<u>Examiner:</u>
Cees Leeuwis

<u>Supervisor:</u>
Janice Jiggins

<u>Co-supervisor:</u>
Edith Lammerts van Bueren

<u>Student:</u>
Juliette Prazak
870818-670-020
MOA
Specialization:
Consumers and Market

How are pre-analytical values surrounding sustainable agriculture expressed in science? An exploration of the debate

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“My subject is food, which concerns everyone; it is health, which concerns everyone: it is the soil, which concerns everyone – even if they do not realise it…"
Lady Eve Balfour, 1946

“Starvation is the characteristics of some people not having enough food to eat. It is not the characteristic of there not being enough food to eat"
Amartya Sen, 1982, Nobel Prize Economist

Abstract

This thesis aims to understand how researchers and scientists' framing of one problem can give insight into why the scientific debate surrounding sustainable agriculture is not moving forward and why drastically different interpretations and solutions to the question at stake are put forward.

Hoppe and Hischemöller's (2001) theory on intractable controversies was applied to the study of four mega-reports published in the past four years, each dealing with the same topic and yet bringing forward different and sometimes contradictory conclusions and recommendations. The reports studied were the International Assessment of Agricultural Knowledge, Science and Technology (IAASTD, the UK Foresight Study on the Future of Food and Farming, the US National Academy of Science Report for Sustainable Farming in the 21st century, and the Report by the UN Special Rapporteur on the Right to Food from December 2010.

The main findings are that papers published on the topic of food security and agricultural sustainability articulate their assessments and solutions around pre-analytical values; their declared research goals suggest what these might be. To address the issue purely in terms of sufficiency is to simplify it, thus making it possible to narrow the scope of what is taken into account and to give structured answers to the questions posed. Conversely, to articulate one's answer around a high number of social and technical themes, guarantees a complex answer, which can appear 'messy' to some, and of which the implications are difficult to grasp, let alone act on.

The conclusion is that it is possible that there is a bias in science to prefer structured problems over messy ones; an admission of the inherent 'messiness' of a given topic, and attempts not to overtly structure it, is seemingly associated with a lack of rigour. Empathy and kindness, when incorporated into scientific work, carry an aura of misplaced sentimentalism which is considered a hindrance to the conduct of 'real' science. On the other hand, insisting on consideration only of structured problems seems likely to lead politicians towards dealing with the wrong problems.

Key words: sustainable agriculture, debate framing, intractable controversies, Hoppe and Hischemöller, IAASTD, UK Foresight Study on the Future of Food and Farming, US National Academy of Science Report for Sustainable Farming in the 21st Century, Special Rapporteur on the Right to Food,

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Chapter 1: Presentation of the thesis

This chapter presents the work that has been done in this thesis. Agriculture has been a burning topic for some decades already; however the debate seems to be in a permanent state of transformation, as it adapts to both new technologies and changing global circumstances. In its wake, much academic and research literature is being produced, among which four so-called “mega-reports”, which are being summarised and analysed in this thesis, and which have each brought their individual take on the matter to the debate table. This work attempts to unearth the pre-analytical values which each participant brings with them, and which - without ever being explicated - greatly influence the outcomes of deliberations. Pre-analytical values are understood here as abstract ideas which are already present in individuals’ minds before they commence the examination of a problem (1.2). The conceptual framework used throughout this work is Hoppe and Hischemöller’s theory on “intractable controversies” (2001), when extraordinary complicated problems emerge, and how to recognise them and attempt to deal with them in an effective manner. Intractable controversies define problems with unclear boundaries, which are closely intertwined with other problems and issues, and which affect and involve a wide range of stakeholders, each bringing their own set of values and priorities to the debate table. This theory is presented in detail in 1.3. This research’s objective (1.4) was to understand how different stakeholders’ interpretation of the same topic is framed according to their values, and the extent to which this forms and influences their responses to it. Lastly, the methodology is detailed in 1.6, to help guide readers in understanding the thinking that went into the preparation of this work.

1.1 Introduction

The future of agriculture has been hotly debated in the past decade. In a context of wide-spread hunger and rampant food insecurity, climate change, volatile food prices on the global market, biodiversity loss, natural resource exhaustion and general anxiety about the future sustainability of global agricultural food systems, the debate on the future of global food systems, which encompasses both the social and the technical sciences, runs wild among the proponents of solutions. After the 2009 publication of the multi-stakeholder and multi-disciplinary report of the International Assessment of Agricultural Knowledge, Science and Technology (IAASTD) which called for an overhaul of the current food system, grand-scale reports emanating from different institutions and respected figures of the political and scientific world, and academic papers, are regularly published on the topic, each offering their own set of conclusions and recommendations to policy-makers, researchers, NGOs, charities and farmers. In addition to the IAASTD (2009), three influential mega-reports have been published in the last three years, namely the UK Foresight Study on the Future of Food and Farming (2011), the US National Academy Report for Sustainable Farming in the 21st century (2010), and the Report by the UN Special Rapporteur on the Right to Food from December 2010.

1.2 Problem Statement

1.2.1. Understanding the debate: framing mechanisms

This proliferation of opinions, while bringing about confusing and sometimes opposing conclusions and recommendations, is also an excellent terrain for researchers to study the impact of how problems are framed as researchable topics. Each author (or their affiliated institution) brings pre-analytical values to the research table, thus influencing the outcome of their deliberations. In the maze of information available, little consensus seems to emerge and sides firmly camp on their respective positions. Because of this, the debate is not moving forward as swiftly as desirable. It is interesting to understand how participants frame their own interpretation of the stakes in order to better understand how and why they devise the opinions they do and, more crucially, what they gain from this appropriation (framing) of the topic.

1.2.2. Pre-analytical values definition

For the purpose of this analysis, values here are being conceptualised following the guidelines provided by two definitions found in the scientific literature. According to Guth and Tagiuri (1965), values are concepts about what is desirable, which then provide the foundations on which individuals and groups can “select from among alternative modes the means and ends of action”. In other words, values guide reflection, thus enabling considered action. Rokeach (1959, cited in Badr et al., 1982), rather emphasises the notion that values “are abstract ideas, positive or negative, not tied to any specific object or situation, representing a person’s beliefs about modes of conduct and ideal terminal modes”.

In this thesis, values are defined as abstract ideas, positive or negative, existing in individual minds and within groups’ collective consciousness, but outside of specific objects and situations, and used to guide reflection and enable choices and action. Analysis is defined as the careful examination of the elements of a problem as a basis for its discussion and interpretation. The preposition “pre” conveys a meaning of anteriority, “what comes before” (Oxford English Dictionary, 2012).

As such, pre-analytical values are understood here as abstract ideas that normally guide reflection and action, but which are already present in the individuals’ minds before they commence the examination of a problem with a view to understand, discuss and interpret it. This work is based on the premise that pre-analytical values can potentially shape the analysis about to take place and model it in such a way as to reinforce them. Pre-analytical values can have a negative impact on the objectivity of a research process when they are not being ‘declared’; however, if scientists were aware of their own pre-analytical values and made them obvious from the start, their researches and science as a whole would gain in intellectual honesty.

1.2.3. Structured and unstructured problems

Because no closure to the debate is emerging, it seems necessary to take a closer look at the agreements and disagreements and try and see if any common ground can be found at all between the parties. It maybe that part of the problem relates to the tendency on some voices’ part to address the subject of this report as if it were very well structured, technical and for which the knowledge needed was easily defined and easily accessible. This is the main proposition we examine in this thesis (see conceptual framework).

1.3 Conceptual Framework

The concept of structured and unstructured problems is put forward and compellingly explained by Hoppe and Hischemöller (2001). They offer a convincing argument for examining the nature of "intractable controversies" (Schön and Rein, 1994 cited in Hoppe and Hischemöller, 2001), when extraordinary complicated problems emerge, and the conditions under which these controversies can be successfully dealt with. In so doing, they discern four types of problems: structured, unstructured and two moderately structured problems (Figure 1.3 below). They argue that policymakers tend to try and move away from unstructured problems and to focus on structured ones instead, thus sometimes addressing the "wrong" policy problems, which in term can lead to intractable controversies, linked to messy problems. Policy problems are not objective states of affairs, they are "social and political constructs" and, as such, they articulate values as well as facts. "What one person considers a matter of fact, another may well consider a matter of ideology or a lie" (Hoppe and Hischemöller, 2001).

Messy or unstructured problems are characterised by diffuse boundaries, they are difficult to distinguish from other problems, diverse disciplines are called on to address them and different values and facts are interlocked within them. This tends to mean that a range of actors become involved in the problem-solving process. As a result, these problems are better defined as political because "to address the whole problem is more than to address each of its parts" (Ibid). It is often suggested that problem structuring is needed to solve unstructured problems: new insight needs to be put forward as to what the problem is about. This raises in turn the question of who is authorised to structure the problem and offer solutions.

Technical or structured problems are well-defined and they can be solved by standardised (quantitative) techniques and procedures. "The disciplines and specialisations to be invoked are clearly defined and the policy-making responsibility is in the hand of one actor". The knowledge (disciplines and specialisations) needed to solve them is obvious, easy to define, and readily available. To simplify matters further, the decision-making regarding the solving of this problem is in the hands of one only actor.

Hoppe (1989 cited in Hoppe and Hischemöller, 2001) drew a typology of problems to categorize the four types of policy problems, mapped out in two dimensions (see Figure 3.1 below). The first dimension is about certainty (or lack of certainty) regarding knowledge of the problematic situation and ways to make it easier to understand and deal with; the second dimension concerns consensus (or lack of consensus) among actors regarding relevant values.

Structured problems: have a high degree of consensus on values and a high degree of certainty on knowledge.
Moderately structured problems (ends): have a high degree of consensus on values but lack certainty on knowledge.
Moderately structured problems (means): have a lack of consensus on values and a high degree of certainty on knowledge.
Unstructured problems: have a lack of consensus on values and a lack of certainty on knowledge, "yet there is still a widespread sense of discomfort with the status quo" (Hoppe and Hischemöller, 2001; my emphasis).

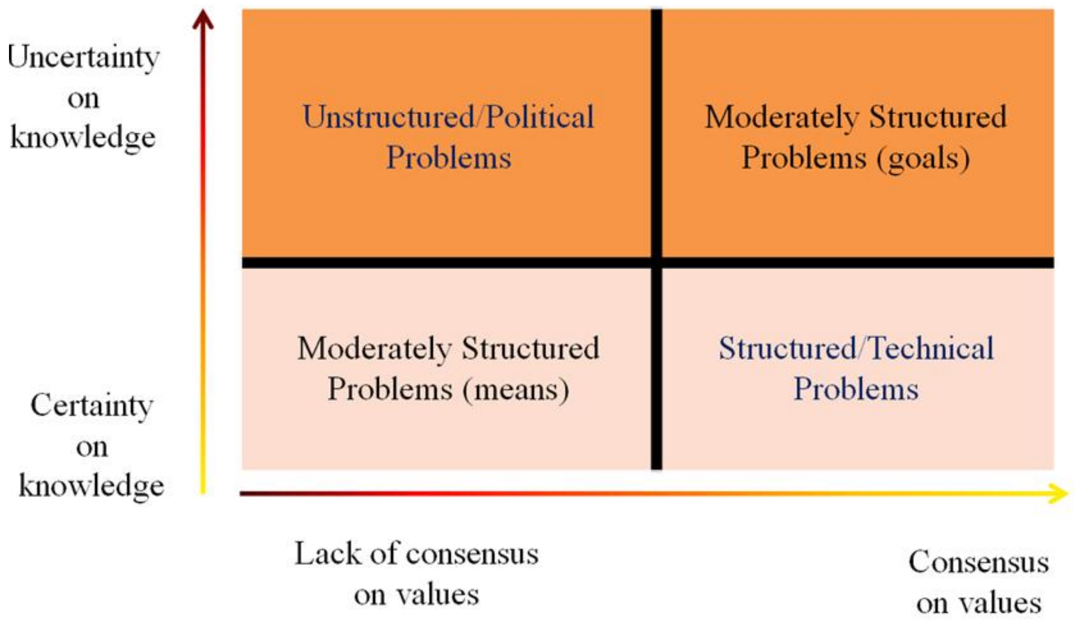

Figure 1.3. Intractable controversies, adapted from Hoppe, 1989

1.4 Objectives of the research

This research's objective was to understand how different stakeholders' interpretation of the same topic (which type of agriculture will benefit global future of food security best?) is framed according to their values, and the extent to which this forms and influences their responses to it. It is the hope that this work can enable the actors in the debate to learn a better way forward.

1.5 Research questions

In order to address the research objectives mentioned above, the following research questions are analysed and discussed:

- How is the problem structured in the four reports, and more specifically how are pre-analytical values and knowledge certainty expressed in them (namely the IAASTD (2009), the UK Foresight Study on the Future of Food and Farming (2011), the US National Academy Report for Sustainable Farming in the 21st century (2010), and the Report by the UN Special Rapporteur on the Right to Food from December 2010)?

- What explicit or implicit pre-analytical values underlie these reports?

- What kinds of issues do the reports address and what not?

- How are roles and responsibilities of different stakeholders portrayed in mega-reports?

1.6 Methodology

This research has four parts. I first summarised four mega-reports (the IAASTD, the UK Foresight Study on the Future of Food and Farming, the US National Academy Report for Sustainable Farming in the 21st century, and the Report by the UN Special Rapporteur on the Right to Food from December 2010). They characterise four of the most politically visible efforts by the international and scientific communities to bring together pieces of the puzzle. Each in their own way has been influential in policy and practice. Together they represent significant efforts to place science to solve societal problems, through collective effort on a never-seen-before scale. In each, I have looked for statements which expressed pre-values, uncertainty vis-à-vis the knowledge deemed necessary to adequately deal with the issues tackled, as well as knowledge gaps. I have selected and collected them in order to compare and contrast them in four tables, each revealing diverse sides of their creation processes. One of the tables (Table 2.3) used a short content analysis to reveal the main focus of each report's research objective. Key words and phrases in the four primary animating questions of the mega reports were isolated and clustered as either being technical or political in nature. Clusters were then counted for each report in order to clarify the pre-analytical foundations on which each report was built.
Secondly, two texts, namely Parrot and Marsden (2002) and Avery (1995), have been purposely selected from a wide array of scientific paper and books (see below), because they each represented one extreme of the opinion spectrum on the wide topic of agriculture according to Hoppe and Hischemöller's matrix. I have looked for value statements, and statement expressing knowledge certainty and uncertainty in those two texts. After selecting them, I compared and contrasted them around the three topics of agricultural inputs, markets, and the socio-cultural aspects of farming. The aim was to reveal each authors' certainty or uncertainty regarding the knowledge (disciplines and specialisations) they deem to be needed to best address the discussion surrounding the adequacy and desirability of different types of agriculture.

Thirdly, 48 peer-reviewed articles and books were accessed; each deals with several of the many issues surrounding agriculture and food production. Those selected were referenced and used as background information in at least two of the main mega-reports. The purpose here was to examine in finer detail a representation of the entire spectrum of opinions, from one extreme to the other. The information, data, opinions, discussions and conclusions they contain have been used to write an extensive essay which aims to address the major topics in the debate surrounding sustainable agriculture. The aim here is to give the reader a thorough overview of the state of knowledge currently displayed by science on this topic, and of the virulent dispute that accompanies it. These articles were accessed manually using key words such as: "organic agriculture", "conventional agriculture", "agro-ecology", "low input agriculture", "high input agriculture", "sustainable agriculture", "unsustainable agriculture", "small-holders", "rural development", "rural development farming", "subsistence farming", "industrialisation farming", "organic conventional performance", "organic conventional yields", "biodiversity in farming", "loss of biodiversity", "pesticides biodiversity", "rural livelihoods", "pesticides organic farming", "natural resources farming", "natural resources management farming", "natural resources stress farming", "green revolution", "organic agriculture feed world", "food security". I operated a purposeful selection to represent the diversity of the material cited in the mega-reports. These 48 papers were divided into two clusters depending on their framing of the topic, following the axis of knowledge in Hoppe's matrix. Cluster 1 considers the questions surrounding agriculture as mostly technical ones, whereby they are easy to define and the knowledge to solve them is obvious and readily available. Cluster 2 considers the questions surrounding agriculture are mostly political, whereby they display unclear boundaries, are difficult to distinguish from other problems and articulate contradictory values and facts. Quotes were extracted from each text to illustrate this dichotomy.

Lastly, a final round of analysis was carried out, applying the four dimensions of the controversies, as drawn by Hoppe and Hischemöller (2001), to the material that has been accessed, in order to try and fit each mega-report into one cell of their matrix.

1.7 Thesis Outline

This thesis is organised into three parts. Firstly, I offer a summary of the four mega-reports which are later analysed in details with the help of tables. This part specifically focuses on the axis of the value consensus (or lack of it) in the Hoppe and Hischemöller's matrix (2001).

The second part focuses on the knowledge certainty/uncertainty axis in the Hoppe and Hischemöller's matrix. The analysis first revolves around two papers chosen to represent one extreme of the spectrum each, it then opens up to all 48 papers read for the redaction of this thesis, and clusters them into two categories according to the way they frame their analysis as either representing a political or a technical problem. Quotes directly extracted from each paper are presented in order to illustrate and justify the clustering each individual paper was selected for.

Thirdly, the research questions are being answered individually, followed by the discussion which in turn raises further questions for future research. The thesis is then wrapped up in the conclusion.

Chapter 2: Uncovering pre-analytical values in the mega-reports

This chapter aims to first summarise and second analyse the four mega reports of the IAASTD, the UK Foresight, the US National Academy of Science and the Special Rapporteur in order to uncover the pre-analytical values which may have guided them. Considering the background of each research paper, the IAASTD and the Special Rapporteur are expected to share a significant number of values with each other, while the UK Foresight and the National Academy of Science are expected to reflect along similar lines.

More specifically, the pre-analytical values which are being searched for are that the IAASTD and the Special Rapporteur are pro-poor, concerned with rural livelihoods and equality. As such, they favour directly applicable technologies and knowledge, and hold the value that such technology should be available free of charge to be indefinitely replicated and shared unrestricted. The UK Foresight and the US National Academy of Science are suspected of thinking differently, and while not being ‘anti-poor’, hold the value that the private sector has an important role to play in sustainable agriculture, and that technology transfers from the North to the South can mostly be beneficial for the latter.

In relation to this, a second pre-analytical value which is being looked for is that the IAASTD and the Special Rapporteur will have faith in human ingenuity and in the relevance of the ancestral knowledge of communities. Contrary to this, the UK Foresight and the National Academy of Science are expected to display a more techno-centric approach, valuing innovation brought about by science and technology.

Thirdly, The IAASTD and the Special Rapporteur are anticipated to value local food production as well as the livelihood and welfare of small-scale farmers in industrialising nations. The US Academy of Science and the UK Foresight are anticipated to share the value that large-scale farming is a desirable option.

2.1 International mega-reports

2.1.1 The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), 2009.

Starting point
The Global IAASTD report is the common work of about 400 world’s experts nominated by a range of geographically balanced stakeholders from both the public and private sectors. The experts worked on the IAASTD project between 2005 and 2007. These experts worked in their own capacity; they did not represent any particular stakeholders. The peer-review process was carried out by organisations, governments and other individuals. The project was financed by the governments of Australia, Canada, Finland, France, Ireland, Sweden, Switzerland, the United States and the United Kingdom as well as by the European Commission and by the following cosponsoring agencies: the Food and Agriculture Organisation of the United Nations (FAO), the Global Environmental Facility (GEF), the United Nations Development Programme (UNDP), the United Nations Environment

Programme (UNEP), the United Nations Educational, Scientific and Cultural Organisation (UNESCO), the World Bank and the World Health Organisation (WHO).

The IAASTDS endorsed a number of development and sustainability goals around which to articulate its work. These goals are coherent with a number of UN Millennium Development Goals. They are:

- The reduction of hunger and poverty
- The improvement of rural livelihoods and human health
- The facilitation of equitable, socially, environmentally and economically sustainable development.

The IAASTD is a response to the realisation that despite human kind's success in improving agricultural productivity through science and technology, we have neglected the unintended social and environmental consequences of this massive achievement. The IAASTD pays special attention to issues and opportunities faced by the current AKST (Agriculture, Knowledge, Science and Technology) system to improve and enhance the livelihoods of poor rural populations, especially small-scale farmers and farm labourers and those with limited resources. However, it does not advocate specific policies but rather points in the direction of relevant options for action in the field of AKST to meet development and sustainability goals. Options for action are not given a specific order of priority, as the IAASTD notes that different actions can be taken by different stakeholders in line with their values, priorities and circumstances.

To successfully meet these development and sustainability goals, a shift in AKST is needed which would encompass science, technology, policies, institutions, capacity development and investment. This shift would recognise and account for the multi-functionality of agriculture and recognise all the ecological and social complexity within which different agricultural systems operate. This would entail an integrative approach to the development and application of AKST. Furthermore, it would give a renewed status to farmers and farming communities as both producers and ecosystems managers (stewards of the land). The IAASTD warns that this shift can potentially entail a change in the incentives systems for all actors involved along the value chain to internalise as many costs as possible (no more cost-shifting). The policies and institutional changes should benefit those which have been least advantaged by past AKST approaches such as resource-poor farmers, women and ethnic minorities. This new approach would need extra investments from public and private stakeholders in AKST, the coming about of new supportive institutions, the revalorisation of traditional and local knowledge as well as a holistic approach to knowledge production, application and dispersion.

The IAASTD defined sustainability as a "more holistic integration of natural resources management (NRM) with food and nutritional security. A holistic, or systems-oriented approach, is preferable because it can address the difficult issues associated with the complexity of food and other production systems in different ecologies, locations and cultures".

The Synthesis Report of the IAASTD articulated its findings around six topics which together offer options for action of the Global Report.

Poverty and Livelihoods:
Rural livelihoods can be improved by ameliorating farmers' access to profitable farming land and to local urban and export markets as well as by increasing the value retained by small-scale farmers and labourers. Farmers should be encouraged to develop innovative management of soils, biological diversity and resources, water, pests and disease vectors and to conserve natural resources in manners which are culturally appropriate. New partnerships to create exchanges of knowledge between local farmers, scientists and other stakeholders would also be helpful. Policies to help improve rural livelihoods for the farming poor include access to micro-credit, legal frameworks to secure access to land, water and just conflict resolution procedures, as well as a "progressive evolution and proactive engagement in intellectual property rights regimes (IPR)".

Food Security:
While the IAASTD recognises the importance of production measures to create adequate food security, it also notes the parallel and equally important issue of people's physical access to food as well as their ability to absorb the nutrients they consume. Food security is achieved through the necessity of accessing food whether through own production, exchange or other forms of entitlement and through its twin issue of effective nutrient absorption enabled by water and sanitation, adequate diet and nutritional information.

Local and formal AKST can be used to develop locally-adapted cultivars, ensure on-farm diversity, conserve and enhance soil, water and biological diversity, and improve pest management at all levels of the food production chain. Policy option to reach these targets include using under-utilised but high-value crops which are particularly consumed by poor people in rain-fed areas, widen the range of agricultural imports and exports, including organic and fair trade products, beef-up local markets and farmers' safety nets and increase food safety and quality. Because the global market is increasingly vulnerable to price shocks and extreme weather, a global monitoring system should be put in place for advance prediction regarding potential food shortages and market-induced hunger.

Environmental Stability:
There is a pressing need to pay more attention to sustainability without jeopardising the high productivity that is going to be needed in the future. Policy options to achieve this all-encompassing aim include terminating subsidies that do not pay enough attention to environmental impacts of the production systems they promote and using market mechanisms instead to reward agricultural management that provides ecological services. Examples are incentives for using integral pest management (IPM) and for ecosystem services, certification schemes for organic agriculture and practices applied to forest and fisheries, and the facilitation of alternative marketing routes and local markets. Furthermore, modes of governance which enhance participatory democracy and a common pool of knowledge should be fostered.

Human Health and Nutrition

- Increasing food security can be achieved through the promotion of policies to diversify diets and enhance micronutrients diets.
- Increasing food safety can be done through investments for infrastructures dealing with public and veterinary health and through the coordination of national and international food safety systems.
- The incidence of infectious disease can be decreased through proactive coordination of

agricultural, veterinary and public health systems, as well as through the development of new AKST to identify, prevent and treat diseases.

- The incidence of chronic diseases can be decreased through the development of policies that acknowledge the significance of nutrition on human health, thus leading to regulations in food products formulation and labelling and thought the creation of incentives to consume healthy food.
- Occupational and public health can be improved by enacting health assessments that take into account the "trade-offs between maximising livelihoods benefits, the environment, and improving health", as well as by enforcing health and safety regulations and cross-borders issues relating to health.

Equity

Fairness in AKST is a real issue and investments are needed to enhance farmers' access to education and technologies. Additionally, formal science and technology can be made to work together with traditional knowledge. AKST and its related organisations should go through a reform to enable them to improve the role they can play in enhancing communities' scientific knowledge and include their concerns in research priorities. Equity means a greater working synergy among development stakeholders including farmers and rural workers, banks, civil society, public agencies and the private sector. Furthermore, equity encompasses the reduction of gender and ethnic issues.

Investments

Development and sustainability goals can be increased through increased investments and a wider base of funding mechanisms for agricultural and development research and knowledge such as:

- Public investments to increase the provision of public goods;
- Public investments to promote communities of knowledge;
- Public-private partnerships to enhance the commercialisation and economic benefits of technologies and science;
- Rewards for private and civil society investments that contribute to sustainable development goals;
- Increased investments in infrastructures in developing countries.

The IAASTD Global Report identified eight themes of critical interests in the field of development and sustainability goals.

Bioenergy

Millions of people in the developing world rely on natural bioenergy (such as wood) for cooking and heating, this is mainly due to a lack of alternatives but poses as a threat to the environment, health, and economic and social stability.
Furthermore, bioenergy is now used for biofuels which diverts land normally used to farm food and feed; this directly challenges alleviation of hunger throughout the world. Next generation biofuels can potentially be more effective but uncertainty remains.

Biotechnology

The most controversial form of biotechnology is the so-called "recombinant DNA technique" that produces transgene which are then inserted into genomes. The IAASTD has found that assessment of this modern technology is lagging behind its development and that uncertainty on the technology's benefits and harms on human health, the environment and the economy are still unknown. Because biotechnology products are usually tied to Intellectual Property Rights framework (IPR), they attract investments while concentrating their ownership. The use of patents on transgene products may drive up costs of production, restrict farmers and research and even undermine food security and economic sustainability as they prevent rural seed-saving traditions, thus limiting farmers' scope to experiment and trade with their seeds.

Climate change
Farming negatively contributes to climate change in a number of ways while climate change can potentially damage the very natural resource base on which agriculture depends. Climate change predicts to be mostly negative for agriculture although a small number of positive outcomes are possible. Strong cuts in GHG emissions are necessary now to stabilise their concentrations. Additionally, developing tools for farming to address and adapt to climate change is needed.

Human health
Although agricultural policies rarely have the goal to improve human health, there is a need to replace dietary quality back at the centre of agricultural production. Agriculture should not just be about quantity and price. Strategies to achieve this could include fiscal policies to make healthy food more attractive as well as new regulations on the formulation, labelling and advertising of food.

Natural resource management
Natural resources management promises to present with new challenges in the future that will call for creative approaches from all stakeholders to resolve. The IAASTD offers the following options for actions in this field:

- Decline in agricultural productivity can be directly linked to natural resources mismanagement. AKST can help identify and solve the complexity of this issue
- Increased investments can help support natural capital (i.e.: giving a financial value to ecosystems services and environmental degradation)
- Promote research for better resource resilience
- Develop networks of AKST practitioners to enhance long-term resource management.
- Link natural resource management knowledge and innovations to public and private AKST.

Trade and markets
Opening national agricultural markets to international competition before basic governance and infrastructures are in place has potential long-term negative effects. As such, developing countries should be allowed to pursue the attainment of their food security and development goals while benefiting from a special trade treatment which removes tariff barriers for products for which they have an advantage.

Traditional knowledge and community-based innovation
Traditional knowledge should be incorporated in AKST to allow for more scope in dealing with issues of genetic resources, community-based innovations and IPR regimes.

Women in agriculture
Women represent between 20-70 per cent of the work done in agricultural production and post-harvest activities. However, gender issues are not addressed enough as integral parts of

the attainment of development goals. Priority should be given to women's access to education, information, technology as well as ownership of land and control over natural resources.

2.1.2. The Future of Food and Farming: Challenges and Choices for Global Sustainability. UK Foresight Study, 2011.

Starting Point

The Foresight Study aimed to study the pressures that will arise on the global food system between now and 2050 to help decision-makers and stakeholders make the right decisions in order that a global population of 9 billion can be fed "sustainably and equitably". Around 400 experts and stakeholders were involved in the project coming from some 35 low-, middle-, and high-income countries around the world. The project drew upon 100 peer-reviewed evidence papers. It was financially sponsored by the UK Government's Department for Environment, Food and Rural Affairs (Defra) and the Department for International Development (DFID).

The Foresight report urges for a redesign of the global food systems if it is to meet the challenge to feed the world population in the next 40 years. It identified five key challenges that call for a pragmatic actions, these are:

A. Balancing future demand and supply sustainably – to make food supplies affordable.
B. Ensuring food supply stability and protect those who are most vulnerable when/if price volatility happens.
C. Ensuring a fair access to food for all. High production is not enough if distribution cannot be ensured
D. Managing the food system's participation to climate change
E. Feed the world while ensuring the integrity of biodiversity and ecosystems services.

The Report recognises that despite some price volatility in the past three years, today's food system continues to feed the majority of the world population with an abundance and variety of affordable food. However, it is also failing in two major ways:

- Hunger remains a concern as 925 million people still experience hunger in the world today, while one billion is over-eating, creating a new epidemics of so-called 'non-communicable' diseases. The root causes of both these phenomenon lie in the current food system.
- Many farming systems as practiced in the world today are unsustainable and they compromise their own ability to produce food in the future.

Policy makers need to recognise food as a unique "class of commodity" and adopt a broader, all-encompassing perspective when considering the global food system. The UK Foresight Report defines sustainability as "the use of resources at rates that do not exceed the capacity of the Earth to replace them".

Challenge A: Balancing future demand and supply sustainably

Production alone is not enough although it is necessary. Food security can only be achieved when both the positive and negative externalities of food production are acknowledged and when the needs of poor rural communities are taken into account.

- There is a need for the renewal of extension services to achieve both sustainability and an increase in food production. Women should be particularly targeted as they are often the base producers of food.
- Markets' functioning and their access need to be improved for low-income countries.
- Physical infrastructures should be improved in middle and low income countries so as to enhance access to markets and to investments.
- Rights to land and natural resources should be strengthened.

Science and technology can and should raise the limits of increased, sustainable food production, as such it can:
- Develop new breeds of crops, livestock and aquatic organisms
- Preserve the diversity of breeds already in existence including both wild and domesticated ones
- Create advances in the field of nutrition
- Create advances in the fields of soil sciences
- Invest in research areas which have received little investments in recent years.

