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Abstract

Sustainable food production and consumption is fundamental to the achievement of the worldwide UN Sustainable Development Goals. For a food system to be sustainable, it needs to provide adequate nutrition and food security while ensuring that all the conditions necessary for food security and adequate nutrition of future generations are not compromised. Among all economic sectors, food has the most significant impact on the environment, especially with regards to animal products, and meat in particular. Thus, dietary choices, and the levels of meat consumption specifically, have a heavy impact on the use of global resources, making the adoption of more sustainable diets very relevant worldwide. This also makes a fitting case for *wicked problems*, characterized by a considerable scientific uncertainty, non-linear development and lack of consensus, and for which solutions can only be developed as "better or worse". The objective of this work is first to contribute, with evidence from data analysis, to an increasing awareness of how meat consumption impacts environmental resources globally and why it should be considered a wicked problem that should be managed adequately. The second aim is to investigate the status of action and awareness in civil society regarding the environmental impacts of meat, and to assess the potential of academia to foster change.

For the first part of the analysis, the main input was quantitative data from the statistical database of the Food and Agriculture Organization (FAO). Three different indicators considering the amount of land required for animal products production, the amount of (beef, poultry and pig) meat eaten per capita per year, and the number of animals slaughtered per capita per year were analyzed through a statistical converge assessment. The timeframe of the analysis was 1961-2009. Open-source data from Terra-i and PRODES added information on specific aspects related to land use. The first results underlined the fact that meat consumption is already converging globally, with slight decreases in consumption levels in a few Western countries, but major increases in some developing countries. While the number of animals slaughtered per capita has decreased in Northern America, Oceania, and Southern Europe during the last decade, the global average has more than tripled, due to significant increases in Eastern Asia, Central, and South America, especially as regards poultry meat: such developments have resulted in an overall decrease of consistency equal to 260%. Overall, the results supported the hypothesis that different regions are progressing towards the same patterns of meat consumption at different speeds. In a case example, the data concerning land use in the biodiversity hotspot of Madre de Dios in Peru showed how deforestation is driven by the demand for meat; with a considerable percentage of the forest being converted to permanent meadows and pastures, with a noteworthy correlation between the amount of forest cleared and the distance from road infrastructures. It can therefore be concluded that if alternative and more sustainable agricultural practices (including agroforestry)

were to be introduced throughout the region, there would be a much greater prospect for biodiversity conservation.

The second part of the analysis was carried out as a review of existing food policies and dietary guidelines worldwide, including a literature review and data available from the FAO database. A semi-structured questionnaire was also used to assess the potential role of academia in fostering the change towards more sustainable diets. The review showed that awareness and policy action concerning the impact of meat consumption on environmental resources is relatively scarce. It can be argued that this general lack of policies and supporting guidelines related to sustainable diets hinders a more consistent awareness in civil society concerning the relevance and urgency of this matter: as earlier research has shown, currently, the majority of people still struggle to see the connection between the reduction of individual meat consumption levels and global environmental benefits. This thesis concludes that, when looking at meat consumption as a wicked problem, it then becomes evident that a more widespread cooperation among all sectors and stakeholders would be key to bringing about a significant change, and academia could have a more relevant role in this sense. Participatory and action research approaches in academia could contribute to the adoption of sustainable diets, particularly with regard to reducing meat consumption. The thesis, furthermore, discusses how serious and urgent it is to reduce the environmental impacts generated by meat consumption, and how academia could act as an example for the rest of society.

Tiivistelmä

Globaalisti kestävälle pohjalle rakentuva ruokajärjestelmä on yksi keskeisimpiä tekijöitä YK:n kestävän kehityksen ohjelman tavoitteiden saavuttamisessa. Kestävä ruokajärjestelmä takaa kaikille riittävän ravinnon saannin, sekä ruokaturvallisuuden, kuitenkaan vaarantamatta näiden reunaehtojen toteutumista myös tulevilla sukupolvilla. Eri talouden aloista juuri ruoalla on merkittävin vaikutus ympäristöön. Eläinperäisten tuotteiden, erityisesti lihan, merkitys korostuu ruoantuotannon sekä -kulutuksen ympäristövaikutuksia tarkasteltaessa. Ihmisten ruokavalioihin liittyvät valinnat ohjaavatkin ruoantuotannon hyödyntämien resurssien käyttöä globaalissa mittakaavassa. Erityisesti lihan osalta kestävämpiin tuotanto ja kulutuskäytäntöhin siirtyminen on ensiarvoisen tärkeää niin paikallisella kuin globaalillakin tasolla. Lihantuotantoon nojaavaa ruokajärjestelmää koskevat haasteet ovat oiva esimerkki *pirullisesta ongelmasta*, jota leimaa tieteellinen epävarmuus, epälineaarisuus sekä konsensuksen puute. *Pirulliselle ongelmalle* ei ole yksiselitteisiä, ”oikeita tai vääriä” vastauksia.

Tämän työ tarkastelee empiirisesti lihan kulutuksen vaikutuksia ympäristöresurssien käyttöön globaalissa mittakaavassa. Edelleen työssä perustellaan miksi nykyistä ruokajärjestelmää koskevia haasteita on syytä lähestyä *pirullisina ongelmina*, jotta niitä osataan hallita asianmukaisesti. Toiseksi tavoitteena on selvittää, millä tasolla lihankulutuksen ympäristövaikutukset tiedostetaan sekä kansalaisyhteiskunnassa että käytännön ruokapolitiikassa eri puolilla maailmaa. Työssä myös hahmotetaan akateemisen kentän mahdollisuuksia toimia muutosta tukevana voimana matkalla kohti kestävämpää ruokajärjestelmää.

Työn ensimmäisessä, kvantitatiivisessa osassa hyödynnettiin Food and Agriculture Organization (FAO) ylläpitämää tietokantaa. Analyysissä tarkasteltiin lihantuotannon sekä -kulutuksen globaalia kehitystä 1961 – 2009. Käytetyt kansalliset indikaattorit koskivat eläinperäisten tuotteiden tuotantoon käytettyä pinta-alaa, vuotuista asukaslukuun suhteutettua teurastettujen eläinten määrää sekä vuotuista naudan-, sian- ja linnunlihan kulutusta henkeä kohden. Analyysi suoritettiin käyttämällä statistical converge assessment. Lisäksi maankäyttöä koskevia tietoja täydennettiin Terra-I ja PRODES tietokantojen datalla. Tuloksista havaittiin, että kokonaisuudessaan lihan kulutus on kasvanut merkittävästi: vaikka joissain länsimaissa kulutus on hieman vähenynyt, niin vastaavasti kehittyvissä maissa, kuten Kiinassa, kulutus on usein noussut huomattavasti. Myös teuraaksi päätyneiden eläinten globaali keskiarvo on kasvanut yli kolminkertaiseksi viimeisen 10-15 aikana. Kasvu selittyy pitkälti Itä-Aasian sekä Keski- ja Etelä-Amerikan kasvaneella siipikarjan kulutuksella, jossa teurastettujen eläinten määrä on kasvanut 260 %. Pohjois-Amerikassa, Etelä-Euroopassa sekä Oseaniassa määrät ovat sen sijaan vähentyneet. Kaiken kaikkiaan tulokset tukivat hypoteesia siitä, että lihan tuotanto- ja kulutuskäytännöt ovat globaalisti tarkasteltuna

yhdenmukaistumassa vaihtelevin nopeuksin alueesta riippuen. Case tutkimus biodiversiteetiltään monipuolisen Perun Madre de Diosin alueen maankäytöstä toi esiin, miten kasvava lihan kysyntä on yhteydessä metsien häviämiseen. Tuloksista havaittiin, että suuria osia metsää on muutettu pysyvästi laiduinmaiksi sekä niityiksi, hakkuiden korreloidessa merkittävästi tieverkon etäisyyden kanssa. Onkin selvää, että vaihtoehtoisten, kestävämpien maanviljelykäytäntöjen käyttöönotto parantaisi huomattavasti alueen biodiversiteetin suojelumahdollisuuksia.

Lihan tuotanto- ja kulutuskäytäntöjen lisäksi tässä väitöksessä vertaillaan vallitsevia ruokapoliittisia linjanvetoja sekä virallisia ruokasuosituksia. Tämä globaali vertailu suoritettiin hyödyntämällä keskeisiä kansallisia ruokapolittisia ja ravintosuosituksia koskevia dokumentteja sekä FAO:n tietokannan tietoja. Lisäksi alan opiskelijoille tehdyn puolistrukturoidun kyselyn perusteella arvioitiin akateemisen yhteisön potentiaalia kohti kestävämpiä ruokavalioita suuntautuvan muutoksen fasilitoijana. Vallitsevan ruokapolitiikan sekä ravintosuositusten vertailu osoitti, että lihankulutuksen ympäristövaikutusten tiedostaminen sekä huomioiminen käytännön toimissa on globaalilla tasolla verrattain vähäistä. Kestävien ruokapoliittisten linjanvetojen sekä käytännön ohjenuorien puutteen voikin nähdä esteenä ongelman mittakaavan sekä kiireellisyyden laajemmalle tiedostamiselle – myös aiemman tutkimuksen mukaan tällä hetkellä suurin osa ihmisistä ei nää yhteyttä yksilöllisen lihankulutuksen vähentämisen sekä globaalien ympäristöhyötyjen välillä. Lihankulutusta olisikin syytä käsitellä *pirullisena onglemana,* jolloin olisi helpompi tunnistaa, että entistä laaja-alaisempi yhteistyö keskeisten sidösryhmien kesken on avainasemassa muutoksen aikaansaamisessa. Edelleen myös akateemisella yhteisöllä voisi olla aiempaa keskeisempi rooli kestävämpien ruoankulutuskäytäntöjen omaksumisessa esimerkiksi toimintatutkimuksen kautta. Lisäksi väitöskirjassa pohditaan, kuinka kiireellinen asia lihankulutuksen vähentäminen ympäristön kannalta on, ja miten akateeminen kenttä voisi toimia esimerkkinä yhteiskunnan muille osa-alueille.

Acknowledgements

It all started in my grandfather's vegetable garden, on a sunny, summer afternoon: I walked to the tomatoes, picked up a ripe one, and ate it on the spot. The feeling of that warm, tasty and juicy fruit has stayed with me since then. I was probably 5 or 6 years old at the time, but farming had already begun to fascinate me. I have been lucky enough to obtain most of my vegetables from that same vegetable garden for many years, and to witness my grandfather working that plot of land with his rugged hands and his own father's tools.

Many years have passed since that summer and much has happened in between, but my fascination has stayed the same and thus dealing with food and agriculture on a global scale in my PhD feels like the natural outcome of a process that had already started in my childhood: the connection with the soil is in my genes and I feel privileged to have the chance to do research on issues that I am so passionate about.

My grandfather has always been one of my greatest supporters and I wish he was still as bright as he used to be, so that he could understand the content of my work. He has taught me what it means to do your part, work hard and be proud to have always tried your best. Finishing my PhD has been a daunting task, and there have been many times when frustration took over and led me to think I was better off giving it all up. I owe it to many people that I did not, starting with my supervisor Professor Risto Kalliola who listened, read, and commented on everything that lead to this manuscript, my colleagues at the Finland Futures Research Centre, especially Professor Jyrki Luukkanen and Dr. Jarmo Vehmas for their teachings and support. Thanks to Dr. Hardi Auffermann for leading the Suomen Akatemia project in which my PhD started. Thanks to Dr. Tahdg O'Mahony for the fun shared at the office. Thanks also to Professor Sonia Massari for setting a positive example, for her guidance in co-authoring two of the publications included this dissertation. Thanks also to Dr. Markus Vinnari for being not only a co-author but also an antagonist pushing my limits (patience included). Thanks to Professor Domenico Dentoni for looking at a very early and incomplete version of this manuscript, and giving precious feedback. I extend my sincerest thanks to the preliminary examiners of this dissertation, Dr. Annika Carlsson-Kanyama and Dr. Johanna Mäkelä for their constructive feedbacks and suggestions. My gratitude is extended to my distinguished opponent Professor Idil Gaziulusoy: her innovative research approach, as well as her strength and passion, are what makes it an honor to have her as my opponent. I also gratefully acknowledge the funding from Suomen Akatemia and University of Turku received to support the first part of this research and the completion of this thesis respectively. The Barilla Center for Food and Nutrition, as well as ArBio and other smaller cooperations carried out alongside to my academic research, have also

contributed in broadening my perspective on food sustainability issues, which I believe brings an added value to this work.

On a more personal level, much has happened in conjuction to this PhD process and I owe getting it done also to the "sisu" I have gained while living in Finland, but for sure I owe it also to my grandfather and to everything I witnessed happening in that greengarden many years ago. He worked hard all his life, but despite having had to give up school at an early age, he has a genuine curiosity and he is never tired of learning. I believe pursuing a PhD is mainly about this: you need to be curious and eager to learn something new in order to keep pushing through the times you lack motivation or energy, you need to do it first of all for yourself, for your own yearning for knowledge and improvement, because it is only by becoming a better version of yourself that you can play a role in changing the world around you.

This would have not been possible without the many wonderful people that have been in my life during the past years. Very special thanks to my dog Mila for reminding me to play also on work days, to William for all the salsa and the appreciation of my pizza, to Henni and Pete for making me feel at home, to Alper for the 'technical help' on more than one occasion, to Oguz for our music, to Ville and Heikki for the times we went to take pictures together, to Giovanna and Jute for welcoming me in their family, to Jaakko for the ice-cream, the saunas and his patience with my Finnish, to Ilkka and Sanni for their friendship and for letting me watch Aapo grow, to Nina and Henkka for the walks in the forest and for treating me with a good dinner when I needed it, to Jenny for teaching me resilience, to Jonna for sharing this PhD journey until the end, to Anna for the 'food webinars', to Giuseppe for his help in many forms, to Henriikka for our discussions on the benefits of retirement, to Guido, Luca, Erica and Anne for every, invaluable time when they listened to me, to Francesca for answering all my phone calls, to Serena for finding a way to be close despite the distance, to Angela and Gianluca for their incredible support, to Juha for always being in my corner, to my uncle Gualtiero, my aunt Mariateresa, my cousins Silvia and Giorgia, and Alfredo and Giovanna for always being there when needed, and big thanks to my grandmother Tina and my mum for their endless understanding and encouragement through the hard times that, despite everything, we have faced together.

My hope is that the findings of my PhD, as well as the passion with which I continue to advocate and teach these topics, will contribute to making other people genuinely curious about our food system's dynamics and to fostering its change towards a more sustainable direction: it is only when you know and care about something, that you can change for it.

Contents

List of original articles

This thesis consists of summary, synopsis and the following articles that are referred to in the text by their Arabic numerals:

(1) Allievi, F., Vinnari, M. & Luukkanen, J. (2015). Meat consumption and production - analysis of efficiency, sufficiency and consistency of global trends, *Journal of Cleaner Production,* 92, 142-151.

(**2**) Recanati F., Allievi F., Scaccabarozzi G., Espinosa T., Dotelli G. & Saini M. (2015). Global meat consumption trends and local deforestation in Madre de Dios: assessing land use changes and other environmental impacts. *Procedia Engineering,* 118, 630 – 638.

(**3**) Massari S. & Allievi F. (2016). The Milan Protocol: Challenges and Promises for a Better Future. Food Studies. *Food Studies: An Interdisciplinary Journal*, 6(2),1-13.

(**4**) Allievi F. & Massari S. (2017). Non -formal Food Systems Education in On-campus Food Services: Challenges in Changing Policies and Food Industry. The Case of Meat Consumption. Manuscript.

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1. Introduction

This dissertation seeks to assess the wicked problem of global meat consumption and its use of environmental resources, and to highlight what role academia and research can play in tackling it. This research challenge is approached through four different articles, each of which aims at answering those specific aspects described in the following sections.

