases in China”, *Lancet* vol. 372, November 8th, 2008, pp. 1697-1705

York R., Rosa E. A., and Dietz T (2003), “Footprints on the Earth: the Environmental Consequences of Modernity”, *American Sociological Review* vol. 68, No. 2 (Apr., 2003), pp. 279-300

Zhai F. *et al*. (2009), “Prospective study on nutrition transition in China”, *Nutrition Reviews* vol. 67, suppl. 1, pp. S 56-S61

Websites

Angelo M. J. (2009), "Corn, carbon and conservation: rethinking U.S. agricultural policy in a changing global environment" ExpressO Available at: http://works.bepress.com

FAO (2011), *Food wastage footprint*, concept note, March 2012, internet: http://www.fao.org/ (consulted on July, 31th, 2013)

FAOSTAT database (2012), internet: http://faostat3.fao.org (consulted on August, 14th, 2013)

OECD (2012), "*Sustainable agriculture productivity growth and bridging the gap for small-family farms, Interagency report to the Mexican G20 presidency*", 12 June 2012, internet: www.oecd.org (consulted on July 15th, 2013)

Pretty, J. (2009), "Can ecological agriculture feed nine billion people?", available at www.monthlyreview.org

Reisch L., Eberle U., Lorek S. (2013), " Sustainable food consumption: an overview of contemporary issues and policies", *Sustainability: Science, Practice, and Policy* vol. 9 no. 2, summer 2013, available at: http://sspp.proquest.com/

UNEP (2011), *Agriculture – Investing in natural capital*, internet: http://www.unep.org/greeneconomy/ (Consulted on August 25th, 2013)

UNEP (2012), "*GEO 5 – Global Environmental Outlook*", internet : http://www.unep.org/geo/ (consulted on June 25th, 2013)

United Nations (2013), "*World Population Prospects: The 2012 Revision"*, internet: http://esa.un.org/ (consulted on June 20th, 2013)

Vorley, B. (2001), "The chains of agriculture: sustainability and restructuring agri-food markets", internet: http://pubs.iied.org/ (Consulted on August 25th, 2013)

WHO (2013), internet: http://www.who.int (consulted on August 16th, 2013)