Reducing waste appears as an increasingly pressing need if food security is to be achieved. Estimates of food wastage range between 30 to 50 per cent of all the food grown worldwide. Food waste means all food that is intended for human use but which is discarded, lost, damaged or consumed by pests instead, on its journey through the food chain. Food waste is also food which was intended for human consumption but which was fed to animals instead. The Report suggests that halving the amount of food wasted by 2050 is realistic and will significantly reduce food production requirements. Interventions are required in low-income countries to:
- Invest in new or existing technology to improve storage and transportation.
- Reform access to market information to enable producers to sell at the best price

In high-income countries, interventions are required to:
- Campaign in order to raise awareness of the extent of food waste
- Develop mass-produce sensor technology to detect spoilage in food which would be more reliable than the 'guesstimates' of the 'best before' dates in the retail industry;
- Recycle non-premium surplus food
- Spread best practices among people through education and technology

Governance of the food system can and should be improved. As such:
- Fair and functioning markets do more for food security than policies that promote self-sufficiency. Countries should rely on the global market for their food security all the while keeping a responsibility for the provision of food in times of crisis.
- International institutions should be allowed to prevent countries from enacting trade restrictions in times of price volatility in order to prevent a worsening of the situation.
- Food subsidies should be done away with, as they raise consumer prices in protected countries and harm global markets.
- Rural communities should be supported.
- Environmental issues should be included when international organisations such as the World Trade Organisation go through a reform.
- Irresponsible fishing need to be monitored and punished, and pressures should be exerted on the industry by consumers and retailers.

Healthy competitions between companies in the food industry should be possible at local levels, and intervention to control their numbers should not be enacted so long as to not threaten competition.

Challenge B: Addressing the threat of future volatility in the food system

Food price spikes can cause disruptions to the global food system, have adverse effects on consumers and producers alike and can even disrupt economical and political regimes. It is nearly impossible to assess what the future magnitude and fluctuations of food prices will be in the coming half century. As such, the Report suggests that the most vulnerable groups be protected from the worst effects of price fluctuations by trying to indirectly influence markets and improve their functioning and by providing safety nets to poor consumers and producers.

The Project did not find compelling evidence to put in place a global system of grain reserves to help temper price fluctuations.

Challenge C: Ending hunger

It is estimated that 925 million people suffer from hunger and that an additional billion are probably suffering from a chronic deficiency of macro-nutrients, the so-called ‘hidden hunger’ of not having enough vitamins and minerals. It is however difficult to define and measure hunger, under-nutrition and more generally what food security constitutes for different people.

It is important that policy-makers understand how food-insecurity and under-nutrition interact in complex ways at different levels. “Strong levels of political courage and leadership will be required” to tackle hunger.

Chronic hunger is most prevalent in the areas of south Asia and sub-Saharan Africa. There, agricultural development policies should be tied closely with hunger reduction as primary goals. Food production enables physical access to food, it raises farm income and generates employment, it reduces food prices and it has the potential to address social issues such as deliberately empowering women and excluded groups.

Governments need to replace agriculture as a real profession that can lead to multiple ends one of which being the reduction of hunger, poverty and exclusion. However, agriculture cannot end hunger alone, social interventions are vital too. These include:

- Social protection to improve access to food (such as cash transfers to help vulnerable households be more resilient to a number of shocks). However, because social protection can compete with agriculture for political support, it is important not to see it as a silver bullet.
- Gender power relations should be proactively placed at the heart of agricultural research and development.
- Under-nutrition need to be tackled on the two fronts of direct and indirect interventions. Direct intervention aims to improve nutritional status while indirect nutrition relies on policies for which nutrition improvement is not a core aim but which have the potential to be efficient through other means.

“The international community must challenge itself over the apparent ease with which hunger is ignored and ask why hunger is so easy to neglect”. Tackling hunger has rarely been a political priority (except in Brazil this past decade) since the poorest segments of the population usually exert little power or pressure on governments. "Donor fashion" in the field of development aid has been changing in the past decades resulting in a dip in agricultural development investments. It is time to put the pressure back on issues of hunger, pro-poor investments and anti-hunger agricultural policies.

Challenge D: Meeting the challenges of a low emissions world

The global food system is responsible for a substantial amount of greenhouse gas (GHG) emissions and as such, it needs to be an angle from which to tackle climate change. Equally, agriculture being vital for human survival, policies aiming to decrease GHG emissions will walk a fine line. Agriculture contributes to 30 per cent of all global greenhouse gas emissions; this figure includes fertiliser production, land conversion and all the post-harvest handling and processing. Interestingly, low and middle income countries are currently responsible for about three quarters of agricultural greenhouse gas emissions, and this share is increasing. The first and most important agricultural contribution to greenhouse gas emissions is the production and application of nitrogen fertilisers, the second one is livestock production and the enteric fermentation and manure it generates. A massive amount of carbon is tied into farmland and there is nearly as much carbon in the organic compounds in the 30 top centimetres of topsoil as there is in the entire atmosphere.

Many techniques that improve sustainable food production also reduce greenhouse gas emissions.

Challenge E: Maintaining biodiversity and ecosystem services while feeding the world

"The political reality is that sustainability cannot be pursued in the absence of food security". It used to be the case that these two issues were developed away from each other, although this trend seems to be reversing now. However there are important trade-offs that policy makers need to be aware of when developing joined development and sustainability policies: for example the richest, most diverse and most vulnerable habitats are found in developing countries and interventions to make farming more sustainable in these areas may become major threats to the livelihoods of local populations.

Because agricultural production is reliant on ecosystems services produced on both cultivated and wild land, policies touching to these areas need to be inter-connected at all levels and at landscape scale. As such:

- At global and international levels there is a need to understand and accept the fact that food security and environmental protection are interwoven
- At national and landscape levels, urban and rural landscapes should be planned with biodiversity protection in mind, ensure minimum environmental flow and implement land sparing agriculture.

One of the major conclusions of this report is the vital importance of interconnected policy-making. Furthermore, policies for other sectors such as energy, water, land-use etc...need to be developed in closer conjunction with food policies.

2.1.3. Towards Sustainable Agriculture Systems in the 21st Century. National Academy of Science, USA, 2010

Starting Point

The Report of the National Research Committee on Twenty-First Century Systems Agriculture aimed to review the state of knowledge on agriculture practices and technologies which can potentially improve the sustainability of agriculture at the environmental, social and economic levels. It aimed to assess the risks and trade-offs which an adoption of those sustainability-improving practices and technologies would entail. Furthermore, the Report points to knowledge gaps as well as making recommendations for future actions.

The Committee puts forward two “parallel and overlapping” approaches: the incremental and the transformative approaches, which together can secure the sustained improvement of US agriculture’s sustainability.

This study was financially supported by the Bill and Melinda Gates Foundation and the W.K. Kellogg Foundation.

The Committee was given seven tasks:

1. Give an economic overview of US agriculture domestically and abroad and find out the major challenges US farmers face with regards to the environmental, social and economic sustainability of agriculture.
2. Assess the knowledge available on farming practices which positively impact the environmental, social and economic sustainability of agriculture.
3. Review which factors impact on the adoption of sustainable farming practices.
4. Provide an update to the 1989 National Research Council Committee’s Report’s methodology.
5. Analyse several case studies illustrating the working of sustainable practices.
6. Identify research and development needs to encourage a system approach to farming in the United States, as well as suggest ways to strengthen federal policies to improve farming production.
7. Judge on the feasibility of transferring principles and practices of sustainable farming systems in different agricultural settings.

Defining Agricultural Sustainability
Despite the lack of a collective and societal vision of what the future of sustainable agriculture should be, the Committee has identified four goals to define sustainable agriculture which most stakeholders can generally agree on:

- Adequately supply food, feed, fibber and contribute to biofuel needs
- Conserve and raise environmental quality and the base of resources
- Uphold the economic viability of farming
- Improve farmers and farm workers’ quality of life and that of society as a whole.

Sustainability is best thought of as a continuous process that moves along the four goals rather than as a rigid end-goal. The Committee argues that if US agriculture is going to respond adequately to these goals, it needs to accelerate its progress towards them.

Scientific foundation for improving sustainability

The Committee proposed two "parallel and overlapping" approaches to drive forward US agriculture's sustainability achievements: the incremental and the transformative approaches.

The incremental approach calls for continuous research, extension and experimentation by researchers and farmers to devise solutions for agro-ecosystems to reach long-term sustainability. The incremental approach should be directed at all American farms, regardless of size, location or farming practices and aims to develop and implement piece-meal sustainability-focused practices, many of which are still the objects of research.

The incremental approach needs to be supplemented by a transformative approach which role should be to focus on integrative research and link up together multiple fields of sustainability beyond sole agroecological principles. The transformative approach applies a system perspective to address linkages between farming and social principles to increase systems' resilience and strength.

The incremental approach to improve sustainability of US agriculture

The incremental approach entails some focused research on the overlapping themes of agricultural production, environmental, economic and social issues as well as policies designed to increase the overall sustainability performance of "mainstream agriculture". Despite its importance, there is still little research on the inter-locking social and economic dimensions of agricultural sustainability.

As such, the committee recommends that more publicly funded research, extensions and experimentation should be carried out by researchers. Furthermore, support to better understand the economic and social aspects of agricultural sustainability should be increased. Continuous research and experimentation by farmers needs to be encouraged too.

The transformative approach to improving sustainability of US agriculture

The transformative approach's role is to bring together a number of disciplines to cover simultaneously key inter-locking dimensions of sustainability. It can help to develop approaches to production which "capitalise on synergies, efficiencies and resilience characteristics associated with complex ecosystems". The transformative approach also calls for the development of new markets, new policies and new paradigms of research which together will sustain a "system-oriented agriculture". The Committee acknowledges the fact that the dominant agricultural production model might limit the range of opportunities to pursue increased sustainability. As such, the report mentions many agroecological practices which have the potential to increase systems' sustainability.

Interdisciplinary Systems Research

A system approach is needed to understand and make the best use of the linkages that exist between farming component and the wealth of environmental and social aspect that relate to it. Organic agriculture is recognised by the Committee as a system approach which integrate the many aspects needed to reach the sustainability goals listed earlier. Despite the need for research to address and improve the sustainability of farming systems, the bulk of public research funds is still directed at improving productivity and reducing production costs. The predecessor report *Alternative Agriculture* (1989 cited by National Academy of Science, 2010) by the National Academy of Science already emphasised the importance of developing a system approach to agriculture, to no avail.

The Committee recommends that "federal and state agricultural research and development programs […] aggressively fund and pursue integrated research and extension of farming systems that focus on interactions among productivity, environmental, economic and social sustainability outcomes". Programmes that take a landscape approach to agricultural research do not exist yet although they would be useful in informing the design of sustainable agro-ecosystems. As such, The US Department of Agriculture and other federal and state agencies linked to agriculture should encourage agricultural researchers to involve farmers-led researches and trials in their own research.

Key drivers of change: markets and federal and local policies

Some scholars have blamed the increasing use of farm inputs, the decrease of crop diversity and the extensive hydrological changes of landscape to subsidies policies which have provided farmers with a strong incentive to monocrop and to maximise production. Because institutional policies influence farmers significantly, the US department of Agriculture should enhance investments in empirical studies to better understand the way market structures, knowledge institutions and policies supply opportunities or erect barriers to the development of sustainable farming systems. This will result in changes being operated at institutional levels to allow for the meeting of these goals.
The Committee is aware that this transformation of the agricultural production sector is a long-term process and that it needs research and experimentations from the public and private sectors and farmers.

Relevance of lessons learned to sub-Saharan Africa

The Committee recommends that agencies and charities which support the development of sustainable agriculture in developing countries take a system approach to their mission. They should fund programmes which promote adaptation and resilience of local socioeconomic and biophysical conditions as well as improve and increase market access.

2.1.4 Report submitted by the Special Rapporteur on the right to food, Olivier de Schutter, December 2010.

Starting point:

Olivier de Schutter, the United Nations Special Rapporteur on the Right to Food, submitted a report in December 2010 arguing that agro-ecology was the most desirable form of agriculture to adequately meet "the concrete realisation of the right to food". He argues that "States can and must achieve a reorientation of their agricultural systems towards modes of production that are highly productive, highly sustainable and that contribute to the progressive realisation of the human right to adequate food".

The Special Rapporteur wrote in his own capacity, but based his analysis and opinion on a larger number of papers submitted by experts from all regions, as well as on an international experts' seminar on the topic of agroecology that he organised on 21-22 June 2010. Unlike other reports, the Special Rapporteur did not provide a definition for 'sustainability'.

I. Introduction

Agriculture has suffered from a lack of interest and a lack of investment from both the private sector and governments in the past 30 years. Although an increase in food production is needed to meet future needs, it is not sufficient in its own right. Combating hunger and malnutrition can only be done through higher incomes and increased livelihoods for the poorest and most vulnerable, especially small-scale farmers in developing countries. Furthermore, agriculture depends on ecosystems' health, and increasing production cannot be done at the expense of ecological degradation. Agroecology makes it possible to raise production where it is most needed (in poor, food-insecure countries), while promoting small-holders' livelihoods and preserving ecosystems integrity. However, this change in favour of agroecology "can only happen by design" through political will.

II. Diagnosis: three objectives of food systems

"Ensuring the right to food requires the possibility either to feed oneself directly from productive land or other natural resources, or to purchase food". Food systems should be re-organised to meet the following three objectives:

1. Food must be available to everyone who needs it: "supply must match world needs". The Special Rapporteur is concerned that today, nearly half of the world's cereal production is used as animal feed, and that world consumption of animal protein is set to increase further. To reallocate these cereals to human consumption "could go a long way towards meeting the increased needs".
2. Agriculture needs to increase small-holders' income. Because hunger today is mostly attributable to poverty, increasing the income of the poorest is one of the best ways to fight it.
3. Agriculture relies on biodiversity, clean water, healthy soils etc…As such it cannot afford to compromise natural resources' ability to support it in the future and should instead aim to enhance the health and availability of these resources. Furthermore, climate change destabilises markets thus increasing its negative effects on food availability.

The Special Rapporteur suggests that scaling up agroecology can "simultaneously increase farm productivity and food security, improve incomes and rural livelihoods, and reverse the trend towards species loss and genetic erosion".

III. Contribution of agroecology to the right to food

The core principles of agroecology are to recycle the nutrients and energy produced on the farm rather than rely on external inputs, to integrate crops and livestock, and to diversify the genetic resources and species. Agroecology is particularly knowledge-intensive, especially at the start, but this knowledge is not delivered top-down but instead developed over time through farmers' experimentations.

A. Availability: agroecology raises production at field level

A large number of options are available to the agroecological farmer, these include the maintenance or introduction of agricultural biodiversity, integrated natural management, water harvesting, the integration of livestock into farming systems etc…Despite the fact that good results can be had with nutrient recycling and home-made fertilisers, and while investments into organic fertilisers should be a priority, the use of other fertilisers should not be excluded.

B. Accessibility: agroecology reduces rural poverty

Agroecology reduces farmers' dependence on external inputs and state subsidies, thus in turn making small-holders less vulnerable to local inputs retailers and money-lenders. This is especially important for the poorest farmers who are least likely to be able to afford inorganic fertilisers, and/or to have access to them when they live in very remote areas.

Agroecology is highly labour-intensive, particularly in the launching period. This does not have to be a bad thing: rural under-employment is currently massive in many developing countries while demographic growth remains high. These intensified labour-requirements can be an advantage rather than a liability and help slow down rural-urban migration. Furthermore, agroecology also needs specific mechanised equipment to perform conservation agriculture techniques, which might trigger more jobs being created in the manufacturing sector of developing countries.

C. Adequacy: agroecology contributes to improving nutrition

Contrary to the Green Revolution which focused almost entirely on improving cereal crops, agroecology encourages inter-cropping and the integration of livestock in the farming system. The Green Revolution, by putting such a strong focus on cereals, contributed to micro-nutrient malnutrition in many developing countries. Cereals are mainly sources of carbohydrates and contain very little vitamins or minerals.

D. Sustainability: agroecology contributes to adapting to climate change

"Agroecology improves resilience to climate change". Climate change triggers extreme weather events; these can be "significantly cushioned" by agroecological techniques and the promotion of a wide biodiversity. On-farm experiments in countries as diverse as Ethiopia, India, and the Netherlands have proven that soil's physical properties on organic farms improve crops' resistance to drought.

E. Farmer participation: an asset for the dissemination of best practices

Agroecology's vitally needs the support of farmers and farmers' movements throughout the world if it is to spread its practices. So far, agroecology has been developed by grassroots organisation and NGOs on the ground, as well as through farmer field school and farmers movements. Farmer field schools have been shown to empower farmers with knowledge, thus helping them reduce their dependency on external inputs. States should not only support those efforts, but build on them to enable a fast and effective dissemination of good farming practices. Farmer field school are particularly effective when farmers become actors in their training as opposed to being mere recipients of it.

IV. Public policies for the scaling up of agroecology

The scaling-up of agroecology is two-fold: increase the areas cultivated by agroecological techniques (horizontal scaling up) and create an enabling framework for farmers (vertical scaling up). The Special Rapporteur focuses on the vertical dimension, namely "the establishment of an enabling framework". He sees governments as having a key role to play in this regards, however, policy-making on this topic needs to be "a mode of social learning rather than an exercise in political authority" (Diop, cited in de Schutter, 2001).

A. Prioritizing public goods

Agroecological practices require proper public infrastructures, such as extension services, storage facilities, roads, electricity and communication technologies (especially in rural areas), access to local markets, credits, education, and support for farmers' movements and cooperatives.

B. Investing in knowledge

Investments in agricultural extension and agricultural research are crucial for the success of agroecology's development, "agricultural research has the greatest overall impact on poverty and agricultural productivity in developing countries". Furthermore, farmers' communities need to be empowered through ecological literacy and autonomous decision-making skills.

C. Strengthening social organisation by co-construction

While extension services play a key role in the development and dissemination of agroecology, knowledge needs to become the product of a network, and thus needs to be shared. Co-construction of knowledge ensures that farmers and experts work together to identify innovative solutions which can benefit all farmers, especially small-holders. "Co-construction is key for the realization of the right to food". Co-construction lets public authorities benefit from farmers' knowledge, it ensures that public policies address the needs of the most vulnerable farmers, and it empowers the poor. "Lack of power is a source of poverty", and poverty in turn exacerbate this lack of power thus creating a vicious circle. Co-construction also ensures that policies have a high degree of legitimacy because they have been designed in partnership with farmers.

D. Gender empowerment

Women play a crucial role in agriculture and as such, specifically targeted schemes should address their needs and encourage them to participate in this construction of knowledge. The Special Rapporteur expresses his concern that while women face a higher number of obstacles than men (poor access to capital and to land, combining their work and family responsibilities…) gender issues are present in less than 10% of development programmes for agriculture, and women farmers receive only 5% of agriculture extension services in the world today. Agroecology can benefit women farmers most because they are the ones who tend to encounter the most difficulties in accessing external inputs or subsidies. However, this supposed ability to benefit most from agroecology should not be taken for granted: it requires that affirmative actions targeted specifically to women be taken.

E. Organising markets

Farmers should be encouraged to add value to their products "by moving up the value chain" through taking on the added roles of packaging, processing and marketing their products. This can be done with the help of local cooperatives to achieve economies of scale. Additionally, agroecology will fail to gain support and to achieve its desired results if markets are not organised in a way that protect vulnerable farmers from volatile prices and/or the dumping of subsidised products on their local markets.

V. Recommendations

States should
- Include agroecology and the right to food in their national strategy
- Ensure the provision of public goods such as rural infrastructures and agricultural research
- Support the dissemination of knowledge and empower women
- Improve access to markets for agroecological farmers

Donors should
- Enter long-term relationships with partner countries to scale-up agroecological approaches
- Encourage South-South and North-South cooperation on knowledge dissemination
- Invest in public goods rather than private goods and encourage co-construction
- Fund "knowledge platforms"

The research community should:
- Increase their budget for field researches into agroecological practices
- Train scientists to work in partnership with farmers
- Assess projects on the basis of their performance aims, and monitor them through improvements in the status of vulnerable populations.

2.2 Summary of the four mega-reports analysed, their declared objectives and their main participants

Table 2.2 below summarizes each mega-report's assessment's objectives as well as the main participants who took part in their elaboration processes. The reports, (the IAASTD, the UK Foresight Study on the Future of Food and Farming, the US National Academy Report for Sustainable Farming in the 21st century, and the Report by the UN Special Rapporteur on the Right to Food from December 2010), all had different research objectives and reasons for embarking on their respective research projects. Furthermore, each report displayed a different viewpoint that relates to prior decisions about who should be invited to participate. The IAASTD put a never-seen-before emphasis on including a comprehensive range of experts and stakeholders from all backgrounds and philosophies, the UK Foresight and the National Academy of Sciences preferred to use mostly scientific experts' knowledge, and the Special Rapporteur on the Right to Food, Olivier de Schutter, wrote in his own capacity but drew on a number of papers written by experts from all over the world, taking a broad definition of who might be considered ‘expert’.

With respect to Hoppe and Hischemöller’s theory on intractable controversies, it appears that the IAASTD report framed its assessment objectives around a messy problem. Its objective went beyond the sole identification of “relevant options for action” to include issues of social justice, decent livelihood and human development themes. This was similar to the objectives formulated in Oliver de Schutter’s report, which had the ambition to “identify how States can reorient their agriculture systems towards modes of production that are highly productive and highly sustainable”.

Conversely, the objectives of the UK Foresight Study and the National Academy of Science were mainly to produce an objective assessment on what they saw as the current situation and state of the art in scientific terms. The UK Foresight claimed to want to “study the pressures that will arise on the global food system between now and 2050” and the National Academy of Science aimed to “review the state of knowledge” on sustainable agricultural practices and technologies, as well as to assess the risks and trade-offs of these practices.

This illustrates that each pair of studies very probably started with their own set of pre-analytical values. The IAASTD and de Schutter made it obvious from the start that they were pro-poor and confident that the real solutions were to be found in the realm of sustainable agriculture. The two other studies, the UK Foresight and the National Academy of Science, displayed a more sceptical approach towards the claims of what sustainable agriculture might be and, instead of outright endorsing it, mainly aimed to assess its achievements and potential risks. Neither included any reference towards rural livelihoods, small-holding farming or social issues in general in developing nations, in their assessment objectives. They considered instead their topic to be structured around agricultural productivity and policy-making, as the foremost issues to deal with. A further analysis of each report’s objectives is provided in Table 2.2.

The unique participation formats that each report saw fit to put in place reflects the hidden pre-analytical values which they each worked with. True to its pro-poor approach and values emphasising the desirability of small-scale farming, ancestral knowledge, free technology and small-holders’ welfare, the IAASTD invited a large number of experts coming from a diversity of background, including NGOs, the civil society, the international organisations community and researchers from both the academic and the private spheres. Inviting representatives from the private sector was an interesting choice that reflected a desire to be as all-encompassing as possible, but which eventually fell through, when representatives from the biotechnology industry pulled out a few months before final publication, citing that the report had failed to “adequately reflect the role of modern science and technology, in particular our own industry’s technologies” (Keith, 2008 cited in Hilbeck, 2008).

The UK Foresight Study also involved around 400 participants, however they were predominantly drawn from the academic and the private research worlds, with a much more discrete presence from representatives of NGOs, the civil society, the international donor community, and private sector executives. This is in line with the pre-analytical values attached to the UK Foresight, namely the focus that technology and innovation steaming from research conducted in industrialised countries should be at the core of agricultural development in industrialising countries, and large scale farming is desirable. These values serve the interests and relate to the activities of the main participants to this report.

The US National Academy of Science report incorporated the work of some 40 experts, coming mainly from industrialised countries and from the worlds of public and private research, as well as a significant representation from private sector executives. Experts from the international organisations and the donors community, as well as researchers from environmental and development NGOs an the civil society were offered a smaller share of the representation. This coincides with the pre-analytical values looked for in this report, including the high consideration given to innovative technology and technology transfers, the desirability of large-scale farming and that of including the private sector from developed countries into the agricultural development of the developing countries, all of which serving the interests of the participants to this report.

The Special Rapporteur for the Right to Food wrote his December 2010 report in his own capacity, drawing on three knowledge-sources including: the contributions made during a symposium specially organised for the preparation of this report, papers submitted to him by experts from all over the world, and on his own experience and expertise working as a human rights expert and academic lawyer. De Schutter in his capacity of Special Rapporteur is in charge of identifying the structural problems hindering access to adequate food around the world; as such his analysis is not, in principle, influenced by private economical and/or philosophical interests. As such, the values guiding his work are purely pro-poor (valuing ancestral knowledge and rural welfare and employment, being weary of expensive and legally restrictive technology...) his goal being straight-forward and uncluttered by additional concerns.

Table 2.2 Summary of the four mega-reports analysed, their declared objectives and their main participants

	Declared Objectives	Main Participants
International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), 2009	To identify relevant options for action in the field of AKST to meet the following development and sustainability goals: o The reduction of hunger and poverty o The improvement of rural livelihoods and human health o The facilitation of equitable, socially, environmentally and economically sustainable development.	400 world's experts nominated by a range of geographically balanced stakeholders from both the public and private sectors. Fairly represented were: o researchers from environmental and development NGOs, and civil society organisations o academic researchers, o academic scientists o private sector scientists o specialists from the United Nations community and bilateral/international donor community
The Future of Food and Farming: Challenges and Choices for Global Sustainability. UK Foresight Study, 2011	To study the pressures that will arise on the global food system between now and 2050 To help decision-makers and stakeholders to make the right decisions in order to feed a global population of 9 billion "sustainably and equitably"	Around 400 experts and stakeholders coming from 35 low-, middle-, and high-income countries around the world were involved in the project. o academic researchers, o academic scientists o private sector scientists were predominantly represented and some: o researchers from environmental and development NGOs, and civil society organisations o private sector executives o specialists from the United Nations community and bilateral/international donor community also participated.

	Declared Objectives	Main Participants
Towards Sustainable Agriculture Systems in the 21st century. National Academy of Science, USA, 2010	To review the state of knowledge on agriculture practices and technologies which potentially can improve the sustainability of agriculture at the environmental, social and economic levels. To assess the risks and trade-offs which adoption of sustainability-improving practices and technologies would entail. To point to knowledge gaps as well as making recommendations for future actions.	Around 40 experts and stakeholders, coming mainly from industrialised countries were involved, especially: ○ academic scientists ○ private sector scientists ○ private sector executives with some participation from: ○ specialists from the United Nations community and bilateral/international donor community ○ researchers from environmental and development NGOs, and civil society academic researchers.
Report Submitted by the Special Rapporteur on the right to food, Olivier de Schutter. Human Rights Council, Sixteenth Session, December 2010.	To identify how States can reorient their agriculture systems towards "modes of production that are highly productive, highly sustainable and that contribute to the progressive realisation of the human right to adequate food".	○ Olivier de Schutter, writing in his capacity as UN Special Rapporteur on the Right to Food (2008- present). De Schutter is an academic lawyer and human rights expert. His function as UN Special Rapporteur on the Right to Food is to address all structural issues threatening or preventing "the full enjoyment of the right to food" (Special Rapporteur on the Right to Food, no date). ○ He drew on academic and scientific papers and reports submitted by experts from all over the world.

2.3 Content analysis of individual reports' aims and objectives

Our preliminary analysis suggested that the points made by each party have a lot to do with their starting points. One could say that each report has its own pair of "colour glasses" through which they see the problem at stake under different lights and, as an inevitable result, give different - sometimes even opposing - answers.

A short content analysis on the key words and phrases in the four primary animating questions of the mega reports was conducted in Table 2.3 to determine the degree of emphasis they each put on technical versus social issues. The formal aims and objectives pose the foundations on which each report is built: it is a road-map in a nutshell. This makes them very relevant to study and a good place to carry out a preliminary analysis of the values and knowledge on which each report rests. Social and technical issues are large enough that together they cover the whole spectrum of issues mentioned in relation to agricultural matters, and different enough that there should be no shocking overlaps between them.

Key words and phrases that referred to technical issues such as "highly productive", "agricultural sustainability", "between now and 2050", have been coded under the umbrella of "technical terms". Key words and phrases that referred to social welfare issues such as "social sustainability", "the right to food", "sustainable development" have been coded under the umbrella of "social terms". Admittedly, some of the coding is arbitrary and open for debate and for a different interpretation as it unescapably reflects the author's own pre-analytical values. For example, the phrase "between now and 2050" was coded under the term "technical" because the author's sensibility 'felt 'that is where it belonged; due to the hard, accountable, easy to assess and measure nature of this phrase, the author believed it belonged more into the "technical" section of this content analysis, but she is aware of the fact that this might be challenged by some readers. By the same token, "equitably" was coded as a "social" term as the author understood it in this context as a social welfare issue although some readers might argue that "equity" can in fact be technically assessed and measured, and thus has as much its place under the "technical" column of this table.

The results show that the IAASTD achieved good balance between the two, with a slight emphasis on social issues (54.4% for social and 45.5% for technical), while the UK Foresight and the National Academy of Science had a stronger focus on technical issues, devoting two-thirds and 7/8th respectively of their research aims to technical key words, while the Report of the Special Rapporteur reached perfect balance between the two.

The starting point of the IAASTD was the question: "How can Agricultural Knowledge, Science and Technology (AKST) be used to reduce hunger and poverty, improve rural livelihoods, and facilitate equitable environmentally, socially, and economically sustainable development?" The starting point of the UK Foresight Report was to "explore the pressures on the global food system between now and 2050 and identify the decisions that policy makers need to take today, and in the years ahead, to ensure that a global population rising to nine billion or more can be fed sustainably and equitably". The starting point of the National Academy of Science was to review the state of knowledge on farming practices, technologies, and management systems that have the potential to improve the environmental, social, and economic sustainability of agriculture, and it discusses the trade-offs and risks that might occur if more farms were to adopt those practices, technologies, and systems. The report furthermore aims to "identify knowledge gaps and make recommendations for future actions to improve agricultural sustainability." The starting point of the report submitted by the Special Rapporteur on the Right to Food is that reinvestment in agriculture is essential to the concrete realisation of the right to food, but that "in a context of ecological, food and energy crises, the most pressing issues regarding reinvestment is not how much but how". It explores "how States can and must achieve a reorientation of their agricultural systems towards modes of production that are highly productive, highly sustainable and that contribute to the progressive realisation of the human right to adequate food".

The second axis of the Hoppe matrix (refer to Figure 1.3) is about certainty or lack of it, regarding knowledge of the problematic situation and ways to make it easier to understand and deal with. After examination, it appears that all report display some degree of certainty regarding their own knowledge of the situation, without which these projects would have probably never started. Clues about the presence of some degree of certainty appear in the project aims and objectives of each report, where the themes to be processed are announced. There again, differences appear with regards to knowledge certainty. I argue that the knowledge which the reports consider to have and to need on their topic directly relates to the pre-analytical values which they individually entertain.

For example, the US National Academy of Science whose main participants were drawn from public and private research institutes as well as private interests, states aims and objectives which strongly veer on the side of technical issues; as such, they are mainly going to be addressed with technical knowledge, with only a minor foray into social issues surrounding agriculture. It can therefore be argued that the individuals behind this report are confident and certain that they have the "right knowledge" and enough of it to satisfactorily answer the objectives they set for themselves. By the same token, the IAASTD framed its own research objectives with the help and expertise of its wide range of participants, each representing values which clustered together to spell out questions which they saw as relevant, and which they were certain they had adequate knowledge to answer.

Whether outsiders agree that this was indeed the case that reports had the right knowledge to tackle their questions, and whether they consider the aims and objectives set by individual reports to be pertinent in the first place, is not applicable in this situation: all reports have certainty regarding their own knowledge and ability to answer their own, custom-framed controversies.