A *food system* consists of all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outcomes of these activities; namely nutrition and health status, socio-economic growth and equity and environmental sustainability (HLPE, 2014). From this definition, it is easy to understand how food is also a central issue for the achievement of Sustainable Development Goals (UN, 2015), as they reiterate the importance of sustainability as an overarching goal for food systems in the context of climate change and economic development (Whitmee *et al.,* 2015). More specifically, a *sustainable food system* (SFS) can be defined as a food system that ensures food security and nutrition for all in such a way that the economic, social, and environmental bases that generate food security and nutrition of future generations are not compromised. In Figure 1 a visual summary of this concept (adapted from Garrett and Feenstra, 1999) is presented. A food system, therefore, does not exist in isolation. It interacts with other systems such as health, energy, and transportation systems. A shock to one system, such as a natural disaster or conflict, can disturb another system. These systems are interlinked and in continual adaptive cycles of growth, restructuring, and renewal (Gunderson *et al*., 2012).

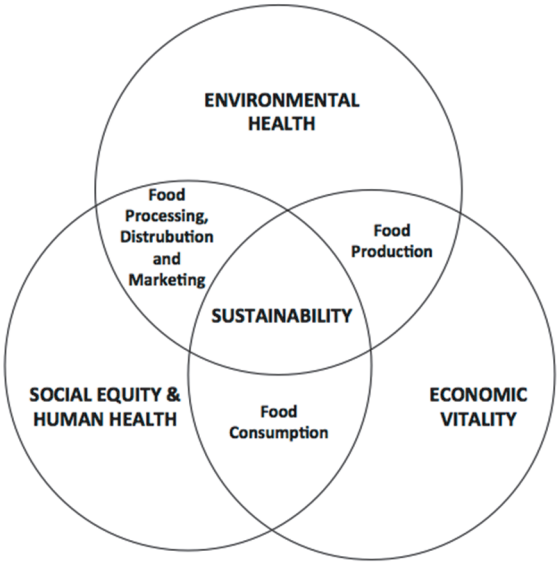

Figure 1: the sustainable food system

A large number of actors (or stakeholders) are involved in the food system and act together according to the dynamics created by specific drivers. These include biophysical elements and constraints, innovation and research, political and economic inputs, socio-cultural aspects, including food traditions, religious rules, and demographic issues. When scaling this picture to the regional, national, continental, and global levels, it becomes increasingly complex, creating a high level of uncertainty when trying to assess the interaction among its parts.

Among all the economic sectors, the one which results in the highest burden on the environment is food production, specifically food derived from animal products (Steinfeld et al., 2006). While each step of the food chain affects environmental resources, it is the agricultural stage which contributes the most to creating an environmental impact, with tangible effects in each of the environmental domains: air, land, and water. In each domain, the production of animal products and meat in particular, has the greatest impacts.

The amount of greenhouse gas (GHG) emissions which can be linked directly with the production of food is very large, and in particular the greatest contribution is that of the animal farming sector. The quotas which are found most often in literature vary according to how the calculations are carried out, but they range between 18% and 51% (Steinfeld, 2006; Goodland and Anhang, 2009). Food production also affects global water use: it has been calculated by the Water Footprint Network that on average as much as 92% of daily personal water use can be linked to food (Hoekstra and Mekonnen, 2012). This figure includes the *virtual water* which is the water used in each step of the

life cycle of food production, from the watering of raw ingredients, to the cooling of the packaging plant. While there is variation according to the production methods and the type of cattle feed used, the amount of water required, on average, for animal products is strikingly greater than that for the production of vegetables and fruits. Another very important environmental impact is the one related to land use. This has many forms, with the most straightforward being direct pollution of arable areas with, for example fertilizers and antibiotics, or through an excessive discharge of animal waste. Currently, as much as 80% of the available cropland worldwide is used for animal farming either to grow animal feed ingredients or as pasture (Steinfeld et al., 2006).

When such environmental impacts are taken into account, it becomes evident that dietary choices play a decisive role in the use of global resources. Therefore, the adoption of *sustainable diets* worldwide should be fostered, in order to lower their environmental impacts, increase their food security and nutritional value, and protect biodiversity.

After acknowledging the seriousness and complexity of the implications that the food system has for people and the environment, as well as the considerable number of stakeholders involved in the transition towards more sustainable diets, the need also arises for a theory able to handle and embrace this complexity. A number of the social issues are not only hard to define and solve, but also have high degrees of scientific uncertainty and lack of consensus, for which there are currently no correct or optimal solutions. Such issues are referred to as *wicked problems* (Rittel, 1973). Sustainability (and more specifically food sustainability) is one fitting case for wicked problems. First, it has no exact formulation for its meaning, therefore no exact solution for its achievement can be developed. Second, its solution can only be realized in the realm of "better" or "worse", suggesting that it is through the right balance of criteria from different fields that the use of resources can be steered towards a more sustainable direction. Third, different stakeholders will tend to define sustainability in a way that is more advantageous for them, with clear contrasts between for example NGOs and business people. Fourth, the interconnections that also characterize the current food system make it nearly impossible to define what a 'sustainable' food system looks like. Given how important the production and consumption of meat are in the context of food sustainability and how intertwined their consequences are on the environment and public health, the issue can be classified as a wicked problem, and will be dealt with from this perspective throughout this dissertation. Being a wicked problem, such an issue cannot be solved but only managed. In this sense, those research methods which are reflexive and adaptive to a changing society, should be encouraged, with action research playing a major role. Action research is defined as a participatory process, bringing together actions and reflections which aim at the development of knowledge useful to creating practical solutions to problems that concern people and their communities (Greenwood and Levin, 1998). Throughout this dissertation, I will present my personal experience

with this approach and how experiences outside academia have contributed to and shaped my research, for example by steering the focus towards the analysis of food policies.

In the analytical process presented here, the evidence from data concerning the global convergence towards the same levels and patterns in meat consumption, prompted the investigation of existing policies that could avert the inevitable collapse predicted to follow the current trends. Globally, food policies focus mainly on issues related to the excess of food (i.e. junk food taxation), food access, as in the case of food security policies, or food safety. Only four countries account for sustainability in their dietary guidelines, namely Brazil, Sweden, Qatar, and Germany (Fischer and Garnett, 2016), while a few other countries give, for example, specific recommendations on meat consumption levels (Finland and Iceland). In a few other cases, sustainability is discussed in the policies' supporting information. Australia and USA have attempted to include environmental concerns, but no endorsement from the government has been received. In countries such as the UK, France, the Netherlands, and Estonia quasi-official guidelines accounting for sustainability have been developed and potentially they could play a role in official processes too. More holistic approaches have been recommended for the development of policies for public health and the monitoring of their progress; these policies start from the evidence that improvements in both human and environmental health can be achieved simultaneously, no matter whether overconsumption or hunger are the main issues.

While a large room for improvement exists regarding dietary guidelines, they still represent a very relevant aspect of food policies and actions. The link between health and environmental targets represents an increasing interest stemming from civil society and academia. Universities and their campuses have both the responsibility and opportunity to be role models for the rest of society. This can be done by shaping students' values and consumption behaviors, as well as by implementing innovative projects (for example farm-to-college projects) and policies. Academia can also act as an incubator of principles and ideas, which can be disseminated through engagement with local communities, as well as through the implementation of these values by students and researchers in their lives outside the universities.

The scientific community has focused for several decades on the issues of climate change and its drivers, but it is only in the most recent years that research has focused specifically on the role played by the food system and dietary choices (Garnett, 2014; Aleksandrowicz et al., 2016). A growing body of research has identified how animal products, and especially meat, are the most relevant foodstuffs in respect of environmental impact (Macdiarmid, 2014). Action is needed in order to avoid the variety of problems caused by meat production and consumption becoming too great to

handle. The work carried out in this PhD contributes to this line of research, bringing evidence from both data analysis and policy analysis, with the aim of increasing awareness at all levels about the importance of our dietary choices for the continuation of human life on Earth; as well as assessing what role academia can play in tackling a global transition towards more sustainable diets.

Outlines of the articles

The first article aims at analyzing the consumption of animal products worldwide using the point of view of three strategies: efficiency, sufficiency, and consistency. While efficiency (usually linked with improvements in terms of technology) and sufficiency (connected with a reduction in production or consumption) have been traditionally used for describing changes occurring in the food system, consistency is suggested as an innovative yet necessary approach that accounts for the ethical dimension of food production as well. The analysis was carried out in the timeframe 1962-2009, in 140 countries, which were also divided into 10 regions, in order to have an analysis of the three aforementioned strategies done both at a regional and global level. The main results include an overall increase of efficiency of 13 percent in the time frame considered, and, a significant decrease in both sufficiency and consistency, equal to 91 and 264 percent respectively. A convergence analysis was also performed, revealing that developing countries are following the example set by industrialized areas, resulting in similar patterns of animal products consumption. Such a picture clearly describes why and how urgently measures should be taken for a food system that is efficient as well as ethically just.

The second article builds on the first one, by investigating how the global trends in meat consumption affect the environment, and in particular how they may be driving what is happening in terms of land use change in a highly sensitive area of the World. The region of Madre de Dios, in Peru, is used as a case study because it has a very high environmental value and, at the same time, is endangered by the Inter-Oceanic highway, a massive infrastructure connecting the coast of Brazil with that of Peru. On the Brazilian side, about 50 kilometers of rainforest have been cleared on each side and mainly converted into cattle ranching or monocultures. On the Peruvian side, the highway was only opened in 2011 and there is a risk that the neighboring areas of rainforest will undergo the same kind of development. Other economic activities in Madre de Dios (for example gold mining), threaten the correct estimation of the extent to which cattle ranching and monocultures affect deforestation: by recognizing the preliminary signs of the contribution of these two activities to local deforestations, the analysis in the second article provides the basis for a future more comprehensive monitoring work of local biodiversity loss and greenhouse gas emissions. For this paper, data from the FAO as well as remote sensing data from other projects is provided. Through the integration of trends in regional meat consumption and trading effects (which become increasingly

relevant with the new highway), the analysis highlights the risk that the global convergence in meat consumption greatly influences the deforestation which is currently ongoing in Madre de Dios; thus, underlining the relevance of connecting global and local analysis, as in the food system, global trends can seriously affect the most environmentally sensitive areas of the world.

The third article contributes to the policy discussion concerning food sustainability. As international cooperation is fundamental to tackling the present challenges to the food system, this paper presents an analysis of the state of the art of food policies worldwide. Furthermore, the case study of the Milan Protocol is investigated as an example of best practice for the development of policies through a bottom-up approach and a wider involvement of stakeholders. The Milan Protocol is constructed on three pillars: malnutrition and obesity, sustainable agriculture, and food waste. These themes are also at the core of the work carried out by the Barilla Center for Food and Nutrition Foundation, which has coordinated and promoted the work of the Milan Protocol. The guidelines described in the Milan Protocol also include some relevant policy suggestions related to meat production and consumption, such as an increased attention to animal welfare and directions for a more equitable allocation of land. This is in contrast to the other policies analyzed, where a general lack of meat-related policies and dietary guidelines was detected, with the exception of few countries. Furthermore, the Milan Protocol fundamentally contributes to the Milan Charter, a global food policy proposal resulting from EXPO, the universal exhibition on food issues that was held in Milan in 2015, and which will be further explained in section 3.2 of this dissertation.

The fourth article further investigates how food policies can be developed, by assessing what is the potential for contribution in this sense by higher education. Examples in literature show that universities, not only affect their students' behavior through educational programs and teaching methods, but they can also play a pivotal role in the communities that they belong to: consumption patterns can be changed and positive change in the food industry can be created through specific programs and policies aimed at improving the sustainability of food. As dining services are an integral part of life on campus, they are the starting point for an analysis of how academia can influence or be influenced by the food industry. Given that the literature analyzed dealt mainly with examples from the United States and Canada, this paper also aimed at answering this geographical gap by presenting the results of a dedicated questionnaire on food sustainability in higher education. The questionnaire was delivered to over 80 students and young researchers involved in food issues and belonging to the Barilla Center for Food and Nutrition Alumni Association. The qualitative analysis which derives from the experiences of this group also gives a picture of how sustainable diets are perceived by undergraduates, graduates, and post-graduates around the World. Given its relevance in terms of environmental impact, meat consumption is used as a case study to evaluate

how and if universities food services are responding to the increasing pressures on global resources.

In this thesis, I will summarize the main results of these journal articles (referred to by numbers 1-4 from now onwards) and present a further integration of the multifaceted environmental consequences of meat production, as well as an assessment of the existing food policies worldwide and how they are acting on the increasing levels of meat consumption. While the available tools and approaches to analyze this issue are many, here I will discuss the definition and concept of a *wicked problem*, with a particular focus on how it can be applied to the central topic of my analysis. This is in order to assess the role of academia and action research in tackling it.

2. Theoretical framework

2.1 Food production and consumption: the role of animal products in generating environmental impacts

Among all the economic sectors, the one which results in the highest burden on the environment is food production, specifically food derived from animal products (Steinfeld et al., 2006). While the whole food chain (including transportation, cooking and disposal of waste) affects environmental resources, it is the agricultural stage which contributes the most to creating an environmental impact, with tangible effects in each of the environmental domains: air, land, and water.

The amount of GHG emissions which can be linked directly with the production of food is very large, and in particular the greatest contribution is that of the animal farming sector. A consensus has yet to be reached regarding the exact share of emissions related to livestock raising, but the percentages most often found in the literature range between 18% and 51% (Steinfeld et al., 2006; Goodland and Anhang, 2009). The 18% value is the one most often cited and referred to: it was calculated as part of the report "Livestock's long shadow" edited by Steinfeld in 2006. While this report has set the foundation for the calculations of the greenhouse gas emissions of livestock production, and has played a major role in setting up the discussion on animal farming and the environment, the figures given by the authors have been debated by other authors in the 10 years since its publication. One of the most controversial publications in this sense is the one published by Goodland and Anhang of the Worldwatch Institute in 2009, in which a 51% of GHGs emissions linked to animal agriculture was reported as a result of their analysis. In that publication, the authors declare that a number of wrong assumptions and misleading calculations had been made by Steinfeld et al.; for example, they state that the breathing of the farmed animals themselves had not been included, while another of their arguments was that the data used by Steinfeld et al. (2006) was linked to a much lower level of meat consumption than the current one. Taking into account that Goodland and Anhang (2009) added an extrapolation of data from 2002 to 2009 to their calculations, it is possible that the figure might have changed even more since then. A more recent report by Gerber et al. (2013) published by the FAO, reports a figure of 14.5% of GHG emissions linked to the livestock sector, but there is no evidence of the remarks made by Goodland and Anhang having been taken into account. Nevertheless, even considering the multitude of accounting differences and assumptions, it is evident that the emissions from the food system make up one of the largest portions, even when compared to other economic sectors, and meat plays the most relevant role: in a study by Tukker and Jansen (2006), it was estimated that the emissions of greenhouse gases of food production are 31% of the total, surpassing those of heating (about 24%) and transportation (about 18%).

Moreover, it should be noted that the GHGs emissions from the agricultural sector are constituted mainly by CH_4 (52%) and N_2O (44%) (Baumert et al., 2005 – van Beek et al., 2011): these gases are far more heat absorptive than CO_2, respectively 21 and 310 times more. While differences occur worldwide concerning the proportion of agricultural emissions over the total national emissions, globally their weight is absolutely the most relevant and, given these characteristics, it is easy to imagine that an increase in GHGs emissions from agriculture would represent a very serious threat to the rise of the global temperature. If agricultural production, and more specifically livestock farming, is to grow as a consequence of the expected growth in population, this would result in an even more consistent amount of CH_4 and N_2O in the atmosphere. Such a scenario could only be avoided with a decoupling of emissions from agriculture and population growth (van Beek et al., 2011). In fact, even if production was intensified and the amount of emissions per unit of protein or product was reduced, the overall increased production would still result in higher GHGs emissions.