Table 2.3. Count of "technical" and "social" key words and phrases mentioned in each of the project aim of the mega-reports

	Technical key words and phrases	**Total and overall percentage times mentioned**	**Social key words and phrases**	**Total and overall percentage times mentioned**
IAASTD	○ "environmentally"; ○ "hunger"; ○ "economically"; ○ "poverty"; ○ "health";	5 times (45.5%)	○ "sustainability goals"; ○ "development"; ○ "rural livelihoods"; ○ equitable; ○ socially; ○ "sustainable development";	6 times (54.5%)
UK Foresight Study	○ "pressures on the global food system" ○ "between now and 2050" ○ "global population rising to nine billion or more"; ○ "fed sustainably";	4 times (66.6%)	○ "decisions that policy makers"; ○ "equitably";	2 times (33.3%)
US National Academy of Science	○ "the state of knowledge" ○ "farming practices, technologies, and management systems" ○ "environmental sustainability" ○ "trade-offs and risks" ○ "knowledge gaps" ○ "agricultural sustainability" ○ "economic sustainability"	7 times (87.5%)	○ "social sustainability"	1 time (12.5%)
UN Special Rapporteur on the Right to Food	○ "context of ecological, food and energy crises"; ○ "agricultural systems"; ○ "highly productive"; ○ "highly sustainable	4 times (50%)	○ "the right to food"; ○ "not how much but how"; ○ "the human right" ○ "adequate food"	4 times (50%)

2.4 Summary and comparison of broad themes individually tackled by the four mega-reports

Table 2.4 below summarizes the main points studied by each report. When “Yes” appears in a cell, it means that the topic mentioned in the corresponding column has been treated by the report, “No” indicates it has not been touched on to any great extent. The summary nuances the findings summarised in Table 2.2.

While all reports agreed that “more” agricultural sustainability was needed, individual reports display diverging views on what topics are relevant to tackle to reach this goal. As seen previously in Table 2.2 the IAASTD and de Schutter seem to share many similar values, while the UK Foresight and the National Academy of Sciences have more values in common with each other.

When listing the topics addressed by each report, one finds that the core structuring of their argument shows clear pre-analytical values. Two ways to increase agricultural productivity are generally offered: increase overall agricultural productivity which usually entails the conversion of non-agricultural land into farming, or increase agricultural production per unit, which usually entails a higher per hectare production on already farmed land (rather than bringing more land into agriculture). The IAASTD, the UK Foresight and de Schutter mention the desirability of higher productivity on farmland without emphasising the option of bringing more land into farming. This approach is characteristic of a pro-poor bias, whereby augmenting productivity for small-holders is considered more important to food security, rather than augmenting overall world production, (which does not guarantee that the extra food will be accessible to those who most need it). Conversely, the US National Academy of Science does not mention the issue of increasing farming productivity on farmland, but instead is the only one of the four to mention increasing overall agricultural production. This bias is probably due to the fact that it almost exclusively US agriculture-centred, and as such only deals with topics which appear most relevant in this particular context.

The IAASTD and de Schutter show strong similarities in terms of the topics they address, while the UK Foresight and the National Academy of Science reports have more in common. Both de Schutter and the IAASTD offer a strong conceptual framework which emphasises social issues, as such, they are the only ones to single out rural livelihoods, welfare for the rural poor and farmers’ empowerment (through the recognition and celebration of their traditional knowledge) as important issues which need addressing through agriculture.

The UK Foresight study tends to adopt an ‘in the middle’ position, alternating at times between an approach that seemingly considers the question at hand as structured, and as unstructured at other times. For instance, it mentions a significant number of topics which are also studied by the IAASTD and de Schutter, such as the need to prioritise women’s empowerment, to increase public infrastructures, to strengthen access to land by small-holders, to protect biodiversity in agriculture, or to move forwards with sustainable natural resource management, but omits to mention the role and fate of the rural poor.

The four issues mentioned by all four reports (besides the need for increased agricultural sustainability), are: the interconnection of social and environmental issues; investments in public agricultural research; the improvement of market access for small-holders, and the need to make agriculture more resilient to climate change. These four topics would appear to represent significant common ground. Details of each report's opinion on the best resolution routes for these topics are explained in more detail in Table 2.5.

It is noteworthy to note also that de Schutter was the only one to mention the need to help farmers become more independent vis-à-vis fossil energy, thus again displaying a strong pro-poor focus. By the same token, the UK Foresight Study was the only one to consistently mention the need to reduce food waste at all levels of the food chain throughout its report, which put a very strong emphasis on this topic. This argument however, was mostly developed with an industrialised food distribution network in mind.

Table 2.4. Summary and comparison of broad themes individually tackled by the four mega-reports

Included in Report:	IAASTD	UK Foresight Study	US National Academy of Science	Olivier de Schutter
More agricultural sustainability is needed[1]	Yes	Yes	Yes	Yes
Overall agricultural production needs to increase[2]	No	No	Yes	No
Agricultural production per unit needs to increase[3]	Yes	Yes	No	Yes
Enhance rural livelihoods for the poor[4]	Yes	Yes	No	Yes
Increased fairness for the rural poor	Yes	Yes	No	Yes

[1] The IAASTD defines agricultural sustainability as: "maintaining productivity in ways that protect the natural resource base and ecological provisioning of agricultural systems"
The UK Foresight Study defines agricultural sustainability as: "food production that does not compromise the world's capacity to produce food in the future".
The US National Academy of Science defines agricultural sustainability as: to "satisfy human food, feed, and fiber needs, and contribute to biofuel needs. Enhance environmental quality and the resource base. Sustain the economic viability of agriculture. Enhance the quality of life for farmers, farm workers, and society as a whole".
Olivier de Schutter defines agricultural sustainability as: food production that neither "compromises its ability to satisfy future needs" nor "the continuing ability for natural resources to support agriculture".
[2] An overall increase in agricultural production entails the conversion of non-agricultural land into farmland in order to produce more food overall.
[3] An increase of productivity per unit entails reaching a higher productivity per hectare (higher yields) on already farmed land, though not necessarily bringing more land into farming.
[4] The IAASTD and de Schutter in particular put special emphasis on the livelihoods of small-holders.

Included in Report:	IAASTD	UK Foresight Study	US National Academy of Science	Olivier de Schutter
Enhance farmers' access to education and technology	Yes	No	No	Yes
Priority should be given to women for education, technology and land access[5]	Yes	Yes	No	Yes
Use traditional and communities' knowledge	Yes	No	No	Yes
Create and strengthen knowledge networks for farmers (farmer' field schools)	Yes	No	No	Yes
Interconnect social and environmental issue	Yes	Yes	Yes	Yes
Tackle macro-nutrient deficiency	No	Yes	No	Yes
Strengthening of right/access to land by small-holders	Yes	Yes	No	Yes
Invest in public agricultural and development research	Yes	Yes[6]	Yes	Yes
More public physical infrastructures are needed (such as roads…)	Yes	Yes	No	Yes
Improve market access for small-holders	Yes[7]	Yes	Yes	Yes

[5] The IAASTD and de Schutter in particular put special emphasis on the necessity to give more opportunities to women.
[6] The UK Foresight Study and the National Academy of Science also put a strong emphasis on the need for increased private research
[7] The IAASTD puts a special emphasis on the need to develop local markets for small-scale producers

Included in Report:	IAASTD	UK Foresight Study	US National Academy of Science	Olivier de Schutter
Fair and functioning world markets	Yes	Yes	No	Yes
Move towards more sustainable natural resource management	Yes	Yes[8]	No	Yes
Protect biodiversity in agriculture	Yes	Yes	No	Yes
Bring about cuts in GHG emissions	Yes	Yes	No	Yes
Help agriculture to become more resilient to climate change effects	Yes	Yes	Yes	Yes
Help farmers become more independent vis-à-vis fossil energy	No	No	No	Yes
Reduce waste[9]	No	Yes	No	No

[8] The UK Foresight only emphasises water use
[9] The UK Foresight Study was the only one to put a strong emphasis on the need to reduce food waste.

2.5 Roles of the different stakeholders as viewed by the mega-reports

Table 2.5 identifies each report's viewpoint on the role of four groups of stakeholders: researchers, policy makers and donors, farmers and private sector actors, in the debate. As seen already in Tables 2.2; 2.3 and 2.4 above, the IAASTD and de Schutter display similar opinions and are mostly oriented towards practical, grass-roots solutions, whereas the UK Foresight and the US National Academy of Science focus mostly on scientific and policy issues. The trade-offs between higher productivity and increased sustainability as identified by each report are mentioned in the fifth row. The last row is devoted to each report's definition of food security (except for the National Academy of Science which did not offer one).

To analyse how roles and responsibilities are portrayed by each report reinforces the search for pre-analytical values, and adds to the characterisation of knowledge certainty. When reports distribute roles (after having identified the issues that they think need resolving) they reveal their values on who should be charge, and as such reinforce their individual conception of the problem. They also reinforce the certainty they hold regarding the knowledge needed for the adequate resolution of the issues at hand. For example, one of the measures cited by the US National Academy of Science concerning the role of policy makers and international donors is to invest public money into research aimed at increasing the "overall performance of mainstream agriculture". They are in fact calling for the upkeep of current agricultural practices in US agriculture - which already include enormous profits for a handful of corporations coupled to large federal subsidies for high production - with some changes done to increase overall ecological sustainability, funded by public research. As such, the status quo prevalent in modern US agriculture whereby many profits are private while many risks and deficits are public, is not being challenged much. Public money is designated once again as the cash cow onto which losses and spending which do not increase economical profits can be offloaded.

This approach is in sharp contrast with the IAASTD's vision concerning the roles and responsibilities of policy makers and international donors, who among a significant list of tasks are elected to give a financial value to ecosystems services and environmental degradation. This approach is different because it puts the state back at the centre of being the main decision maker and beneficiary of its own measures. Giving a hard cash value to environmental degradation, whereby polluters have to pay for the damages they caused, acts like an extra tax on polluting groups, and tends to provide a particularly efficient method of curbing undesirable and anti-social behaviour. The threat of a financial loss also acts as a quick-fix to stop undesirable behaviour, notwithstanding the fact that the state gets extra-money which can then be used to try and correct the damages incurred and/or fund education and awareness campaigns. By the same token, giving a financial value to environmental services rewards groups which protect and nurture agro-environmental systems, and acts as further incentives for others to do the same.

While all reports agreed that more agricultural sustainability is needed, the individual reports display diverging views on what topics are relevant to tackle to reach this goal. As seen previously in Tables 2.2; 2.3 and 2.4, the IAASTD and de Schutter again share similar values while the UK Foresight and the National Academy of Sciences argue on analogous grounds. This is revealed again in Table 2.4. For example on the topic of the role of research, the

IAASTD and de Schutter both address the need to create and foster partnerships with farmers (small-holders); although the IAASTD calls this process “knowledge partnerships” while the Special Rapporteur calls it “co-construction”, they appear to mean the same thing. Conversely, the UK Foresight Report calls for more scientific, ‘simple’ or ‘structured’ measures such as the development of “new breeds of crops, livestock and aquatic organisms”, the preservation of diversity, and advances in the field of nutrition and in that of soil science. For its part, the National Academy of Science views the role of research as to increase the sustainability of mainstream agriculture; this implies a pre-analytical view that an overhaul of the current US farming paradigm is not necessary but rather that some adjustments are enough. The National Academy of Science report also argues in favour of more linkages between different disciplines and farming but it is not clearly stated which these should be; this argument in favour of wider linkages between farming and social principles could potentially mean that the report is aware that the problem they are addressing needs to be considered within a wider frame (that is, as a messy problem), but the argumentation never seems to take a stance on this point, and limits itself to calls for more research and experimentation which would eventually lead to new “paradigms of research” to sustain a ‘system-oriented agriculture’. In conclusion it calls for more research but shies away from offering concrete suggestions.

All reports saw the role of policy-makers and international donors as crucial; this is the richest and longest row of the table for all four reports. While the National Academy of Science considers this topic to be simple, and offers structured solutions to solve it (such as ‘develop new policies to increase the overall sustainability of mainstream agriculture’ or ‘enhance investments in empirical studies to better understand how barriers to the development of sustainable agriculture are brought about’), the IAASTD, the UK Foresight report and de Schutter are much more practical and inter-twine social, political and scientific issues, and mixed solutions. For example, they all agree that public infrastructures need investments to benefit farmers, and that farmers can be helped in a multitude of ways, for instance by strengthening access to land and natural resources (IAASTD and UK Foresight), through support for farmers’ movements (de Schutter), or by including environmental and food issues at the highest policy-making level (all three). Furthermore, all three also stress the role of women and the fact that they, above all, need to be privileged and helped.
It is possible that the National Academy of Science report does not mention these very grass-roots-oriented topics because its focus is almost exclusively on US agriculture.

Interestingly, the National Academy of Science report hardly mentions the role of farmers at all; by not including these rather vital actors in such a report it is clear that the authors have chosen to structure the problem in a rather techno-centric way, where farmers are merely executants rather than actual decision-makers in their own right. The IAASTD and de Schutter in contrast view farmers as research actors who should carry out their own experiments and share their knowledge with each other and with established researchers. The UK Foresight sees farmers as co-actors in the development of more energy-efficient farming techniques.

When addressing the role of the private sector, the IAASTD and de Schutter again show a considerable coherence in their line of argument. They reason that markets ought to be entirely reorganised to a) protect small-holders against unfair competition from subsidised agricultural products coming from the industrialised word, and b) benefit them more. The IAASTD, in line with its multi-participatory model, puts forward additional functions for the private sector. These include extra investments towards sustainable farming and resource resilience tools, restraint when pushing for international competition, as well as the overarchingly important issue of letting farmers save their own seeds and not enforce Intellectual Property Rights related to seeds. On their part the UK Foresight Study and the National Academy of Science reports both argue for a 'light' reorganisation of international markets to improve their fairness (UK Foresight) and to sustain a "system oriented agriculture" (National Academy of Science). Consequently, they do not view markets as needing to have a protective role towards the most vulnerable actors and present free trade as a viable option without acknowledging its numerous deficiencies (which are well-represented in the reports by the IAASTD and de Schutter).

When it comes to assessing trade-offs between higher production and increased sustainability, the IAASTD, the UK Foresight Study and de Schutter all clearly acknowledge the vital link between ecological sustainability and agricultural productivity. The National Academy of Science does not make such trenchant statements, although it deplores the fact that national US subsidies have 'provided farmers with a strong incentive to mono-crop and to maximise production'. Interestingly, the National Academy of Science is the only report of the four to ask for extra research into the mechanisms that prevent or enhance the development of sustainable agriculture. Other reports seem to be satisfied with the scientific resources already available on this topic. This might suggest that the National Academy of Science might feel it lacks authority and needs extra back-up from other sources, or that it lacks autonomy and independence and therefore that its authors did not feel entirely free to express their opinions.

The IAASTD, the UK Foresight Study and de Schutter offer a similar definitions of food security: all three stress physical access to food (through personal production or access through trade) as paramount, by which they acknowledge that high food production alone is not enough to ensure a food security for all. The National Academy of Science does not offer a definition of food security, possibly because it focuses on US agriculture and thus considers this issue as not pertinent in this context.

Table 2.5. Summary of the four mega-reports' conclusions on the roles of research, policy makers, international donor, farmers and private sector, and a summary of each report's definition of food security and their view on the trade-offs between higher productivity and increased sustainability

	IAASTD	**UK Foresight Study**	**US National Academy of Science**	**Olivier de Schutter**
Role of research Role of research	Enter and maintain "knowledge partnerships" with farmers and their traditional knowledge To develop and encourage locally-adapted cultivars, ensure on-farm diversity, conserve and enhance soil, water and biological diversity, improve pest management along the food production and distribution chain Develop tools for farming to address and adapt to climate change Develop AKST tools for better agricultural resilience Prioritise women	Develop new breeds of crops, livestock and aquatic organisms Preserve the diversity of breeds already in existence including both wild and domesticated ones Create advances in the field of nutrition Create advances in the fields of soil sciences Invest in research areas which have received little investments in recent years Invest in new or existing technology to improve storage and transportation. Develop tools to detect reliably in advance spoilage in food Develop tools to reduce agricultural consumption of fossil energy	Address linkages between farming and social principles to increase systems' resilience and strength Carry out more research, extensions and experimentation to increase the overall sustainability of "mainstream agriculture" Bring together a number of disciplines to cover simultaneously key inter-locking dimensions of sustainability Develop new paradigms of research to sustain a "system-oriented agriculture"	Increase public financial involvement in agroecological research and extension services Train scientists in agroecological approaches and co-construction with farmers Assess projects based on their usefulness for the targeted populations with indicators properly defined and validated by the latter to allow for an effective monitoring of progress.

	IAASTD	UK Foresight Study	US National Academy of Science	Olivier de Schutter
Role of policy makers and international donors Role of policy makers and international donors	Encourage and train farmers to practice sustainable agriculture in a culturally appropriate manner Ensure access to land, water, training, micro-credit, legal framework for farmers Ensure farmers can enter "progressive evolution and proactive engagement in intellectual property rights" Promote policies to diversify diets and enhance micro-nutrients absorption Invest in infrastructures that deal with public and veterinary health Acknowledge the significance of nutrition on human health, enact regulations in food products formulation and labelling create incentives to consume healthy food. Enhance farmers' access to	Recognise food as a unique "class of commodity" and adopt a broader, all-encompassing perspective when considering the global food system Orchestrate a renewal of extension services to achieve both sustainability and an increase in food production Privilege women Improve physical infrastructures in middle and low income countries so as to enhance access to markets and to investments Strengthen rights to land and access to natural resources Reform access to market information to enable producers from developing countries to sell at the best price Campaign in order to raise	Design policies to increase the overall sustainability performance of "mainstream agriculture" Fund research with public money to increase the overall sustainability performance of "mainstream agriculture Develop new policies to sustain a "system-oriented agriculture" Federal and state agricultural research and development programs should "aggressively fund and pursue integrated research and extension of farming systems that focus on interactions among productivity, environmental, economic and social sustainability outcomes" Agencies linked to agriculture should	<u>States:</u> Include sustainability in their national strategies for the attainment of the right to food Invest in agricultural research, extension services, rural infrastructures, education, support for farmers' movements, insurance against weather-risks, as well as access to regional markets and credits. Support farmers' movements and use their networks to promote sustainable practices Design schemes targeted specifically to women Improve farmers' access to markets Prioritize women <u>Donors:</u> Donors should develop long-term strategies with partner countries to develop and

	IAASTD	UK Foresight Study	US National Academy of Science	Olivier de Schutter
Role of policy makers and international donors Role of policy makers and international donors	education and technologies Ensure equity among genders and ethnic issues Increase the provision of public good (including physical infrastructures) Develop tools for farming to address and adapt to climate change Develop AKST tools for better resource resilience Give a financial value to ecosystems services and environmental degradation Link natural resource management knowledge and innovations to public and private AKST Prevent international competition before basic governance and infrastructures are in place Prioritise women	awareness of the extent of food waste and recycle surplus food Be allowed to prevent countries from enacting trade restrictions in times of price volatility in order to prevent a worsening of the situation Include environmental issues when contemplating public reforms Monitor and punish irresponsible fishing and urge retailers to exert pressure on malpractices Protect the most vulnerable groups from the worst effects of price fluctuations Governments need to replace agriculture as a real and valuable profession Enact social protection to improve access to food for the poorest	encourage agricultural researchers to involve farmers-led researches and trials in their own research Design programmes that take a landscape approach to agricultural research Enhance investments in empirical studies to better understand the way market structures, knowledge institutions and policies supply opportunities or erect barriers to the development of sustainable farming systems Allow changes to be operated at institutional levels to allow for the meeting of sustainable farming goals Agencies and charities which support the development of	maintain agro-ecology Encourage cooperation between South-South and North-South countries Fund local and national “knowledge platforms” to gather and share agroecological knowledge Prioritize women

	IAASTD	UK Foresight Study	US National Academy of Science	Olivier de Schutter
Role of policy makers and international donors		Put the pressure back on issues of hunger, malnutrition, pro-poor investments and anti-hunger agricultural policies Encourage the development of tools to reduce agriculture's reliance on fossil energy Interconnected policy-making is vital	sustainable agriculture in developing countries should take a system approach to their mission. They should fund programmes which promote adaptation and resilience of local socioeconomic and biophysical conditions as well as improve and increase market access.	
Role of farmers	Experiment with and sustain ecological agriculture practices Retain a higher value of their production Enter and maintain "knowledge partnerships" with scientific research" Experiment and train to adapt to climate change Keep their traditional knowledge and species alive	Develop techniques to reduce agriculture's reliance on fossil energy		Attend and share their knowledge in farmers' field schools Enter knowledge partnerships with other farmers and the research and policy sectors

	IAASTD	UK Foresight Study	US National Academy of Science	Olivier de Schutter
Role of the private sector Role of the private sector	Market mechanisms should reward agricultural management that promotes ecological services and not the opposite Create public-private partnerships to enhance commercialisation and economic benefits of technologies and science Reward private and civil society investments that contribute to sustainable development goals Do not prevent farmers from saving their own seeds and do not push for Intellectual Property Rights (IPR) Develop tools for farming to address and adapt to climate change Develop AKST tools for better resource resilience. Do not push for international competition before basic governance and infrastructures are in place	Markets' functioning, fairness and their access need to be improved for low-income countries. Healthy competition between companies in the food industry should be possible at local levels	Develop new markets to sustain a "system-oriented agriculture"	Markets need to be organised in a way that can protect farmers from volatile food prices and from the dumping of foreign, subsidised production on local markets in under-industrialised countries

	IAASTD	UK Foresight Study	US National Academy of Science	Olivier de Schutter
Trade-offs between higher production and increased sustainability Trade-offs between higher production and increased sustainability	More attention needs to be given to sustainability without jeopardising the high productivity that is going to be needed in the future Terminate subsidies that do not pay enough attention to the environmental effects of the production systems they promote	Do away with food subsidies as they raise consumer prices in protected countries and harm global markets At global and international levels there is a need to understand and accept the fact that food security and environmental protection are interwoven At national and landscape levels, urban and rural landscapes should be planned with biodiversity protection in mind, ensure minimum environmental flow and implement land sparing agriculture.	The Committee acknowledges the fact that the dominant agricultural production model might limit the range of opportunities to pursue increased sustainability. As such, the report mentions many agroecological practices which have the potential to increase systems' sustainability. Some scholars have blamed the increasing use of farm inputs, the decrease of crop diversity and the extensive hydrological changes of landscape on subsidy policies which have provided farmers with a strong incentive to monocrop and to maximise production. Because of this, more studies are needed to better understand the mechanisms that prevent or enhance the development of	Agriculture must conserve and enhance its own resources or it risks compromising its ability to meet future needs. Agriculture relies on natural resources such as biodiversity, water, healthy soils etc…and when those get damaged, agricultural productivity is threatened. Agro-ecology cannot succeed if markets are not organised in a way that can protect farmers from volatile food prices and from the dumping of foreign, subsidised production on local markets in under-industrialised countries, which negatively affects the local production.

	IAASTD	UK Foresight Study	US National Academy of Science	Olivier de Schutter
Trade-offs between higher production and increased sustainability Trade-offs between higher production and increased sustainability			sustainable agriculture Despite the need for research to address and improve the sustainability of farming systems, the bulk of public research funds is still directed at improving productivity and reducing production costs The Committee is aware that the transformation of the agricultural production sector is a long-term process and that it needs research and experimentation from the public and private sector and farmers.	

	IAASTD	UK Foresight Study	US National Academy of Science	Olivier de Schutter
Definition of food security	Food security means physical access to food, whether through means of personal production buying or bartering it, and the ability to absorb the nutrients consumed	Ensuring a fair access to food for all. High production is not enough if distribution cannot be ensured. Eliminating waste in industrial food chains and in local food systems is an integral part for ensuring food security.	Not given	Food security means that individuals are able to feed themselves from their land and other natural resources, or that they have the adequate means to buy food

Table 2.5 listed the roles and responsibilities that each mega-report bestowed upon four major groups revolving around the issue of food and agricultural sustainability, namely the research world, farmers, policy makers and international donors and the private sector. Some disparities emerged between the distribution of roles and responsibilities in each individual reports, acting as further indication of pre-analytical values and degrees of knowledge certainty on their part. Some propositions were remarkably precise and targeted such as the propositions for the research world to "invest in new or existing technology to improve storage and transportation" and "develop tools to detect reliably in advance spoilage in food" , while others were strikingly vague and non-commitmental, such as "bring together a number of disciplines to cover simultaneously key inter-locking dimensions of sustainability" from the US National Academy of Science.

This distribution of roles and responsibilities from each report informs us on their pre-analytical values, which transpire from the solutions they offer, themselves steaming from the issues they value most and deem most worthy of consideration by the appropriate groups.

Chapter 3: Uncovering knowledge (un)certainty in the scientific literature

This chapter will address the certainty (or lack of) concerning the knowledge necessary to solve problems. 3.1 describes in details Hoppe and Hischemöller's definition of political/unstructured and technical/structured problems in relation to the degree of knowledge certainty they each articulate. 48 peer-reviewed articles and books were accessed for the writing of this thesis; each deals with several of the many issues surrounding agriculture and food production. Those selected were referenced and used as background information in at least two of the main mega-reports. A long essay was written to summarise this material, it can be found in Annex II. The purpose was to examine in finer detail a representation of the entire spectrum of opinions, from one extreme to the other, and to give the reader a thorough overview of the state of knowledge currently displayed by science on this topic, and of the virulent dispute that accompanies it. These papers are used here to understand the knowledge axis in Hoppe and Hischemöller (2001) in relation to our topic.
I first zoom in on two specific papers, each chosen because they each represent one extreme of the spectrum on the Hoppe and Hischemöller's knowledge axis. Parrot and Marsden (2002) articulate their topic as unstructured, messy, entrenched together with other problems, entertaining opposing facts and values, and calling for the attention of many actors to be resolved, as such they see it as inherently political. On the opposite side, Avery (1995) strongly communicates his view that issues surrounding agriculture are structured, "technical" problems which call for obvious and simple to define knowledge. The demonstration supporting this claim is to be found in 3.2, it is organised around three themes : agricultural inputs, markets and the socio-cultural aspects of farming. Lastly, quotes directly extracted from the remaining forty-six articles are being presented in 3.3, they have each been chosen to represent the general 'spirit' in which each paper was written, and when possible, quotes relate to the degree of certainty regarding the knowledge on their topic that individual papers display and/or call for.

3.1 The (un)certainty of knowledge in Hoppe and Hischemöller

According to Hoppe and Hischemöller (2001): "when a problem is properly defined and structured, it is to be solved by standardised (quantitative) techniques and procedures. The disciplines and specialisations to be invoked are clearly defined and the policy-making responsibility is in the hand of one actor". Hoppe and Hischemöller qualify these problems as technical problems. The knowledge (disciplines and specialisations) needed to solve them is obvious, easy to define, and readily available. To simplify matters further, the decision-making regarding the solving of this problem is in the hands of one only actor.

On the contrary, technical methods 'appear' inadequate for solving unstructured problems. "The boundaries of the problem are diffuse, so it can hardly be separated from other problems. To address the whole problem is more than to address each of its parts. One cannot be sure what disciplines and specialisations are the be invoked for problem solving. Conflicting values and facts are interwoven, and many actors become involved in the policy process". Hoppe and Hischemöller find it more fitting to define these problems as political problems. The knowledge (disciplines and specialisations) needed to solve them is uncertain, prone to be debated, discussed and disagreed on, specifically since several disciplines need to be engaged into the problem resolution process. To make matters more uncertain, contradicting facts and actors (need to) become involved in the resolution process.

It is thus understandable that policy and decision-makers tend to prefer to frame the policy problems they encounter as 'structured' as it provides for a simpler resolution pathway, despite the fact that Hoppe and Hischemöller argue that mal-structuring a problem leads to its poor and/or temporary resolution.

3.2 Comparing and contrasting two approaches to a similar issue: 'messy' versus 'structured' problem framing

Forty-eight articles and books have been read for the purpose of writing this thesis. A bibliography and a summary of them are to be found in Annexes I and II respectively, and quotes directly extracted from them can be found in 3.3. The two articles chosen here have been extracted from this list of papers and explored in details in order to assess their certainty or uncertainty regarding the knowledge (disciplines and specialisations) they deem to be needed to best address the discussion surrounding the adequacy and desirability of different types of agriculture.

These two texts, have been purposely selected because they each represent one extreme of the opinion spectrum, and one extreme of the knowledge spectrum in Hoppe's matrix of intractable controversies (refer to Figure 1.3) . Comparing the works of Parrot and Marsden (2002) and that of Avery (1995) is a good way to show how different authors comprehend the issues at stake differently and as such, come up with widely different responses and solutions to them with regards to the necessary knowledge to address them.

When applying Hoppe and Hischemöller (2001)'s definition of policy problems, we can see that Avery (1995) very much frames issues surrounding food production and distribution as a structured, "technical" problems for which the knowledge needed to solve it is obvious, easy to define, and readily available. Avery (1995) argues for the generalised use of pesticides and brushes entirely aside the health and environmental concerns that this approach poses. Parrot and Marsden (2002) comprehend their problem as unstructured, messy, embedded together with other problems, entertaining opposing facts and values, and calling for the attention of many actors to be resolved. They define the topic of the adequacy and desirability of different types of agriculture as a political problem. Parrot and Marsden (2002), put forward a rich and deep argument in favour of sustainable agriculture when possible, although without de-facto excluding pesticides, and reviewing issues closely pertaining to agriculture in the field of market access, subsidies, social fairness, health and safety of rural workers, the valorisation of traditional knowledge etc... Consequently, each deals with these issues in opposing ways and offer different views on what they perceive to be the 'problem' and what they perceive to be the solution.

The following section attempts to compare and contrast Avery and Parrot and Marsden's approach to the knowledge needed to answer the questions they pose. This short analysis is articulated around three themes: agricultural inputs, markets and the socio-cultural aspects of farming.

Agricultural inputs

Avery argues that pesticides have brought ample food to millions around the globe, and that many countries rely entirely on them for sufficient food supply. In contrast, Parrot and Marsden note that use of synthetic inputs is declining in many poor areas (starting from an already low adoption base), mostly because of the long-term un-affordability of such technology. They cite a study by Harris et al., (1998) which found that two-third of sub-Sahara African farmers who used organic agriculture did so because of their personal economic circumstances which did not allow them to buy these inputs. Harris et al. (1998 cited in Parrot and Marsden, 2002) distinguish two major reasons for farmers in developing countries to adopt agro-ecology/organic agriculture. Some do it for purely economic reasons, as their products benefit from market advantages and/or enhance the food security of their community. The second group is probably just "jumping off" the agrochemical treadmill due to adverse economic circumstances and probably because of health and environmental reasons too, though data are lacking.

It is obvious here that Avery has a strong bias towards simplifying the issue at stake, namely the use of pesticides in the world. When writing "pesticides have brought ample food to millions around the world", he commits a generalisation by seemingly putting every country and their inhabitants in the 'same bag', without refining his argument to allow for specific countries' and/or regions' specific circumstances. The use of language also points towards a tendency towards 'easy' solutions; by stating that 'pesticides have brought ample food', it is implied that before the advent of pesticides, there was not enough food to feed these 'millions around the globe', and that pesticides solved this problem. Because the locations where this 'solution' applies are not specified, this statement is meaningless: pesticides have certainly helped increase food production in some places but they have not helped resolve issues such as their collateral harm to the environment and human health, access to food, access to land, poverty etc…which are in fact crucial if food is to be physically accessed by people. Parrot and Marsden account for these factors better, by citing small-holders' personal economic circumstances and that of their communities and the technology's long term un-affordability and how these considerations determine their (non)-use of pesticides. Avery puts forward a simple, structured sufficiency argument, while Parrot and Marsden put forward a social and economic argument which, without refuting the possible benefits of pesticides, demonstrates that many more aspects of the question need to be addressed in order to bring 'ample food to millions'.

When discussing the risks associated with pesticide use, Parrot and Marsden cite a study by Paarlberg (1994) which demonstrated that pesticides are linked to "second generation rural environmental problems". These encompass decreasing returns from repeated pesticide use and fertilizer spraying, health issues, biodiversity loss, decreasing quality in soils and water, diminishing ground water levels, and a heightening of crop disease risks. Partly, these problems arise directly from the toxic nature of many pesticides but they are increased by inadequate application methods, a problem that is especially prevalent in the developing world. For his part, Avery acknowledges the fact that Third World farmers use more dangerous pesticides (type I and II, WHO classification) than farmers in developed countries and that too few of these farmers use protective gear or are aware of the precautions to take when mixing, spraying or cleaning pesticide containers. He goes on to claim that even under these conditions, the health risks posed by pesticides are rarely severe. Once again, Parrot and Marsden see the problems posed by pesticides as encompassing a broad range of topics, from human health to biodiversity losses to decreasing soil fertility, thus bringing forth a complex set of inter-locked problems with ramifications running wide and deep. Avery focuses exclusively on the topic of human health, more specifically that of Third World farmers - thus creating a distance between 'them over there far away' and 'us here'- and minimises the scientific evidence when stating that the health risks posed by pesticides are rarely severe (101-104).

Market access

Avery views free-trade as a solution which can bring about a sufficient and stable supply of food with as little economic and environmental costs as possible. "Free-trade means that only the best and highest-yielding areas will be farmed, wherever they are. However, free trade must also mean the end of subsidies [in order] to be effective" (354-70).

Parrot and Marsden argue that organic agriculture has a strong social side which tends to be overlooked, even though it fits right in the development agenda in its widest scope. "It is therefore puzzling and potentially counter-productive that the main argument in support of exporting organic agriculture to the South is the promise of better access to markets in the North".

Parrot and Marsden open up the scope of their argument to human development issues, citing the fact that the 'development agenda' encompasses a very wide range of topics, and that the social side of organic agriculture can have positive repercussions to help reach these goals. Contrariwise, Avery's argument concerns itself with economic aspects only, believing that the end of subsidies is enough to bring about fair free-trade which will lead to a high and stable supply of food. His discourse implies that this, which again is exclusively a sufficiency argument, will be enough to solve hunger and malnourishment. The social aspects of concentrated and intensive farming of 'the best and highest yielding areas, wherever they are', whether positive or negative, are not touched upon. In the same way, ecological concerns are brushed aside: "free-trade can bring about a stable supply of food with as little environmental costs as possible".

Social and cultural concerns

Parrot and Marsden argue that organic agriculture generates an unconventional 'world view' where local farmers knowledge is celebrated and used and regarded with pride as opposed to shame. Additionally, they argue that organic agriculture and agro-ecology have a fundamental cultural dimension. Organic agriculture and agro-ecology draw and rely upon local, traditional and indigenous knowledge in 'plant science' (Kotschi, 2000 cited in Parrot and Marsden, 2002). From this valorisation of indigenous knowledge flows a number of consequences. Firstly, it highlights the importance of farmers' participation where 'learning from' farmers is equally or even more important than 'teaching' them.
Secondly, it deeply challenges the notion that unilateral technology transfers from the North into the South are a vital necessity and instead argues for a more measured and selective adoption of Northern technologies (Kotschi, 2000 cited in Parrot and Marsden, 2002).
Thirdly, it respects the value systems of rural communities, that extend beyond agricultural productivity and into a range of activities that promote household security (Parrot and Marsden, 2002).

Concluding remarks

As seen above, Parrot and Marsden focus their argument on the social and community aspects of farming as well as on its scientific side (although, in their case, indigenous knowledge is included in their understanding of scientific knowledge too) which makes for a complex argument. They acknowledge the fact that knowledge for solving this issue comes from a wealth of different sources, and that addressing the issue of agriculture takes them in all directions, forcing them to interact with many different disciplines (economical, sociological, ethnological, developmental...), and to interweave different sources of knowledge, facts and values, with uncertain results. As such, they treat their problem as a political one.
On the other hand, Avery focuses his argument on the simplified issue of yields and argues that it is best to farm the most productive land for all it is worth and leave to rest to nature and to recreational purposes. As such, pesticides should be used now and into the future, until we find "still-safer" ways to achieve sufficient yields. There is no room in his argument for the several points that Parrot and Marsden make such as the importance of farmers' participation (who are not mentioned in Avery's argument) or the idea that technology transfer from North to South needs to be more selective. Avery places technology in a one-size-fits-all format at the centre of his argument and through that device excludes many aspects that are inherent to farming. In effect, he treats his topic as a technical one which can be solved by standardised (quantitative) techniques and procedures (Hoppe and Hischemöller, 2001), such as pesticides. He presents the topic at stake as a properly defined and structured one, with inherent clarity as to what knowledge should be invoked in relation to it. The decision-making to solve the problem he present is mostly in the hands of one actor, namely the farmer who is the one to decide on the usage of and apply pesticides.

In conclusion, Parrot and Marsden account for a wealth of considerations and knowledge sources and facts, which allow them to make a rich argument in favour of organic agriculture and agro-ecology, but this prevents them from giving a square (certain) answer as to what the practical solutions to hunger and malnourishment would be; on the other hand Avery offers an unclouded answer, bringing forward certainty in knowledge (pesticides and free trade) which grossly fails to account for the diversity of needs and circumstances that his solution would address.

3.3 Clustering of selected research papers based on the knowledge axis in Hoppe

As mentioned previously, forty-eight additional documents have been consulted for the writing of this work. They are synthetized in detail in Annex I. The purposes here was to examine in finer detail a representation of the entire spectrum of opinions, from one extreme to the other, regarding the knowledge and values held by different parties in the debate, as well as give readers a wide overview of the topic of sustainable agriculture and the numerous issues surrounding it. These forty-eight additional documents have been classified in a similar way as Avery (1995) and Parrot and Marsden (2002), in order to assess their perceived certainty or uncertainty regarding the knowledge (disciplines and specialisations) necessary to best address the debate at hand. Individual documents have been classified into two clusters, and quotes directly extracted from each individual text are being presented to illustrate this classification. The clustered bibliography for these documents can be found in Annex II.

Cluster 1: Agriculture is a Technical Question:

Papers and authors that see science alone as a problem solver; they frame questions surrounding food and agriculture as structured and technical, and as such, in need of straight-forward, mostly scientific solutions. They tend to address problems surrounding agriculture and food access by essentially focusing on their technical aspects (mainly the increase in yields). As such, they put technology at the centre of the solutions they offer and often under-emphasise the human side of agriculture as well as the collateral risks and harm that technology can bring about. The disciplines and knowledge they see as needing to be called up are clearly defined and readily available.

Cluster 2: Agriculture is a Political Question

Papers and authors that insist the agriculture and food conundrum is a 'messy', unstructured, overall political problem which will not go away or become easier simply by pretending it is a structured, technical one. These papers tend to favour the 'learning strategy' elaborated by Hoppe and Hischemöller (2001), and to integrate contradictory information ranging from the welfare of human communities, biodiversity, soil as well as questions of yields and market access. They frame their reflection around the multiple and inter-locking aspects of the problem at hand. As a result, they come up with diverse, complex and often un-prioritised solutions, which call up on many different disciplines, sources of knowledge and stakeholders. Interestingly, although they generally tend to be strongly in favour of sustainable agriculture, many acknowledge the benefits of synthetic agricultural inputs and a few are even cautiously favourable to gene technology.

Nine papers belong to cluster 1 and thirty-nine papers belong to cluster 2; the papers framing their argument around the values of science and technology (cluster 1) were less numerous. This was not deliberately sought at all; I believe it is representative of how agricultural topics are being dealt with in research papers. Through a surprising artefact of the method, the list of authors for this cluster ends at the letter "K", this has no further implications. Through another artefact of the clustering criteria, some papers by researchers openly in favour of sustainable agriculture have been filed under cluster 1. These papers tend to consider the topic of sustainable agriculture through a techno-centric prism and, by attempting to address the arguments of the partisans of conventional agriculture with their own methods of problem simplification, reduce the magnitude of their topic.

Cluster 1: Agriculture is a technical question:

Papers and authors that see science alone as a problem solver; they frame questions surrounding food and agriculture as structured and technical, and as such, in need of straight-forward, mostly scientific solutions. They tend to address problems surrounding agriculture and food access by essentially focusing on their technical aspects (mainly the increase in yields). As such, they put technology at the centre of the solutions they offer and often under-emphasise the human side of agriculture as well as the collateral risks and harm that technology can bring about. The disciplines and knowledge they see as needing to be called up are clearly defined and readily available.

Nine papers are classified in this category

Almekinders, Fresco and Struik, 1995. "Agrodiversity is defined as the variation resulting from the interaction between these factors [the environment, genetic resources and management]. This variation manifests itself in many different forms, at different scales and levels of aggregation. Examples show that poor management of agrodiversity is high and low external inputs agriculture reduces output, output stability, resource-use efficiency, and the production potential of the natural resource base. A better understanding of agrodiversity is required to improve its management".

Avery, 2006. "A resurgence of 18th century American farm community structure- complete with tens of thousands of small rural towns, each surrounded by hundreds of 50-acre diversified farms raising their own food staples and selling/trading/ bartering a modest surplus of grains, meats, and dairy products – is unrealistic. It is unrealistic primarily because we must feed and clothe 9 billion human beings in the year 2050 from a decidedly limited land and resource base. It's also unrealistic because few people in the modern world want the hard physical labor, the long hours, and the harsh outdoor working conditions on a small farm.

Badgley et al., 2007. "The principal objections to the proposition that organic agriculture can contribute significantly to the global food supply are low yields and insufficient quantities of organically acceptable fertilizers. We evaluated the universality of both claims. For the first claim, we compared yields of organic versus conventional or low-intensive food production for a global dataset of 293 examples and estimated the average yield ration (organic: non-organic) of different food categories for the developed and the developing world. [...] We also evaluated the amount of nitrogen potentially available from fixation by leguminous cover crops used as fertilizer. Data from temperate and tropical agroecosystems suggest that leguminous cover crops could fix enough nitrogen to replace the amount of synthetic fertilizer currently in use. These results indicate that organic agriculture has the potential to contribute quite substantially to the global food supply, while reducing the detrimental environmental impacts of conventional agriculture".

Badgley and Perfecto, 2007. "The first [critical point] is that the relative yields of organic versus non-organic methods (green-revolution methods in the developed world, low intensive methods in the developing world) suffice to provide enough calories to support the whole human population eating today as it does. [...] Data from 77 published studies suggest that nitrogen-fixing legumes used as green manures can provide enough biologically fixed nitrogen to replace the entire amount of synthetic nitrogen fertilizer currently in use".

Bindraban and Rabbinge, 2011. "Assuming Europe is to secure its own food demand, to make a contribution to other food deficit regions in the world and to fulfil the non-food needs and desires of its wealthy population, it ought to pursue a dual agricultural pathway. Integrated production systems to secure sufficient and safe food should be efficient in terms of natural resource use, have high labour productivity, use precision and other advanced technologies and exploit economies of scale. Alternatively, organic and multifunctional agriculture and land use can be stimulated to satisfy non-food desires, such as for recreation and for therapeutic health purposes. Their economic viability ought to be guaranteed from income generated from these services rather than from food production alone".

Cassman, 2007. "The most relevant parameters to address the question of food security is food output per unit area-time. The time dimension is critical because organic systems often require rotations that include non-food crops, such as legume cover crops or lower yielding legume crops, to provide nitrogen input from symbiotic nitrogen fixation. While yield of the same crop species grown in organic and conventional systems may be similar, total food output of the cropping system may differ depending on the rotation".

Connor, 2008. "Existing analyses have put the carrying capacity of OA [organic agriculture] at 3-4 billion, well below the present world population (6.2 billion) and that projected for 2050 (9 billion). Those analyses (Buringh and van Heemst, 1979; Smil, 2011, 2004) are based on the performances of OA systems as practices in C19 [19^{th} century] before the widespread use of inorganic fertilizers and when the world population was around 1 billion. They remain relevant to the present discussion, because advances in crop yield since those times have not changed the essential metabolism of plant growth and nutrient requirement to support it".

Hendrix, 2007. "It is elitist to condemn people to the drudgery of hand labour required on small organic farms; only those who have never done it believe it is an employment solution. [...] In the developed world of agriculture, producers respond to market incentives. Given sufficient net returns to attract adequate capital and management, producers will industrialise the production of organic food. We are not driven by ideological concepts, political correctness or environmental persuasions; we are driven by the market-place".

Kirchmann and Thorvaldsson, 2000. "Use of pesticides in agriculture will lead to their occurrence in other environments. To guarantee minimal negative side-effects in ecosystems other than the soil-plant systems, pesticides whether natural or synthetic, should have no or low toxicity, except for the target organisms. [...]Excessive use of plant nutrients must be avoided, which does not mean that no intensive agriculture can be practised. [...] From an environmental point of view, it does not matter whether the nutrients come from inorganic or organic sources. What matters is when, how and in what quantity plant nutrients are available to crops, i.e. if nutrient supply is in synchronicity with the demand of the crop (Myers et al, 1997)."

Cluster 2: Agriculture is a political question

Papers and authors that insist the agriculture and food conundrum is a 'messy', unstructured, overall political problem which will not go away or become easier simply by pretending it is a structured, technical one. These papers tend to favour the 'learning strategy' elaborated by Hoppe and Hischemöller (2001), and to integrate contradictory information ranging from the welfare of human communities, biodiversity, soil as well as questions of yields and market access. They frame their reflection around the multiple and inter-locking aspects of the problem at hand. As a result, they come up with diverse, complex and often un-prioritised solutions, which call up on many different disciplines, sources of knowledge and stakeholders. Interestingly, although they generally tend to be strongly in favour of sustainable agriculture, many acknowledge the benefits of synthetic agricultural inputs and a few are even cautiously favourable to gene technology.

Thirty-nine papers are classified in this category

Altieri, 1995. "In the search to reinstate a more ecological rationale into agricultural production, scientists and developers have disregarded a key point in the development of a more self-sufficient and sustaining agriculture: a deep understanding of the nature of agroecosystems and the principles by which they function. […] Agro-ecology encourages researchers to tap into farmers' knowledge and skills and to identify the unlimited potential of assembling biodiversity to create beneficial synergisms that provide agroecosystems with the ability to remain or return an innate state of natural stability".

Azadi et al. 2011. "Therefore, the SFPS [Sustainable Food Production System] will be reinforced by OA [organic agriculture], especially compared with the conventional and biotechnological approaches which often neglect indigenous knowledge (Niggli et al., 2008); are based mostly on monocultures (which stimulate soil degradation); are less resistant to drought (Ramesh et al., 2005); and use water less efficiently (Lotter et al., 2003). [...] In conclusion, a long-term transition towards OA could be encouraged. However, as OA, at least in the short term, produces lower crop yields (Maeder et al., 2002), there are some kinds of trade-offs between organic and the two other approaches with respect to sustainability (in terms of long-term potential to produce enough food) and productivity. This means that although in the short-term OA may produce fewer, in the long-term it may produce higher yields (Badgley and Perfectto, 2007) because it can better address important threats of food security such as soil degradation, climate change and pest problems. [...] Therefore, given the low productivity of OA at the present time, we still need the conventional and safe biotechnological methods to feed the hungry bellies. Accordingly, the transition should be regarded as a gradual shift to be able to challenge with the dilemma of the hungers and the malnourished people".

Balfour, 1949. "It is the first purpose of this book to present some of this evidence and to show that, when considering matters of health, it is misleading to separate man, animals, and plants. All are part and parcel of the same nutrition cycle which governs all living cells. If we attempt interference with it, other than along the general lines of co-operation, dire results follow. [...] It is as though man's ignorant and greedy exploitation of the soil had put into reverse the wheel of health. [...] If, when it is concluded, the results of this, or other similar experiment, were to prove beyond any reasonable doubt that health is in fact to a large degree dependent upon correct soil management, then we should be faced with a revolutionary situation, for clearly in that event, any Public Health system of the future would have to be based on soil fertility".

Benton, Vickery and Wilson, 2003. "We argue that the loss of ecological heterogeneity at multiple spatial and temporal scales is a universal consequence of multivariate agricultural intensification and, therefore, that future research should develop cross-cutting policy frameworks and management solutions that recreate that heterogeneity as they key to restoring and sustaining biodiversity in temperate agricultural systems. [...] Recognition that there has been erosion of heterogeneity at multiple spatial and temporal scales as a consequence of agricultural intensification can help to unify the response of conservation management because all agricultural practices (including agrochemical usage, cultivation practices, rotation planning and management of noncrop habitats) can, in principle, be tailored and targeted to increase rather than eliminate heterogeneity. [...] We suggest that reversing declines in farmland biodiversity will require enhancing heterogeneity of farmland from within individual fields to whole landscapes. In principle, this is a hypothesis testable by experiment: it heterogeneity more important than the practices used to create it?".

Conway, 1997. "In many ways, pest control is like a multidimensional game of chess. We pit ourselves against a variety of pests, drawing on a range of methods of control; the pests respond by evolving new defences. As we have learnt, it is not an unequal contest – there is rarely a final check-mate. Sustainable pest control depends on developing new strategies and tactics, in a continuing game".

Crowder et al., 2010. "Human activity can degrade ecosystem function by reducing species number (richness) and by skewing the relative abundance of species (evenness). [...] In farmlands, agricultural pest management practices often lead to altered food web structure and communities dominated by a few common species, which together contribute to pest outbreaks. Here, we show that organic farming methods mitigate this ecological damage by promoting evenness among natural enemies. [...] Our results strengthen the argument that rejuvenation of ecosystem function requires restoration of species evenness, rather than just richness. Organic farming potentially offers a means of returning functional evenness to ecosystems".

Dunn, 2011. "The obsession of the modern food industry in producing ever-higher yields and ever-larger quantities, has given rise to a variety of environmental and public health costs and concerns. The environmental impact of the rapid industrialisation of the global food production chain, for example, has been significant, with the collapse of fish stocks, soil erosion, deforestation and falling water tables in areas of key agricultural production. There has been increased public concern regarding the impact of pesticide residues, antibiotics and veterinary drugs, food pathogens, environmental toxins such as lead and mercury, organic pollutants such as dioxins, on public health".

FAO, 2007. "Today's total global agricultural production is sufficient to feed the current world population and both necessary technologies and multilateral environmental agreements are available to help meet development and conservation needs. [...] Moreover, the last decades provide uncompromising evidence of diminishing returns on grains despite the rapid increases of chemical pesticide and fertilizer applications, resulting in lower confidence that these high input technologies will provide for equitable household and national food security in the next decades. [...] In well-endowed areas where small-holders lack capital (e.g. one third of the poor in Asia), organic agriculture breaks the vicious circle of indebtedness (due to agricultural input purchases) which causes an alarming number of farmer suicides. In contrast, organic agriculture attracts new entrepreneurial entrants into farming who have more optimism about their future due to the value of their jobs in local economies".

Fernandes, Pell and Uphoff, 2005. "Efforts to raise agricultural productivity have been guided for many decades by four presumptions. These have produced some impressive results, so our objection is not that they are wrong. Rather, they have become too dominant in our thinking, with too hegemonic an influence on policy and practices. It has been taken for granted that they represent superior ways to boost production. This thinking can be stated in four tacit equations that have shaped contemporary agricultural research, extension and investment.

1. Control of pests and diseases = application of pesticides or other agrochemicals.
2. Overcoming soil fertility constraints = application of chemical fertilizers.
3. Solving water problems = construction of irrigation systems.
4. Raising productivity beyond these three methods = genetic modifications.

Equating certain kinds of solutions with broad categories of problems limits the search for other methods to solve those problems, even when alternative practices might have a lower cost and be more beneficial in environmental and social terms. More progress in agriculture will be made if the above propositions are broadened."

Fresco, 2009. "Soon we will live in a world where never before in human history the responsibility for the food of so many has been borne by such a small minority of farmers and food processors and retailers. A minority that is barely recognised by an increasingly dominant urban population, and often blamed for many of the ills of environmental damage and globalization. In bringing about such a policy, based on new thinking, we need the concerted efforts of all, science, government, the UN and other international and non-governmental organisations. Food needs to become an issue of concern to all and needs to be put back on the political agenda as well as on the educational curriculum. Because, in the end, food is what links human kind, now and in the future".

Gliessman, 2004. "We need to be able to analyse both the immediate and future impacts of agroecosystem design and management so we can identify the key areas in each system on which to focus the search for alternatives or solutions to problems. We must learn to be more competent in our agroecological analysis in order to avoid problems or negative changes before they occur, rather than struggling to reverse the problems after they have been created".

Godfray et al., 2010. "Exactly how best to facilitate increased food production is highly site-specific. In the most extreme cases of failed states and non-functioning markets, the solution lies completely outside the food system. [...] An unfettered market can also penalise particular communities and sectors, especially the poorest who have the least influence on how global markets are structured and regulated. [...] Conversely, a highly connected food system may lead to the more widespread propagation of economic perturbations, as in the recent banking crisis, thus affecting more people. There is an urgent need for a better understanding of the effects of globalisation on the full food system and its externalities".

Green et al., 2005. "What kinds of farming give the best prospect of minimizing losses of wild nature to habitat removal and change while providing food for a growing and more demanding human population? This paper does not provide an answer to that question. [...] Above all, our analysis highlights the need to know more about density-yields functions of real species in the real world, about how they might be modified by changes in agricultural and conservation methods, and about how far different kinds of farming influence the wildlife of nonfarmed areas. We also need to know much more about the extent and limits to which land is spared from agricultural use because of increased yields . Rapidly acquiring the data to address these issues is essential if we are to make wise and informed choices about how and where we farm. Few other decisions will have as great an influence on the fate of wild nature".

Hilbeck, 2008. "The paradigm of industrial agriculture was maximising profits from land by focusing on one factor only: productivity – the increase of yields literally at any costs. [...] This came at the expense of the health of humans and the environment, the costs of which were never factored into the economic equation in any meaningful way. [...] The old 'one size fits all' approach of industrial agriculture was not sufficient to abolish poverty and hunger and caused irreversible damage to the environment everywhere it was introduced. For poverty and hunger alleviation the paradigm shift will have to include solution packages that are tailored to the given situation and will include initially low-tech and certainly cost-free strategies".

Hole et al., 2005. "The majority of the 76 studies reviewed in this paper clearly demonstrate that species abundance and/or richness, across a wide-range of taxa, tend to be higher on organic farms than on locally representative conventional farms. Of particular importance form a conservation perspective is that many of these differences apply to species known to have experienced declines in range and/or abundance as a consequence of past agricultural intensification, a significant number of which are now the subject of direct conservation legislation. [...] Several important caveats apply to this generalization however. First a minority of studies indicated little or no difference between systems or that conventional systems are beneficial for some species, across a variety of taxa. [...] However, these inconsistencies also indicate that the benefits to biodiversity of organic farming may vary according to factors such as location, climate, crop-type and species, and are likely to be strongly influenced by the specific management practices adopted. [...] The extent to which the potential beneficial impacts of organic farming are met on individual farms will therefore be influenced not only by the standards enforced, but also by the attitude and ethical beliefs of the farmer (Greenwood, 2000; Shepherd et al., 2003), and on the economic realities of the marketplace. Second, this review highlights a number of methodological inconsistencies and concerns inherent in the design of many of these studies that may have resulted in unintentional bias, leading to erroneous conclusions being drawn (including a tendency to underestimate any positive effects of organic farming on biodiversity). Third, the majority of comparative studies have been carried out in arable or mixed systems. As a result, there is a dearth of information pertaining to the impacts of organic agriculture in pastoral systems”.

Howards, 1945. “Food is the chief necessity of life. The plans for social security which are now being discussed merely guarantee to the population a share in a variable, and in present circumstances, an uncertain quantity of food, most of it of very doubtful quality. Real security against want and ill health can only be assured by an abundant supply of fresh food properly grown in good soil in good heart. The first place in post-war plans of reconstruction must be given to soil fertility in every part of the world. The land of this country and the Colonial Empire, which is the direct responsibility of parliament, must be raised to a higher level of productivity by a rational system of farming which puts a stop to the exploitation of land for the purpose of profit and takes into account the importance of humus in producing food of good quality. This electorate alone has the power of enforcing this and to do so it must first realise the full implications of the problem”.

IFOAM, 2006. “Although soil fertility is a cause of Africa’s food insecurity, it is certainly not the only cause. Social and economic determinants are at least as important. They, however, will not be changed by using more fertilizers! The preoccupation with productivity per hectare ignores the increasing evidence that it is not supply factors, such as productivity per hectare, but demand factors, such as market opportunities, that determine agricultural development outcomes in Africa. [...] The causes of starvation are plenty, but only seldom are they related to the rate of agricultural productivity. Rather, developing countries are highly in debt and must therefore export food, feed and other agricultural products (so called cash crops) to the wealthy countries of the northern hemisphere in order to generate income. And enormous amounts of these foodstuffs are fed to animals. This often occurs despite the fact that much of the population of the country in question goes hungry [...] Other factors can include a lack of labour or healthy labour, bad governance, lack of distribution capacity, poor infrastructures, lack of good storage facility and policies that discourage or undermine food production”.

Kiers et al., 2008. “There is a need to capitalise on human ingenuity, deployed for centuries to solve agricultural challenges. [...] Success is not based on technological performance in isolation, but rather how technology builds knowledge, networks and capacity. Simply put, plant breeding and natural resource management practices are very ‘blunt tools for social change’; innovation demands sophisticated integration with local partners. [...] Continued Science & Technology advancements need to be accompanied by investments in rural infrastructures (physical, market and finance) and local governance. Countries lagging behind in these investments simply cannot compete in domestic or international markets”.

Kline, 1996. “What took years to harm takes years to heal. It is estimated that it takes nature several hundred years to build an inch of top soil (150 tonnes per acres). With poor farming practices this amount can be lost to erosion in ten years. [...] Quite often the most overlooked and perhaps the most abused part of nature is the life in the soil. The healing process begins there. A gram of good soil may hold as many as four billion microbiotic organisms. [...] The health of a farm and nature is not brought about by some ‘heroic feat of technology, but rather by thousands of small acts and restraints handed down by generations of experiences' to quote Wendell Berry. [...] What might appear to be a conflict between exploiter and nurturer could be more accurately described as farmer and land involved on a sort of dance. It is an attempt to achieve a balance between give and take, without too much stepping on each other's toes".

Kloppenburg, Hendrickson and Stevenson, 1996. "Ultimately, what sustainability requires of us is change in global society as a whole. We need the recovery and reconstitution of community generally, not simply in relation to food. Although we may strive to think like mountains, we must act like as human being. To start the global task to which we are called, we need a specific place to begin, a specific place to stand, a specific place to initiate the small, reformist changes that we can only hope may someday become radically transformative. We start with food. Given the centrality of food in our lives and its capacity to connect us materially and spiritually to one another and to the earth, we believe that it is a an appropriate place to begin. We offer the term 'foodshed' to encompass the physical, biological, social and intellectual components of the multidimensional space in which we live and eat. We understand the foodshed as a framework for both thought and action"

Kristiansen and Merfield, 2006. "While organic agriculture aims to be environmentally sustainable, it has not yet reached its goals and there are issues that still need to be addressed. [...] a common question asked of the organic movement relates to its yields: can organic agriculture feed the world? Like questions about sustainability, productivity also depends on many factors including the farmer's background, the farm's resourcefulness and local and national support mechanisms. The appropriate answer may be: does conventional agriculture successfully feed the world now? High input-high yielding systems are currently failing to feed the world, not because of problems with productivity, but because of problems with food distribution and social organisation, and serious concerns such as poverty, racism and gender imbalance (Woodward, 1996). Comparisons of organic and conventional farming have been a common feature of the organic literature since the 1980s.[...] Rather than limiting the analysis of organic agriculture to a comparative approach, it is more worthwhile to look for the underlying mechanisms and general principles. By identifying the strengths and weaknesses in the organic system, improvements can be made for organic farmers and relevant knowledge transferred to receptive conventional farmers".

Lang and Heasman, 2004. "Addressing the challenges of health will requite better processes for making food policies and reform of the institutions of food governance; they need to be shaped in an integrative way. Unless this is done, we believe that he food supply chain will lose public trust. […] We set out to write this book because we were frustrated that the key figures in food policy appeared to be skirting around major problems rather than facing them, or too often dealing with the challenges separately in neat policy boxes rather than holistically".

Lotter, Seidel, Liebhardt, 2003. "The 1999 severe crop season drought in the northeastern US was followed by hurricane-driven torrential rains in September, offering a unique opportunity to observe how managed and natural systems respond to climate-related stress.

Organic management of soils leads to improved soil stability and resistance to water-erosion compared to conventional managed soils, due to higher soil C content and improved soil aggregation , permeability, and lower bulk density, as well as higher resistance to wind erosion. [...] Organic crop management techniques will be a valuable resource in an era of climatic variability, providing soil and crop characteristics that can better buffer environmental extremes".

Low and Ward, 1997. " As Law writes " the social world is complex and messy" (Law, 1994: 5), but in wanting to cleave to an order, we are merely clinging to the unrealisable modernist dream which seeks to monitor, control, and legislate […] We are, however, suggesting that the search for new, all-encompassing paradigms is an insufficiently modest objective. Better to revel in theoretical and methodological diversity and be promiscuous in our interests and approaches. […] We propose a blending of insights from implementation theory (on street-level bureaucrats) and development studies (on encounters at the interface, moral economies and the weapons of the weak)".

Navdanya, 1993. "Traditional agriculture does not recognise the concept of "weeds". All plants have their uses: some plants have more than one use; in some cases the various parts of a single plant each have a separate use. [...] It is now well documented that the 'miracle' seeds [of the Green Revolution] are not high-yielding in and of themselves. They were merely as High Response Varieties, since their distinguishing features were that they responded to heavy chemical inputs. [...] The question of high yield is not merely one of high external input because output is not independent of environmental factors such as the vagaries of weather and drought conditions which more often than not prevail in the country in various pockets".

Noorgaard and Sikor, 1995. "It has been argued here that a coevolutionary paradigm of development may be complementary with an agroecological approach. Other paradigms, of course, will also give helpful insights. The strengths of the coevolutionary paradigm, however, appear to identify some of the key differences between agroecology and conventional agriculture. The paradigm very readily illustrates how social and environmental systems are intertwined, each reflecting the other, yet each changing in response to the other. This helps us understand why social and environmental change must occur together. It easily shows why agroecologists prefer to experiment within farms, adapting existing systems of farming rather than radically redesigning agriculture. The coevolutionary perspective, furthermore, gives legitimacy to farmers' knowledge and helps explain why change must include them in the experimental process".

Pimentel et al, 2005. "Nutrients from fertilizers and animal manure have been associated with the deterioration of some large fisheries in North America (Frankenberg and Turco, 2003), and runoff of soil and nitrogen fertilizers from agricultural production in the Corn Belt has contributed to the "dead zone" in the Gulf of Mexico. [...] The estimated annual costs of public and environmental health losses related to soil erosion exceed $45 billion (Pimentel et al. 1995)".

Posner, Baldock and Hedtcked, 2008. "When organic price premiums are included with the government payment, returns to the organic grain system (S3) increased by 85 to 110% and in the forage system by 35 to 40%, placing both of them with higher returns than any of the Midwestern standards of no-till corn-soybean (S2), continuous corn (S1), or intensive alfalfa production (S4). Our analysis explores the role of risk exposure and of its associated cost (as measured by a risk premium) across systems. The more diverse rotations were found to generate moderate risk exposure, with risk premiums rarely more than 5% of returns or significantly different among those systems. This indicates that the management practices associated with the lower input or organic systems are, overall, no less effective than those associated with high input systems".