Water use is also heavily affected by food production globally: depending on the diet, up to 92% of personal water use can be linked to agricultural production (Hoekstra and Mekonnen, 2012). This figure results from the inclusion of *virtual water*, which is used in each step of the food production, from raw ingredients production, to the cooling of the packaging plant. While this share of water use changes according to different eating patterns (as the most water-intensive foodstuff is meat, a vegetarian or vegan diet would imply a lower impact in terms of water usage), it still gives an idea of just how large the amount of water is that is needed to produce the food we eat daily. Using Tony Allan's words *"Farmers are the water managers of the world. They manage the big water, the invisible 80-90% of all water used in the global economy*" (Allan, 2016). Such an aspect should not be overlooked, because the amount of water available globally for food production is limited. This idea was followed by Professor Arjen Hoekstra who developed it into the *water footprint*, a metric which enables the calculation of the amount of water used during the whole production chain of goods or services (Hoekstra and Mekonnen, 2012). In the 2000s, this concept grew in popularity and interest, including some large companies (e.g. Unilever and Coca-Cola), and in 2008 the Water Footprint Network was founded, with the aim of continuing research on how to make water use more sustainable globally. The Global Water Footprint Standard is now an internationally accepted methodology for carrying out a Water Footprint Assessment (more information is available at: http://waterfootprint.org/en/). According to this concept, water can be distinguished as being of three types: *green* (water from precipitation that is stored in the root zone of the soil and evaporated, transpired or incorporated by plants), *blue* (water that has been sourced from surface or groundwater resources) and *grey* (fresh water required to assimilate pollutants to meet specific water quality standards). The resulting water footprint will include proportions of each of these types, indicating the amount of water used, but also the volume of fresh water necessary for the assimilation of pollutants

generated in the production process. The calculation protocol adopted by the WFN also allows for the possible externalization of the water footprint to be taken into account; thus, increased international trades has put pressure on those countries exporting water-intensive goods, creating further problems for food security in these areas. Animal products are the food that requires most water in comparison with other types of food and while production methods and the type of cattle feed used vary and influence the amount of water needed, it is, on average, still considerably greater than the amount of water required for the production of most vegetables and fruits. Giving one specific example, the average water footprint (measured in liters of water over liters or kilograms of food) for beef is 15,415 (WFN, 2013), while it is 5,874 for lentils (Mekonnen and Hoekstra, 2010).

A clear impact of meat production on water resources can also be seen also in the so-called "ocean dead zones", which are the result of large scale animal farming, often referred to as Concentrated Automated Feeding Operations - CAFOs (Imhoff, 2010). Such type of animal farming is very popular in some regions, especially in the USA (for example, California and Idaho lead the industrial dairies sector, while Iowa and North Carolina have the highest concentration of swine CAFOs – Imhoff, 2010). The ocean dead zones are formed by untreated animal waste, which creates runoff from these CAFOs, reaches the water streams and then collects in the ocean. The animal waste is in such a high concentration that it overloads the water with nutrients, depletes the oxygen available in the water and results in lethal consequences on the pre-existing ocean ecosystem. The number and size of dead marine zones has doubled during each decade since the 60s (Diaz and Rosenberg, 2008), and currently they are concentrated mainly on the Eastern coast of the USA, in Northern Europe and in Southern China (NASA, 2008).

Another very relevant environmental impact of food production is on land, ranging from localized nutrients excess, to deforestation, and including the direct pollution of arable areas with fertilizers, antibiotics, or animal waste in excessive quantities. The side effects are many: if chemicals are used in large amounts, the result is sterile land which needs even more chemicals to be productive, thus leading to an endless cycle of chemicals use. This is a consequence of the green revolution, which allowed productivity to increase in areas of the world with limited access to food, but also led to large areas of cropland being entirely depleted of their organic matter and being constantly dependent on external inputs for continuous production. Moreover, such cultivation methods usually imply a widespread use of monocultures, which in turn leads to other sorts of environmental consequences, such as biodiversity loss and a strong reduction in CO_2 absorption. The initial increase in efficiency created by this heavily mechanized agriculture has peaked and seems to be declining, with the main crops worldwide having reached their peak in productivity (Khoury et al., 2014). Moreover, this is particularly evident in the amount of land being used globally for the production of animal products, which in the last decades has been constantly increasing. In the next chapter, a more in-depth analysis of the data

concerning the land requirements for animal products will be presented. The current debate on sustainable intensification, defined as a form of agriculture in which production is increased without adverse environmental impacts and without increasing the amount of farmland used (The Royal Society, 2009), should therefore be interpreted not as an exact model of production aimed only at increasing crops productivity, but as a broad goal to be achieved thanks to a mix of solutions. These solutions include adapting to the bio-physical, social, cultural, and economic characteristics of the area under consideration (Garnett and Godfray, 2012).

Land is affected by food production, also through the changes occurring in land use: often, forested areas are cleared to make room for fields and pastures, depleting the ecosystem services once associated with that same area. The focus of attention in this dissertation, is centered on meat production, with 80% of available cropland worldwide being used either for animal feed ingredients or pastures and hence linked to animal farming (Steinfeld et al., 2006). The problem is particularly evident in some areas of the world, including the Amazon rainforest, where the leading cause of deforestation is represented by meat production (Boucher et al., 2011). This is due to the amount of land converted to grazing areas for livestock, or to grow feed crops, which results in biodiversity loss and land degradation (Gerber et al., 2013). The Amazon rainforest is a unique ecosystem: it expands over nine countries in South America, for a total of 6 million km^2, making it the largest tropical forest in the World. It plays a fundamental role for the well-functioning of the whole planet, and the survival of the human species. For this reason, damages occurring in this ecosystem have an even greater impact than if they took place elsewhere.

During the last 40 years, deforestation in the Amazon due to human activities has been very relevant, and the trend continues. There exists a monitoring system called Terra-i, which provides vegetation and rainfall data with good spatial and temporal resolution, and over the period 2004-2011 it documented a deforestation equal to 14,159,913 hectares across the countries it encompasses (Article 2). While factors such as the demand for firewood and mineral exploitation all contribute to this, the one key driver for the magnitude of this phenomenon is the increased global demand for meat products, which leads to the expansion of monocultures and cattle-ranching. This process is further enhanced if access to the rainforest is made easier. For this reason, the introduction of new infrastructures is crucial; they influence negatively the forest adjacent to the roads, and such effects should be monitored carefully. A peculiar case is that of the Inter-Oceanic Highway, which connects the coast of Brazil with the coast of Peru (Fraser, 2014). This road has been functioning in Brazil for about 30 years, with devastating effects on the rainforest, which has been completely destroyed for about 50km on either side. The Peruvian side was completed only in 2011, and the risk is that the same development will take place there as well. Investigating the link between the changes in the global demand for meat products and the local deforestation, is key for a better

understanding of how global food trends influence precious and limited environmental resources, like biodiversity hotspots. While monitoring the Amazon as a whole is a daunting task, in a part of the analysis presented in this dissertation, a specific case study was considered. Among the regions in Peru, one of the most relevant in terms of environmental value and biodiversity rate is the region of Madre de Dios. For example, it is the area with the highest number of butterfly species in the world (Lamas, 1997). However, the ecological balance of this area of rainforest is now threatened by the aforementioned Inter-Oceanic Highway. In order to offer a sustainable alternative to the advancing deforestation caused by large-scale agriculture, a set of actions needs to be implemented, but some help can come from small scale initiatives that introduce environmentally, socially, and economically sustainable ways to live with the rainforest and the resources it offers.

From all the points raised so far, a clear picture of the multitude of impacts that the global food system has on the environment emerges. Understanding what has the greatest impact and how such impacts can be diminished is a priority in order to ensure that future generations are granted enough resources for their sustainment.

2.2 Sustainable diets: definition and impact on SDGs

There is a growing consensus regarding how the food system in use nowadays needs to evolve into a different form in order to address issues like climate change adaptation, food security, nutritional challenges, and its environmental impacts (Garnett, 2014); however, no consensus has yet been reached concerning which are the actions that need to be implemented. So far, less attention has been dedicated to changes in food consumption than improvements in production efficiency, and their contribution to attaining a more sustainable food system should be explored further.

The question then arises as to what are sustainable diets? The most common definition of sustainability is the one taken from the report “Our Common Future” (UN, 1987), but it still has different meanings for different stakeholders, with some only focusing on environmental concerns, and others also including health and ethical aspects, as well as economic issues, according to the “three pillars of sustainability” (Garnett, 2014b). For this reason, sustainable development is often represented as a triangle with social, economic, and environmental dimensions (Munasinghe, 1993; Rawles, 2010). All these three dimensions have close links with the food system, with meat production and consumption playing a relevant role (D'Silva and Webster, 2010).

A common definition of *sustainable diets* was reached at the International Scientific Symposium “Biodiversity and Sustainable Diets: United Against Hunger” organized

jointly by the FAO and Bioversity International in 2010. During this meeting, sustainable diets were defined as (FAO, 2010):

"those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources."

A global transition towards eating patterns that account for such a definition is a complex challenge. Previous research (Auestad and Fulgoni, 2015) reviewed the status of the research on sustainable diets and highlighted the need for cross-disciplinary research to address gaps and trade-offs.

Fischer and Garnett (2016) have identified the following three fundamental actions needed to foster the adoption of sustainable diets: i) account for power imbalances: an emphasis should be put on solving distortions due to subsidies and affordability, while ensuring support and fairer terms to smallholder farmers; also, transport and storage should be improved; ii) reduce food waste and losses (currently equal to about 33% of food production), which threaten food security and are linked also with the waste of environmental resources; iii) advocate for the need of dietary changes, as they still represent an untapped potential for the reduction of the environmental burden created by the food system, as assessed also in the Fifth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC, 2014).

In particular, this last point should be linked with diminishing the consumption of meat and dairy products in those societies where these are consumed in high quantities, as raising animals and growing feed crops for them has the highest environmental impacts (Macdiarmid, 2014; Weber and Matthews, 2008). On the other hand, when assessing this issue from a global perspective, it should also be taken into account that animal products can be a valuable source of protein and micronutrients, especially in areas where their supply is limited (Milward and Garnett, 2010). As geographical and contextual conditions vary greatly across the world, a comprehensive definition of how sustainable a certain diet is should span over a range of environmental, economic, and social indicators (Aleksandrowicz et al., 2016).

In fact, the implications of a widespread adoption of sustainable diets are much greater than a reduction in environmental impacts; such a societal transformation should also be linked to a number of Sustainable Development Goals (SDGs). These 17 goals came into force on 1st January 2016, as part of the 2030 Agenda for Sustainable Development, which was adopted by world leaders in September 2015 at the UN Sustainable Development Summit. Until 2030, the SDGs will see all countries focusing their efforts towards ending

all inequalities, fighting poverty, and tackling climate change. Issues related to food production and consumption, constitute an integral component of the SDGs, with six of these stating clearly how food is crucial for goals ranging from health to environmental protection goals: these are summarized in Table 1 (EIU, 2016).

Table 1: Overview of those SDGs most connected with food sustainability issues (adapted from EIU, 2016)

Sustainable Development Goal	Connections with food sustainability
SDG 2 - To end hunger and all forms of malnutrition by 2030	• Access to affordable and nutritious food • Food fortification and vitamin supplementation programs to needy populations
SDG 3 - To ensure health and well-being for all, at every stage of life	• Early years' nutrition education for mothers • Encouraging exclusive breastfeeding • Regulating marketing and sale of obesogenic foods • Public education campaigns on optimal diets
SDG 10 - Reduced inequalities	• Nutritional deficits in the early years of life can cause lifelong deficits such as stunting and impaired cognitive development, deepening inequality cycles as malnourished children are unable to participate in the labor force
SDG 12 - To ensure sustainable consumption and production patterns	• Sustainable use of arable land • Sustainable water management practices • Limiting agriculture-related pollution and emissions
SDG 13 - Take urgent action to combat climate change and its impacts	• Agriculture is both a cause of climate change, through the emissions it produces, and a victim as changes in temperature and rainfall impact crop growth and agricultural productivity
SDG 15 - To protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, and halt biodiversity loss	• Managing deforestation related to food and non-food activities, including livestock, soy, and biofuels • Lower use of harmful chemicals and related substances in agriculture

From the summary reported above, it is clear that sustainable diets are particularly relevant for the achievement of SDGs number 12, 13 and 15. However, the close link

between environmental and health concerns should not be forgotten. While the main benefits in environmental terms are largely linked to the amount of meat (especially from ruminants) and dairy products that are spared in consumption, such changes would most likely also be followed by health benefits too (Aleksandrowicz et al., 2016). Such a link is paramount in advocating for a transition towards sustainable diets globally and it also points out the need for new tools to monitor its progress, with one existing example being the Food Sustainability Index (EIU, 2016). The connection of food with many SDGs, also highlights how central an increased policy coherence would be for their achievement, so as to promote synergies. Traditionally, the governance of the food sector has had its main focus on agriculture, for example with research on the environmental impact of agricultural policies (Huttunen, 2015). However, some authors have called for a more comprehensive approach that would encompass the whole food system (Lang & Barling, 2012; MacRae, 2011), and this could prove to be beneficial also in this context.

2.3 Wicked problems: definition and applications

Given the complexity of our current food system, the great number of stakeholders involved, and the serious affects it has on both people and the environment, a theory to manage this complexity is needed. When considering today's society, a number of social issues, are not only hard to define and solve, but also have an indeterminate scope and scale. In the context of Geography, there are many human-environment problems characterized by high degrees of scientific uncertainty and lack of consensus, for which there are currently no correct or optimal solutions; nevertheless, planners and politicians are required to make decisions (Brown et al., 2010). Such *wicked problems* include global environmental and social changes such as human-induced climate change (Levin et al., 2012), global poverty and food insecurity (Dentoni et al., 2012), and biodiversity loss (Jentoft and Cheunpagdee, 2009). By definition, wicked problems "*cannot be solved but only managed*" (Batie, 2008) through a mix of actions that aims at the mitigation of the negative consequences of such wicked problems. The resulting process of implementation aims then at developing a new societal trajectory which moves towards a more desirable direction.

According to Rittel (1973), who was among those who initiated a formalization of wicked problems theory, ten characteristics can be used for their description:

1. wicked problems have no definitive formulation, as they can be similar but also discretely different in different geographic areas
2. every wicked problem is unique
3. as social, economic, environmental, and political qualities of a system are all interconnected, each wicked problem represents the symptom of another problem
4. success in solving wicked problems is difficult to measure because they influence each other and cross the boundaries of traditional design problemswhich have a clear definition
5. those involved in tackling wicked problems and designing solutions for them, must be fully responsible for their actions
6. their solutions can be classified as “better” or “worse” but not “true” or “false”: wicked problems should be approached by finding ways to improve them instead of solving them
7. no template or protocol can be followed, though past experiences can serve as a guide. When tackling a wicked problem, teams need to find the path as they progress
8. different explanations can be found for the same wicked problem, with the designer’s individual perspective playing a great role in the selection of the most appropriate one
9. as science is used to understand natural phenomena, strategies for wicked problems cannot be assessed through a scientific test
10. as solutions to wicked problems often require significant interventions which change the design space, they are a unique design effort, with almost no room for a trial and error process

To summarize, the three main characteristics associated with wicked problems are firstly, that they evolve in time, with little room for predictions (*dynamic complexity*), secondly, that there is no clear consensus among scientists on their assessment, a protocol of analysis is difficult to define given their non-linear nature (*knowledge uncertainty*), and thirdly, that they create strong divisions in terms of stakeholders’ perspectives and lines of action (*value conflict*) (Dentoni and Bitzer, 2015; Dentoni, Bitzer and Schouten, 2017; Ferraro, Etzion and Gehman, 2015).

When approaching wicked problems, Peterson (2013), suggests that two sets of outcomes need to be taken into account: system outcomes and process outcomes. *System outcomes* refer to the systems components (the economic, social, and environmental dimensions): all their trajectories need to be moved towards a more sustainable direction

in order for the system as a whole to be sustainable. *Process outcomes* instead, are related to stakeholders; their engagement in the process needs to allow change on the positive side while not halting development through their power of veto. If either of these outcomes is not accounted for correctly, sustainability cannot be ensured. Options to improve the system cannot be put into practice if stakeholders, for example, seek only regulation through governmental prohibition, or if, on the other hand, the debate results in an endless, unresolved process.

Some recent literature has also described features of *super-wicked problems* (for example, climate change) for which *"time is running out"* and *"those seeking to end the problem are also causing it"*, with policies considering only the present day and *"discounting the future irrationally"* (Lazarus, 2008; Levin et al., 2012). Given its characteristics, sustainability (and more specifically food sustainability) is one fitting case for (super) wicked problems theory. First, there is no exact formulation of its meaning, therefore no exact solution for its achievement can be developed. Second, its solution can only be realized in the realm of "better" or "worse": the most common definitions of sustainability refer to either the three pillars (economic, social, and environmental), or to the three Ps (Profit, People, and Planet), thus hinting that it is through the right balance of criteria from different fields that the use of resources can be steered towards a more sustainable direction. Third, different stakeholders will certainly tend to define sustainability in a way that is more advantageous for them, with clear contrasts between for example NGOs and business people. Fourth, the feedback loops that characterize the current food system make it nearly impossible to define what a 'sustainable' food system looks like (Peterson, 2013). Fifth, the environmental problems (already described in Chapter 2.1) connected with food production, and animal products in particular, highlight its urgency.

A summary of how the theory of wicked problems can be applied in the context of sustainability, and therefore also food sustainability, is reported in Table 2.

Table 2: Summary of wicked problem characteristics and criteria and how they apply to (food) sustainability issues.

Characteristics of a wicked problem*	Criteria for a wicked problem**	(Food) Sustainability
Knowledge uncertainty	No definitive formulation of the problem exists	Ideal definition lacks specificity and is reduced to a tagline, for example the triple (economic, social, and environmental) bottom line performance.
	Its solution is not true or false, but rather better or worse	One can never know whether (food) sustainability has been achieved. Only progress in its trajectory can be assessed.
Value conflict	Stakeholders have radically different frames of reference concerning the problem, and are often passionate in their position on the problem	Business strongly support economic outcomes. Environmental groups strongly favor environmental outcomes. Social justice groups strongly favor social outcomes, such as fair wages and equitable access.
Dynamic complexity	System components and cause/effect relationships are uncertain or radically changing	Many claims are made about what is a sustainable food system like (for example "local food systems are sustainable while global food systems are not"), but knowledge on what systems characteristics promote sustainability is unclear.

*from: Dentoni&Bitzer, 2015; Dentoni, Bitzer&Schouten, 2017; Ferraro, Etzion&Gehman, 2015
**from: Peterson, 2013

As the global population is projected to increase, it is estimated that the demand for those more environmentally intensive foods (meat and other animal products in particular) will escalate; thus, all stakeholders, from NGOs to policy makers, agree that a change is needed in our current food system, however, no agreement has been reached on what exact actions should be taken (Fischer and Garnett, 2016). As the production and consumption of meat is an important issue in the context of food sustainability and has numerous, intertwined consequences on the environment and on public health worldwide, it can be classified as a wicked problem, and will be dealt with from this perspective throughout this dissertation. The argument is that the definition of meat consumption as a wicked problem is crucial in order to develop a new approach to its management.

2.4 Action research as a method to tackle wicked problems

2.4.1 Action research: definitions and background

For wicked problems to be handled constructively, research methods which allow for adaptation and reflection are of uppermost relevance. Action research has thus the potential to be of key relevance in contributing to managing wicked problems, including food sustainability.

There is a mix of theoretical backgrounds on which action research is based, in some cases the origins are traced to indigenous traditions, or the work of Marx and Gramsci (Reason and Bradbury, 2007). However, action research (AR) is most commonly referred to as a concept first defined in the 40s by Kurt Lewin (1946), who developed it in the field of social democracy as part of his practice as a social psychologist. Moreover, he defined three consecutive actions for social change: unfreeze existing structures, change them and freeze them again in an improved version (Greenwood and Levin, 1998). Such an approach has become increasingly popular in the context of collective work aimed at changing the political or environmental constraints that influence the social condition of the community in which the researcher is involved. Action research has been found to be applicable in a number of settings, such as schools and businesses, where the interactions between teachers/managers and students/staff, can be seen to benefit. The starting point for AR can be a problem or a hypothesis, as well as a conflict or a specific concern, and it develops both through the action for improvement and through the research (data collection, theory generation and dissemination). Action research finds its application in a large range of fields, from practical concerns such as the environmental preservation of specific areas, to how non-ordinary realities are

experienced, and in disciplines varying from medicine or education, to psychological sciences (Reason and Bradbury, 2007).

Two definitions can be found in literature to describe its process:

"A form of collective, self-reflective enquiry undertaken by participants in social situations in order to improve the rationality, coherence, satisfactoriness or justice of their own social or educational practices, as well as the under- standing of these practices and the situations in which these practices are carried out." (Kemmis and McTaggart 1988:5)

A *"continuous and participative learning process…to create sustainable learning capacities and give participants the option of increasing control over their own situation" (Greenwood and Levin 1998:18)*

Action research is thus a participatory process, bringing together action and reflection, which aims at the development of knowledge useful to create practical solutions to problems that concern people and their communities (Reason and Bradbury, 2007). A number of variations exist in terms of how action research is implemented in practice, however, Reason and Bradbury (2007) have identified five recurring characteristics. First, AR aims at producing practical knowledge, which can benefit people in their daily life. Second, its broader purpose is to contribute to the improvement of the wellbeing of people and communities, and to a more sustainable relationship of humanity with the ecology of which it is part. Third, it is a participatory and democratic approach, as it can only be performed with, for, and by those people who can both inform the research and be targeted by its action (ideally with the contribute of all stakeholders). Fourth, AR is emancipatory because the knowledge it creates is an evolving process stemming from direct experience, rather than the result of a fast method, thus generating new ways through which such knowledge can emerge. Fifth, when action research is good, it is the result of an evolutionary and developmental process, with inquiry skills developing at the individual level and communities of practice developing communities of inquiry within themselves.

2.4.2 Action research: process and applications

Action research is set to bring a considerable contribution to the much-needed transition towards new ways of thinking. The Industrial Revolution and the beginning of the modern scientific era, put the basis for great increases in material welfare as well as increased control over human life, but this process has gone hand in hand with, for example, social fragmentation and ecological destruction (Reason and Bradbury, 2007). For (food) sustainability to become central to our society, it is necessary for a new evolution to occur through the challenge of creating opportunities for a new worldview.

This has been claimed as the most relevant task for humanity today, if we are to overcome those epistemological errors that result in negative consequences for justice and sustainability (Bateson, 1972). Such results can be achieved if we shift away from the vision that science is completely separate from everyday reality, and that progress is linear, as a result of rational planning (Harvey, 1990). The target of this transition should be to reach a participatory worldview characterized by a holistic and experiential approach, and one which considers humans as the co-creators of their world (Reason and Bradbury, 2007).

Webb (1991) codified the cycle that structures the action research method as a sequence of planning, acting, observing, and reflecting, and then the repetition of these steps. Each cycle stresses the action and subsequently the critical assessment (review of what happened in the previous cycle, plus planning of the actions for the next cycle) on the whole process and its outcomes (Melrose, 2001). While both quantitative and qualitative data can contribute to these cycles, the fact that change, improvement, and emancipation are emphasized in the process, makes AR more appealing to those researchers more interested in qualitative data than figures. Melrose (2001) has described how action research cannot be understood as repeatable and "rigorous" in a scientific sense, given how it is built on the values and perceptions of the participants; therefore, she also called upon the more experienced practitioners of AR to develop guidelines targeted at increasing rigor (with the meaning of being scrupulous, constant, ethical, defensible etc.) in action research, especially for the benefit of the postgraduate students and teaching staff that are becoming increasingly interested in this practice.

However, how can action research principles be integrated in governance mechanisms that can create change in today's society? One of the strategies that could contribute to tackling wicked problems, is multi-stakeholder partnerships (MSPs). This is an organizational form with an increasingly important role in global governance and in which public and private actors combine their efforts to reach a common approach to the same problem that affects all of them (Selsky and Parker, 2005; Roloff, 2008; Rasche, 2012). MSPs can be both formal (alliances, partnerships etc.) and informal (networks and interactions) (Russo and Tencati, 2009). Examples in the context of food and agriculture include the Water Footprint Network (cited also in section 1 of this dissertation), the Roundtable on Sustainable Palm Oil and the United Nations Global Compact (more information available at: http://www.rspo.org/about and https://www.unglobalcompact.org). In the context of meat production, examples of MSPs include the Brazilian Roundtable for Sustainable Livestock (GTPS) officially constituted in 2009. The GTPS members are, in the words of Eduardo Bastos, GTPS president, "committed to zero deforestation, with the creation of the conditions and forms of compensations to make it viable,". Another example is that of the Global Roundtable for Sustainable Beef (GRSB) formally established in 2011 and aimed at

advancing continuous improvement in the sustainability of the global beef value chain. GRSB also stimulates and supports the establishment of roundtables at a national level. Additionally, the Global Agenda of Action in support of Sustainable Livestock Sector Development is a multi-stakeholder partnership and it aims at catalyzing and guiding the continuous improvement of livestock sector practices towards a more efficient use of natural resources.

It has been discussed (Dentoni et. al, 2016) how further evidence is needed in order to increase the incorporation of a wicked problems perspective in the governance of MSPs, so that they can play a more relevant role in fostering significant changes in social, environmental, and/or environmental systems. Furthermore, the highly beneficial role that academics can play in MSPs has been highlighted in the results of a review of 41 MSPs (Dentoni and Bitzer, 2014), which present how academics can act as: i) knowledge experts – as they contribute with expertise from their own field; ii) agenda-setting advisors – as they help MSPs members to build a shared vision; and iii) facilitators – as they develop and implement a shared strategy. The importance of academics is further reflected in how they also affect the so-called "communities of practices" which are created around MSPs. In this context, they both develop new knowledge, through the integration of different scientific disciplines, and build bridges between MSPs and students, who will be the future leaders handling wicked problems (Dentoni and Bitzer, 2014). This also responds to the universities' fourth mission (Trencher et al., 2013), that of being an open system in relation to the surrounding environment, engaging municipalities, industries etc. and becoming "co-creators" of sustainability (Dentoni and Bitzer, 2014). Action research is thus becoming progressively more popular as a tool for PhD theses, with self-reflection and learning being important actions of the thesis development itself, and the postgraduate students being often the main driver and facilitator of the AR process (Melrose, 2001). In the Methods section, the application of this research method to this dissertation through my personal experience will be presented.

3. Methods

3.1 Overview of the Methods used

In this section, an overview is reported of the methods used to carry out the research questions addressed in the articles included in this dissertation. Moreover, the geographical coverage used in each case is also addressed.

Table 3: Summary of the research methods and geographical focus used in the dissertation articles

	Article 1	*Article 2*	*Article 3*	*Article 4*
Literature review	*x*	*x*	*x*	*x*
Action research		*x*	*x*	*x*
Meat supply statistical data analysis	*x*	*x*		
Land use statistical data analysis	*x*	*x*		
Convergence assessment	*x*		*x*	
Semi-structured questionnaire				*x*
Global geographical focus	*x*	*x*	*x*	*x*
Regional geographical focus	*x*	*x*		*x*

Table 3 summarizes the research methods used in the dissertation articles and how they apply to each article. The first article was based exclusively on statistical analysis and a literature review. The data concerning meat supply (including the number of animals slaughtered) were collected from the FAOSTAT database, while the database connected to the publication of Kastner et al. (2012) was used to obtain information concerning the land requirement of animal products. The population data was derived from the online Data Catalog of the World Bank. All the countries available in the FAOSTAT database were taken into consideration and arranged into ten regions, named Africa, Eastern Asia, South Eastern Asia, Southern Asia, Western Asia, Northern America, and Oceania, Central and South America, Southern Europe, and Western and Northern Europe. The first indicator chosen was the land requirement for animal products, which provided information on the progress in *efficiency* (defined as "the improvement of resources productivity" in Article 1) of the production of animal products. This was analyzed over the period 1962-2007. The second indicator analyzed is the most straightforward, namely the amount of meat per capita consumed in each region. As the exact amount of

consumption is not available, the per capita meat supply was used as a suitable proxy. In FAOSTAT the meat supply is defined as carcass weight, and takes into account the losses from production to household, but it does not include the waste of food after the retail level. The total meat supply per capita is useful in order to assess the level of *sufficiency* (defined as "the consumption of commodities and services in amounts that are just enough for ideal health" in Article 1) worldwide. This indicator was analyzed in the period 1962-2009. The third indicator, also analyzed in the timeframe 1962-2009, is the number of animals slaughtered per capita per year. This has not been used in literature before, but brings the ethical dimension of *consistency* (defined as "consistent views of the way we treat humans and other animals", with the implication that humans would turn towards vegetarianism, according to what discussed in Article 1) into the discussion. The results of these three indicators have been analyzed separately but also as a whole, by assessing their convergence. Moreover, in this case, different points of view have been considered, as three types of convergence, namely sigma, beta and gamma have been analyzed. Beta convergence indicates the speed of convergence, and was calculated using a specific regression equation (Article 1), for each of the three indicators considered in this analysis. In the case of sigma-convergence, the calculation was performed among the ten regions, by assessing the standard deviation of each of the three indicators. By calculating the coefficient of variation, gamma-convergence was assessed: for this purpose, the sigma-convergence, or standard deviation, of each year was divided by the mean of the values of each indicator for each year.

The Literature review concerned the theoretical framework of efficiency, sufficiency, and consistency, as well as the statistical background on the convergence analysis.

Elements of action research, which will be explained in detail in the next chapter, started to emerge in parallel with the development of Article 2, due to my personal involvement with a sustainable agriculture and productive conservation project in the Amazon rainforest in Peru (Madre de Dios region); this will be described in detail in the next section. Being part of that project allowed me to focus the efforts of Article 2 on the analysis of meat supply and land use data specific to South America and Peru, through an analysis of the trends in meat consumption and production in Peru and South America, and a comparison with global values. Data was obtained from FAOSTAT database, for the timeframe 1961-2011. A preliminary analysis of the land-use changes was also carried out with the aid of open-source data, including values reported in FAOSTAT, Terra-i and PRODES databases (see Article 2 for complete References). In the future, the analysis could be further developed by adding more accurate field data. The meat dependency ratio (calculated as the share of imported meat in the corresponding meat supply), was also assessed for each meat type and for both South America and Peru.

The process, using an action research mindset, also continues in Article 3, as it deals with the Milan Protocol, a food policy action in which I played a very active role, by participating in the working group on sustainable agriculture policies. In Article 3, the literature review deals mainly with the status of food policies worldwide (thus including the grey literature), while the convergence assessment was targeted at their qualitative analysis in order to find a common direction in an increasingly multi-polar world. In Article 4, the method of action research was applied because the recipients of the semi-structured questionnaire that contributed to the analysis were the members of the Alumni Association of which I have been the President since the beginning of 2016; this presents perhaps the most evident and practical element of action research in this dissertation. In Article 4, the literature review deals with the topics of non-formal education in universities and how such projects affect the services and communities linked to them, with a focus on how meat consumption is dealt with. A review of the sustainable food services offered in a selection of universities in the United States was also performed.

A global geographical focus is common to all the articles presented here. In Article 1, data from 140 countries was included in the analysis and part of this data was also used to frame the regional and local analysis in Article 2. In Article 3, a global focus was kept as food policies from all over the world were taken into account, while in Article 4, the questionnaire was submitted to respondents from all continents and the literature review was performed at a global level. However, a regional or local focus was also key at different stages of the work presented here: in Article 1 the 140 countries included in the assessment were further grouped into 10 regions and each region was analyzed singularly; in Article 2, the global trends of meat consumption were the starting point in order to focus attention firstly on the region of South America and secondly on the national situation in Peru; a special focus on the region of Madre de Dios was also the object of the analysis. In Article 4, the global level literature review revealed a wide gap in terms of literature availability from regions other than North America, for this reason, a more in depth analysis of the non-formal food education in that area of the world was performed.

3.2 Action research: storytelling of personal experiences applied to the wicked problem of meat consumption

Action research has played a very relevant role in the research process underlying this dissertation. Undertaking other projects related to food sustainability alongside the academic research has resulted in these contributing to my dissertation either by supplying additional data (especially in the case of Article 2 and Article 4) or by shaping the research questions to be dealt with (Article 3 and Article 4). In this section, this process is described in further detail.