Pretty, 2002. "Food is getting cheaper relative to other goods, and many believe that this must benefit everyone as we all need to eat food. But we have come to believe in a damaging myth. Food is not cheap. It only appears cheap in the shop because we are not encouraged to think of the hidden costs of damage caused to the environment and human health by certain systems of agricultural production. Thus we pay three times for our food. Once at the till in the shop, a second time through taxes that are used to subsidise farmers or support agricultural development, and a third time to clean up the environmental and health-side effects. Food looks cheap because we count these costs elsewhere in society. As economists put it, the real costs are not internalised in prices. [..] The external costs of UK agriculture are alarming. They should call into question what we mean by efficiency. Farming receives £3 billion of public subsidies each year, yet causes another £1.5 billion of costs elsewhere in the economy. If we had no alternatives, then we would have to accept these costs. But in every case, there are choices. Pesticides do not have to get into water. Indeed, they do not need to be used at all in many farm systems. The pesticides market in the UK is £500 million, yet we pay £120 million just to clean them out of drinking water. We do not need farming that damages biodiversity and landscapes; we do not need intensive livestock production that encourages infections and overuse of antibiotics. Not all costs, though, are subject to immediate elimination with sustainable methods of production. [...] But it is clear that many of these massive distortions could be removed with some clear thinking, firm policy actions, and brave action by farmers".

Pretty et al., 2010. "Moreover, the intensification of agriculture has been central to the degradation of ecosystem services, and has both increased the production of greenhouse gases and the reduced levels of carbon sequestration (UNEP, 2010). The major challenge is to understand the best compromises between increasing food production while minimising the negative impacts on biodiversity, eco-system services and society. [...] However, pest research has tended to be dominated by an insect bias, with diseases in second place and weeds third. Research needs to broaden to study causal organisms in proportion to damage they cause. [...] On governance, it is important to establish safe-guards against risks and assurances for the wellbeing and social and economic benefits to smallholders, where the state has an important role in influencing technology and policy options".

Rigby and Caceres, 2001. "Hall, an organic inspector with the Organic Crop Improvement Association (OCIA) in the USA, states that this idea that a crop is organic because 'nothing has been put on it' is all too common. This, he argues, is not a sustainable approach and does a major disservice to the majority of organic farmers who are making excellent progress in developing a healthy and naturally resilient whole farm systems"(Hall, 1996). [...] The sustainability of organic farms runs across the entire range of sustainability, just like it does for conventional farms".

Robinson and Sutherland, 2002. "Analyses integrating social, economic and environmental objectives are needed to determine the optimal trade-offs between these in each region, to create a landscape that satisfies many different needs in a relatively restricted area. Incorporating broader environmental objectives within the farming remit could reconcile these multiple requirements. [...] More generally, farmers' attitudes are likely to have a major influence on how new technologies are applied, and hence their biodiversity impacts (Watkinson et al., 2000). Understanding these processes is likely to be just as important for biodiversity as auto-ecological studies. [...] Understanding how, indeed if, results from the many plots – or field –scale studies apply at regional or national scales, and the scaling processes involved, is a key area where research is required. Interactions between factors, for example predation and the structural complexity of habitats (Donald and Vickery, 2000) and regional variation in habitat use (Robinson, Wilson and Crick, 2001), also need to be considered. Such distinctions will be critical for agri-environment schemes which need to develop regionally, and locally, flexible approaches (Bignal, Jones and McCracken, 2001). With so many factors impacting on biodiversity, the need for large scale monitoring to inform environmental management has never been greater".

Röling, 2000. "The current human project is largely driven by economic concerns. [..] Ecological issues provide worrisome noise but are not part of current political and governance systems. [...] There is as yet no political advantage to be gained with ecological issues. [...] What we have not developed is widespread *reflexive knowledge* about ourselves and our collective actions which could be the basis for effectively dealing with the eco-challenge. Although humans have become a major force of nature, we lack the intellectual instruments to deal with that force. Yet, increasingly, success on that score is a condition for our survival. Neither purely scientific nor economic knowledge, alone or in combination, can be expected to provide the basis for getting us out of our ecological predicament. There is no technological fix and the market fails when it comes to eco-challenge. In fact, our predilection to technical solutions and reliance on market forces increasingly seem part of the problem (Funtowicz and Ravetz, 1993; Beck, 1994). This is not to say that technology and economics cannot be part of the solution. What this lecture will emphasise is that technology and economics can only be applied towards a sustainable society within a framework of collective action that overrides instrumental and economic rationality".

Schlosser, 2001. "Some herds of American cattle may have been infected with E. coli 0157:H7 decades ago. But the recent changes in how cattle are raised, slaughtered, and processed have created an ideal means for the pathogen to spread. The problem begins in today's vast feedlots. A government health official, who prefers not to be named, compared the sanitary conditions in a modern feedlot to those in a crowded European city during the

Middle Ages, when people dumped their chamber pots out the window, raw sewage ran in the streets, and epidemics raged. The cattle now packed into feedlots get little exercise and live amid pools of manure. "You shouldn't eat dirty food and dirty water," the official told me. "But we still think we can give animals dirty food and dirty water." Feedlots have become an extremely efficient mechanism for "recirculating the manure," which is unfortunate, since E. coli 0157:H7 can replicate in cattle troughs and survive in manure for up to ninety days”.

Sherwood, Cole, Crissman and Paredes, 2004. “Much conventional thinking in agricultural development places emphasis on scientific understanding, technology transfer, farming practice transformation and market linkages as the means to better futures. Consequently, the focus of research and interventions tends to be on the crops, the bugs and the pesticides, rather than on the people who design, chose and manage practices. Recent experiences of rural development and community health, however, argue for a different approach. [...] Of course, technologies can play an important role in enabling change, but the root causes of the ecosystem crisis such as in Carchi appear to be fundamentally conceptual and social in nature, that is, people sourced and dependent. [...] The search for innovative practice less dependent on agrochemical markets tend to focus on the diversity of farming and the socio-technical networks that enable more socially and ecologically viable alternatives. Progress in this area would require a new degree of political commitment from governments to support localised farming diversity and the change of preconceived, externally designed interventions towards more flexible, locally driven initiatives. [...] Our modern explanations are ultimately embedded in subtle mechanisms of social control that can lead to destructive human activity”.

Shiva, 1999. “What are weeds for Monsanto are food, fodder and medicine for Third World women. In Indian agriculture women use 150 different species of plants for vegetables, fodder and health care. In West Bengal 124 ‘weed’ species collected from rice fields have economic importance for farmers (Shand, 1997)”.

Soil Association, 2010. “The two figures on increasing global food production (50% by 2030 and doubling by 2050) are being widely used by key individuals in current agricultural policy debates. The figures are claimed to be the increases in food production that scientists say are needed to feed the world’s growing population.[…] What the reports on which the claims are based do say is that certain sectors, in certain parts of the world, may have to increase food production by significant amounts. For example, for cereals, there is a projected increase of 1 billion tonnes annually over the 2 billion tonnes of 2005, a 50% increase by 2050, mainly to feed animals. For meat, in developing countries only (except China), the reports say that some of the growth potential (for increased per capita meat consumption) will materialise as effective demand, and their per capita consumption could double by 2050. So this is a projected doubling of meat consumption in some developing countries – not a doubling of global food production.[…] A recent scoping study examined how we can feed and fuel a world of 9 billion people in 2050 sustainably, fairly and humanely. Significantly, the report provides evidence “that organic agriculture can probably feed the world population of 9.2 billion in 2050, if relatively modest diets are adopted”.

Tegtmeier and Duffy, 2004. “Many is the US pride themselves on out ‘cheap’ food. [But] we pay for our food in our utility bills and taxes and in our declining environmental and personal health. [...] What can be done? By using ‘ecological’ or ‘sustainable’ methods, some agricultural producers claim to be internalising many of these external costs. However, the market and policy structure in which most producers operate offers narrow return margins and discourage changes in production methods. [...] Political intention is required to reassess and reform agricultural policy. Programmes that highlight sustainable methods rather than destructive, risky practices would be a start at internalising the true costs of the present system”.

Valoqueren and Baret, 2009. “Many scientists do not explore these agroecological innovations because “it goes against the flow”, as a scientist explicitly stated during an interview, when asked why cultivar mixtures were not being researched to create system resistant to fungal diseases. Scientist and stakeholders refer to current social and economic barriers impeding the use of some possible innovations by farmers today to justify the research deficit. Current barriers are seen as permanent immovable obstacles. [...] past agricultural systems are rarely seen as sources of insights for innovation in mainstream agricultural science, where modernization remains an important leitmotiv. [...] On the contrary, agroecology values past systems as a source of insight for the improvement of current systems”.

Chapter 4: Discussion and Conclusion

I begin this chapter by discussing the research questions each in turn before opening the discussion to a more general perspective. After carrying out this analysis, it was decided that no less than three of the mega-reports fit in the “unstructured/political problems” cell of the Hoppe’s matrix. This is due to the fact that each one of those three report, each in their own way and to varied degrees, framed the analysis of their topic around a political canvas, interweaving together issues pertaining purely to the technical realms and issues concerning the wider social, political, ethnological, developmental etc.... fields. The US National Academy of Science report was put into the “moderately structured problems by ends” cell; despite its pronounced technocentric approach (values), it mentions social and political issues as well - even though these are much less developed than in the other reports - and, on several occasions, it calls for more knowledge and more research to be brought about in the debate. The discussion then brings forward Hoppe and Hischemöller’s solution to solve intractable controversies which they call “the shared learning strategy”. They argue that the key pathway out of intractable controversies is to define an adequate policy strategy and outline its political preconditions. Mainly, the learning strategy demands a pro-active choice on the part of politicians to solve the problem, to involve the public and to enable a climate of equality among actors, even if only temporarily. This lays the foundation for a problem solving process which can then be widely perceived as legitimate.

To conclude, it is possible that just as in politics, there is a bias in science to prefer structured problems over messy ones; an admission of the inherent ‘messiness’ of a given topic, and not attempting to overtly structure it, is seemingly associated to a lack of rigour on the researcher’s part, and as such is less likely to be taken seriously.

4.1 How is the problem structured in the four reports, and more specifically how are pre-analytical values and knowledge certainty expressed in them?

I have classified the IAASTD report, the UK Foresight Report and the report by the Special Rapporteur as approaching their topic as unstructured ones, and I have classified the US Academy of Science report as addressing its topic as a moderately structured problem in its ends.

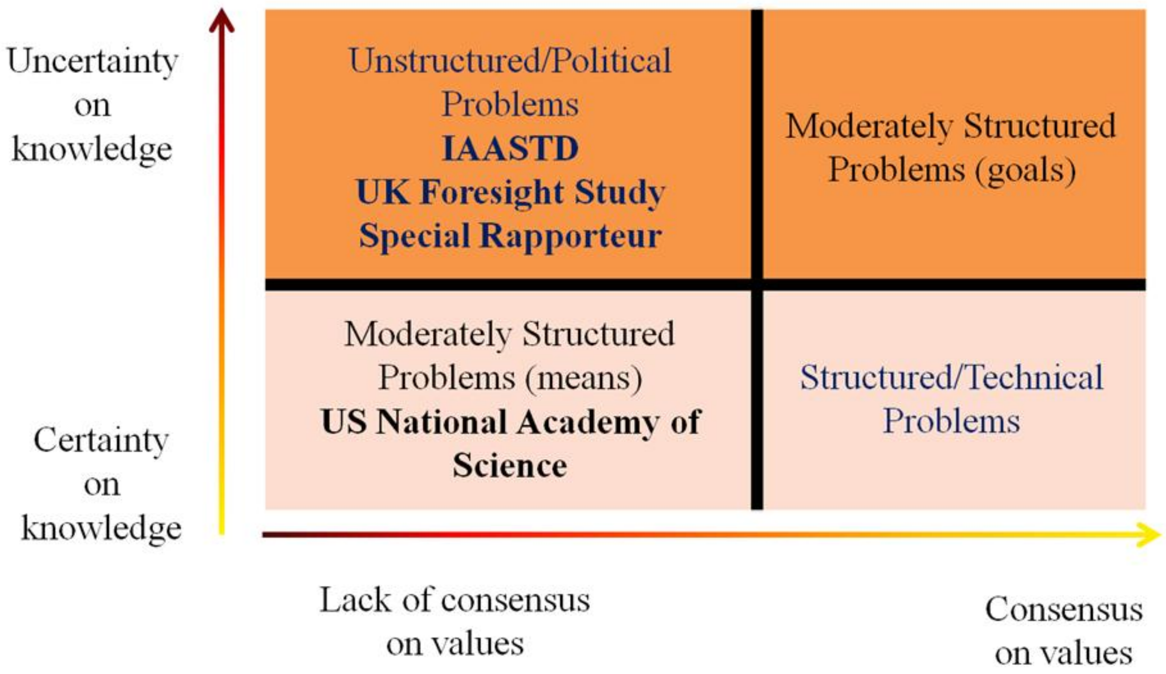

Figure 4.1 Hoppe's (1989) matrix as applied to the four mega-reports

A messy or an unstructured problem displays unclear boundaries and are closely intertwined with other problems and issues, which means that different and numerous disciplines, sources of knowledge and stakeholders have to be called in to attend to them. As such, the IAASTD, the UK Foresight Report and the report by the Special Rapporteur fit in this category.

The IAASTD: was written with the combined participation of no less than 400 of the world's experts writing in their own capacity on their topics of expertise, all gravitating around agriculture to some degree. They argued that a shift in AKST is needed which would encompass science, technology, policies, institutions, capacity development and investment. One of the premise (value) of their work was that the ecological and the social complexity within which different agricultural systems operate need to be recognised. They treated their topic as a political one by citing a wide range of issues that needed addressing to solve the global hunger and malnourishment problem, each calling for specific and different sources of knowledge, ranging from farmers' access to land and to markets near and far, women's empowerment, rural livelihoods, access to food and effective nutrient absorption, adequate sanitation and clean water, increasing productivity while balancing sustainability, improving infrastructures dealing with public and veterinary health, increasing both public and private investments and partnership to promote research and knowledge, enhancing equity etc....

The UK Foresight Report: was written with the contribution of 400 experts and stakeholders coming from some 35 low-, middle-, and high-income countries. Its primary aim was to study the pressures that will arise on the global food system between now and 2050. Its primary conclusion was that a redesign of the current global food systems is urgent. One of its premise (value) was that increasing production alone is not enough although it is necessary, but that many more issues need to be dealt with to reach this goal. They treated their topic as a political one by citing a wide range of issues that needed addressing to solve the global hunger and malnourishment problem, each calling for specific and different sources of knowledge, ranging from women's rights, local and international markets' functioning, the need to improve physical infrastructures, the improvement of the rights to land and natural resources, the importance of science and technology to help increase production and develop new ways to reduce the current global food spoilage rate of 30-50%, to improve the governance of the global food system, reduce or supress subsidies, punish irresponsible fishing, foster a healthy competition in the food system, understand the crucial linkage between food-insecurity and under-nutrition, maintain biodiversity and ecosystem services while feeding the world, curb GHG emissions, understand that food security and environmental protection are interwoven etc...

The Special Rapporteur: wrote in his own capacity by drawing on his own knowledge and experience and by pooling together the knowledge of several experts globally. His primary premise or value was that agroecology can adequately meet "the concrete realisation of the right to food". He argued that combating hunger and malnutrition can only be done through higher incomes and increased livelihoods for the poorest and most vulnerable, and that increasing production cannot be done at the expense of ecological degradation, as this would surely threaten future food production. One of the overarching points of his report was that a change in favour of agroecology "can only happen by design" through political will. He treated his topic as a political one by citing a wide range of issues that needed addressing to solve the global hunger and malnourishment problem, each calling for specific and different sources of knowledge, including technic al facts such as that "supply must match world needs", that agriculture needs to increase small-holders income, that it cannot afford to compromise natural resources' ability to support it in the future and should instead aim to enhance the health and availability of these resources, all the while recognising the fact that synthetic fertilisers should not be excluded, that agriculture needs to adapt to climate change and to improve nutrition; and political facts such as the need to prioritize public good, to strengthen social organisation by co-construction, to empower women and minorities and to organise fair markets. While he sees governments as having a key role to play in this regard, however, he believes that policy-making on this topic needs to be "a mode of social learning rather than an exercise in political authority" (Diop, cited in de Schutter, 2001).

The US Academy of Science: structures its topic as moderately-structured problems in its ends (consensus on values but uncertainty of knowledge). The reason why it has been categorised in this way is because despite the fact that they present the values surrounding this debate as rather certain - the report is based on the premise that US agriculture needs to improve its sustainability at the environmental, social and economic levels - almost all points considered in the report trigger a demand for more research (knowledge) to be done on the topic mentioned: "there is still little research on the inter-locking social and economic dimensions of agricultural sustainability"; "the transformative approach also calls for the development of new markets, new policies and new paradigms of research which together will sustain a "system-oriented agriculture"; "a system approach is needed to understand and make the best use of the linkages that exist between farming component and the wealth of environmental and social aspect that relate to it" etc... This comes in contrast with the other reports' attitude with regards to knowledge certainty as they generally seem content with the level of knowledge available in the literature and in the research world on their topic.

4.2 What explicit or implicit pre-analytical values underlie these reports?

Broadly speaking, the UK Foresight Study and the National Academy of Science display three pre-analytical values:

1. A bias in favour of the private sector to transfer technology from the North to the South and 'save' small-holders this way.
2. The value that innovation begins with science and technology rather than within society and human ingenuity.
3. The value that farming on large-scales will benefit a growing global population.

The IAASTD and the Special Rapporteur display opposite pre-analytical values:

1. A bias in favour of the livelihoods and welfare of small-holders and the rural poor, which in turn leads to the value that useful technologies and knowledge should be free and available to be indefinitely replicated and shared unrestricted.
2. The value that innovation begins within communities thanks to human ingenuity and common ancestral knowledge, which is valuable and needs to be celebrated rather than shun.
3. The value that small-scale farmers should be privileged when designing food and agricultural policies as they are the most numerous type of farmers in the world today and feed the most people worldwide.

4.3 What kinds of issues do the reports address and what not?

Although all reports could claim to be comprehensive in their own right, the UK Foresight is the only one to thoroughly address the topic of food waste while the other three reports only very briefly mention it. Approximately one third of the food produced in the world ends up wasted, as such this is clearly a major issue that needs attention and policy action. This emphasis is very much to put to the credit of the UK Foresight report.

The topic of genetically modified food crops is generally regarded as a debating ground in its own right; however, even though the topic is somewhat present in all reports, none give it a strong emphasis (one way or the other). The IAASTD clearly mentions its negative opinion of this technology in terms of current applications in relation to its declared policy goals, the UK Foresight and the National Academy of Science display a bias in favour but do not expand their argument much, while the report by Olivier de Schutter, through the solutions he put forward (which are at the extreme opposite of what is argued by GMO partisans), is clearly biased against its current usages.

4.4 How are the roles and responsibilities of different stakeholders

portrayed in the mega-reports?

On the topic of the role of research, the IAASTD and de Schutter both address the need to create and foster partnerships with farmers (small-holders). Conversely, the UK Foresight Report calls for more scientific, 'simple' or 'structured' measures such as the development of "new breeds of crops, livestock and aquatic organisms", the preservation of diversity, advances in the field of nutrition and in that of soil science, as well as the development of new technologies to prevent and more accurately foresee food spoilage. For its part, the National Academy of Science views the role of research as to increase the sustainability of mainstream agriculture; this implies a pre-analytical view that an overhaul of the current US farming paradigm is not necessary but rather that some adjustments are enough.

All reports saw the role of policy-makers and international donors as crucial. While the National Academy of Science puts forward slightly unclear propositions such as "develop new policies to increase the overall sustainability of mainstream agriculture" or "enhance investments in empirical studies to better understand how barriers to the development of sustainable agriculture are brought about", the IAASTD, the UK Foresight report and de Schutter are much more practical and inter-twine social, political and scientific issues, and mixed solutions.

Interestingly, the National Academy of Science report hardly mentions the role of farmers at all. The IAASTD and de Schutter in contrast view farmers as research actors who should carry out their own experiments and share their knowledge with each other and with established researchers. The UK Foresight sees farmers as co-actors in the development of more energy-efficient farming techniques.

When addressing the role of the private sector, the IAASTD and de Schutter believe that markets ought to be entirely reorganised to a) protect small-holders against unfair competition from subsidised agricultural products coming from the industrialised world, and b) benefit them more. The IAASTD puts forward additional functions for the private sector. These include extra investments towards sustainable farming and resource resilience tools, restraint when pushing for international competition, as well as the overarchingly important issue of letting farmers save their own seeds and not enforce Intellectual Property Rights related to seeds. On their part the UK Foresight Study and the National Academy of Science reports both argue for a 'light' reorganisation of international markets to improve their fairness (UK Foresight) and to sustain a "system oriented agriculture" (National Academy of Science). Consequently, they do not view markets as needing to have a protective role towards the most vulnerable actors and present free trade as a viable option without acknowledging its numerous deficiencies.

4.5 Overall Discussion

I have suggested in this work that pre-analytical values shape arguments.

Chapter two has shown that authors' structuring of the issue at stake leads to radically different answers. To address the issue of food and agricultural security purely in terms of sufficiency is to simplify it, thus making it possible to give it structured, technical answers, articulated around a small number of themes. Recurrent elements include yields and a (soft) reorganisation of free trade.

Conversely, to articulate one's answer around a high number of themes, mixing together the realms of agricultural sciences and that of social sciences, guarantees a complex answer, political in nature , which can appear 'messy' to some, and which implications are difficult to grasp, let alone act on. As Hischemöller and Hoppe (2001) argued, policy makers tend to avoid messy problems; and prefer instead to focus on structured ones, at the risk of sometimes addressing the 'wrong' problems and altogether miss the mark of what really matters. It is obvious that each report articulates its assessment and solutions around pre-analytical values, which may be glimpsed at in their research goals. As such, pre-analytical values define the framework into which both a problem and its solutions are going to be fitted.

Among the mega-reports, the IAASTD and the Special Rapporteur on the Right to Food displayed the value that issues such as trade justice, women's empowerment, and equity of outcomes were inherently part of the solution. The UK Foresight on the Future of Food and Farming and the US National Academy of Science had a stronger bias to see solutions in terms of increasing technology use to increase yields, and displayed a measured though favourable opinion on biotechnology products, but despite this, they too mentioned the importance of social issues in the debate. The analysis also reveals their different starting points when tackling the question: the IAASTD and the Special Rapporteur focused mainly on small-holders in under-industrialised countries, whereas the UK Foresight and the National Academy of Science focused more on industrialised agriculture.

We can see from the analysis and discussion in this paper that however hard researchers might try to structure and sometimes simplify this topic, it remains a messy, intractable controversy and the real world keeps on breaking through.

If this is indeed the case, one might wonder how and if a constructive debate can proceed at all. Hope and Hischemöller (2001) propose the shared learning proposition, i.e.: they argue that the key pathway out of intractable controversies is to define an adequate policy strategy and outline its political preconditions. The learning strategy's main characteristics are as follows:

1. Political representatives make choices as a result of political conflict among many actors.
2. Involve the public: the learning strategy is based on the assumption that citizens are capable of rational opinion on issues they are concerned with.
3. Equality among actors, even if temporary.
4. Diminish the status gap between experts and non-experts.

The controversies that the IAASTD encountered in its execution, and in terms of the policy response (personal communication, Jiggins, 2012), however suggests that these four conditions are not sufficient to resolve contentious issues. Problem structuring means "the confrontation, evaluation, and integration of as much contradictory information as possible" (Hischemöller, 1993; Roe, 1990 cited in Hoppe and Hischemöller, 2001). When participants get involved in the debate, they develop a shared sense of social and political responsibility and get insight into the multiple aspects of the problem at hand. The authors argue that this type of "socially rational interactions" helps to resolve emotional conflicts.

Hoppe and Hischemöller (2001) further identify three factors that are required for problem structuring to happen. Firstly, at least some segment of the policy elite (here, the official experts on the topic) must interact with segments which hold diverging views to theirs; secondly, all actors involved must be willing to participate. This means that all views must become part of the discussion, including those which are taken for granted. Intractable controversies often happen when interaction between actors with different views is restricted or non-existent. Additionally, if one party crucial for the outcome of the controversy refuses to participate, the controversy might remain intractable, or become mal-structured as a result. Thirdly, the exercise in problem restructuring must address "concrete cases and the experiences of those involved". We suggest that none of these three factors as yet has been adequately orchestrated in the debate.

Despite the fact that their argument refers mainly to policy practice, Hoppe and Hischemöller (2001) believe that it can also apply to the policy sciences by focusing on the mechanisms which exclude participants or issues from the policy process. They feel that many policy analysts, even those in favour of frame-reflective analysis, are biased towards giving priority to "legitimate" issues embodied by "legitimate" participants. Ultimately, because unstructured policy problems are socio-political constructs, structuring them requires intensive socio-political interactions.

The resultant multi-actor problem restructuring cannot ensure that a consensus will emerge, but it does lay the ground for "a reasoned choice of a problem frame, in a process that is widely regarded as legitimate" (Ibid). It is clear from our analysis that legitimate representation and a legitimate framing of the issues has not yet been achieved.

However, despite Hoppe and Hischemöller's theory, it is arguable whether the learning strategy can really work, whether it can be applied to all intractable controversies, and whether it has ever been applied with successful results to such a dense policy problem as the one posed by agriculture today. Furthermore, it is interesting to ask if structuring intractable controversies is in fact a desirable thing to do at all. Some might want to argue that structuring an intractable controversies might in fact make it lose some substance, and possibly even downplay it, stripping it completely or partially of meaning, and thus rendering it a useless strategy.

Of course, the main theory behind intractable controversies structuring is to make these controversies actionable and to remove them from the policy dead-end they often end up in, without downplaying them in any shape or form. Because Hoppe and Hischemöller are well-aware of the fact that policy-makers have a strong tendency to choose 'simple' policy problems over 'complicated' ones, they have carefully designed the learning strategy in order to prevent policy-makers from making intractable controversies 'too simple' and 'too easy' to solve.

Despite this, the example of the IAASTD shows us that even carefully designed and conducted experiments in learning strategy can fail. Among the four mega-reports, the IAASTD is the one that came closest to trying to be a learning strategy. The IAASTD process involved a very wide range of participants, coming from very diverse backgrounds, mixed in together public and private interests, and tried as much as possible to level up the playing field for every actor, putting all participants and interests on an equal footing. Despite this, the biotechnology industry pulled out a few weeks before the final draft was produced, citing that the report had failed to "adequately reflect the role of modern science and technology, in particular our own industry's technologies" (Keith, 2008 cited in Hilbeck, 2008). This happened because all participants involved (except for the biotech industry) felt that modern plant gene technology had very little positive to bring to alleviate poverty and hunger, to improve rural livelihoods, and to facilitate equitable environmentally, socially, and economically sustainable development, which were the research objectives of the IAASTD. In this very instance, it turned out that such a vast multi-disciplinary, multi-stakeholder process 'allied' to fully reject the values and activities of one of its stakeholders, thus bringing this stakeholder to quit a process which was not only publically dis-serving its interests, but also warning against the potential dangers of its core activity.

This failed example of the learning strategy illustrates the inherent problematic situation that such a process can bring about. It is likely to happen that one or a group of stakeholders will have interests which are fundamentally opposed and possibly even hostile to the interests of the rest of the group. When this happens, some form of choice needs to be made and preference will have to be given to one group, as one scientific report cannot endorse utterly opposite opinions and recommendations but instead needs to choose one single line of argument. As such, some form of simplification inevitably happens when several groups with wildly divergent interests attempt to reach a consensus, as the IAASTD was the example.

It is possible that just as in politics, there is a bias in science too to prefer structured problems over messy ones; an admission of the inherent 'messiness' of a given topic, and not attempting to overtly structure it, is seemingly associated to a lack of rigour on the researcher's part, and as such is less likely to be taken seriously. The example of the IAASTD clearly brings out that dealing with unstructured problems with all protagonists' participation will bring about unstructured solutions which might not please all stake-holders. Interestingly, the US government did not formally endorse the final IAASTD report, and chose instead to reproduce the exercise but to reduce the issue to a simple scientifically-manageable question. This, too, has not delivered the intended definite analysis and policy consensus that was desired.

To open up a broader debate, it is interesting to wonder whether it makes sense at all to write such reports, which aim to give an overview of what they perceive to be to situation and the problems at stake, and what they estimate can be done to improve it and solve the problems. Hoppe and Hischemöller put forward the learning strategy with the aim to lay the ground for "a reasoned choice of a problem frame, in a process that is widely regarded as legitimate" (2001).This presumes that all stakeholders have an interest in making the process a legitimate one, and that this issues of legitimacy be widely embraced by them all. However, it is possible that not all stakeholders want a legitimate process to take place as the result might threaten their interests. They will therefore oppose such a process and, as in the case of the biotech industry and the IAASTD, remove themselves completely from it in protest, but also because such an action undermines the legitimacy of a process which has become undesirable for them.

I therefore argue that for a report dealing with agriculture to attain full legitimacy is right-down impossible. It is unworkable, and one might even say foolish, to expect that stakeholders with wildly divergent values and financial interests at stake could ever "meet in the middle", let alone agree along one single argumentation line.

4.6 Conclusion

This thesis analysed four mega-reports and forty-eight peer-reviewed papers and books in depth, all dealing with topics revolving around agriculture. One of the main aims of this work was to understand how different stakeholders' interpretation of the topic of sustainable agriculture is framed according to their values, and the extent to which this forms and influences their responses to it.

The conceptual framework was provided by Hoppe and Hischemöller's theory on intractable controversies, how to define them and attempt to solve them (2001). Their theory identified four types of policy problems, mapped along the two axis of values consensus and knowledge certainty. More specifically two major types of problems were distinguished: political, unstructured problems, and technical, structured problems. I attempted to discover how each mega-report dealt with their topic and what this meant with regards to the pre-analytical values carried out into the research process by their writers. Lastly, I analysed the forty-eight additional papers along the knowledge axis of Hoppe and Hischemöller, in order to give a finer representation of the entire spectrum of opinions surrounding the topic of sustainable agriculture, from one extreme to the other,

I have concluded that pre-analytical values were real in the scientific papers I have examined, that they changed and morphed from report to report and that they influenced the research objectives and processes for these four reports, as well as guided their conclusions. Furthermore, I have shown that the way writers perceive the knowledge needed to solve a specific situation shapes a problem into being a technical problem or a policy problem, which subsequently guides its resolution process (or its attempt).

I have concluded that however hard researchers might try to structure and sometimes simplify the agricultural topic, it remains a messy, intractable controversy and the real world keeps on breaking through. Hoppe and Hischemöller have offered the learning strategy which they propose as the key pathway out of intractable controversies, and which mainly argues for the involvement of all stakeholders and their (temporary) equality before the topic at hand. Despite this laudable attempt, I have however wondered whether the learning strategy can really work, whether it can be applied to all intractable controversies, and whether it has ever been applied with successful results to such a dense policy problem as the one posed by agriculture today. I have used the failed attempt at the learning strategy by the IAASTD, which is the only one of the four reports to have really tried it, to support this legitimate question. I conclude that this failed attempt at the learning strategy illustrates the inherent problematic situation that such a process can bring about. Groups with fundamentally opposed interests will inevitably clash and some form of choice will have to be made in favour of one group, as one scientific report cannot endorse utterly opposite opinions and recommendations but instead needs to choose one single line of argument. The fact that not all stakeholders might want a legitimate process to take place because it could potentially threaten their interests further complicate the debate.

I therefore argue that for a report dealing with agriculture to attain full legitimacy is right-down impossible, as it is unworkable, and one might even say foolish, to expect that stakeholders with wildly divergent values and financial interests at stake could ever "meet in the middle", let alone agree along one single argumentation line.

The art of effective communication lies in the ability to translate one's values into a solid argumentation. This point alone might provide a sufficient reason why the scientific debate on the desirability of sustainable forms of agriculture is so challenging to apprehend and move forward: the pre-analytical values of the different stakeholders, and the knowledge certainty they display 'rule the game', and risking agreement with the other side would be risking the integrity of these self-defining values, as well as lucrative interests in the case of some stakeholders.