While working on this dissertation, a personal connection developed with a small-scale agriculture project in Madre de Dios, Peru. Seeing the effects of deforestation occurring locally, led to the realization that this was indeed an important aspect of the impact of the increasing meat demand globally and contributed to the analysis described in Article 2. In January 2014, I started my experience as a volunteer in the project of ArBio (Association for the resilience of the forest to the inter-oceanic highway), a no-profit association which was founded in 2010 to develop a buffer zone for the deforestation resulting from the development of the inter-oceanic highway. ArBio manages a land concession of 916 hectares (received from the Peruvian government, for a period of 40 years, with the possibility of renewal) and aims not only at preserving this area of rainforest, but also at finding ways in which a *productive conservation* can be implemented. The concession is located about 30km away from the inter-oceanic highway, and partly along the Rio Las Piedras river; a base camp was set up by the river and is used by a guardian and members of ArBio for monitoring and management activities. Sustainable agriculture is the main focus of ArBio, and it is implemented through the use of *analog forestry*. This is an agricultural technique according to which a variety of local plants of different heights and with different properties are planted in the same plot of land, thus mimicking the structure of the virgin forest. Each of the species planted is productive, bearing fruits or allowing the production of essential oils. This allows multiple harvests to be obtained throughout the year, providing food and income for the farmers. Such a technique is much more resilient than monocultures and ensures that the ecosystem services of the cultivated area are almost comparable with those of the nearby forest. Agroforestry (of which analog forestry is a specific technique) has been recognized as beneficial for biodiversity conservation, forest regeneration, and ecosystem services preservation (Harvey et al., 2008). A mosaic of old-growth and second-growth forests seems to be the most promising structure for human-modified landscapes in tropical areas (Zermeño-Hernández et al., 2016). The social sustainability of the project is also accounted for, as the connection with the local populations is of fundamental importance, and ensures the actual long term success of the actions implemented. The cooperatives of Brazilian nut gatherers (a very common activity in this region) are one of the main target groups for such development. The economic sustainability is also included in the example of ArBio, as two of the fruits cultivated (carambola and copoazu') are used to make jams locally, which are then distributed internationally through the fair-trade circuit. The basic idea of ArBio's work is that, if analog forestry and other productive conservation principles could be spread throughout the land concessions as a sensible and economically profitable alternative, a strong enough buffer zone will be created to stop deforestation around the highway. While not openly stated in Article 2, my role of both activist and researcher contributed greatly to developing the idea for Article 2, and the decision to also include this local perspective in the dissertation. This inclusion makes even clearer the close and direct link between

meat consumption and environmental resources depletion, and how geographically distant places are interconnected.

Two years into my research, after the publication of my first paper and the start of my cooperation with the Barilla Center for Food and Nutrition, and I was invited to hold lectures on food sustainability issues in different settings, including universities and events for the general public. This activity peaked in 2015, as I spent some months living near the headquarters of *EXPO 2015*. EXPO is a universal exhibition, which started in 1851. The 2015 exhibition was held just outside Milan, Italy and its headline was "Feeding the Planet, energy for life". Consequently, all topics related to the sustainability of the food system were of central importance. A total of 145 countries participated, together with other institutions such as the European Community and the United Nations (UN), as well as international organizations, including Slow Food and Save the Children. The exhibition was open for six months, from 1st May to 31st October, 2015 and welcomed 22,200,000 visitors in total. While the strictly academic relevance of my participation to EXPO 2015 might be limited, to me it was of uppermost importance to become familiar with that event first hand, especially in order to understand where civil society is currently with regard to making informed dietary choices. This, together with my involvement with the Milan Protocol, was essential in deciding what to focus the next research question on. An analysis was thus conducted focusing on food policies worldwide, and included in Article 3. This was then followed by an investigation of how dietary guidelines might be affecting the implementation of the transition towards sustainable diets, keeping the focus of analysis especially on how meat consumption is handled in this context. For this purpose, dietary guidelines currently in place worldwide were reviewed, with the aim of assessing how animal products and sustainability concerns are accounted for. Two main sources were used for this purpose: i) the report published by Fischer and Garnett (2016) and ii) the dedicated website (http://www.fao.org/nutrition/education/food-dietary-guidelines/home/en/) developed by FAO to gather and summarize the most up to date information concerning dietary guidelines published in all countries.

3.3 Food policies review

Being involved first hand in a project focusing on food policies, required me to open up the initial research question even more. The estimation that there is a global convergence towards the same levels and patterns in meat consumption, prompted the investigation of the possible policy measures which could be implemented in order to avert the inevitable collapse that would follow the current trends.

The second part of the analysis was thus to investigate whether there would also be convergence in the development of policies targeted at minimizing the environmental

impact of the food system, and in particular at reducing the burden generated by meat production and consumption. A literature review of food policies was undertaken, which soon revealed the overall lack of policies with a specific focus on meat (or animal products in general) and their related environmental impacts. Globally, food policies focus mainly on issues related to the excess of food (for example: junk food taxation, incentives for healthy foods or improved food labeling), food access (such as food security policies) (BCFN, 2015), or food safety. As explained in detail in Article 3, convergence only exists in some cases (for example in relation to subsidies), with a few showing signs of increasing attention towards supporting sustainable agriculture and animal welfare practice. Given the increasingly important role of some emerging countries (Brazil, China etc.) on a political level, *competition* (defined in Article 3) may arise in global public policies, with a significant effect on food sustainability regulations. This may consequentially have a detrimental effect on public health as well, especially in the most vulnerable areas of food security; a combination of top-down and bottom up policies and initiatives has been suggested as ideal for successful international negotiations. In this framework, the Milan Protocol of BCFN described in Article 3 is a good example of a bottom up initiative on which policy development could be based and translated into top-down actions, while the Double Pyramid (Figure 2) can serve the in same capacity for dietary guidelines.

In November 2014, during the Second International Conference on Nutrition held by the Food and Agriculture Organization of the United Nations and by the World Health Organization, the Rome Declaration on Nutrition was released and it was recognized how currently there are a number of challenges in providing safe and adequate foods that are necessary for healthy diets globally. This resulted in Members committing to "*enhance sustainable food systems by developing public policies from production to consumption and across relevant sectors to provide year-round access to food that meets peoples' nutrition and promote safe and diversified healthy diets*" (ICN2, 2014). In this direction, it is then useful to look at what countries suggest as *food-based dietary guidelines* (FBDG). These guidelines are a set of directions offered by governments (possibly also as part of their public food policies) concerning how citizens can have an adequate diet. Such FBDG can foster the adoption of healthy diets among the population and also be the basis for other food and agriculture policies. According to Fischer and Garnett (2016), only 83 out of 215 countries presented such FBDG, with their lack being evident especially in areas of the world with low incomes; moreover, the authors point out how often these guidelines are not easy to find and their target audience is unclear, especially in the poorer countries. Fischer and Garnett report only four countries which account for sustainability in their FBDGs, namely Brazil, Sweden, Qatar, and Germany. In a few other cases, sustainability is discussed in the policies' supporting information. In those four countries where environmental sustainability is clearly discussed in their

guidelines, the guidance provided is based on a similar line of thought: a mostly plant-based diet is beneficial for both health and the environment. In Table 4 (adapted from Fischer and Garnett, 2016) a summary of these FBDGs is shown. In most cases, the high environmental burden of meat is mentioned (expect in Qatar's guidelines), but no more specific advice is given, with maximum levels recommendations being presented only from the point of view of health.

Table 4: Summary of the main messages in the guidelines that include sustainability (adapted from Fischer and Garnett, 2016)

	Germany	Brazil	Sweden	Qatar
Meat	Eat meat in moderation. White meat is healthier than red meat.	Try to restrict the amount of red meat	Eat less red and processed meat (no more than 500 grams of cooked meat a week). Only a small amount of this should be processed.	Choose lean cuts of meat. Limit red meat (500g per week) Avoid processed meats.
Dairy	Consume milk and dairy products daily. Choose low fat.	Milk drinks and yogurts that have been sweetened, colored and flavored are ultra-processed foods, and as such should be avoided	Choose low-fat, unsweetened products enriched with vitamin D.	Consume milk and dairy products daily. Choose low fat. If you do not drink milk or eat dairy products, choose other calcium and vitamin D rich foods (e.g. fortified soy drinks, almonds, chickpeas).

Australia and USA have attempted to include environmental concerns in FBDGs, but no endorsement from the government was received. Some countries state specific recommended levels for meat consumption, for example Finland and Iceland

recommend < 500 grams per week (FAO, 2017). The Finnish Food Safety Authority also presents specific guidelines for "sustainable food choices (available at: https://www.evira.fi/en/foodstuff/healthy-diet/sustainable-food-choices/), which include recommendations for consuming less red meat and describe how "nutrient use efficiency per unit of energy and protein in foodstuffs of animal origin is always weaker than in plant production".

The fact that only few countries currently include sustainability in an explicit manner in their FBDGs, does not necessarily mean that other guidelines are not following some sustainable principles: increasing the consumption of fruits, vegetables and whole grains is for example a recurring recommendation with both health and environmental benefits, as resulted from the review of the FBDG available in the FAO database available at: http://www.fao.org/nutrition/education/food-dietary-guidelines/home/en/. However, there is an overall lack of more specific advice on the recommended levels of meat consumption that are also compatible with environmental targets, with only some countries setting such a level to 500g per week (a quantity not far from the current average consumption in those countries, and with no contextualization in the country's cultural context and/or in the sustainability discussion). The addition of more specific targets as regards meat consumption would also be beneficial in terms of energy consumption efficiency. As described in the study by Carlsson-Kanyama et al. (2003), there exists a large variation in the energy inputs required for different types of meat and FBDGs could be clearer in steering choices towards those energy-efficient alternatives.

One of the main pieces of evidence from the summary of the FBDGs presented in the report by Fischer and Garnett is that currently their coordination is restricted mostly to the Ministry of Health, thus hindering the inclusion of a wider range of issues in the development and implementation of FBDGs. There are some important remarks in the report by Fischer and Garnett which further support the need for a wider engagement of various stakeholders, such as that most guidelines seem to have a limited target audience (namely health practitioners) and do not seem to be easily accessible by the general public. This points to the need for more research targeted firstly at identifying a strategy to communicate more effectively and simply with civil society, and secondly to gaining an understanding of how dietary guidelines could be connected with other policies. Moreover, the need for monitoring processes aimed at assessing if the guidelines are creating an impact on society is also indicated. While guidelines (even without any mention of sustainability) are found in 50% of high income countries, only two low income countries (Benin and Nepal) have them. This highlights the need, globally, for a more consistent commitment towards food sustainability to be accounted for at the policy level.

A more comprehensive set of suggestions is presented in the order for FBDGs to:

- have a real effect on food consumption: guidelines should be owned by the government and supported by various departments; they should be differentiated according to the target audience – civil society, health professionals etc.; have a widespread promotion and clear links with existing policies related to, for example, industry standards or advertising regulations;

- have a real effect on the environmental impact of diets: guidelines should portray clearly both the links between health and sustainability, and the need for more environmentally friendly dietary patterns; they should be accessible but ambitious, considering the cultural context and the ongoing food consumption, but promoting a significant adjustment to its unsustainable aspects; guidance on the limitation of meat intake should be clear and adapted to each context – in high consuming countries consumption should be reduced, while in low income countries the recommendations should be steered towards an increased variation in the diet with only a limited amount of meat and dairy products; other environmental issues related to food waste should be accounted for; suggestions for those wishing to eat vegetarian or vegan should also be included.

It should be noted that in connection with dietary guidelines, it is not only the governments that are in charge of their development, as a number of quasi-official guidelines (produced by institutions supported by the government) exist in different countries, such as in the case of the Netherlands, Nordic countries (Denmark, Finland, Sweden, Iceland, and Norway), Estonia, the United Kingdom, and France. Only in some cases, are environmental issues considered, underlining the lack of actions to increase awareness in this direction. Positive examples, apart from the Double Pyramid presented in Figure 2, include the United Kingdom, where the WWF launched the One Planet Food program in 2009, with the aim of promoting diets that contribute to the reduction of environmental and social impacts. Together with the contribution of the Rowett Institute of Nutrition and Health at the University of Aberdeen, this program developed diets targeted at reducing emissions from food by 25% by 2020 and 70% by 2050, with about 56% of these reductions resulting from dietary changes and the rest from improved efficiency. Guidelines have also been developed by the Food Climate Research Network (FCRN), which in 2008 published "Cooking up a storm: food, greenhouse gas emissions and our changing climate", including a chapter describing the possibility that a healthier diet can be directly linked with a more sustainable one.

In order for FBDGs to be effective both from a health and environmental perspective, the consultation of a wide range of experts (such as economists, sociologists, life cycle assessment professionals, animal welfare and environmental scientists) and a more consistent engagement of academia (in line with the principles of action research), would result in the development and implementation of more holistic guidelines.

Box 1 – The Double Pyramid of BCFN as an example of non-official dietary guidelines

The Double Pyramid was presented publicly for the first time in 2010 (BCFN, 2010) and portrays the traditional Food Pyramid (with foods in the lower layer being those for which the highest consumption is recommended) next to the Environmental Pyramid (with the tip facing downwards and the foods in the lowest layer representing those with the smallest environmental impact). The latter is constructed on the basis of the Life Cycle Assessment (LCA), an objective method for evaluating energy and environmental impact for a given process, including the generation of green-house gases (Carbon Footprint – measured in grams of equivalent CO_2 per kilogram or liter of food), the consumption of water resources (Water Footprint – measured in liters of water per kilogram or liter of food) and the Earth's capacity of regenerating resources and absorb emissions (Ecological Footprint – measured in global square meters per kilogram or liter of food) (BCFN, 2010). The Double Pyramid has been the subject of a dedicated publication by BCFN since 2010, and the research behind it has been constantly updated. The database of scientific data used for the first edition was around 140 values, while the latest version (BCFN, 2015) is the result of data gathered from over 1,200 publications. This enhances the scientific validity of the Double Pyramid, making it also a reliable and efficient communication tool for a non-expert audience and a guideline for choosing the foods that are good for human health – whilst also being positive from an environmental point of view. This is reflected in the slogan that accompanies the Double Pyramid: "Good for you, good for the planet.", which makes the link between health and environmental benefits easily understandable by laypersons. The Double Pyramid, cited also in Fischer and Garnett (2016) is thus an example of good practice of non-official guidelines laying the ground for dietary recommendations to account for environmental sustainability. When it comes to meat, the Double Pyramid becomes a powerful visual tool to show that the consumption of meat (and animal products in general) should be kept at a minimum for both health and environmental reasons. The findings of the Double Pyramid are supported also by other research addressing the link between nutritional value and environmental impact of foods (see for example: Masset et al., 2014).

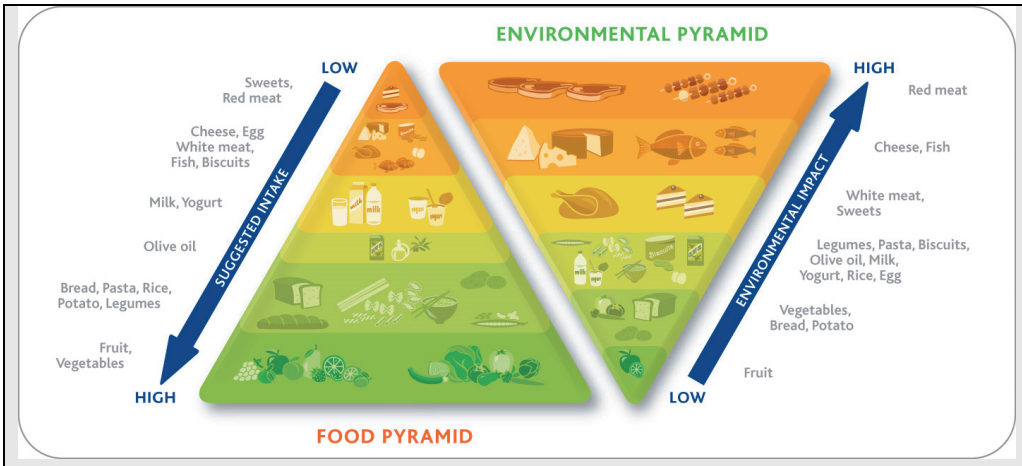

Figure 2: The Double Pyramid model developed by the Barilla Center for Food and Nutrition

The existence and effectiveness of food policies in the context of higher education was the object of the last research question of this dissertation. A review (fully reported in Article 4) was carried out to map virtuous examples of universities implementing projects and/or educational programs on food sustainability; the focus was kept on meat consumption policies and initiatives, in line with the rest of the analysis.