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Annex I: Chapter Three: Clustering of selected research papers based on the knowledge axis in Hoppe

Cluster 1: Agriculture is a technical question:

Almekinders, C.J.M., Fresco, L.O., Struik, P.C., 1995. The need to study and manage variations in agro-ecosystems. Netherlands Journal of Agricultural Science, 43, pp. 127-142.

Avery, D.T., 1995. Saving the Planet with Pesticides and Plastic. Indianapolis: Hudson Institute.

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Connor, D.J., 2008. Organic agriculture cannot feed the world. Field Crop Research, 106, pp.187-190.

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Kirchmann, H., Thorvaldsson, G., 2000. Challenging targets for future agriculture. European Journal of Agronomy, 12, pp. 145-161. [10]

[10] The fact that the list for Cluster 1 ends at the letter "K" is an artefact of the method and has no further implications.

Cluster 2: Agriculture is a political question:

Altierri, M.A. ed., 1995. Agroecology the Science of Sustainable Agriculture. Boulder: Westview Press.

Azadi, H., Schoonbeek, S., Mahmoudi, H., Derudder, B., Maeyer De, P., Witlox, F., 2011. Organic agriculture and sustainable food production systems: Main potentials. Agriculture, Ecosystems and Environment, 144, pp.92-94.

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Annex II: Chapter Three: Opposing Approaches

II.1 Fundamental differences between organic and conventional agricultures

II.1.1 Organic agriculture

Here, the term 'organic agriculture' is use in its broadest sense and encompasses both organically labelled agriculture as well as so-called "agro-ecology", "ecological or sustainable agriculture" and "organic by default" as is practiced by a wealth of small-holders in developing countries. A number of definitions exist as to what constitute organic agriculture, but they all share the same broad common ground.

Unofficially and in its broadest sense, it first and foremost defines an agricultural philosophy which aims to feed the soil [as opposed to conventional agriculture which is most interested in feeding the plants (IFOAM, 2006)]. This is what Lady Eve Balfour (1949: 19) termed the "Rule of Return" through which everything which has been taken from the soil needs to "faithfully" be returned to it in due course.

Additionally, organic agriculture utilises non-synthetic nutrient cycling processes, excludes or restrains the use of synthetic inputs and thrives to sustain and regenerate soil health (Badgley et al., 2007). Genetically modified seeds, plants and feed are disallowed when producing organic food. Rules also encompass provisions to encourage or enforce crop rotations and intercropping and regulate tillage which serves to improve crop nutrition, build up and conserve soil fertility, limit pests and weed damages and enhance soil's structure (Connor, 2008). Importantly, the "true" concept of organic farming (organic to the heart) emphasises the concept of wholeness, implying a "systematic connexion or co-ordination of parts in a whole" (Scofield, 1986: 5 cited in Rigby and Cáceres, 2001).

It has only been in the past 30 years that the 'official' organic agriculture principles (organic to the letter) have been codified and made explicit. They used to be tacitly known as they were so inherently part of the philosophy of farmers practicing it (Kristiansen and Merfield, 2006).

The main principles are (Ibid):

- The farm is a living organism which must tend towards a closed nutrient cycle
- Soil fertility, "the living soil" is central to the organic ethics. Soil fertility can and should be enhanced
- All parts of the production system constitute a whole, the dynamic of which is possibly still mysterious

Roberts (1992 cited in Altieri, 1995) lists the most common elements of organic farming practices:

- Soil organic matter build-up
- Use of legumes as a primary nitrogen source

- Application of natural fertilizers
- Crop rotations to minimise pest and weed build-up
- Prevention of wasteful water runoff
- Elimination of potentially toxic chemicals from the land

Bagley et al (2007) add:

- cover crops
- intercropping
- biological pest control

Lampkin (1994, cited in Kristiansen and Merfield, 2006) provides a modern definition of organic agriculture as follow: “to create integrated, humane, environmentally and economically sustainable production systems, which maximise reliance on farm-derived renewable resources and the management of ecological and biological processes and interactions, so as to provide acceptable levels of crop, livestock and human nutrition, protection from pests and diseases, and an appropriate return to the human and other resources”.

For the FAO, organic agriculture broadly implies that no agro-chemical inputs or genetically engineered organisms are used, that air, soil and water pollution are minimised to the maximum, and that the health and productivity of the agro-ecosystems within which farming and wild collection are carried out, is fostered (FAO, 2007).

Organic agriculture sees humans as a part of nature, and not as higher or separate entities that could control and dominate it. Organic agriculture believes in the usefulness of the precautionary principle and the fact that changes brought about without a long-term view, can negatively impact production systems. Organic agriculture is also preoccupied with ethical issues, which are applied to animal welfare and social justice (Kristiansen and Merfield, 2006).

Norgaard and Sikor (1995) argue that agro-ecology is a fundamentally different approach to agriculture from conventional farming because it roots in wider philosophical premises than the latter. Without rejecting the currently dominant paradigm of farming, it adds to it through new ways of conceptualising farming and rural change. Agro-ecology is able to account for the wealth of diversity between farming methods, farming environments and farmers themselves. It addresses the fact that “multiple logics give multiple answers” and that farmers should devise their own ways of understanding to implement lasting changes. In low-input agriculture, variation (the result of the interactions between the environment, genetic resources and management) is more wide-spread, and is generally recognised by farmers as an asset to diversify production and reduce risks. This approach is contrary to that of high-input agriculture (Almekinders, Fresco and Struik, 1995).

The agro-ecology philosophy is more likely -and often forced- to take a “system perspective”. Some researchers even view agro-ecology as an ecosystem approach applied to agriculture. On top of that, the agroecological tradition is equally concerned with the social system surrounding the agricultural systems and believes that their coupled interaction needs to be workable and advantageous for all (Norgaard and Sikor,1995). Agro-ecology seeks to “mimic” nature and to step away from the industrial method of production which consists of providing inputs to enhance yields as the sole concern (De Schutter, 2010).

Organic agriculture and agro-ecology have a fundamental cultural dimension which conventional agriculture cannot claim for itself. Organic agriculture and agro-ecology draw and rely upon local, traditional and indigenous knowledge in 'plant science' (Kotschi, 2000 cited in Parrot and Marsden, 2002).

From this valorisation of indigenous knowledge flows a number of consequences. Firstly, it highlights the importance of farmers' participation where 'learning from' farmers is equally or even more important than 'teaching' them. Secondly, it deeply challenges the notion that unilateral technology transfers from the North into the South are a vital necessity and instead contends for a more measured and selective adoption of Northern technologies (Kotschi, 2000 cited in Parrot and Marsden, 2002). Thirdly, it respects the values systems of rural communities, thus letting them extend beyond agricultural productivity and into further activities which promote household security (Parrot and Marsden, 2002).

Statistics:

The total area under organic cultivation in the world today is growing from 28 million hectares in 2005 to 35 million in 2008. In 2008, it accounted for 1.7 per cent of the European agricultural area with 8 million hectares (Organic World, 2009 cited in Bindraban and Rabbinge, 2011).

Organic agriculture currently uses only 0.3% of agricultural land, most of it in developed countries (Connor, 2008). This statistic, however, only encompasses registered organic land, and does not account for agricultural systems which operate on an "organic by default" basis, most of it in developing countries and to a lesser extent in developed countries too.

Practices:

Organic agriculture systems can differ considerably from one another because they each tailor their practices to meet the specificities of their environment and of their individual economic needs. It is now widely accepted that organic agriculture does not mean a return to pre-industrial farming. It is in fact presented as a partnership between modern technology and science and traditional, conservation, and self-reliant agricultural techniques. Organic farmers need modern, post-industrial inventions as they rely on modern equipment too, certified seeds and soils, and the latest innovations in water conservation and livestock handling (Altieri, 1995).

"Agro-ecology is both a science and a set of practices": it is not a form of agriculture which can be delivered top-down as it relies instead on farmers' knowledge and experimentation (De Schutter, 2010). Farming ecologically involves the introduction and maintenance of a wide range of agricultural biodiversity: crops, livestock, trees, fish, pollinators, soil biota etc…) in order to achieve adequate results in productivity (De Schutter, 2010). Organic agriculture is not backward. Instead it is a continual learning process and there is plenty left to be understood in terms of ecological cycles and how to improve techniques (IFOAM, 2006).

Pests:

Pests, pathogens and weeds appear as the most spectacular threats to ecological food production. Data is approximate as to how much damage they are responsible for, ‘guesstimates’ range between 10 to 40 per cent. However, they can cause more losses than visible when for example they affect a crop with a very high market value; when that happens the farmer incurs serious financial losses (Conway, 1997). Because one of agro-ecology’s goals is to decrease farmers’ dependency on external inputs controlled by outside forces, it ideally should rely on using locally available or ‘home-made’ pesticides (Norgaard and Sikor,1995). As such, agro-ecology has four methods of pest control at its disposal (Conway, 1997):

- Pesticide control: chemical compounds are sprayed to eliminate pests or to keep them away
- Biological control: using natural enemies
- Cultural control: adversely impact pests’ habitats through a change in agricultural practices
- Plant resistance: breeding crops for resistance and/or resilience to specific pests

Furthermore, research has shown that adding compost and organic matter in agricultural systems reduces crop diseases (Cook, 1988 and Hoitink et al., 1991 cited in Pimentel et al, 2005), and increases the number of species of microbes (Van Elsen, 2000 cited in Pimentel et al, 2005). This does not imply that organic farmers do not use any pesticides, they use natural pesticides among which sulphur, bacillus *thuringiensis* or pyrethins (a chlorinated pesticides derived from a plant flower) (Avery, 1995: 166). Avery (Ibid) claims that organic farmers use “more pesticides and more often than non-organic farmers”, though there is no data to verify this claim.

Fertilisers:

Organic agriculture relies on manures as main sources of fertilizers. Organic manures can potentially show the same effects as inorganic fertilizers but because nutrients are usually less concentrated and released more slowly in organic manures, their deleterious impacts tend to be reduced (Simpson and Jefferson, 1996 cited in Robinson and Sutherland, 2002). Avery (1995: 166), criticises organic farming refusal to use manmade nitrogen on the ground that it is “bad for the soil”; he argues that “all nitrogen is elemental and chemically identical”. Indeed, research shows that plants do not differentiate between nutrients coming from organic or inorganic inputs (Pretty et al., 2010).

Bos (2005 cited in Bindraban and Rabbinge, 2011) has shown that organic yields that reach 60-80 per cent of yields of conventional systems can only do so when nutrients from “at least another hectare” are used in input.

Bindraban and Rabbinge (2011) claim that because neither organic agriculture nor multifunctional agriculture aim to reach highest production per unit area, the claims they will make on natural resources will be higher than under integrated agriculture, per unit of food product. Because of claims of the sort, organic agriculture is sometimes decried as not efficient enough, but IFOAM (2006) claims that it all depends on what one calls “efficient”. All aspects of a farming system should be included in the definition of efficient and should not limit itself to a mere evaluation of yields; as such organic agriculture is efficient in “water use, fossil energy use, biodiversity conservation and clean air production”.

Balfour would add that an increase in production is not the same as an increase in fertility. Increased production can be achieved by using up the soil's fertility without replenishing it (Balfour, 1949: 18). Moreover, organic agriculture uses optimal breeds which may yield less but which are stronger and more resilient than maximal breeds often used in conventional farming (IFOAM, 2006).

Interestingly the notion that a crop is organic because "nothing has been put on it" is quite common and does a significant disservice to farmers who painstakingly develop healthy and fertile agro-ecosystems. Unfortunately, "organic by neglect" approaches are still witnessed today (Hall, 1996 cited in Rigby and Cáceres, 2001). A farming system does not need to be heavily mechanised and using high doses of synthetic inputs to be "profoundly unsustainable". In a research published in 1974 by Carter and Dale (cited in Rigby and Cáceres, 2001), the destruction of soil fertility in large parts of Greece, Lebanon, Crete, and North Africa was explained by low input, chemical-free unsustainable agricultural practices which eventually depleted soil nutrients. The farmers who contributed to this and the erosion which ensued would have certainly been called "organic" in terms of the inputs used, by they were "organic by neglect", because they were mining the soil.

II.1.2 Conventional Agriculture:

Since the 1960s, world population has been multiplied by two and food production has increased by 25 per cent (FAO, 2004 cited in Fresco, 2009). Globally, households now spend a historic low on their food, roughly 10-15 per cent in OECD countries, down from 40 per cent in the middle of the last century (OECD, 2004 cited in Fresco, 2009). Even if developing countries still spend significantly higher percentages, those are declining too (Fresco, 2009). The application of agricultural and food system science has brought about a diversity, quality and safety in food which human kind had never enjoyed before. As such, conventional agriculture deserves to be called a human success story (Fresco, 2009). Food production has enjoyed a tremendous increase in the twentieth century thanks to mechanisation, synthetic fertilizers and pesticides, and improved plant breeding. These breakthroughs have also made farming possible on land previously deemed uncultivable (Kirchmann and Thorvaldsson, 2000).

To the defenders of conventional agriculture, it is best to farm the most productive land for all it is worth and leave to rest to nature and to recreational purposes. As such, pesticides should be used now and into the future and this until we find "still-safer" ways to achieve sufficient yields. This philosophy however, does not mean that pesticides should be misused or overused, or that pesticides which are knowingly dangerous for wildlife should be used when there are better alternatives. It does not imply either that integrated pest management should be ruled out or that dangerous pesticides runoff should be tolerated, but it does mean that pesticides should be used in sufficient quantities now (Avery, 1995: 36).

Since WWII, the 'normal' approach has been to destroy pests and pathogens with a variety of pesticides (insecticides, nematocides, bactericides, fungicides and herbicides), all derived from petroleum-based resources. Conway (1997) argues that these products have been on average costly and inefficient. Modern insecticides need to be repeatedly applied to sustain control and it has been demonstrated that many have now become resistant to them. Pesticides are known to potentially make the problems worse by killing off natural enemies of the pests they target, thus leading to secondary outbreaks of pests (Conway, 1971 cited in Conway, 1997).

By the mid-1980s, it was accounted that 450 pest species globally had become resistant to at least one pesticide type, and another 150 fungi and bacteria were resistant to herbicides. What is more, several important families of pests are now resistant to every major class of insecticides (Dover and Croft, 1984 cited in Conway, 1997).
Pests and pathogens are also able to evolve resistance to plants' natural repellents or to overcome those artificially bred into them. For example, in the 1950s a new race of wheat-stem rust burst out in the USA and Canada and later in Mexico (Hanson, Borlaug and Anderson, 1982 cited in Conway, 1997). This first wave announced an epidemic of increasingly resistant strains of wheat-rust which the wheat-breeding programme was only able to keep up with by virtue of having new resistant varieties ready when the 'old' ones became vulnerable. The pervasive effect of such a situation was to encourage a breeding treadmill.

At the beginning of the 1960s, after having been very successful adopted in newly industrialised nation, conventional agriculture gave rise to the Green Revolution, whereby its technologies were transferred into the Third World. The biological basis for the Green Revolution was rather simple according to Fresco (2009): by adding nitrogen and a few other nutrients, water, creating shorter plants and intensifying pest control, yields and land devoted to farming could be increased by significant margins.
It was based on the creation and cultivation of new cultivars of major cereal crops, and this has probably saved millions from extreme hunger and malnutrition and tens of millions from outright starvation globally. However, these new cultivars 'momentum' was not up-kept. Cereal yield increases were 2.4 per cent in the 1970s, 2 per cent in the 1980s and down to 1 per cent in the 1990s (Fernandes, Pell and Uphoff, 2002). Intensification of agriculture has generally meant an increase of biomass per unit of land as well as crop uniformity. However, in many cases, intensification has also meant that output stability and resource-use efficiency were reduced, while at the same time increasing over-exploitation of the natural resource base and thus reducing the sustainability of agro-ecosystems (Edwards, 1990 cited in Almekinders, Fresco and Struik, 1995).

Organic agriculture defendants argue that conventional agriculture scientists have been only "moderately successful" when trying to solve the problems associated with technology transfers in the South. Norgaard and Sikor, (1995) argue that this is because these problems are inherent to the very premises on which conventional agriculture is based. For example, they have mostly failed to listen to farmers and to what they wanted because the philosophy of conventional farming is based on the supremacy of science over traditional skills and partnership with nature. They see conventional agriculture as believing in a reductionist approach to farming whereby each of its components is managed separately. As such issues of nutrition, pests and diseases are all dealt with in isolation of each other. Industrialised farming also displays a belief that humans are separate from nature and need to fight it in order to survive. This is clearly exhibited in the aggressive and militaristic names given to a number of herbicides and pesticides such as "Invade", "Ambush" or "Warrior" (Kristiansen and Merfield, 2006). Furthermore, industrialised farming does not consider itself to be much related to society, but instead to be just another means of production which is not held to more or less obligations than other production sectors (Reeve, 1992 cited in Kristiansen and Merfield, 2006).

As such, it has been accused of having treated environmental capital such as land, fossil resources, soil fertility and genetic diversity as if it were income (Holden, 2010), because its paradigm was always to maximise the yields and profits one can extract from the land (Hilbeck, 2008).

II.1.3 The question of sustainability

The concept of sustainability is central to the current debate about the planet's ability to support humankind. Yet there is no consensus as to what sustainability mean (Park and Seaton, 1996 cited in Rigby and Cáceres, 2001). There is no further consensus on what agricultural sustainability means (Rigby and Cáceres, 2001).

The American Health Public Association (APHA, 2007 cited in Azadi et al., 2011), provides a valuable definition of a sustainable food production systems as " one that provides healthy food to meet current food needs while maintaining healthy ecosystems that can also provide food for generations to come with minimal negative impact to the environment. A sustainable food system also encourages local production and distribution infrastructure and makes nutritious food available, accessible and affordable to all". Azadi et al. (2011) argues that neither conventional, biotechnological or organic modes of agriculture could address all these aspects of sustainable food systems. In fact, according to Carvalho, (2006 cited in Azadi et al., 2011) the different aspects of sustainable food systems appear differently across countries and regions, thus proving that there no silver bullet available. Furthermore, all the aspects aforementioned are inter-related to each other, and interact on several different local and global levels.

Interestingly, some regard organic farming and agricultural sustainability to be synonymous, others see them as clearly different (Rigby and Cáceres, 2001). Henning et al., (1991:877 cited in Rigby and Cáceres, 2001) claimed that organic farming "could serve equally well as a definition of sustainable agriculture". Similarly, Rodale even suggested that "sustainable was just a polite word for organic farming (York, 1991: 1254 cited in Rigby and Cáceres, 2001).

Pretty (1995: 9 cited in Rigby and Cáceres, 2001) mentions that although "organic agriculture is generally a form of sustainable agriculture", it can very well have negative environmental effects such as nitrate leaching, ammonia volatilisation, and the accumulation of heavy metals in soils following applications of Bordeaux mixture (of which copper is the active ingredient (Or Brun, 2011) Ironically, some conventional farms can have higher levels of sustainability than some organic farms (Rigby and Cáceres, 2001). Furthermore, research has not demonstrated an increase in nutrient use efficiency in long-term trials for either organically or conventionally treated soils (Bindraban and Rabbinge, 2011). The UN Special Rapporteur on the Right to Food argues that for the time being, investment of resources into organic fertilizers needs to be a priority but it is not desirable that it excludes the use of chemical fertilizers when they are needed (De Schutter, 2010).

II.2 Technical Implications

II.2.1 Industrial agriculture's outcomes

In many instances, the price to pay for dramatic increases in crop productivity of modern agricultural systems has been hefty. It includes (Altierri, 1995):

- Environmental degradation such as soil erosion, pesticide pollution and salinisation of soils
- Loss of social diversity such as the marked disappearance of family farms, concentration of land and inputs into a few hands, domination of agri-business over increasing amount of agricultural production and fast urbanisation trends
- Unjustifiably high use of natural, non-renewable resources
- Ever increasing dependence on the fluctuation of petroleum prices

These problems can become even bigger when the conventional northern technology which was developed in a specific sociological and ecological context is applied 'as is' to developing countries which do not adhere to the same sociological and ecological paradigms at all (Ibid).

In natural ecosystems (i.e.: not farms), biomass productivity is closely related to the annual rate at which nutrients can be recycled. By contrast, it is possible to farm without recycling nutrients much, letting them be lost at harvest or through erosion (Tivy, 1990 cited in Gliessman, 2005). However this then leads to a heavy reliance on nutrient inputs to replenish these 'leaks'. The vision of wholeness of the agricultural system whereby the needs of future generations are accounted for and conserved has been lost by industrialised agriculture which mostly concerns itself with its own immediate needs for profit and high yields (Gliessman, 2005). Agro-ecosystems in modern agriculture have tended to become "flow-through systems", by which is meant that considerable amounts of inputs (often petrochemical derivatives) are injected into the systems, and that an equally or bigger amount of energy is directed out of the system at each harvest. This renders the agro-ecosystems unable to become self-sufficient, biomass is generally not allowed to accumulate, and the system becomes dependent on external inputs and unable to cope when a disruption occurs (Ibid). Disruptions can take the form of natural disasters such as a hurricane or that of an economic crisis such as an oil shock whereby agrochemical inputs become more expensive leading to lesser quantities being suddenly applied. However, Kirchmann and Thorvaldsson (2000) argue that the avoidance of excessive use of plant nutrients does not mean that intensive agriculture cannot be practised.

Industrialised agro-ecosystems, have given rise to a production system which tries to operate outside of natural regulating processes and local resources, resting instead on heavy inputs from non-renewable sources. In effect, this breaks natural systems and increases the harshness of pests and diseases outbreaks as well as heightening nutrient management problems. A vicious circle is instituted when more chemical inputs are brought in to fix these problems (IFOAM, 2006). Additionally, this over-dependence on fossil fuels and external inputs have come to inflict damages to the soil, water resources as well as the genetic and cultural resources on which it has traditionally relied. These problems can only be 'masked' for so long by high input technologies until they become visible. Modern farming borrows resources from future generations to sustain its current survival (Gliessman, 2001 cited in Gliessman, 2005).

Due to the genetic simplification and homogenisation of many agro-ecosystems, populations or crop plants are seldom self-reproducing or self-regulating. Populations' sizes and health are dependent on human inputs, thus leading to a loss biological diversity and a disruption of natural pest control mechanisms. The threat of pests or disease outbreaks is high despite intensive human interferences and "quick-fixes" (Gliessman, 2005). This heightened vulnerability has been a long-term cause of concern for a number of researchers since the Green Revolution. Pest management issues perfectly illustrate this problem: the aggravation of pest problems is increasingly linked to the expansion of monocultures which erase the native surrounding vegetation and natural predators' habitat diversity with it (Altierri and Letourneau, 1982, Flint and Roberts, 1988 cited in Altierri, 1995). The expansion of monocultures [sometimes referred to as "green concrete" (Lang and Heasman, 2004: 148)] is the main reason behind the wake of pests and disease outbreaks recorded after the Green Revolution's start (Smith, 1972 cited in Conway, 1997). Narrowing the genetic base of crops increases the likelihood of losing genetic resources which in turn, impairs potential for future crop breeding (Harla, 1992 cited in Almekinders, Fresco and Struik, 1995).

Furthermore, monocultures 'breed' an 'agricultural treadmill' whereby prices are pressured downwards and inputs' needs are pressured upwards. Farmers are then forced to adopt new technologies and expand the scale of their production or go out of business (Barling and Land, 2003 cited in Lang and Heasman, 2004: 148-9). Over the years, this had led to the concentration of production centres: farms became bigger and more specialised (Kirchmann and Thorvaldsson, 2000). This has led to a "shift of the food dollar away from farmers and into other parts of the food chain" (agro-chemical companies, food processors and retailers) (Barling and Land, 2003 cited in Lang and Heasman, 2004: 148-9). Over the past 55 years, the number of actual farmers has fell by 85 per cent in Germany, 86 per cent in France and Japan, 59 per cent in the UK and 64 per cent in the USA (OECD, 1999 cited in Lang and Heasman, 2004: 149).

Modern agriculture is "shockingly" dependent on a rather limited number of varieties of major crops (Altierri, 1995). According to the FAO (1996 cited in Lang and Heasman, 2004: 222), around three quarters of all agricultural diversity has been lost in the course of the 20th century, this is the direct result of the pursuit of uniformity, predictability and stability of food pursued by the agro-food industry and retailers. Agriculture and the modern food culture are "teaming up" to decrease farm biodiversity (Lang and Heasman, 2004: 150-1). Plants which are modified and adapted to fit human methods of cultivation tend to become increasingly fragile to pest damage; as a general rule, the more plant communities are modified the more numerous and serious the pests they face (Altierri, 1995). It is possible that industrialised agriculture loses the important benefits which it could derive from agro-ecosystems variations because of its efforts to homogenise its environment (Almekinders, Fresco and Struik, 1995). Kirchmann and Thorvaldsson (2000) argue that many problems found in conventional agriculture also occur in organic farming. These include erosion, nitrogen leaching, volatilisation of ammonia from animal waste, high levels of native soil cadmium, accumulation of trace metals in soil and subsoil, soil compaction from farm machinery etc…Organic farming does not offer satisfactory solutions to most of these problems.

Excluding easily soluble inorganic fertilizers does not prevent nutrient leaching or eutrophication. In fact, if measured over several years, total N leaching from soils receiving animal manure can potentially be much higher than those which receive inorganic N fertilizer at the same time (Bergström and Kirchmann, 1999 cited in Kirchmann and Thorvaldsson, 2000).

II.2.2 The Green Revolution:

Despite the fact the Green Revolution has been the “accomplishment of the century”, it has known some shortcomings (Fernandes, Pell and Uphoff, 2005). It is failing to see the whole picture in addition to being counter-productive to try and improve only single components of farming. For example, many farmers in Asia did not adopt the short-stalked, high-yielding cereal varieties that were offered by the Green Revolution because they provided too little fodder for their animals to meet their needs. Plant breeders had focused on improving yields and had ‘forgotten’ the other major use that cereal crops played for these peasants. As such, farmers were willing to farm lower yielding varieties which could sustain their livestock which represented a precious resource as they gave manure and provided traction to till the soil (Ibid). Despite this, The Green Revolution has engendered a drop in genetic diversity; for example, there were 30.000 indigenous varieties of rice grown in India prior to the Green Revolution and only 50 left in 1993 (Navdanya, 1993).
The so-called ‘miracle seeds’ of the Green Revolution were not intrinsically high-yielding, instead they have been dubbed “high response varieties” since they were reliant on heavy chemical inputs to yield in big amounts. The Green Revolution focused on boosting yields of the three starch crops it focused exclusively on [rice, wheat and maize (Ibid)] which contain little protein and few of the other nutrients indispensable for a healthy diet. In effect, this switch to a carbohydrate-based diet partly led to wide-spread micronutrient malnutrition in many developing countries (De Schutter, 2010).
Additionally, monocultures and homogeneity require a technology ‘bundle’ (mechanisation, agro-chemicals, special breeds, antibiotics and livestock growth stimulants), without which they are not sustainable and very likely to incur serious damages when the technology fails to deliver (Lang and Heasman, 2004: 148).

II.2.3 Soil Integrity

Kline (2005), an Amish farmer in Ohio argues that the most neglected and abused part of nature is soil life. One single gram of good soil can hold up to four billion micro-biotic organisms but as he writes: “in soil management, what takes years to harm takes years to heal”. Research estimates that nature needs several hundred years to build an inch of top soil (150 tonnes per hectare) but that poor farming practices can deplete and loose this amount to erosion in ten years only. (Kline, 2005).

Agriculture as an activity both relies on and creates a balance with its natural environment. Kline (2005) prettily describes this relationship between land and farmer as a sort of dance where both attempt to reach a balance between give and take without stepping on each other’s toes too much. Kimbrell (2002 cited in Gliessman, 2005) argues that modern agriculture has lost the balance it needs for long-term sustainability. The long-term use of agro-chemical inputs has generated such dramatic changes in the soil that many farmers find themselves unable to break away from their reliance on them (Navdanya, 1993). Wendell Berry (cited in Kline, 2005) wrote that the health of a farm or an ecosystem does not come from some ‘heroic feat of technology, but rather by thousands of small acts and restraints handed down by generations of experience”.

Studies have shown that soil organic carbon is 14 per cent higher in organic soil, and that the labile fraction is 30 to 40 per cent higher. This higher proportion of soil organic carbon (C) combined with better soil aggregation improves soil stability and resistance to water erosion (Clark et al., 1998; Drinkwater et al., 1995; Liebig and Doran, 1999; Peterson et al., 1999 and Reganold et al., 1993, all cited in Lotter et al., 2003) and wind erosion (Jaenicke, 1998 cited in Lotter et al., 2003) when compared to conventionally managed soils. Organic agriculture also enhances microbial biomass which in turn improves soil physiological functions such as faster phosphorus uptake by plants (FAO, 2007).

Lotter et al (2003) also demonstrate that water harvest (i.e.: groundwater recharge) is significantly better in organic systems, during both severe drought and over a five-year period. Today, agriculture is the major contributor to soil erosion (Tegtmeier and Duffy, 2004). Following Hurricane Mitch in 1998 in the Americas, a large-scale study on 180 small-holders in Nicaragua discovered that plots which were farmed with simple agro-ecological methods had lost on average 18 per cent less arable land to landslides and had 69 per cent less gully erosion as compared to conventional farms (De Schutter, 2010). Crowder et al., (2010) have also shown that organic agriculture mitigates the ecological damages an agro-ecosystem can suffer because it enhances the evenness (abundance) as well as the species richness of natural predators of pests. Human activities such as farming almost always generate a skewing in the relative commonness of species (Hillebrand, Bennet anc Cadotte, 2008 cited in Crowder et al., 2010); research has shown that uneven communities are more likely to fall victims of invasion (Wilsey and Polley, 2002 cited in Crowder et al., 2010) and are less resilient to disturbances in general (Wittebolle et al., 2009 cited in Crowder et al., 2010).

However, some organic agriculture systems have been shown to cause high nitrate leaching and losses, because nutrient release from organic manures is rarely synchronised with crop uptake, thus leading to mineralization of the soil when this happens without crops being present. Furthermore, ammonia volatilisation is mainly caused by animal manure and not by N fertilizers (Kirchmann et al., 1998 cited in Kirchmann and Thorvaldsson, 2000). Additionally, because some organic farms rely entirely on their own feed production, they run the risk of nutrient depletion of their soils (Nolte and Werner, 1994 cited in Kirchmann and Thorvaldsson, 2000). Nolte and Werner (Ibid) argues that recirculation of nutrients is not enough to maintain soil fertility because of leaching of plant nutrients and their gaseous emissions, as well as “removal of nutrients through pet animal waste, dead pets and removal through dead humans”. As such, cropping systems which rely entirely on plant nutrient re-cycling will only result in negative nutrient balance. Soils under pastoral use are an exception as their nitrogen levels can be maintained when they include N-fixing leguminous crops (Ibid).

Organic agriculture’s defendants could reply that a basic agronomic rule is that all nutrients harvested from the soil need to be replaced in order to insure that the capital of the soil is not eroded. As such, intensively managed ecosystems are by nature not sustainable, they can only be maintained if all the outputs produced are replaced in equal quantity by the adequate inputs (Pretty et al., 2010). An appropriate management of nutrients ensures that crops and soils are supplied with the appropriate nutrients in adequate forms and at the critical stages of their development when they need it the most for optimum growth, yields and resistance. On average, nutrients needs vary between 5-10Mg/ha/year. This amount multiplied by the 1.5 billion hectares of cropland poses potential logistical problems in terms of availability, transportation and application to the specific zones where it is needed (Ibid).

Applying high levels of agro-chemical fertilizers creates a uniform nutrient distribution in the field as it over-powers naturally occurring nutrient variations; but at the same time this can also lead to a reduced use efficiency of nitrogen and other nutrients (Mulla, 1993 cited in Almekinders, Fresco and Struik, 1995). This means that applications of fertilizers may be higher than necessary and thus leach in ecologically unacceptable quantities (Van Noordwijk and Wadman, 1992 cited in Almekinders, Fresco and Struik, 1995).