Figure 3 summarizes how my research process developed on the basis of using action research as an approach to the objective of the wicked problem. After starting by focusing only on the analysis of meat consumption data, the volunteer work in the ArBio project and the cooperation with BCFN and EXPO, brought about the analysis of different areas of the food system, namely the land use/deforestation and the food/sustainability policies. After this, being the President of the BCFN Alumni Association, allowed me to reflect more specifically on how higher education contributes to food sustainability and more broadly on what role academia can play in tackling the wicked problem of meat consumption. Each experience outside the academic context has contributed with data and additional knowledge to my research and to the scientific publications resulting from it.

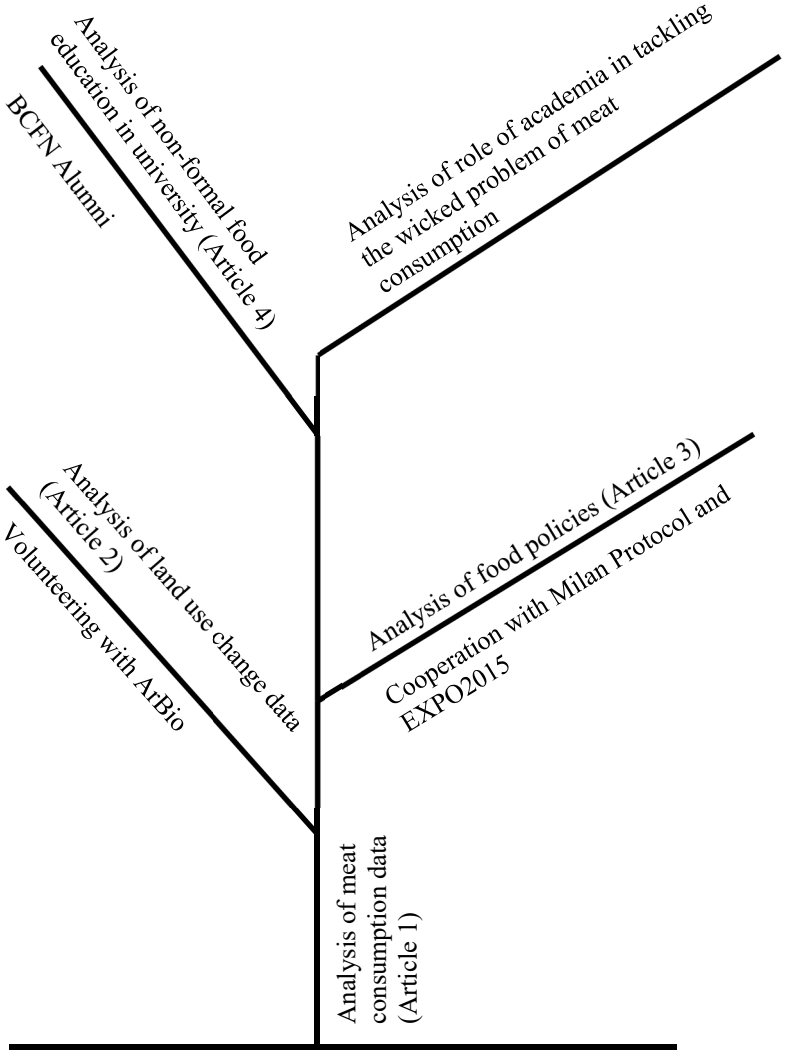

Figure 3: Overview of this dissertation process from the perspective of action research

3.4 Limitations and research ethics

The research presented in this dissertation has some shortcomings and limitations which should be taken into account.

The most significant is that a consistent share of the analysis has been done on initiatives carried out and materials produced by BCFN, an organization in which I have also been employed. While it should be recognized that this could potentially hinder an objective

assessment of its activities, I believe that the ethics developed in the years spent as a full-time researcher prior to the start of my cooperation with BCFN provided me with a solid basis on which to develop enough critical thinking to be objective in this process. Furthermore, the work of BCFN has received recognition from other researchers as well, for example the Double Pyramid has been cited also by Fischer and Garnett, 2016 and has been presented in a scientific publication by Ruini et al. (2015). Moreover, the Milan Charter, developed by the Italian government, has recognized the validity of the Milan Protocol, by acknowledging it as one of its contributors (see: http://carta.milano.it/contributors/).

Concerning the action research, I believe one characteristic is that it is possible to go through the experience with different roles at the same time: the researcher can also be, for example, a consultant or an activist, and one role is affected by the other. However, if a transition towards a more sustainable society is to occur successfully, the most traditional sectoralization, i.e. academia, the private sector and civil society will need to become more fluid: this work proceeds in that direction.

Another note that should be included here is that, as explained in the manuscript of Article 4, the sample size for the questionnaire is relatively small so its results can only offer a partial insight into the current status of meat consumption policies in higher education. For this reason, it should be considered as an exploratory study.

4. Results and Discussion

This section will present the main evidence gathered as a result of the research carried out within the four articles included in this dissertation.

4.1 Global analysis of meat consumption reveals an increasing number of livestock slaughtered

For the analysis of efficiency, in the last year of the time series, the total area harvested for animal products was equal to 440 million hectares, which is the highest value for the period considered and represents an increase equal to 30% since the beginning of the 1960s (Article 1). While efficiency in land requirements for animal products per capita has increased by about 13% in this period, the values of this indicator have increased slightly more since the 1990s, as a result of the higher demand for animal products in some regions, such as Eastern Asia (which carries about 25% of the global population). The land requirement for animal products has almost tripled in this area within the time series analyzed, reaching 640 square meters per capita in 2007. However, the consumption patterns of the richest regions (Northern America and Oceania, Western and Northern Europe, and Southern Europe) were still responsible for the highest land requirements throughout the entire time series. These were followed by Western Asia, while Africa, South Eastern Asia and Southern Asia presented the lowest values for this indicator, with no significant changes taking place.

For sufficiency, specific targets have been suggested for the achievement of social and environmental sustainability targets (McMichael et al., 2007) and such development would imply that the richer regions would need to reduce their consumption levels significantly (Boulanger, 2010). In the last year of the time series, the global average meat consumption per capita was 41 kg, leading to a production of about 280 Mt of meat (Article 1). The region with the greatest weight in this sense is Eastern Asia, which consumes about 34% of the total meat supply worldwide, while Northern America, and Oceania and Europe combined, consume 17 and 14% of the global meat supply respectively. The highest peaks in meat supply per capita are in Northern America and Oceania, Southern Europe, and Western and Northern Europe (for example, Northern America and Oceania had a consumption level equal to 120kg per capita in 2007), but, on the other hand, these are also the only regions where, during the last decade, the consumption of meat has followed a downward trend (Article 1). Southern Asia and Africa did not show significant variations in the period analyzed, while regions such as Eastern Asia have undergone enormous changes in this sense, with a 10-fold increase which led to a consumption level of 58kg per capita in 2009 (Article 1). Globally, the amount of meat supply per capita has increased steadily since the 1960s, with an annual change equal to 1.5%; such a trend is a consequence of the increased meat consumption

per capita which has taken place in all regions (despite the strong regional differences). These changes lead to sufficiency being diminished by about 91% worldwide during the time investigated (Article 1).

When performing the analysis of consistency, it was found that in the last year of the investigation over ten animals were slaughtered per capita, resulting in a total of about 63 billion animals slaughtered in the countries analyzed (Article 1). However, during the last decade there has been a decrease in the number of animals slaughtered in Northern America and Oceania, and Southern Europe; such trends are reflected in the World averages, which shows them to have the slowest average annual percent increase in the entire time series. Such change can be a consequence of both a larger carcass size and the decreased meat consumption in some regions. What can be noted from the data analyzed is that the number of animals slaughtered yearly per capita is indeed increasing in many regions: for example, it has risen about 9-times in Eastern Asia (the region with the highest annual percent increase, equal to 5.1%), and Central and South America (Article 1). This pattern is reflected in the global average as well, with values that have more than tripled and which have undergone rapid growth, especially after 1990. Such results have led to a worldwide decrease in consistency of about 260%, thus indicating the importance of including the dimension of animal ethics in such analysis (Article 1).

While poultry meat might have a lower environmental impact, and might be better for human health, its increased consumption also implies that enormous numbers of chickens, ducks, geese etc. are slaughtered each year to satisfy this type of consumption. From an ethical perspective, this is not a desirable scenario, as it means that globally the number of lives that are lost is rising.

4.2 Convergence analysis shows meat consumption patterns becoming increasingly similar in different areas of the world

In Article 1, efficiency, sufficiency, and consistency were also analyzed as a whole through convergence analysis. In all cases, the values of beta convergence gave statistical support for the hypothesis of different regions progressing towards similar consumption patterns at different paces. Absolute convergence was thus confirmed for each case.

When performing sigma-convergence analysis, the data calculated for the land requirement of animal products per capita showed decreasing values over time, a confirmation of convergence taking place at a global level. While land use efficiency for animal products has been increasing, the amount of land needed per capita has, in contrast, increased as a consequence of a greater demand for animal products, especially in some regions.

In the case of the other two indicators, it seemed that divergence is taking place, with only a slight tendency towards sigma convergence in the last years of the analysis. In the case of the animals slaughtered per capita indicator, a more detailed analysis produced evidence that the standard deviation increased constantly throughout the time series, with only a minor decrease in the last five years. Such a result is the consequence of the still prevailing heterogeneity of some regions, such as Africa and Southern Asia, in which meat consumption per capita is not expected to increase significantly in the near future; the reasons for this being cultural, religious, and geographical (Kearney, 2010).

The results of the gamma-convergence analysis, confirmed that it existed in all cases, with stronger evidence being produced by the total meat supply per capita and the number of animals slaughtered per capita. This is because in most regions, the values for both these two indicators have increased consistently. In contrast, in the case of the land requirement for animal products, convergence was only detected after the mid-1990s.

The analysis presented in Article 1 is an example of the complexity of the food system. Only by using different points of view is it possible to obtain a comprehensive picture and even then, the drivers might not always be evident. However, some facts are clear, for example, some regions of the World are undergoing a very fast transition towards a Western diet and consumption patterns of animal products are in the process of becoming increasingly homogeneous globally (despite some persisting regional differences). Such evidence underlines how increases in the consumption of animal products worldwide also contributes to reducing the number and variety of crops being used (Khoury et al., 2014), with the inevitable consequences to food security.

For the reasons above, the possible rebound effects of reducing meat consumption should be accounted for too. The logic in some sources (for example, Nellemann et al., 2009) stated that a substantial reduction in meat demand would certainly reclaim a large number of plant crops, thus feeding those who are hungry and freeing significant areas of farmland. Moreover, the availability of food calories would increase by 70%, given the current mix of crop uses, if crops were grown only for direct human consumption (Cassidy et al., 2013). In reality, there is a higher degree of complexity, which makes it simplistic to assume that merely by diminishing the amount of meat consumed per capita, issues of malnutrition worldwide could be curbed. According to a study by Rosegrant et al. (1999) if meat demand in developed countries fell, it would result in a rise in meat consumption (about 13%) in developing areas, as a result of an increased affordability. While this is a step forward towards “meat equity”, it does not imply a much larger consumption of grains in these areas. According to the simulation, the increase in per capita cereal consumption would be equal to only 1.5% in developing countries. This is due to the differences in animal and human diets. In intensive livestock farming, animals are fed mostly soybeans and corn, so if the farmers produce less meat,

the demand for these drops and the affordability of grains increases. This is helpful in those areas where corn is part of the traditional diet (Africa and Latin America), but does not affect consumption in other areas where rice and wheat are mainly consumed (for example Asia). Climate and soil conditions might also affect the possibility to switch cultivations. Moreover, the simulation by Rosegrant et al. suggested that if developed countries would substitute meat with bread and pasta, wheat prices would rise: a difficult situation for areas like India, where wheat is a staple. While this issue is not very often debated, it is very important to underline that, in order to increase food security worldwide, other actions should be implemented too. Specifically, countermeasures related to policies and subsidies have the potential of providing greater contributions to global food security than personal responsibility. Raising meat prices to include the actual climate costs and reducing subsidies to livestock rearing or ranching could prove to be more effective on the large scale (Stokstad, 2010). However, individual changes in consumption are still an important part in the creation of a widespread cultural shift.

4.3 Increased meat demand threatens the Amazon ecosystem: evidence from Madre de Dios

One of the greatest environmental threats derived from the production of meat on a massive scale, is deforestation. Areas of pristine forest, especially in the Amazon rainforest, are cleared and replaced with pastures or soy cultivations, which are necessary to supply the increasing demand for animal feeds. The consequences of this phenomenon are multi-faceted and very relevant and include the fact that: biodiversity declines, the potential for carbon storage is gradually lost, the water cycle is altered, and a number of ecosystem services are reduced.

Meat consumption worldwide has increased steadily during the last 50 years, and in the case of South America the most striking increase has been in poultry meat consumption, while the production of cattle meat has gained more relevance in the last 10 years of the time series studied. These exports have increased four-fold since the 1960s, reaching 1,350,090 tons in 2011 (Article 2). When specifically considering Peru, poultry meat production is the most relevant, being about 5 times larger than pig or cattle meat production. Values for the meat-dependency ratio were only equal to a few percentage points, as in both pig and cattle meat production is mainly sufficient to satisfy the internal demand for meat products. When observing land-use change and deforestation data, in the timeframe 1990-2012, the forest area decreased at a rate of -9.4% in South America, and -3.5% in Peru. When adding information from the FAOSTAT database, it became evident that about 35% of the deforestation occurring in that period can be linked with meat production, as forests were converted to permanent meadows and pastures.

The specific situation for Madre de Dios was investigated with data from three other

sources (see Article 2) which have information on a regional scale. The annual forest loss rates calculated for the different data sources are on a similar scale, ranging between 0.15% and 0.24%), however, all the data series ended in 2011 and it was therefore not possible to include the peak of forest loss. This peak equal to 250,000 ha occurred in 2012, according to Mongabay – a website founded by the economist Rhett Ayers Butler in 1999, which publishes news about environmental science, with a focus on the tropical rainforest (Article 2). This could be directly linked with the effects of the introduction of the inter-oceanic highway, which was opened in July 2011; while a longer data series would be needed to measure this trend adequately, a preliminary analysis was performed. In Peru, deforestation is occurring mainly because of logging and agricultural activities, with a significant correlation between road distance and forest clearing. By using the web-based data available through Maryland University, it was possible to detect some preliminary outcomes, for example that deforestation is taking place mainly in those land concessions along the road. This result can be confirmed by the direct experience of the local ArBio staff, as in the last 4 years they have directly witnessed illegal logging and deforestation. Even if these are only preliminary results which will require further monitoring, they still represent a confirmation of the business as usual development of deforestation practices in the Amazon rainforest. Such a trend, coupled with the evidence coming from meat consumption data, presents a very critical situation for Peru and the Amazon as a whole. The introduction of alternative and more sustainable practices, like those implemented by Arbio, benefit both humans and the ecosystem on which they depend, and will be of fundamental importance in avoiding the further destruction of this precious ecosystem.

4.4 Data shows meat consumption has serious environmental impacts, but awareness in civil society may still be lacking

The data analysis carried out in the first two articles compiled a gloomy picture of the mid- and long-term future of our Planet, with resources fundamental for the survival of humans being deployed at an increasing rate, and with food (and especially meat products) being one of the main drivers of such a catastrophe. Numerical data show this clearly, as demonstrated by the convergence evidenced in Article 1, nevertheless, the awareness of this issue seems to be fairly limited.