II.2.4. Yields

Productivity of organic systems is management specific and as such, definite comparisons with conventional systems are pointless and potentially misleading. During the conversion period, perennial crops can lose up to 50 per cent in yields, and high external inputs systems can yields up to 40 per cent less. This is generally due to the fact that many soils in industrialised countries have been degraded by decades of tillage, erosion, synthetic fertilizers and general loss of soil fertility. The time it takes for soil fertility to regenerate depends on the amount of damage the soil previously incurred. (National Research Council, 1989 and Pimentel et al., 2005 cited in Badgley et al., 2007). However, in regions where growth conditions are medium and where the use of synthetic inputs in the past had been moderate, organic productivity tends to equate that of its conventional counterpart. Interestingly, in subsistence farming systems, a switch to organic management can result in yields up by 180 per cent higher (FAO, 2007). Many researches on yields look at yield rations for individual crops; this puts research on organic farming at a disadvantage because many organic farms practise polycultures and multiple cropping systems. However, these techniques mean that the total production per unit area is often higher than for single crops (FAO, 1993 and Piper, 1998 cited in Badgley et al., 2007) but this makes it harder to exactly record productivity.

Pimentel et al (2005) demonstrated that organic agriculture is more resistant to the negative impacts of climate change. This is a precious asset, considering how much disturbances such as yield losses can affect world food prices on a grand scale (Lobell et al., 2011 cited in Azadi et al., 2011). In 2008, the FAO (cited in Azadi et al., 2011), reported that organic agriculture: “assists farmers in adapting to climate change by establishing conditions that increase agro-ecosystem resilience to stress. Increasing an agro-ecosystem’s adaptive capacity allows it to better withstand climate variability, including erratic rainfall and temperature variations and other unexpected events”. Therefore, organic agriculture can help enhance food security (Azadi et al., 2011) Pretty and Hine (2001, cited in Lotter et al., 2003) showed average yield increases of 5-10% in irrigated crops and up to 50-100% in rain-fed crops when they surveyed results from projects introducing modern organic practices in developing tropical countries.

Organically managed crops have been reported to out-yield conventionally managed crops under situation of intense climatic stress; for example, organic crops can better buffer the effects of a flooding thanks to a bigger incidence of water-stable aggregates and a “fluffier soil” (less soil compaction) after tillage (Denison, 1996 cited in Lotter et al., 2003), thus allowing for better water penetration and retention. Similarly, organic crop systems have been found to be particularly resistant to water and climate stress situations, and during “bad years” are very likely to out-yield comparable conventionally-managed crops (Dormaar et al., 1988 and Stanhill, 1990 cited in Lotter et al., 2003) by 70-90% under severe drought (Lockeretz et al., 1981; Peterson et al., 1999 and Wynen, 1994 all cited in Lotter et al., 2003). As such, Swift (1994 cited in Lotter et al., 2003) suggested it was pertinent when assessing agricultural systems performance to take into account yield stability from one climatic cycle to the next on top of overall yields.

Stress is easily laid on measurable variables such as gross yields rather than those variables that are much more complex to measure such as sustainability and externalities. This encourages scientists and innovators to focus on yields rather than economic optimum, on monocultures rather than multiple cropping systems. This influence can be traced back to the econometric method of calculating rates of returns on investments in agricultural research, which only takes into account one objective: total net benefits, (or growth), instead of taking into account externalities and multiple socioeconomic and environmental objectives (Alston et al, 1995; Vanloquen and Baret, 2009).

An American research, conducted by Lotter et al. (2003) at the Rodale Institute Farming Systems Trial during the year 1999 when a severe dry spell in the Spring was immediately followed by torrential rain in September, concluded that the organic plots no only captured more water but also retained approximately 100% more water than the conventional plot during the heavy rainy spell. These findings concur with Ramesh et al.'s results (2005, cited in Azadi et al, 2011) that organic systems have higher yields than conventional (from 7% to 90%) under dry or water-stressed conditions. Lotter (2003) has further demonstrated that in North America, organic crops yield on average 90-95% of conventional crops, however, many challenge claims of this type. Posner, Baldock and Hedtcke (2008) conducted a 13 and 8 year-long study of six cropping systems ranging from diversified organic to non-diversified conventional agriculture, at two sites in southern Wisconsin, USA. They found two things: (a) that organic forage crops yielded as much dry matter as their conventional counterparts and cows fed on it produced as much milk; (b) that organic corn, soybean, and winter wheat could produce 90 per cent as well as their conventional counterparts.

A number of studies have concluded that organic systems carrying capacity could only support between 3 to 4 billion people worldwide (Buringh and van Heemst, 1979 and Smil, 2001, 2004 cited in Connor, 2008), which does not meet current needs, let alone future needs when global population is forecasted to jump to 9 billion by 2050 (United Nations, 2011). These studies based themselves on the yield performances of organic agriculture in the 19th century, when world population was around 1 billion and before the advent of agro-chemical inputs (Buringh and van Heemst, 1979 and Smil, 2001, 2004 cited in Connor, 2008). According to Connor (2008), these statistics remain relevant today as crops have not changed their essential metabolism or nutrient needs since the 19th century. Some retrospective calculations show that without the significant yield increases of the past decades in the United States, India and China, achieving the same amount of food as is currently grown there would require 2 to 4 times more land under cultivation than at present (Waggoner, 1995; Borlaug, 2002; Goklany and Sprague, 1992; Waggoner, Ausubel and Wernick, 1996, all cited in Green, Cornell, Scharlemann and Balmford, 2005). Some prospective calculations have determined that without yield increases, maintaining per capita food consumption would necessitate a near doubling of the world's cropland area by 2050 (Waggoner, 1995 cited in Green, Cornell, Scharlemann and Balmford, 2005).

Badgley and Perfecto (2007) have examined data from 77 published studies which suggest that legumes can provide enough nitrogen fertilizer to replace all synthetic nitrogen fertilizer currently being used. They further argue that organic agriculture can produce enough yields to feed the world's population eating as it does today; they make a sufficiency argument regarding global calorific needs. Inversely Avery (1995: 35) argues that even if the world population were to become vegetarian, we could still not feed it organically. He estimates (without citing references) that the world "probably" has less than 20 per cent of the organic nutrients required to maintain current production. Thus, farming organically would mean farming more land to create green manure.

Cassman (2007) answered Badgley et al., (2007) results by arguing that differences between the two systems can be hard or impossible to quantify: many conventional farmers adapt their soil and crop management practices to the agro-ecosystems in which they work, thus generating significant variations from field to field. Furthermore, he claims that rotations may not always be taken into account when comparing conventional and organic yields. Rotations, which are needed in organic agriculture means that some years crops grown in any given field are for fodder as opposed to food. When this is not taken into consideration and studies focus on yearly yields of the same crops, the total food output of the cropping system may be overlooked.

At the moment, it is likely that organic agricultural systems still produce lower crop yields than conventional (Maeder et al., 2002 cited in Azadi et al., 2011), this is a trade-off to make as in the future, organic agriculture is better prepared for issues such as fresh water availability, soil degradation, pests and diseases and potentially climate change, all of which threaten food security (Azadi et al., 2011).

II.2.5 Inputs and Energy

Between 1961 and 1999, food crop yield per unit area grew by 106 per cent; this came parallel to a 97 per cent rise of land under irrigation and was linked to 638 per cent rise in the use of nitrogenous fertilizers, 203 per cent rise in the use of phosphorus fertilizers and an 854 per cent increase in the production of pesticides (FAOSTAT, 2001, Tilman et al., 200, and Tilman, Cassman, Matsonand Naylor, 2002 all cited in Green, Cornell, Scharlemann and Balmford, 2005). Mineral fertilizers are manufactured by the petro-chemical industry and come from oil. Manufacturing nitrogen fertilizers is the first cause of energy use in conventional farming (IFOAM, 2006). As a general rule, organic systems are more energy efficient in the use of natural resources than their conventional counterparts. Organic systems use on average 33 per cent less energy per hectare in organic maize and 56 per cent less in biodynamic systems (FAO, 2007).

The misuse and/or overuse of synthetic fertilizers negatively impact the physical and biological properties of the soil. This in turn negatively affects yields. But synthetic fertilizers can have advantages compared to natural ones in that they are much easier to obtain and apply, they are cheap when subsidised and have much more predictable nutrient contents. Additionally, organic nutrients are sometimes simply not available in adequate amounts (Fernandes, Pell and Uphoff, 2005). Agriculture's dependence on synthetic inputs has given rise to what Paarlberg (1994 cited in Parrot and Marsden, 2002) calls "second generation rural environmental problems". These encompass decreasing returns from repeated pesticides and fertilizer spraying, health issues, biodiversity loss, decreasing quality in soils and water, diminishing ground water levels and heightening of crop diseases risks. Partly, these problems lie directly within the toxic nature of many fertilizers and pesticides, but they are increased by the inadequate application methods which are especially prevalent in the developing world (Parrot and Marsden, 2002).

Organic agriculture is knowledge-intense as opposed to conventional agriculture which is capital intensive. Organic farmers do not need to take out loans to buy their inputs (IFOAM, 2006). Niggli et al. (2008 cited in Azadi et al., 2011) cite the fact that organic agriculture uses indigenous knowledge and as such is more self-reliant as it can manipulate complex agro-ecosystems in order to breed locally adjusted seeds and livestock as well as make inexpensive nature-derived inputs. Indigenous knowledge acts as a “reservoir of adaptations”. Furthermore, organic agriculture encourages the use of local seeds (Kilcher, 2007 cited in Azadi et al., 2011), which are far more likely to be adapted to local farming conditions including climate (Borron, 2006), soils and management traditions, although the total mitigation benefits of OA are hard if not impossible to measure as they are dependent on unique local conditions (Azadi et al., 2011).
In many poor areas, the use of synthetic inputs is declining (starting from an already low adoption base), mostly because of the long-term un-affordability of such technology. Harris et al. (1998 cited in Parrot and Marsden, 2002) found that two-third of sub-Sahara African farmers who used organic agriculture did so because of their personal economic circumstances which did not allow them to buy these inputs. Parrot and Marsden (2002) distinguish two major reasons for farmer in developing countries to adopt agro-ecology/organic agriculture. Some do it for purely economic reasons, as their products benefit from market advantages and/or enhance the food security of their community. The second group is probably just “jumping off” the agrochemical treadmill due to adverse economic circumstances and probably because of health and environmental reasons too, though data are lacking. This latter group constitute a potential base for organic agriculture adopters but is not obvious that they would have the skills and knowledge to farm productively with agro-ecology or organic methods. Both the size of this group and their and farming potential for organic agriculture are unknown.

Kirchmann and Thorvaldsson (2000) argue that organic agriculture places philosophical beliefs above scientific knowledge, even when scientific results contradict them. As an example, the demand for all synthetic fertilizers to be excluded is akin to a dogma (Jansson, 1971 cited in Kirchmann and Thorvaldsson, 2000). Pesticides represent a precious tool for farming (Kirchmann and Thorvaldsson, 2000). The fundamental question to know why plant nutrients should be only under organic forms or as untreated minerals has never been scientifically proven (Ibid). According to Avery (1995: 169), it does not make sense to praise or defend an organic farmer which would manage to match the average yields for his area through importing big amounts of animal manure and/or urban sewage to farm with.

83 million tons of synthetic inorganic nitrogen fertilizers are used in the world today, most of them in developed countries (Borlaug, 2004 cited in Avery, 2006: 202). People who claim that world agriculture can go without inorganic nitrogen fertilizers are talking about it from a rhetorical standpoint and have never tried their hands at farming (Borlaug, 2004 cited in Avery, 2006: 202). Agriculture in developing countries is dominated by conventional methods; conventional methods of farming currently consume 70% of total world fertilizer use (IFA, 2007 cited in Connor, 2008.

The nitrogen used for both organic and inorganic fertilizers come from the earth atmosphere, which is nearly 80 per cent nitrogen gas. However, the air nitrogen (N2 or di-nitrogen) is unusable for plants due to its chemical structure. For plants to be able to uptake atmospheric di-nitrogen, it needs to be chemically converted, or 'fixed' into ammonia or nitrate. This can only be done by bacteria which entertain a symbiotic relation with legume plants which host them in nodules in their roots. The bacteria produce nitrate from the atmospheric di-nitrogen and 'trade' it with its host plant for sugars (Avery, 2006: 205).This legume-sourced nitrogen requires land for production (as opposed to a factory for synthetic nitrogen). To produce non-legume crops such as cereals or vegetables with the required amount of nitrogen, a field needs to either have some legumes growing together with the non-legume crop(s) or use green manure. This means growing a legume crop and ploughing it back into the soil instead of harvesting it, prior to growing a non-legume crop (Ibid: 206).

Connor (2008) argues that a significant increase of land under organic management will lead to competition for limited organic nutrients worldwide. Furthermore, he argues that crop yields and areas currently under cultivation will decrease as more land will be used for biological regeneration of fertility, and growing green manure. Connor (2008) believes that organic agriculture will not be able to feed the world as yield ratios will be insufficient and legume cover-crops will not adequately replace N fertilizers without provoking a significant disruption of current global food production. If a sudden switch to organic agriculture was to happen, resource-poor farmers in developing countries would lose most. He puts forward the case that in nutrient-starved agricultural systems, a switch to organic agriculture will inevitably provide more nutrients but that the benefits of such a switch cannot compete with the benefits of a switch to conventional agriculture where nutrients are provided in greater numbers through the use of agro-chemical inputs.

When pesticides are applied onto arable land, they tend to disseminate around through wind drift as well as being leached to surface and groundwater (Kreuger, 2008 cited in Kirchmann and Thorvaldsson, 2000). They also get distributed across large areas through their volatilisation followed by deposition (Siebers et al., 1994; Lode et al., 1995 cited in Kirchmann and Thorvaldsson, 2000). Because of these natural circumstances, pesticides use will lead to their occurrence in other environments. Kirchmann and Thorvaldsson (2000) argue that to guarantee they have minimal negative side-effects on ecosystems, pesticides (whether natural or synthetic) should have low levels of toxicity except for the targeted organisms.

It is a reality that mainstream farmers have often used pesticides more often than was necessary or desirable and for preventive rather than curative reasons, and that this situation was probably brought about by "a poorly conceived set of government subsidies" (Avery, 1995: 170). However, excluding pesticides entirely can potentially result in higher concentrations of secondary plant metabolites and of mycotoxins and field fungi which plants developed to fight off their natural attackers (Eltun, 1996 cited Kirchmann and Thorvaldsson, 2000). The exclusion of pesticides can have pervasive effects and does not necessarily protect crop products from containing unwanted substances (Kirchmann and Thorvaldsson, 2000).

II.2.6 Pests

Despite the escalating use of pesticides worldwide, pests are still responsible today for about 40% loss in the world's 'potential food' (Oerke, 2006 cited in Azadi et al., 2011). Crops' natural resistance to pests tends to be higher in organic systems than in conventional systems

(Birkhofer et al., 2008 cited in Azadi et al., 2011). Reasons for this are numerous. Firstly, the increased soil quality and matching microbiological biomass ensures a habitat for pests' natural enemies (Birkhofer et al., 2008 cited in Azadi et al., 2011 and Meyling et al., 2010 cited in Azadi et al., 2011). Indeed, organic agriculture systems also tend to benefit from a greater presence and diversity of predatory vertebrates and birds (Hole et al., 2005).

Secondly, organic crops are allowed to grow at their natural, relatively slow rhythm, which contrasts with the unusual speed at which conventional and biotechnological crops are being grown. Slow-grown plants have the time to develop their natural chemical defences which can protect them against most types of pests and diseases. Conventional plants' growth is reliant on chemical nutrients which reduce the adequate accumulation of defence compounds (FAO, 2007 cited in Azadi et al., 2011). Crowder et al (2010) put forward the suggestion that greater evenness in natural enemies populations in organic farms contribute to organic farmers' ability to have lower level of insecticide use while being able to maintain pest densities which are similar to those found in conventional farms. Populations of natural enemies are significantly higher in organic agro-ecosystems than in conventional ones (Crowder et al., 2010).

Agro-ecology allows farmers to experience with their own techniques and cultural knowledge and to come up with their own solutions. These solutions may not always be translatable into scientific ways of understanding, let alone find their way into peer-reviewed scientific journals but they "fit" the systems in which they are utilised and can also be used to better understand the specific systems to which they relate (Norgaard and Sikor,1995). This contrast with conventional agriculture's methods of expanding monocultures and using escalading amounts of agro-chemical inputs which has actually extended the pest problems (Azadi et al., 2011). The pests present in conventional agriculture systems today have co-evolved with the pesticides that were sprayed on them. Pesticides in conventional agriculture are applied based on the philosophical premise that pests can be thought of and dealt with as separate from the system in which they live (Norgaard and Sikor,1995).

Skills in managing weeds are a needed prerequisite for successful organic farming (Lotter et al., 2003). However, very traditional agriculture does not recognise the idea of "weeds". Each and every plant, whether farmed or wild, has its use and sometimes several parts of the same plant can have different uses (Navdanya, 1993). Wild food is an integral part of the diet principally in low and middle-income countries and is often critical for the adequate diet of many communities. Bharucha and Pretty (2010 cited in Godfray et al., 2010) found that a typical rural African community uses around 100 wild species of plants; in West Bengal, 124 species collected from rice fields have economic and/or nutritional importance for local farmers (Shiva, 1999). Additionally, these communities very often intervene in the management of the wild plants they harvest, thus blurring the boundary between agriculture and wild harvest (Bharucha and Pretty, 2010 cited in Godfray et al., 2010).

Many organic agriculture proponents believe that nature in its ideal form operates in a state of perpetual balance. This is at the core of the vision that a farm is an agro-ecosystem as opposed to an artificial environment. However, farms are inevitably artificial as they are human-managed systems of production, and they are kept as stable as possible to ensure a continuous and optimum output (Avery, 2006: 170). Natural ecosystems are by essence dynamic and ever-changing, they constantly need to readjust their balance to keep at what ecologists call a 'dynamic equilibrium'. As such, farmers are not likely to ever be able to entirely discontinue the use of chemical and biochemical pesticides. The incredible amount of food available to pests in a normal, high-yielding modern field forces farmers, including organic ones, to use pesticides. Biocontrol programmes can only reduce, as opposed to eliminate the use of pesticides and they are expensive (Ibid:170-185).

Conventional farmers have the extra option of using herbicide when they suffer from a weed infestation whereas organic agriculture can only rely on mechanical and biological weed control methods. As such, they require around 15 per cent more labour than conventional ones (Sorby, 2002 and Granatstein, 2003 cited in Pimentel et al, 2005). However, the increase in labour input is anything between 7 per cent (Brumfield et al., 2000 cited in Pimentel et al, 2005) to 75 per cent (Karlen et al., 1995 and Nguyen and Haynes, 1995 cited in Pimentel et al, 2005). Agro-ecology and other forms of ecological farming rely on heavier labour needs. However, this needs not be liability as creation of employment in rural areas in developing countries where unemployment is rife may constitute an advantage (De Schutter, 2010). Badgley et al. (2007) made the same claim to which Hendrix (2007) answered that it was "elitist to condemn people to the drudgery of hand labour required on small organic farms", and that only someone who had not done such a job for a significant amount of time would think of it as an employment solution.

II.2.7. Towards the Future

Agriculture encompasses a much broader set of activities than the sole production of food, fuel, fodder and timber. As an economic activity is does more than trying to make as large a profit as possible. Talks about sustainable agriculture must go beyond to sole fences of individual farm, because farming creates complex, interconnected repercussions in the social, environmental and economic realms (Gliessman, 2005). Interrelationships between agricultural production and its environment mean that it is difficult to know which farming methods will be sustainable in which locations (Youngberg and Harwood, 1989 cited in Rigby and Cáceres, 2001). This leads to question whether and how sustainability can be adequately assessed at all, as only in retrospect can sustainable techniques be effectively identified (Rigby and Cáceres, 2001). Systems which are sustainable "for one farmer or farm at one point in time may not be sustainable for another farmer or farm at another point in time" (Ikerd, 1993:31 cited in Ibid).

Mixed-farming, despite its advantages could put the farm's economy at risk, and as such may require additional policy support. As such, where to carry out agriculture is also a political decision as not all land is fit for cultivation within a country (Kirchmann and Thorvaldsson, 2000). Many scientists do not explore agro-ecological innovations because "it goes against the flow" as one scientist put it when interviewed by Vanloquen and Baret, (2009) when asked about why there was no research on cultivar mixtures to create systems resistant to fungal diseases. Researchers use the current social and economic barriers that prevent farmers from using agro-ecological innovations to justify the research deficit. Current barriers are seen as unmovable obstacles. Past agricultural systems are rarely seen as sources of insights for innovation in mainstream agricultural science where modernization remains an important leitmotiv. On the contrary, agro-ecology values past systems as sources of insight for the improvement of current systems. Many scientists consider agroecological innovations to be innovations 'for organic agriculture' because agro-ecology and organic agriculture share common agroecological principles. Research funding is low because organic agriculture is considered a niche market innovations and because of the mainstream view that organic agriculture is unable to feed the world (Ibid, 2009).Innovation policies need to take into account the importance of niches and the true value of agro-ecological innovations in order to face the challenge of the global climate change. Innovations niches are locations where it is possible to deviate from the rules of the existing technological regimes (Geel, 2002, 2004 cited in Vanloquen and Baret, 2009). For Wolfe (2000 cited in Vanloquen and Baret, 2009) agro-ecology is “too simple” to attract interest.

Parrot and Marsden (2002) argue that the extent to which organic agriculture generates an unconventional ‘world view’ where local farmers knowledge is celebrated and used and seen with pride as opposed to shame is key to implementing a lasting change. Agro-ecology calls not only for changes in day-to-day management on the farm, planning and marketing but also a change in philosophy (Gliessman, 2005). Additionally, organic agriculture has a strong social side which tends to be overlooked, even though it fits right in the development agenda in its widest scope. It is therefore puzzling and potentially counter-productive that the main argument to export organic agriculture to the South is the promise of better access to markets in the North (Parrot and Marsden, 2002)

Fernandes, Pell and Uphoff (2005) argue that for the sake of productivity, different forms of agriculture need to be applied to different regions of the world. Industrialised agriculture is most suitable to advantaged producers and areas, whereas ‘hybrid’ agriculture which combines local knowledge and inputs with modern technologies will benefit developing countries best. Gliessman (2005) firmly believes that human society will eventually need to find ways to return the nutrients consumed through food back to their original ecosystems. Many hold a “romantic” view of organic farming. Nature appears to be full of unknown and wonderful secrets, yet at the same time natural activity can have “bad” effects (Kirchmann and Thorvaldsson, 2000).

Environmentally, it does not matter whether nutrients come from inorganic or organic sources. What matters is the timing and quantity of nutrient application and whether the supply is adequate for the plants’ needs (Myers et al., 1997 cited in Kirchmann and Thorvaldsson, 2000). Several researches have shown that the type of fertilization does not affect crop quality, which goes against the organic philosophy (Hansen, 1981; Evers, 1989 cited in Kirchmann and Thorvaldsson, 2000); instead the intensity of fertilization is what matters most (Hogstad et al., 1997 cited in Kirchmann and Thorvaldsson, 2000). Because significant differences can be found in crop quality, regardless of whether the crop is organic or conventional Kirchmann and Thorvaldsson (2000) argue that the division into organic and conventional agriculture makes us lose sight of the central issue of crop quality.

Azadi et al. (2011) argue that the transition to organic agriculture is desirable in the long-run but should be carried out gradually so as to challenge effectively world hunger and malnourishment. Avery’s opinion (1995: 188) is that neither organic farming nor intensive agriculture as is currently practiced deserves to dominate agriculture. Instead, a radical middle-ground is needed where the most effective inputs to produce the highest yields should be used at the lowest economical and environmental prices. This can be achieved through open competition and the abandon of old farm subsidies and international trade barriers

Connor (2008) argues that a productive way to move the debate forward would be to “loosen up” organic standards and create a “replacement organics” to allow for fertilizer use when essential. Another method to optimise both productivity and environmental sustainability as offered by Parrott et al. (2006) is to "more closely align practice with low-input approaches to crop production".

Bindraban and Rabbinge (2011) state that if Europe is to secure its own food supply, contribute to fill the food deficit of some regions of the world and cater for the non-food needs and desires of its own population, it needs to engage in a dual pathway. Food production should be secured by economies of scale, precision technologies, high labour productivity and efficiency of natural resources. Organic agriculture on the other hand can be of service to satisfy non-food desires such as recreational and therapeutic health purposes. Organic agriculture's survival then, ought to come from these services as opposed to from food production. Fernandes, Pell and Uphoff (2005) argue that food production could be doubled using the currently existing genetic base with appropriate research policies and support. They believe that this could only be achieved if systems which capitalise more on biological and agroecological dynamics, rather than on mechanical and petrochemical energy, were more widely developed. This however, requires "some rethinking of what constitutes agriculture".

Vanloquen and Baret (2009) note that the real world is not as clear-cut as theories: hybrid situations exist. Organic agriculture and agro-ecology have many principles in common; organic farmers have implemented many agroecological innovations in their crops, although some replicate productivist approaches which go against agroecological principle.

Regarding the future of research, many scientists think in terms of the most probable future agricultural scenario, not the most desirable. They forecast the future of agriculture by basing themselves on the current trends of globalisation and the liberalisation of agricultural commodities. These trends exacerbate economic pressures on farmers, thus the pursuit of input-intensive approaches is thought to be the most probable evolution. Many scientists frame their research around these constraints and behave as of global warming and the rising costs of energy did not demand major policy shifts (Kirschmann, 2007 cited in Vanloquen and Baret, 2009) or as if there was not alternative to the mainstream economic trends (Patel, 2007 cited in Vanloquen and Baret, 2009). Scientists commonly *assume* that current agricultural systems cannot or should not be changed, save for minor adjustments. Problems such as pesticides risks are acknowledged but the validity of the model itself (i.e. monoculture and a heavy reliance on a high level of external inputs) is not questioned. Thinking on agriculture remains close to the industrial approach that has characterised it for more than a century (Bawden, 1991 cited in Vanloquen and Baret, 2009).

II.3 Vested Interests in Agriculture Today

II.3.1. The costs of cheap food

Food is becoming increasingly cheaper relatively to other goods and many would like to think that this can only be a good thing. This, however is a damaging myth as Pretty (2002) argues. Food in fact is not as cheap as we would be made to think; in fact it is getting increasingly expensive when the hidden costs of environmental damages and ill health are accounted for. Pretty argues we pay for our food no less than three times: once at the shop, where it appears relatively cheap, a second time through taxes which are used to subsidise farmers and a third time to 'clean up' the environmental and health side-effects. Food in fact only appears cheap because its costs are divided are accounted for elsewhere. As economists word it, the true costs are not internalised in prices. If all costs were added up, it would show that industrialised systems perform poorly when compared to sustainable systems. Cost-shifting means that the costs of water pollution, loss of fertility, ill-health etc…are transferred away from farmers and not paid directly at the farm gate either (Ibid).

Agriculture is unique in that it affects the very assets on which it relies on for its success. As such it should work with a clear understanding of the "wholeness" of the systems it operates. Instead, costs externalisation diverts costs away from those who negatively impact the natural resources on which they rely, and does not encourage those who work to enhance and conserve theirs. As an example, pesticides and fertilisers which have been leached into waterways need to be removed from drinking water by water companies, which then pass on the costs to their customers. As such, polluters benefit from not having to clean up any of the mess they created because the costs for that are imposed on the rest of society, thus acting as hidden subsidies; furthermore, they do not have any incentives to change their behaviours. (Ibid).

A study conducted by Hartridge and Pearce (2001 cited in Pretty, 2002) estimated the external costs of industrialised agriculture in the UK to be over £1 billion. Pretty and his team at the University of Essex "conservatively" estimated them to be between £1.5 to 2 billion. By the same token, external costs of US industrialised agriculture amounts to nearly £13 billion per year. These costs should prompt industrialised societies to reassess what they call efficiency. British farming is the recipient of £3 billion in public subsidies each year, yet it is responsible for some 1.5£ billion external costs which are spread elsewhere in the economy. Similarly, the pesticides market in the UK weights £500 million a but causes society to pay £120 million each year to clean them out of drinking water (Pretty, 2002).

Pesticides application affects not only the targeted pests but also their natural predators. When the population of the latter drop, outbreaks of secondary pests occur, which lock farmers into a vicious circle of needing to apply more pesticides. The costs of these subsequent applications and crop losses due to secondary pests are $666.8 million, as calculated by Tegtmeier and Duffy, 2004, from Pimentel's 1992 figure. Using Pimentel's 1992 figures, Morse and Calderone (2000, cited in Tegtmeier and Duffy, 2004) have calculated that the annual value of honeybee pollination to be $14.6 billion, and this only includes increased yields and product quality. They have calculated the economic impact of pesticides on honeybees to be around $319.6 million in terms of colony loss, reduced crop pollination and honey production and the cost of 'bee rental'.

The total cost to human health from pesticides in the USA is estimated by Tegtmeier and Duffy (2004) to be $1,009 million per year. This translates into an external cost to human health of $2.26 per kilogram of active ingredient. Ecological farming claims to internalise many of these costs. However, the structure of the food market and the food and agricultural policies in the USA return very narrow margins for these producers and discourages changes in the production methods of agricultural goods (Ibid).

II.3.2. Agricultural politics

Developing nations

It is worthy to note that gross food prices have, as a general rule, fallen in the past century and have stabilised in the past three decades. However, this process has been marked by price spikes such as the ones created by the oil crisis in the 1970s or in 2008. Many researchers see this recent price spike as announcing a new period of volatile food prices, which main reasons lie in the escalating demands from rapidly developing countries as well as competition for agricultural resources triggered by first generation biofuels (Godfray et al., 2010). The new food economy leads to a situation where small changes in production can lead to important fluctuations in price which echo worldwide. Most countries buy their food on the open global market in search for the lowest prices; this leads to seismic repercussions when one country decides to protect its own market as supply chains worldwide can break down (Royal Society, 2009 cited in Pretty et al., 2010). The Special Rapporteur on the right to food in the United Nations, Olivier de Schutter has stated that states needed to reorient their agricultural systems towards modes of production which are both productive and sustainable. As such, he identifies agro-ecology as an adequate answer to fulfilling the right to food for many vulnerable groups across the world (De Schutter, 2010).

Today's global agricultural production is enough to feed the current human population; moreover, the technologies and the environmental agreements to attain development and conservation needs already exist (FAO, 2007). The last decade provided 'uncompromising' evidence that returns on grains are decreasing, and this despite the increasing use of chemical and fertilizers sales (Sanders, 2006 cited in FAO, 2007; FAO, 2007). Organic agriculture represents a compelling incentive to 'de-industrialise' agriculture, which would be achieved through a drastic reduction in agro-chemical inputs (FAO, 2007).

However, many commentators claim that global food production needs to increase by 50 per cent by 2030 and to double by 2050. However, as the Soil Association (2010) argues, the original FAO report (2006 cited in Soil Association, 2010) that starting spreading these figures, 'only' implies that food production need to increase by 70 per cent by 2050, which is not the same as 100 per cent. The FAO reports does claim a need to increase production in some sectors by significant amounts such as the cereals sector, which needs to sustain a 50 per cent increase by 2050; however the bulk of this increase is to be used to feed livestock. So this is projected doubling of meat consumption, mostly due to developing countries' increasing demand (Soil Association, 2010).

These projections rest on four major assumptions which are (Ibid):

- A sustained increase in world's population and economic prosperity

- An increase of per capita calorific consumption in developing countries
- Sustained imports of food by developing countries (though it is not known where from)
- A structural nutrition transition in developing countries to include more meat and dairies in the average diet.

The FAO (2006 cited in Kiers et al., 2008) estimates that around three quarters of the world's poor and hungry live in rural areas and depend either directly or indirectly on the land for their survival. Because increases in agricultural production have not satisfactorily improved access to food for the world's poor, it is pointless to advocate technological improvements as a silver bullet. There is rather a need to promote human ingenuity and ancestral knowledge to solve agricultural challenges, as this appears to be a more efficient and cheaper approach (Kiers et al., 2008). In areas were small-holders lack capital (one third of Asia for example), organic agriculture can help break the vicious circle of indebtedness which seems to plague large agricultural areas and causes an 'alarming number of suicides', thanks to its independence from the repeated need to buy agro-chemical inputs (FAO, 2007).

Farming monocultures is a risky business and should not be undertaken unless safety nets in case of crop failures have been established as well as secure marketing routes. In situations where these elements are not present, "it is outright dangerous to go down this path" (Hilbeck, 2008). Godfray et al., (2010) argue that a liberalised world market penalise poor communities the most as they have the least control over world markets' functioning. Additionally, our global, extensively connected food system has wide repercussions in case of crisis, thus affecting more people, as illustrated by the 2008 banking crisis (Godfray et al., 2010). For his part, Avery views free-trade as a solution which can bring about a sufficient and stable supply of food with as little economic and environmental costs as possible. Free-trade means that only the best and highest-yielding areas will be farmed, wherever they are. However, free trade must also mean the end of subsidies to be effective (Avery, 1995: 354-70).

To encourage biases towards female farmers in agricultural research and development is a matter of good-sense which will benefit all of society. Women in agriculture receive only 5 per cent of agricultural extension services worldwide and gender issues are incorporated into less than 10 per cent of all development assistance in agriculture (Committee on World Food Security, 2010 cited in De Schutter, 2010). Women experience significantly more difficulties in accessing external inputs and subsidies than men and as such, ecological farming can greatly benefit them as well as their communities. Women in farming deal with different constraints and opportunities than their male counterparts, recognising and enhancing their contribution to agricultural productivity, food security and poverty alleviation is a crucial aspect of agricultural development (Meinzen-Dick et al., 2010 cited in Pretty et al., 2010).

Industrialised nations:

The current 'human project' is predominantly led by economic concerns. Environmental issues "provide worrisome noises" but they are not given political weight, because there is not yet a political advantage to be had through them (Röling, 2000). Agricultural sustainability and land use in Europe is illustrated by a "balancing act" between social, economic and ecological issues which appear to compete with each other (Bindraban and Rabbinge, 2011).

Additionally, the activity of green lobbies on developing an agro-ecological research agenda is not as straightforward. Greenpeace and the Soil Association spent more energy into banning transgenic crops than into promoting agro-ecology. The few scientific organisations which back a stronger research agenda in agro-ecology have significantly less clout than those mainstream scientific organisations which support genetic engineering (Vanloquen and Baret, 2009). This contrasts with Avery's view that the organic movement as a "very vocal and well-funded movement" (2006: 204). It is true though, that conventional farmers historically represent a potent political force and successive governments try and pacify them with nation-wide trade policies (Avery, 1995: 354).

Media have not adopted thinking on technological choices that would have discussed the comparative advantages of transgenic crops and their alternative options. Between 1981 and 2008, the archive of the New York Times contained 2696 for 'genetic engineering', 3 for 'agro-ecology' and 7 for 'agro-forestry' (Vanloquen and Baret, 2009). The media's stance is of great importance considering the power they exercise over public opinion as illustrates Cohen's quote: "[the press] may not be successful much of the time in telling its readers what to think, but it is stunningly successful in telling its readers what to think about" (Cohen, 1963 cited in Vanloquen and Baret, 2009).

There is yet no technological or market fix to the "eco-challenge". In fact, it is arguable that industrialised societies' reliance on technology and market forces reinforces the environmental problems (Funtowicz and Ravetz, 1993; Beck, 1994 cited in Röling, 2000). The existence of this path dependence and lock-in situation in agricultural research legitimizes public intervention. In other words, a global environment favourable to agro-ecology must be created of the recommendations of the IAASTD are to be implemented (Vanloquen and Baret, 2009). Meanwhile, organic farming is even giving 'a new shine' to the farming profession by attracting young entrepreneurial entrants which are leading a revival of the status of farming (this is especially true in Europe) (FAO, 2007).

It is still debated whether the heavy subsidies received by farmers in industrialised countries and the import barriers are actually raising farmers' incomes. Agricultural subsidies have had a marked and pervasive tendency to become capitalised into farmland value, thus raising the costs of production, which was the opposite effect than that desired. Furthermore, subsidies have meant that additional land was brought into production including pieces of land which were unsuitable for farming (Avery, 1995: 354-5) (such as areas prone to drought or to water-logging, hilly, with low fertility, or high in wildlife such as hedgerows). In most countries, subsidies have also resulted in a heavier use of fertilizers and pesticides to maximise yields (Ibid: 354).

It is somewhat ironic that while the agricultural productivist paradigm was to increase national self-sufficiency, it produces surpluses which are then exported and undermine the self-sufficiency of many developing countries, which are urged to embrace free-trade (Lang and Heasman, 2004: 20). For example, almost one-third of US farm income is derived from export sales when only 40 years ago, the USA were net importers of agricultural products. Similarly, land under soy production in Brazil increased from 200,000 hectares 35 years ago to 26 million today (Ibid: 138). Similarly, in 1988, in terms of world agricultural exports, the European Union weighted 50 per cent for eggs, almost 50 per cent for butter and cheese and between 10 to 30 per cent for sugar, beef and wheat (Balassa, 1988 cited in Bindraban and Rabbinge, 2011). In the USA, the 122,000 largest farms, representing 6 per cent only of the total number received over 30 per cent of the payments for commodity programmes, and 60 per cent of total farm receipts (Lang and Heasman, 2004: 150-1).

In the USA, government subsidies have always offered high price support for corn and nothing for legume crops such as alfalfa and clover. This “rigged the game” against organic agriculture which depends on rotations involving legumes, and as such made organic farming less profitable (Avery, 1995: 175). The USA livestock industry could potentially use more legume crops than it does today and less corn, however this is clearly not yet happening. Reasons for this situation range from the government’s ‘bias’ for corn, the high energy value of corn and the extra transport and processing costs associated with legume feeds. Furthermore, animals would need to be fed closer to the legume-producing areas (Ibid: 176) and this appears complicated to say the least.

II.3.3. Research biases

Fernandes, Pell and Uphoff (2005) estimate that between 60-70 per cent of soil research in the past 50 years both in the USA and abroad have been in soil chemistry and that another 20-30 per cent has been on soil physics which leaves around 10 per cent devoted to soil biology. Soil chemistry works simply by measuring deficiencies in the soil and it points to simple remedies: adding the correct amount and combination of nutrients “solves” the problem. What is more, such research benefits from an easy access to funding from fertilizers companies which have primary interest in the results. Microbial activity is essential for nutrients production and uptake. As such, it is an equally valuable field of research, yet it is neglected. Fernandes, Pell and Uphoff (Ibid) argue that this is because biological processes are more complex to study, measure and manage than the chemical composition of soil samples.

Sherwood, Cole, Crissman and Paredes (2004) argue that conventional thinking in agriculture focuses on the scientific aspects of farming, technology transfers and links to the market. As such, research tends to be concentrated on pests, crops and inputs. The human dimension, the farmers, tends to be neglected. As such, when an ecosystem and/or health crisis occur somewhere, the root cause is more likely to be found social in nature.

Despite the fact that around 80 per cent of the world’s population lives in developing countries, only one third ($10 billion) of all global expenditures on agricultural research is spent on solving their problems. This amounts to less than 3 per cent of the money spent by countries of the OECD on subsidies to their agriculture (Evans, 2005 cited in Kiers et al., 2008). This despite research demonstrating that investment in agricultural Research & Development is amongst the most successful solutions to correct hunger and poverty (Alston et al., 2002 cited in Kiers et al., 2008). Save for the notable exception of the Consultative Group on International Agricultural Research (CGIAR) few research organisations have looked to improve the crops which millions of small-holders rely on in developing countries, these include legumes, tubers and small-grain cereals (Kiers et al., 2008). Since private sector companies already dominate the research landscape, it is fair to assume they are in a privileged position to play ‘a vital role’ in this type of research (Ibid).

However, there is a division of innovative labour (Arora and Gambardella, 1994) between the public and private research institutions in the agricultural sector. Public sector focuses on basic research while private sector focuses on applied R&D. Busch et al, (2004 in Vanloquen and Baret, 2009) argue that public-private partnerships have a profound impact on the world of science because they change the very culture of science. A study conducted on the partnership between the University of California and biotech Novartis, found that significant number of university scientists who participated in the partnership defined the public good as research that leads to the creation of commercialized products. Levidow et al (2004 cited in Vanloquen and Baret, 2009) states on the steering of research that "even a small proportion of industry funding can influence overall research priorities: the tail can wag the dog". This trend is favourable to biotech innovations but not to agro-ecology. There are also numerous cases of indirect privatisation of research by the industry: by giving private research access to public funds or via the "industry capture of research programmes" (Alston et al, 1998; 2001 cited in Kiers et al., 2008). This indirect privatisation trend has favoured innovations which benefit the private sector at the expense of innovations which bring in less money but are of genuine public interest (Vanloquen and Baret, 2009). For example, pest research has tended to have an 'insect bias', with diseases coming second and weeds third. Integrated pest management techniques (IPM) has been gaining ground since the 1960s but despite their successes it and the benefits they have brought to farmers and society, research in this area is still lacking (National Research Council, 2010 cited in Pretty et al., 2010).

Private incentives for agro-ecological research are very limited as private companies are unable to capture all the benefit resulting from these innovations (Sunding and Zilberman, 2001 in Vanloquen and Baret, 2009). Innovations in agroforestry systems can hardly be patented, they are hard to promote as their benefits are in the long-term and their benefits are very much in the public good domain: increased biodiversity or carbon sequestration. Consequently, agro-ecology, agroforestry and other alternatives have mainly had to rely on the public sector for their development.

Time and size requirements for research on each paradigm also differ widely. The transposition of a transgene into a host plant can be detected easily within days and lead to scientific discoveries which get to be published in renowned scientific journals. In contrast, sound research on agroecological innovations require long-term and large-scale on-farm experiments. Productivity assessment of an agro-forestry system took years from the planting to the publishable results, a requirement that does not match the short-time frame of research grants (Auclair and Dupraz, 1999 cited in Vanloquen and Baret, 2009).

II.3.4. Private Economical Interests

Today's food system is characterised by a small minority of farmers, processors and retailers carrying the responsibility for the food of plenty. This minority is hardly recognisable by those who depend on it, and who for the most part have been disconnected from the land for several generations already (Fresco, 2009).

Galbraith, an American analysis of large corporations from the 1950s, argued that modern corporations were able to control their markets, and through that to sustain the modern technological progress fundamental to general economic growth (Galbraith, 1952 cited in Dunn, 2011). Agriculture has been dramatically transformed and industrialised by large agrochemical and biotechnology firms, which have concentrated the market through their hold on the seed, fertilizers and pesticides supplies (Dunn 2011). In the late 1980s, twenty firms accounted for 90 per cent of sales (Lang and Clutterbuck, 1991 cited in Ibid), there were only 10 of them by the late 1990s (Lang, 2004 cited in Dunn, 2011) and only seven were left at the turn of the 2000s (Dunn, 2011). As Galbraith pointed in *American Capitalism:* "Those from whom the farmer buys and those to whom he sells do, characteristically have market power. […] The farmer's market for his products […] is typically, although not universally, divided between a relatively small number of large companies. There is no more vigorously debated question in economics than that of the measure of jurisdiction that such companies exercise over their buying prices." (Galbraith, 1952: 159 cited in Ibid).

II.4 Health Outcomes of modern food systems

Industrialised nations:

It is only in recent years that the public of industrialised nations has become intolerant of pollution; it is possible that this is because farm-generated pollution has not appeared to decrease despite heightened awareness from the public. In the UK, water pollution is now considered a criminal offence. The idea of pollution is a "bad thing" is a rather modern one. For proof, the Victorians associated pollution with wealth creation as embodied by the saying: "where there's muck, there's money". Pollution was seen as a necessary result of job creation and prosperity (Low and Ward, 1997).

Howard (1945) wrote in the context of British post-war reconstruction. He claimed that "real security against want (poverty) and ill health can only be assured by an abundant supply of fresh food properly grown in soil in good heart". Howard mentioned the "undernourishment of the soil" as the root cause of many modern ailments; he saw the health of the soil as directly connected to the health of people. "The failure to maintain a healthy agriculture has largely cancelled out all the advantages we have gained from our improvements in hygiene, in housing and in medical discoveries". Interestingly, the mention of farming with "good heart" refers to some form of spirituality as applied to farming, indicating that soil and human health were not purely physical matters. In that same decade, Lady Eve Balfour had written several editions of her well-known book "The Living Soil": "If we destroy our soil –and it is not indestructible –mankind will vanish from the earth as surely as has the dinosaurus" (Balfour, 1949: 15). She described health as more than "merely the absence of illnesses. Not being ill is not an acceptable substitute for health. As such, efforts for the prevention of ill health and for the promotion of health as wholeness should be increased" (Ibid: 150-151). She shared with Howard the belief that the determinant factor in health is food and the health properties of food are directly related to the way it has been grown, prepared and consumed (Ibid: 167).

More presently, the industrialised food industry's obsession to produce ever increasing yields has led to a number of environmental and public health costs and concerns. The large agro-chemical corporations have brought about changes in food growing methods, such as the booming use of agrochemicals, hybrid plant breeding and genetic modifications. Animal farming has met with similar changes with the introduction of factory farming and the preventative use of antibiotics to increase animals' weight (Dunn, 2011) The rapid industrialisation of global food production chains has brought about the collapse of fish stocks, soil erosion, deforestation and falling levels of water table in major production areas. There have been further public concerns on the issues of residues of pesticides, antibiotics and veterinary drugs in food as well on the impacts of food pathogens, and toxins such as lead, mercury and dioxins on public health (Ibid). Nutrients in animal manures and agricultural fertilizers have been linked with the collapse of some of the biggest fisheries in North America (Frankenberger and Turco, 2003 cited in Pimentel et al, 2005). It has now been established that the "Dead Zone" in the Gulf of Mexico results in the runoff of soil and nitrogen fertilizers coming from the Corn Belt (Pimentel et al, 2005). Soil erosion in the US costs $45 billion in public and environmental health losses (Pimentel et al, 1995 cited in Pimentel et al, 2005).

However, health problems caused by synthetic inputs (especially pesticides) are still unclear.

Accidents with them are rare in developed countries (100-200 a year in the UK according to voluntary government reports cited in Pretty, 2002). For its part, the FAO (2007) states that conventional agriculture reports some 20,000 annual deaths directly related to pesticides use worldwide. These are well known to be causing wide-spread illness including Parkinson's disease. However, there is great uncertainty and inadequate understanding as to the chronic effects (such as cancer causation) they may cause within the general public. Pesticides are ingested through food and water and it is still impossible to assess categorically whether some, all or combinations of some play or not a role in cancer causation (Pretty, 2002). There are no further data as of yet regarding the potential health risks for producers who use pesticides permitted under organic labelling schemes such as copper chloride and plant extracts. Although the FAO notes that organic consumers enjoy a lower incidence of allergies (FAO, 2007), "the "organic" label is a process claim, not a health claim". As of yet, there is no authoritative evidence that has demonstrated that organic foods are healthier (Boutrif, 2010).

Many researches now suggest that mono-cropping and feedlot livestock production potentially heightens food-borne pathogens and antibiotic resistance in humans, as well as pest resistance to chemical modes of control (National Research council, 1989; Altierri, 1995; Iowa State University and The University of Iowa Study Group, 2002 all cited in Tegtmeier and Duffy, 2004; Schlosser, 2001). Organic livestock have better immunity and a lower resistance to antibiotics in zoonotic pathogens (such as salmonella). Organic plants show 50 per cent fewer mycotoxins in crops than their conventional counterparts (FAO, 2007).

In 1992, food in the USA travelled around 1,300 miles and changed hands six times on average before being consumed (The Packer, 1992 cited in Kloppenburg, Hendrickson and Stevenson, 1996). North Americans eat food which comes from "a global everywhere, yet from nowhere they know in particular" (Kloppenburg, Hendrickson and Stevenson, 1996). Many researchers have recognised the environmental and social destructiveness of this consumption system, and suggested alternatives based on putting local production back at the centre of food systems (Herrin and Gussow, 1989; Berry, 1992 and Friedmann, 1993 all cited in Kloppenburg, Hendrickson and Stevenson, 1996).

Developing nations:

Pesticides have brought ample food to millions around the globe, and many countries rely entirely on them for sufficient food supply. According to Avery (1995: 64), there is no health trade-off to this situation, there are only health gains. He puts forward two arguments to support this claim. Firstly, pesticides prevent food from being contaminated with bacteria or fungi which in turn produce toxins and mycotoxins which can cause cancer. Secondly, pesticides help produce attractive fruit and vegetables at a low-cost, which constitute humans' best defence against cancer and heart ailments, regardless of whether they are organic or not.

Third World farmers use more dangerous pesticides (type I and II, WHO categorisation) than farmers in developed countries. Additionally, too few of these farmers use protective gear or are aware of the precautions to take when mixing, spraying or cleaning pesticides. However, even under these conditions, the health risks posed by pesticides are rarely severe. (Ibid: 101-104).

Intensive agriculture polluted drinking water in developing countries which cannot afford the filtration of contaminants (Nestlé, 2002 cited in Lang and Heasman, 2004: 224). Furthermore, irrigation is probably reaching its limits, according to a study by the World-Watch Institute; irrigation will require no less than 20 Nile Rivers by 2050 even if water-saving technologies such as drips are used (World Watch Institute, 2011). Additionally, when one known that only 1% of the entire world's freshwater is accessible for direct human uses (FBP, 2011 cited in Azadi et al., 2011), of which 70% is devoted to irrigation agriculture (UNESCO 2003 cited in Azadi et al., 2011), investing to better understand and enhance the soil's capacity to retain water, such as those used in conversion or ecological agricultures, appears to be a good idea (Lang and Heasman, 2004: 225).

On conclusion, despite its limits in addressing challenges posed by modern lifestyles and rampant urbanisation, organic agriculture creates significantly less environmental costs than conventional agriculture and it can even reverse environmental degradation in some areas (FAO, 2007).

II.5 Long-term agro-ecological sustainability

II.5.1.Soil

Soil degradation's expansion is among the most serious bio-physical problems of modern-time agriculture. Despite its little known-effect by the public, it is one of the biggest and most serious threats to food-production systems (Niggli et al., 2007 cited in Azadi et al., 2011); this is especially true in developing countries (Lal, 2009 cited in Azadi et al., 2011). More than 99.7% of calories consumed by humans come from the land, and only 0.3% come from aquatic ecosystems (including oceans) (FAO, 1998 cited in Pimentel cited in Azadi et al., 2011), which illustrates how crucial soil fertility is to human survival.

A number of researchers see soil fertility as a paramount issue to overcome the problem of food insecurity, especially in the developing world (Lal, 2009 cited in Azadi et al., 2011 "Each year, about 10 million hectares of crop land are lost due to soil erosion" (Pimentel, 2006 cited in Azadi et al., 2011). Soil organic matter and plant nutrients are concentrated in surface soils; in case of water or wind erosion they will be removed first, thus leading to serious soil degradation and eventually desertification. This is a major concern in developing countries of Sub-Saharan African, south and South East Asia and the Caribbean, where these problems are exacerbated by depletion of soil organic carbon and systematic use of extracting farming practices (Pretty et al., 2010).

Markus Arbenw, IFOAM executive director is on record claiming that "Conventional practices deplete soils and thereby undermine long term food security…" (Engllish, 2010). It appears that overall, organic soils show a much lower erosion rate than their conventional counterparts (Lotter et al., 2003). This is because organic farming techniques give a better structure to the soil and make it more fertile (Nigli et al., 2007 cited in Azadi et al., 2011), this in turn results in higher soil aggregate stability (Maeder et al., 2002 cited in Azadi et al., 2011) thanks to the fact that the micro and macro fauna are no longer killed by pesticides and can do their job of airing and feeding the soil (Nigli et al., 2007 cited in Azadi et al., 2011). Furthermore, the macro and micro fauna of the soil enables for a better water infiltration, drainage and water holding capacities (Giller et al., 2003 cited in Azadi et al., 2011); this in turn means that the soil and the crop growing in it will benefit from better resistance to water stress and drought (Müller and Davis, 2009 cited in Azadi et al., 2011).

II.5.2. Water

Only 1% of the entire world's freshwater is accessible for direct human uses (FBP, 2011 cited in Azadi et al., 2011), of which 70% is devoted to irrigation agriculture (UNESCO 2003 cited in Azadi et al., 2011). Today, some countries use up to 85% of their diverted water resources into agriculture with the urban and industrial usage increasingly competing against this pattern. As such, the need for improved practises regarding water, soil and crop management is becoming increasingly urgent, particularly with climate change threatening to have unforeseen effects (Pretty et al., 2010).

Due to a higher soil organic matter content in organic soils, crops are less dependent on irrigation (Fan et al., 2005), which saves not only water but also the energy required to irrigate large plots of land (Schnepf, 2004 cited in Azadi et al., 2011). This increased water efficiency in organic systems is especially useful to small-holders in developing countries (Azadi and Ho, 2010) where energy infrastructure are lacking (Tharakan et al., 2007 cited in Azadi et al., 2011) and where drought and an uncertain access to fresh water reserves threatens yields on a continuous basis (Ziesemer, 2007 cited in Azadi et al., 2011).

II.6 The biodiversity issue

II.6.1. Farming versus biodiversity

Agriculture accounts for the dominant land use in most of Western Europe and a significant portion of European biodiversity is linked to this habitat (Robinson and Sutherland, 2002). The second half of the twentieth century has witnessed a never seen before revolution of agricultural practices which surpassed all previous agricultural innovations (Blaxter and Robertson, 1995 cited in Benton, Vickery and Wilson, 2003). It is commonly admitted today that technological and economical incentives and subsidies to increase production in post-war Europe and North America over the past 60 years have led to a fierce intensification of agriculture which in turn, brought about a decrease in farmland biodiversity (Gardner, 1996 and Krebs, 1999 cited in Benton, Vickery and Wilson, 2003).

This occurred because agriculture has been responsible for converting massive amounts of natural habitats such as forests and wetlands, into agricultural land. Farmland which was used by many species as habitat and hunting grounds has also been affected by this loss of heterogeneity at multiple temporal and spatial scales (Benton, Vickery and Wilson, 2003). This is verified across many different taxa (Benton, Vickery and Wilson, 2003; Green et al., 2005). However, data for many taxa is still too scarce to make a comprehensive assessment of the factors involved; habitat reduction was important in the 1950s and 1960s whereas habitat quality is probably more pregnant today (Robinson and Sutherland, 2002). For example, since the beginning of the 1980s, ten species of bird farmland have declined by ten million breeding individuals in the United Kingdom (Krebs, 1999 cited in and Benton, Vickery and Wilson, 2003) and there is evidence of similar declining rates throughout most of Europe (Donald et al., 2001 cited in Benton, Vickery and Wilson, 2003) and for many farmland species (Hole et al., 2005). Green, Cornell, Scharlemann and Balmford (2005) even argue that farming in now known as the greatest extinction threat to birds. A study conducted by Harris et al., (1995 cited in Robinson and Sutherland, 2002) concluded that the most common cause of mammal population changes are habitat change (48 per cent), followed by the use of chemicals (38 per cent, mostly bats and rodents) and lastly deliberate killing (28 per cent). As such, agricultural intensification and expansion is one of the biggest threats to worldwide biodiversity (Hole et al., 2005).

Natural habitats on agriculturally usable land have been reduced by more than 50 per cent today (Richards, 1990 and FAOSTAT, 2001 cited in Green, Cornell, Scharlemann and Balmford, 2005) and a significant portion of what is left has been altered by temporary grazing. This agricultural intensification and loss of biodiversity has in turn led to the degradation of so-called 'ecosystem services' as well as increasing the production of greenhouse gases and a lessening of the level of carbon sequestration in soils (UNEP, 2010 cited in Pretty et al., 2010).

Agricultural intensification means fields have becoming progressively devoid of biodiversity as non-crop plants have become increasingly less tolerated. This was achieved through a monotonic evolution of farming practices with yield increases brandished as sole goal and motto. However, it is very difficult to attribute causal relationships to various combinations of factors and simple correlations are likely to be misleading (Robinson and Sutherland, 2002).

However, many agree that this agricultural intensification has resulted in the biological simplifications of the agricultural landscape and even the creation of semi-artificial ecosystems that require systematic human intervention to regulate their own internal functions (Altierri, 1999 cited in Hole et al., 2005).

Non-cropped areas on farmland increase and maintain biodiversity in significant numbers for wildlife so diverse as weeds (Boatman, 1984, de Snoo, 1999 and Baudry, 2000 cited in Benton, Vickery and Wilson, 2003), insects (the presence of hedges affect beetles population up to 1 km away) (Dover et al., 2000 cited in Benton, Vickery and Wilson, 2003), spiders (Haughton et al, 1999 cited in Benton, Vickery and Wilson, 2003) and by supplying habitats for birds to nest and forage in (O'Connor and Shrubb, 1986 cited in Benton, Vickery and Wilson, 2003). However, agrochemicals affect vegetation structure and the biodiversity related to it, as well as invertebrates and vertebrates (Rands, 1986, Andreasen et al., 1996, Haughton et al., 1999 cited in Benton, Vickery and Wilson, 2003). Increased use of pesticides has led to species-depauperate plant and invertebrate communities (Wilson et al., 1999 cited in Robinson and Sutherland, 2002), which in turn affects the species higher up the food chain. As such, populations are less likely to be resilient to chemical controls in reduced habitat heterogeneity (Lee, Menalled and Landis, 2001 cited in Robinson and Sutherland, 2002). As an example, when Spain and Portugal joined the EU in 1986 and started receiving Common Agricultural Policies (CAP) subsidies, the intensification of their agriculture negatively impacted their wildlife in major ways (Suàrez, Naveso and the Juana, 1997 cited in Robinson and Sutherland, 2002). Today the adverse impact of agriculture on wildlife is set to increase, particularly in developing countries (Green, Cornell, Scharlemann and Balmford, 2005).

II.6.2. Wildlife-friendly or land-sparing farming?

Pretty et al. (2010) argue that two main choices or a combination of them both are available to us when trying to increase food production while minimising its impact on biodiversity, society and ecosystem services: a production increase in areas which are already farmed, so called 'wildlife-friendly farming' which advocates more extensive farming practices and provides more habitat for wildlife but which may decrease yields, or 'land-sparing farming' which strives to increase yields in fields to leave as much land as possible untouched (Green, Cornell, Scharlemann and Balmford, 2005).

Wildlife-friendly farming advocates the retention of patches of natural habitat and semi-natural habitats in the countryside as well as methods of farming which minimise the adverse effects of agro-chemical inputs on non-target organisms (Estrada, Coates-Estrada and Meritt, 1997; Estrada, Coates-Estrada, Dadda and Cammarano, 1998; Pain and Pienkowski, 1997; Daily, 2001, and Rosenzweig, 2003 cited in Green, Cornell, Scharlemann and Balmford, 2005). It has been frequently reported that biodiversity decreases when yields increase (Pain and Pienkowski, 1997; Krebs, Wilson, Bradbury, 1999 and Donald, Green and Heath, 2001 cited in Green, Cornell, Scharlemann and Balmford, 2005), which puts forward the assumption that the prospect of high yields must be foregone. Some agri-environmental schemes to protect wildlife owe their existence to the fact that farmers receive heavy monetary compensation for lost production, illustrating how real these 'yield penalties' are (Green, Cornell, Scharlemann and Balmford, 2005).

Land-sparing considers that wildlife-friendly farming necessitates more farmland to achieve sufficient production targets. Farmland usually hosts fewer species than the surrounding, relatively intact habitats. As such it is best to increase yields on the surfaces already devoted to agricultural production, and thus reduce the need to convert more. Land-sparing could, in theory, even spare former farmland and allow it to be restored to its original function (Green, Cornell, Scharlemann and Balmford, 2005). Waggoner (1994 cited in Connor, 2008) claims that "the world needs a highly productive agriculture that can save as much land as possible for nature". As such, he argues that if global average yields were raised to the levels currently achieved in North America, a significant amount of land could be spared (Waggoner, 1995 cited in Green, Cornell, Scharlemann and Balmford, 2005). This is only true of course if this 'freed up' land is not used for another human activity which would be unfavourable to biodiversity (Green, Cornell, Scharlemann and Balmford, 2005).

These arguments clash with studies finding that (animal) species abundance and/or richness tend to be higher on organic farms than on conventional ones and this across a wide-range of taxa. It is particularly interesting to note that many species known to have suffered from decline because of past agricultural intensification are much more present on organic farmland (Hole et al., 2005 and Azadi et al., 2011). Organic fields usually display higher weed abundance and species richness than their conventional counterparts, regardless of the crops being grown. In addition, organic fields hold a considerably higher number of rare and/or declining species (Hole et al., 2005). It is likely that aquatic ecosystems benefit from organic farming too as by definition, it avoids using pesticides and soluble inorganic fertilisers, thus preventing any leakage into waterways. It is also likely that organic farming practices reduce nitrate leaching which adversely affect water quality (Stolze et al., 2000; Unwin et al., 1995 cited in Hole et al., 2005). As such, organic farming can certainly play an important role in the preservation and enhancement of biodiversity across lowland farmland throughout Europe (Hole et al., 2005) but is not a silver bullet. Interestingly, a conventional farm can achieve the same levels of biodiversity as the ones generally found on organic farms (although this remains rare), through the implementation of specific management practices. This demonstrates that an increase in biodiversity can be the result of targeted changes in management rather than a 'whole farm effect' (Anon, 1999 cited in Hole et al., 2005).

However, today general knowledge about the long-term impacts of organic farming in pastoral and upland farming is still limited (Hole et al., 2005). It remains unclear whether organic or other holistic farming methods provide biodiversity with greater benefits than carefully dosed and targeted conventional methods (including using agro-chemical products) on small areas of cropped and non-cropped areas (Hole et al., 2005). In principle, all agricultural practices (including use of agro-chemicals, rotations, management of non-crop habitat etc...) can be tailored to help increase rather than annihilate heterogeneity and biodiversity within individual fields and into whole landscape. However, biodiversity is also influenced by important factors such as location, climate, crop-types as well as management practices on the farmland. As such, the attitude and beliefs of individual farmers is extremely important as they are the ones to decide on and carry out land management practices (Greenwood, 2000; Shepherd et al., 2003 cited in Hole et al., 2005). The reality of the marketplace also dictates in part these farming practices (Hole et al., 2005).

It remains that habitat heterogeneity is linked to higher levels of biodiversity on farmland on both small and large scales (Benton, Vickery and Wilson, 2003). This is especially true since different species have different habitat requirements and the more an un-cropped areas of farmland is complex and diverse at all spatial scales, the more taxa will be able to use it (Part and Soderson, 1999 cited in Benton, Vickery and Wilson, 2003). Furthermore, fragmentation of habitat is extremely damaging to biodiversity (Hughes, Daily and Ehrlich, 2002 cited in Green, Cornell, Scharlemann and Balmford, 2005) and should therefore be avoided as much as possible.

As such, promoting heterogeneity on large, continuous strips of farmland is a universal management solution that could be widely applied across many agricultural systems (Benton, Vickery and Wilson, 2003) and which is somewhat less drastic than *en masse* conversion of agricultural land to organic farming.