Currently, there is an unprecedented environmental emergency, and institutions and governance mechanisms seem incapable of handling the complex urgency of the food system's challenges. Nonetheless, the role of food and agriculture is absolutely vital for the survival of humankind: globally, the demographic increase, coupled with the rise of the middle class and its consumption levels, is placing critical pressure on natural resources.

An increase in the awareness of civil society to these problems could be further hindered by the lack of supporting policies and institutional guidelines. The review carried out in Article 3 highlights this lack as well as the lack of convergence of policies towards the goal of increasing the sustainability of food choices. The bottom-up process of the Milan Protocol (described in Article 3) has the potential to be a best practice for non-official guidelines to be further developed and adopted at a governmental policy level. A more specific aspect of food policies is dietary guidelines, which still represent a very relevant aspect of food policies and actions that should be put in place in order to use their full potential. The link between health and environmental targets represents an increasing interest stemming from civil society and academia. However, a more inclusive definition of sustainability in food policies should be adopted (accounting for its social and economic concerns as well), and approaches that consider the nutritional and socio-economic context of developing countries are needed, in order to offer a truly global perspective. Therefore, it is hard to assess whether by following the broad dietary recommendations suggested in the guidelines currently in place worldwide, significant reductions in GHG emissions could be actually achieved. In this sense, more holistic approaches to develop policies for public health and monitor their progress, should be used, starting from the evidence that improvements in both human and environmental health can be achieved simultaneously, no matter whether overconsumption or hunger are the main issue. The Milan Protocol (Article 3) is an example of non-government initiatives encouraging countries to act through concrete actions and policy formulations towards the solution of the three paradoxes at the core of the quest for a sustainable food system. As the Milan Protocol states specific recommendations closely linked to animal products consumption and production (such as to accounting for the five freedoms of welfare for farmed animals, and to distribute land more equitably when allocating it for animal feeds or human nutrition), it provides a good example of which sort of policies could be developed at a national level worldwide to favor the transition towards more sustainable (and ethically just) diets.

Events like EXPO (described in the Methods section) might have some positive impacts as well, as it created much more attention around the topics related to food sustainability. However, a considerable number of controversies about this event were debated, especially concerning the presence of multinationals and their influence on the exhibition. Only a few pavilions showcased examples of small scale projects, in an effort to present a variety of environmentally friendly examples of agriculture. This was in contrast with what was presented in the majority of the other pavilions, where sustainability was most often not a criterion. Nevertheless, the media attention that this event received, created a momentum for discussions that were not necessarily previously on political agendas or in the thoughts of civil society. It definitively played a relevant role in bringing food sustainability to the center of discussions at all levels and, at the same time, in underlining the existing lack of awareness about it. As EXPO 2015

approached and the media attention grew in relation to its headline "Feeding the Planet, energy for life", there was an increasing interest in understanding what it was about and, consequently, how food and its sustainability could be scaled down to everyone's daily lives. For this reason, I have presented the content of my research and, more generally, the link between dietary choices and environmental impact to a large range of audiences, but in every case the lack of awareness seemed to be evident. My description of how meat consumption is a direct cause of pollution and environmental damage such as deforestation in the Amazon seemed especially to be an idea that most people were hearing for the first time. This is in line with the findings reported by other researchers, such as Macdiarmid et al. (2016), who conducted an analysis on twelve focus groups and detected a scant awareness by participants of how meat consumption is linked with climate change, and a general belief that the potential contribution of personal meat consumption in climate change mitigation is small. Graça et al. (2014) linked the reluctance to change personal behavior related to meat consumption with the moral disengagement theory, which further hinders the possibility of acting for the benefit of the environment, the animals, and public health.

4.5 Meat consumption is a wicked problem and the role of academia in tackling it could be much greater

As presented in the theoretical background, three main characteristics are used to describe wicked problems: first, they evolve in time, with little room for predictions; second, there is no clear consensus among scientists on their assessment, as a protocol of analysis is difficult to be defined given their non-linear nature; and third, they create strong divisions in terms of stakeholders' perspectives and lines of action. Given that globally meat consumption is undergoing changes due to socio-economic dynamics that will evolve non-linearly over time, and that these implications involve a wide range of stakeholders (for example: businesspeople from the meat industry, environmental activists advocating for sustainable diets etc..), the definition of wicked problem can be applied.

In the context of wicked problems, those research methods which are adaptive to the evolving characteristics of a changing society, need to receive further encouragement. In this sense, action research, defined as a participatory process, bringing together action and reflection and aiming at the development of knowledge useful to create practical solutions to problems that concern people and their communities, has the potential to play an increasingly major role. In the Methods section, various activities that took place outside the strictly academic context but which contributed to this dissertation have been described. This contribution took place either in the form of new research questions (Article 3) or in the form of data (Article 4 and, partly, Article 2).

Policies are fundamental for the implementation of changes at all levels of the food system. Changes are now occurring in national dietary guidelines, with a few countries leading the way. However, the question arises of whether policies can be further strengthened and which sectors of society can be most effective when testing alternatives in the food system. While working on this dissertation and realizing how seriously meat consumption is affecting world resources, I also started questioning, as an academic, if and how academia itself was contributing to finding solutions.

As defined in the Introduction, a food system is sustainable if the environmental, social, and economic issues of each link in the food production chain are taken into account, as well as their interactions with other parts of the system (Garret and Feenstra, 1999). For this reason, sustainable food projects attempting to integrate environmental, economic, and social health are of central importance to verify, on a small scale, how momentum can be generated for greater changes in the food system (Miller, 2008). Collaborative food education has also been suggested as an important starting point to creating a new openness towards the meaning of healthy eating and the value of the education experience itself (Janhonen et al., 2016). Given how influential campuses can be both on their surrounding communities and markets, and on the development of students' values and norms, the argument of how significant is the contribution of educational projects and food services in universities for increasing the sustainability of the food system was explored.

Over the few past years, in those university departments which have agriculture at the core of their curriculum, little emphasis has been placed on educating students about alternative methods and techniques to those used in traditional agriculture (La Charite, 2016), resulting in a limited dissemination and implementation of solutions for sustainable agriculture. Such a trend is now changing, with encouraging signs of an increased awareness towards sustainable agriculture and food sustainability in general. For example, there is a considerable rise in the number of universities which have implemented sustainable food projects of some kind. In the US alone, these projects have increased from 23 in 1992 to nearly 300 today, with courses dealing with these issues also being offered in faculties that do not have agriculture as their main focus (La Charite, 2016). Food studies programs are also becoming increasingly popular since the first two appeared in New York University and Boston University in the 90s. Nowadays, many of the most prestigious universities and colleges offer a range of sustainability programs that also include food studies, with the number of graduates in this field growing every year. As they enter the job market, the food industry will also undergo some changes and evolve in a more sustainable direction. Another noteworthy sign of change is the establishment of the Association for the Advancement of Sustainability in Higher Education (AASHE); as part of its services, a voluntary Sustainability Tracking Assessment and Rating System (STARS) tool is also offered. An ever-greater number

of universities are using STARS worldwide, with currently 658 institutes employing it in the United States alone. The data gathered as a contribution to Article 4, are particularly useful for understanding the potential still untapped in academia to contribute to shaping a more sustainable food system. On campuses, meat consumption and its impact on environmental resources could be lowered where needed, as a consequence of increased efficiency, sufficiency, and consistency (as discussed in Article 1). The sustainable food projects cited in Article 4 are varied and multidisciplinary, drawing attention to how such projects could be the ideal context for action research efforts that could benefit both academia and the surrounding society. However, the review presented in Article 4 also highlighted how development in this direction is, in most cases, hindered by a lack of adequate funding or logistics, or simply by a lack of attention to its relevance. Furthermore, by addressing the research question presented in Article 4, it was possible to detect an important geographical gap regarding the literature available on the issue of sustainable food projects in higher education, with most case studies concerning North America. While this does not mean that sustainable food projects are not active elsewhere, however, it does suggest that such projects are not one of the priorities for deeper scientific analysis, hinting at a lack of awareness about their potential.

This is further supported by the results of the questionnaire delivered to the BCFN Alumni as part of this analysis. Despite the small sample size hindering the development of more general conclusions, some relevant issues can be highlighted: first, information concerning food sustainability is generally lacking in at an institutional level; second, the introduction of new food and sustainability education programs should be the focus of attention; third, policies for healthier and more sustainable diets are recommended, and fourth the implementation of more adequate non-formal education services is requested (Article 4). With specific regard to how meat consumption is handled in the context of higher education, the responses of the BCFN Alumni show that little emphasis is put on this aspect in their institutions. Nearly 90% responded that no specific action or policy was active, and more generally, the importance of a sustainable diet was not highlighted, with only a few students stating that they found some data or information on the sustainability of the food offered in the dining services of their universities. While the sample of this specific analysis is very limited, it does offer some insights in relation to how little attention this topic receives in the practice of the academic settings. While developing formal food sustainability education programs is relevant, these should be further supported by non-formal education as well. Introducing other forms of education and extending the same principles that are taught in classes to the policies implemented at an institutional level, is the path to follow in order to enable academia to become an active change maker in a more sustainable food system. There is evidence that food justice issues can improve from the collaboration between community and the food services

offered in universities, with results on better working conditions for food workers and more positive decision-making processes (Levkoe et al., 2016 – Article 4). All these developments suggest that food sustainability matters are being increasingly integrated in society, with higher education (both in terms of educational programs and research projects offered) playing a significant role in this sense. Universities and campuses have both responsibilities and opportunities to be role models for the rest of society, by shaping students' values and consumption behaviors, as well as by implementing innovative projects (for example farm-to-college projects) and policies. Academia can also act as an incubator of principles and ideas, which can be disseminated through engagement with local communities, as well as through students and researchers implementing these values in their lives outside the universities. This would also act as a counter action to the way in which the food industry has sometimes influenced food-related academic research in the past, for example, it was recently found that the results of research concerning the effects of fats and sugars on coronary diseases, were heavily influenced by food companies (Nestle, 2016 – Article 4). Improvements taking place in the academic contexts, together with results from research projects dealing with food sustainability issues, could influence the food industry; the sustainable food projects in universities could represent new markets with different set of norms (Article 4). While there are signs of developments occurring in a favorable direction to increase the role of academia in promoting sustainable diets and more sustainable food systems, more targeted actions should be researched and implemented, in particular to lower the levels of meat consumption. As described in De Groeve and Bleys (2017), more integrated approaches are needed in order for initiatives at the campus level to engage the support of students.

Moreover, on a personal level, when carrying out the research for this dissertation, the need to step out of the context of academia was pressing at times, and being involved in different projects related to the topic of food sustainability (mainly as an educator or as a volunteer) allowed for a broader understanding of how meat consumption is a wicked problem. These experiences allowed me to assess the level of awareness of civil society on these issues and to gather insights into which type of research could initiate the most positive change in the society I live in. The work carried out for this dissertation fits well with the five characteristics of action research identified by Reason and Bradbury (2007), therefore I believe it serves as an example of how AR can be used to tackle wicked problems, in this case, that of meat consumption. At the end of this process, I have a much broader and richer understanding of how multi-faceted the issues that come into play are when examining the implications of meat consumption and production. By approaching and acknowledging this as a wicked problem, there is a possibility that the work carried out will contribute to building academic roles that are more action-oriented, cross-scaled and cross-domained, and therefore can be aligned with "*practicing what is preached*". Academia has the

potential to give a very significant contribution through more involvement in action research projects targeted, for example, at understanding which mechanisms work best to reduce meat consumption globally.

5. Concluding remarks

Globally, the production of animal products is linked with a number of environmental impacts, including local deforestation of precious ecosystems, such as the Amazon rainforest. On the consumption side, the increasing consumption of meat can also be responsible for some health problems, which are becoming progressively more common as a result of higher incomes. Such issues related to animal products production and consumption are evolving non-linearly and have created numerous debates among scientists in relation to how to account for their impacts on the environment and public health. Moreover, there is a strong polarization by different stakeholders, as they have a wide range of objectives in relation to how animal products, and meat in particular, should be produced and consumed globally. Given these three characteristics, the production and consumption of meat can be considered a wicked problem. As wicked problems "cannot be solved but only managed", a much wider involvement of all stakeholders would be necessary in order to tackle the issue through a coherent global action. The question is then - who should take the lead in promoting immediate and fruitful changes in this direction? While consumers' aspirations and the consequent change of diets need to be encouraged, the potential of the private sector has not been fully tapped in yet. The evidence gathered in this dissertation shows the huge impact that the consumption of meat has on the environmental resources and on biodiversity loss, while also demonstrating how scarce the awareness and action is on this issue. Cooperation among all sectors of society is thus key to a change in the current status and to fostering food policy coherence globally. A favorable policy environment is of fundamental importance in order to tackle the paradoxes of the food system.

Communication and dialogue should be implemented between researchers, managers, educators, farmers, and policy makers. In this sense, it was shown in this dissertation how wide the potential for change is, especially the untapped resources in the context of academia; the benefits could be very large if the agri-business sector could receive input from academia and its non-formal-education activities. The described initiatives such as the Milan Protocol and the Young Earth Solutions competition can be considered best practices, and can offer inputs on strategies and awareness levels which are useful to better define the role of academia in tackling the wicked problem of meat consumption.

As wicked problems have been also defined as requiring "*thinkers who can transcend disciplinary boundaries, work collaboratively, and handle complexity and obstacles*" (Cantor et al., 2015), such definition resonates very much with my own experience. Having had the chance to include in my dissertation and in the articles presented here examples, concepts, and perspectives from experiences outside the academic context has definitively brought an added value to my work and my wish that this holistic view will serve as a further contribution to moving from theory to practice in achieving a more sustainable food

system. This approach supports the fourth mission of academia to become an active change maker in society by indicating a path towards a more sustainable food system. Such change would then be reflected in a more sustainable future.

The sustainability of the food system and the role that the demand for animal products plays in it, are complex issues, yet they are intertwined with the choices taken by everyone, everywhere, everyday. Gaining an understanding of whether people are, on average, aware of this was extremely important for me. Creating change starts from providing consumers with clear and comprehensive information, combined with a level of food education which enables as many people as possible to be fully aware of the consequences of their food choices.

I would like to end with an entreaty to everyone to be fascinated and not limited by the complexity of the food system, to take up the challenge of increasing public awareness and act consequentially. I have come to think that our approach to the food system could be a reflection of our contemporary approach to human nature. I started with describing my childhood experience in my grandfather's vegetable garden and I wish everyone could relate to that, I wish everyone could have a first-hand experience of the – literal – rawness and earthiness of food. However, the situation that the food system faces today on a global scale is the result of an increased distance from that rawness. My grandfather will turn 96 this year; during his lifetime, humanity has moved from a system of small-scale, simple food production, to a globalized system of highly complex interrelations. Could this also be a consequence of our increasingly complex human lives. All aspects of our lives have become far more complex than they were 100 years ago, with a rising need for resources that result in severe consequences for the environment. Food plays an enormous role in this and acts as a reminder of what used to be; when and why did we move from tomatoes in our backyards to a globally increasing consumption of environmentally harmful foodstuffs, like processed meat products? When and why did we stop having the time to cultivate our food and eat it according to the season? I find it fascinating that we now need such a complex system to support our most basic need. I think that by seeing what humanity is doing to the planet's resources through food production and consumption could lead us all to ask ourselves: Do we really need this? Do we really need this complexity? And if not, how can we change it? I believe that an increased efficiency, sufficiency, and consistency in our food system, applied at all levels, are key factors in reducing our impact on the environment, and thus ensuring the endurance of our species. Producing food with less resources and using those resources for the most nutritionally valuable foods, eating just what we actually need, and accounting for ethical dimension, is the mix of actions we have to implement in order to find a renewed simplicity, in food and in life as a whole.

References

Aleksandrowicz, L., Green, R., Joy, E., Smith, P., Haines, A. (2016). The Impacts of Dietary Change on Greenhouse Gas Emissions, Land Use, Water Use, and Health: A Systematic Review. PLoS ONE 11(11): e0165797. doi:10.1371/journal.pone.0165797

Allan, T. (2016). Virtual water between underconsumption and poor management. In *Eating planet – Food and sustainability: building our future*. Edizioni Ambiente, Milano, Italy.

Auestad, N. and Fulgoni, V.I. (2015). What current literature tells us about sustainable diets: emerging research linking dietary patterns, environmental sustainability, and economics. Advances in Nutrition, 6, 19-36.

Barilla Center for Food & Nutrition - BCFN (2010). Double Pyramid 2010: healthy food for people, sustainable food for the Planet, Parma, 2010.

Barilla Center for Food & Nutrition - BCFN (2015). *Double Pyramid 2015: recommendations for a sustainable diet*, Parma, 2015. Available online at: https://www.barillacfn.com/m/publications/dp-2015-en.pdf

Bateson, G. (1972). *Steps to an ecology of mind*. San Francisco. Chandler.

Batie, S. S. (2008). Fellows Address: Wicked Problems and Applied Economics. American Journal of Agricultural Economics, 90(5), 1176-1191.

Baumert, K.A., Herzog, T. and Pershing, J. (2005): Navigating the Numbers. Greenhouse Gas Data and International Climate Policy. Washington D.C., World Resources Institute. Available online at: http://pdf.wri.org/navigating_numbers.pdf

Boucher, D., Elias, P., Lininger, K., May-Tobin, C., Roquemore, S. and Saxon, E. (2011). The root of the problem: whatlem: whatE. (2011). The root o?. The Union of Concerned Scientists publishing. Available online at: http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/UCS_RootoftheProblem_DriversofDeforestation_FullReport.pdf

Boulanger, P. (2010). Three strategies for sustainable consumption. S.A.P.I.E.N.S 3 (2) (Online).

Brown, V. A., Harris, J., and Russell, J. (2010). *Tackling wicked problems: Through the transdisciplinary imagination*. London: Earthscan.

Cassidy, E.S., West, P.C., Gerber, J.S. and Foley, J.A. (2013). Redefining agricultural yields: from tonnes to people nourished per hectare. Environmental Research Letters, 8. Available online at: http://iopscience.iop.org/1748-9326/8/3/034015/

Carlsson-Kanyama, A., Ekström, M.P. and Shanahan, H. (2003). Food and life cycle energy inputs: consequences of diet and ways to increase efficiency. Ecological Econimics, 44, 293 – 307.

De Groeve, B. and Bleys, B. (2017). Less meat initiatives at Ghent University: assessing the support among students and how to increase it. Sustainability, 9, 1550.

Dentoni, D., & Bitzer, V. (2015). The role (s) of universities in dealing with global wicked problems through multi-stakeholder initiatives. Journal of Cleaner Production, 106, 68-78.

Dentoni, D., Bitzer, V., Schouten, G. (2017) Harnessing wicked problems in multi-stakeholder partnerships. Journal of Business Ethics, forthcoming.

Dentoni, D., Bitzer, V. and Pascucci, S. (2012). Cross-Sector partnerships and the co-creation of dynamic capabilities for stakeholder orientation. Journal of Business Ethics, 135 (1), 35-53

Diaz, R. and Rosenberg, R. (2008). Spreading Dead Zones and Consequences for Marine Ecosystems. Science, 321 (5891), 926-929.

D'Silva, J., Webster, J., 2010. The Meat Crisis - Developing More Sustainable Production and Consumption. Earthscan, London.

The Economist Intelligence Unit – EIU on behalf of BCFN (2016). *Fixing Food – towards a more sustainable food system*. Available online at: http://foodsustainability.eiu.com/whitepaper/

FAO (1988). FAO Council, 94th Session. Available online at: http://www.fao.org/docrep/meeting/011/t0087e/t0087e00.htm

FAO (2010). Sustainable diets and biodiversity: directions and solutions for policy, research and action. Proceedings of the International Scientific Symposium: Biodiversity and sustainable diets against hunger.

FAO (2014). Rome Declaration on Nutrition. Available at: http://www.fao.org/3/a-ml542e.pdf

FAO (2017). Food based dietary guidelines. Available online at: http://www.fao.org/nutrition/education/food-dietary-guidelines/home/en/

Ferraro, F., Etzion, D. and Gehman, J. (2015). Tackling Grand Challenges Pragmatically: Robust Action Revisited. Organization Studies, 36(3), 363-390.

Fischer, G. and Garnett, T. (2016). Plates, pyramids, planet - Developments in national healthy and sustainable dietary guidelines: a state of play assessment. Published by the Food and Agriculture Organization of the United Nations and The Food Climate Research Network at The University of Oxford. ISBN 978-92-5-109222-4

Fraser, B. (2014). Deforestation: carving up the Amazon. Nature, 509, 418-419.

Garnett, T. and Godfray, C. (2012). *Sustainable intensification in agriculture*. Available online at: www.fcrn.org.uk/sites/default/files/SI_report_final.pdf

Garnett, T. (2014). Changing what we eat. A call for research & action on widespread adoption of sustainable healthy eating. Food and Climate Research Network.

Garnett, T. (2014)b. *What is a sustainable healthy diet?* Food and Climate Research Network.

Garrett, S. and Feenstra, G. (1999). Growing a Community Food System. Community Ventures: Partnerships in Education and Research Circular Series. Western Regional Extension Publication in Cooperation with the U.S. Department of Agriculture. Washington State University.

Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., and Tempio, G. (2013). *Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities*. Food and Agriculture Organization of the United Nations (FAO).

Goodland, R. and Anhang, J. (2009). Livestock and Climate Change. What if the key actors in climate change were pigs, chickens and cows? Worldwatch Institute, Washington, DC, USA, pp. 10–19.

Graça, J., Calheiros, M. M., and Oliveira, A. (2014). Moral disengagement in harmful but cherished food practices? An exportation into the case of meat. Journal of Agricultural and Environmental Ethics, 27, 749-765.

Greenwood, D. J. and Levin, M. (1998). Introduction to Action Research: Social research for social change. Thousand Oaks: Sage.

Gunderson L.H. and Holling C.S. (2012). Panarchy - Understanding Transformations in Human and Natural Systems. Island Press, USA.

Harvey, D. (1990). The condition of postmodernity: An enquiry into the origins of cultural change. Blackwell, Oxford, England.

High Level Panel of Experts on Food Security and Nutrition - HLPE (2014). Food losses and waste in the context of sustainable food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome 2014.

Hoekstra, A. and Mekonnen, M. (2012). The water footprint of humanity. Proceedings of the National Academy of Sciences of United States of America, 109 (9), 3232–3237.

Huttunen, S. (2015). Farming practices and experienced policy coherence in agri-environmental policies: The case of land clearing in Finland. *Journal of Environmental Policy & Planning,* pp. 1-20.

Imhoff, D. (2010). *The CAFO Reader: The Tragedy of Industrial Animal Factories*. Watershed Media, USA.

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland.

Janhonen, K., Mäkelä, J. and Palojoki, P. (2016). Food education: from normative models to promoting agency. In J. Sumner (ed.), *Learning, Food, and Sustainability*, Palgrave Macmillan US.

Jentoft, S. and Chuenpagdee, R. (2009). Fisheries and coastal governance as a wicked problem. Marine Policy, 33(4), 553-560.

Kastner, T., Ibarrola Rivas, M.J., Koch, W. and Nonhebel, S. (2012). Global changes in diets and the consequences for land requirements for food. Proceedings of the National Academy of Sciences of United States of America, 109 (18), 6868-6872.

Kearney, J. (2010). Food consumption trends and drivers. Philos. Trans. R. Soc. B: Biol. Sci. 365, 2793-2807.

Kemmis, S. and McTaggart, R. (eds.) (1988). *The action research planner*. Victoria, Australia: Deakin University Press.

Khoury C.K., Bjorkman A.D., Dempewolf H., Ramirez-Villegas J., Guarino L., Jarvis A., Rieseberg L.H., Struik P.C. (2014). Increasing homogeneity in global food supplies and the implications for food security. Proceedings of the National Academy of Sciences of United States of America, 111, 4001–4006.

La Charite K. (2016). Re-visioning agriculture in higher education: The role of campus agriculture initiatives in sustainability education. *Agriculture and Human Values, 32*, 1–15.

Lamas, G. (1997). Comparing the butterfly faunas of Pakitza andTambopata, Madre de Dios, Peru, or why is Peru sucha mega-diverse country? In: H. Ulrich (ed.): Tropical biodiversity and systematics. Proceedings of the International Symposium on Biodiversity and Systematics in Tropical Ecosystems,Bonn.

Lang, Tim & Barling, David. (2012), Food security and food sustainability: reformulating the debate. The Geographical Journal, 178: 313–326. doi:10.1111/j.1475-4959.2012.00480.x

Lazarus, R. J. (2008). Super wicked problems and climate change: Restraining the present to liberate the future. Cornell L. Rev., 94, 1153.

Levkoe, C. Z., McClintock, N., Minkoff-Zern, L.-A., Coplen, A. K., Gaddis, J., Lo, J., Tendick-Matesanz, F. and A.M. Weiler (2016). Forging links between food chain labor activists and academics. Journal of Agriculture, Food Systems, and Community Development. Advance online

publication. http://dx.doi.org/10.5304/jafscd.2016.062.009

Levin, K., Cashore, B., Bernstein, S. and Auld, G. (2012). Overcoming the tragedy of super wicked problems: constraining our future selves to ameliorate global climate change. Policy Sciences, 45(2), 123-152.

Lewin, K. (1946). Action research and minority problems. Journal of Social Issues, 2(4), 34-46.

Macdiarmid, J. (2014). Seasonality and dietary requirements: will eating seasonal food contribute to health and environmental sustainability? Proceedings of the Nutrition Society. 2014;73: 368–75. doi: 10.1017/S0029665113003753. pmid:25027288

Macdiarmid, J., Douglas, F., and Campbell, J. (2016). Eating like there's no tomorrow: public awareness of the environmental impact of food and reluctance to eat less meat as part of a sustainable diet. Appetite, 96, 487-493.

MacRae, R. (2011). A Joined-Up Food Policy for Canada. *Journal of Hunger & Environmental Nutrition* 6(4): 424–457.

Masset, G., Soler, L.-G., Vieux, F., and Darmon, N. (2014). Identifying sustainable foods: the relationship between environmental impact, nutritional quality, and prices of foods representative of the French diet. Journal of the Academy of Nutrition and Dietetics, 114, 862-869.

McMichael, A., Powels, J., Butler, C. and Voay, R. (2007). Food, livestock production, energy, climate change and health. Lancet, 370, 1253-1263.

Mekonnen, M.M. and Hoekstra, A.Y. (2010) *The green, blue and grey water footprint of crops and derived crop products*. Value of Water Research Report Series No. 47, UNESCO-IHE, Delft, the Netherlands.

Melrose, M. (2001) Maximizing the Rigor of Action Research: Why Would You Want To? How Could You? Field Methods, 13(2), 160–180.

Miller, S. (2008). Edible action: food activism and alternative economics. Fernwood Publishing, Winnipeg, USA.

Milward, D. and Garnett, T. (2010). Food and the planet: nutritional dilemmas of greenhouse gas emission reductions through reduced intakes of meat and dairy foods. Proceedings of the Nutrition Society. 2010;69:103–18. doi: 10.1017/S0029665109991868. pmid:20003639

Munasinghe, M., 1993. Environmental Economics and Sustainable Development. Environment paper No. 3. World Bank, Washington DC, USA.

NASA (2008). Image available at: https://earthobservatory.nasa.gov/IOTD/view.php?id=44677

Nellemann C., MacDevette M., Manders T., et al., (eds.) (2009). *The Environmental Food Crisis* (Nairobi: United Nations Environment Programme, p. 26)

Nestle, M. (2016). Food Industry Funding of Nutrition Research - The Relevance of History for Current Debates. Journal of the American Medical Association - Internal Medicine. doi:10.1001/jamainternmed.2016.5400

Peterson, H. (2013). Sustainability: a wicked problem. In *Sustainable Animal Agriculture* edited by Kebriab, E. CAB books.

Pretty, J. N., Noble, A. D., Bossio, D., Dixon, J., Hine, R., Penning de Vries, F. and Morison, J. (2006). Resource-conserving agriculture increases yields in developing countries. Environmental Science Technology, 40(4), 1114-1119.

Rasche, A. (2012). Global policies and local practice: loose and tight couplings in multi-stakeholder initiatives. Business Ethics Quarterly, 22(4), 679-708.

Rawles, K., 2010. Developing ethical, sustainable and compassionate food policies. In: D'Silva, J., Webster, J. (Eds.), The Meat Crisis eDeveloping More Sustainable Production and Consumption. Earthscan, London.

Reason, P. and Bradbury, H. (2007). The SAGE Handbook of Action Research: Participative Inquiry and Practice. SAGE.

Rittel, H. (1973). Dilemmas in a General Theory of Planning. Policy Sciences, 155-169.

Roloff, J. (2008). Learning from multi-stakeholder networks: issue-focused stakeholder management. Journal of Business Ethics, 82, 223-250.

Rosegrant M., Leach N. and Gerpacio R. (1999). Alternative futures for world cereal and meat consumption. Proceedings of the Nutrition Society 58, 219–234.

Ruini, L., Ciati, R., Pratesi, C.A., Marino, M., Principato, L. and Vannuzzi, E. (2015). Working toward healthy and sustainable diets: the "Double Pyramid Model" developed by the Barilla Center for Food and Nutrition to raise awareness about the environmental and nutritional impact of foods. Frontiers in Nutrition, https://doi.org/10.3389/fnut.2015.00009

Russo, A. and Tencati, A. (2009). Formal vs. informal CSR strategies: evidence from Italian micro, small, medium-sized, and large firms. Journal of Business Ethics 85(2):339-353

Selsky, J. W. and Parker, B. (2005). Cross-sector parternships to address social issues: challenges to theory and practice. Journal of Management, 31(6), 849-873.

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., and de Haan, C. (2006). Livestock's long shadow. FAO, Rome.

Stokstad, E. (2010). Could Less Meat Mean More Food? Science, 327 (5967), 810-811

The Royal Society (2009). Reaping the benefits: science and the sustainable intensification of global agriculture. London, UK.

United Nations (UN), 1987. Report of the World Commission on Environment and Development. General Assembly Resolution 42/187.

United Nations (2015). Transforming our world: the 2030 Agenda for Sustainable Development. Available online: http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

van Beek, C. L., Pleijter, M., and Kuikman, P. J (2011). Nitrous oxide emissions from fertilized and unfertilized grasslands on peat soil, Nutr. Cycl. Agroecosys. 89, 453–461.

Trencher, G., Yarime, M., McCormick, K.B., Doll, C.N.H. and Kraines, S.B. (2013). Beyond the third mission: exploring the emerging university function of co-creation for sustainability. Sci. Public Policy 1-29.

Tukker A. and Jansen B. (2006). Environmental Impacts of Products. Journal of Industrial Ecology, 10(3), 159–182.

Webb, G. (1991). Putting praxis into practice. In *Proceedings of the first world congress in action research and process management*. Vol. 1: *Theory and praxis frameworks*, edited by C. J. Collins and P. J. Chippendale, 33–42. Sunny Bank Hills, Queensland: Acorn.

Weber, C.L. and Matthews, H.S. (2008). Food-miles and the relative climate impacts of food choices in the United States. Environ Sci Technol., 42(10):3508–13.

Whitmee, S., Haines, A., Beyrer, C., Boltz, F., Capon, A.G., de Souza Dias, B.F., Ezeh, A., Frumkin, H., Gong, P., Head, P., Horton, R., Mace, G.M., Marten, R., Myers, S.S., Nishtar, S., Osofsky, S.A., Pattanayak, S.K., Pongsiri, M.J., Romanelli, C., Soucat, A., Vega, J. and Yach, D. (2015). Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation-Lancet Commission on planetary health. The Lancet, 386,1973-2028.

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